QUEENSLAND GOVERNMENT
Environmental Protection Agency

State of the Environment Queensland 1999

Queensland's environment

Queensland's diverse natural environments, its rich resources and its distinctive cultural heritage support the State's economic wealth and quality of life.

Queensland's environment has undergone significant changes since European settlement. An increasing population and growing demands for natural resources continue to place pressures on the environment.

State of the Environment Queensland 1999

State of the Environment Queensland 1999 is the first comprehensive report on the condition of Queensland's environment.

The report is a milestone for environmental management in Queensland. It establishes an information base that will contribute to improved environmental management and sustainable use of resources in Queensland into the next century.

The report describes:

- the pressures acting on the State's air, land, inland and coastal waters, biodiversity, energy resources and cultural heritage;
- the state or condition of the environment; and
- the responses made by society to reduce pressures and protect and conserve the State's natural and cultural heritage.

The report will be a valuable resource for:

- decision makers in government, business and industry;
- environmental professionals;
- community groups; and
- students.

State of the Environment Queensland 1999

Queensland Government
Environmental Protection Agency

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foreword

FOREWORD

Queensland's natural environment is its defining asset. The State has a wealth of diverse, beautiful and unique settings including unspoilt beaches, coastal islands, coral reefs, tropical rainforests, cool highlands, meandering rivers and the desert outback. Queensland's cultural heritage, shaped by its indigenous and non-indigenous peoples, is a distinctive and enriching element of this environment.

The quality of life enjoyed by Queenslanders is due in no small measure to the quality of the environment. The environment also supports the State's economic wealth through its minerals, agriculture, forests, fisheries, energy resources and natural and cultural assets. It attracts business enterprises, new residents and tourists alike.

While Queensland still has many relatively unspoilt natural areas, population growth and development pressures over the past two hundred years have exerted pressure on our natural and cultural environments. There is evidence that aspects of our biodiversity, air quality, land and soils, inland and coastal waters have been lost or have declined or been degraded to some extent.

Balancing economic development with environmental protection is a major challenge and over recent years the Queensland community has achieved much in protecting, repairing and preserving its rich natural and cultural heritage and working towards ecologically sustainable development (ESD). Governments, industry and the community are increasingly making environmental management a priority consideration in State development. As a result, Queensland is building strong environmental policies and laws, an ethos of environmental stewardship and a broad commitment to ESD. There is increasing recognition that the State's future depends on keeping development 'clean and green'. Our natural environment is the primary source of wealth enjoyed by individuals and society, and must be carefully protected and managed. The challenge for Queenslanders is to maintain economic development, employment opportunities and community wellbeing without compromising environmental quality.

This document is a report on progress towards achieving ESD. It is the first such comprehensive report for Queensland and will be updated every four years as required by both the *Environmental Protection Act 1994* and the *Coastal Protection and Management Act 1995*. Information about the environment is essential to protecting it. This report aims to provide a rigorous information base to help decision makers in government, industry and the community achieve better environmental and natural resource management outcomes.

Production of the report would not have been possible without the efforts of a great number of individuals and organisations, both Government and private, who provided information and time for its development. The EPA is highly appreciative of the cooperation of the contributors and their commitment to the aims of state of environment reporting.

I hope the report will play a key role in improving our capacity to protect and manage our environment and our quality of life.

Barry Carbon
Director-General
Environmental Protection Agency

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CHAPTER 1

INTRODUCTION

Introduction

Contents

THIS REPORT

State of the environment reporting had its genesis in the United Nations Environment Programme (UNEP), following wide recognition that the world's natural resources are under threat. Most member countries of the OECD (Organization for Economic Cooperation and Development) now produce national state of the environment reports as part of their environmental management programs. In Australia, state of the environment reports have been produced, or are being prepared, by various shire and city councils as well as by most States and the Commonwealth.

State of the environment reports summarise and integrate available information on the condition of the environment in a form that is useful to decision makers, policy makers, planners and members of the broader community. They provide information on pressures affecting the environment and trends in its condition or quality. State of the environment reports also summarise society's responses to environmental problems.

Statutory requirements

State of the environment reporting is a statutory requirement under both the *Environmental Protection Act 1994* (the EP Act) and the *Coastal Protection and Management Act 1995* (the CPM Act). The EP Act requirement applies to Queensland's environment generally, while the CPM Act requirement relates specifically to the coastal zone.

The Acts require the Environmental Protection Agency (EPA) to prepare an assessment of the state of the environment and of the coastal zone at least every four years. This report is designed to meet the requirements of both Acts.

Section 218 of the EP Act and section 102 of the CPM Act specify that the report must:

(a) include an assessment of the condition of Queensland's major environmental resources (and major coastal resources);
(b) identify significant trends in environmental (and coastal) values;
(c) review significant programs, activities and achievements of persons and public authorities relating to the protection, restoration or enhancement of Queensland's environment (and coastal zone); and
(d) evaluate the efficiency and effectiveness of environmental (and coastal management) strategies implemented to achieve the objects of the Acts.

Environmental management and state of the environment reporting in Queensland

The EP Act states that the protection of Queensland's environment is to be achieved by an integrated management program that is consistent with ecologically sustainable development (ESD). ESD is defined in the EP Act as 'protecting the environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends'.

Under the EP Act, state of the environment reporting is an integral part of a four-phase planning and management cycle:
phase 1 — establishing the state of the environment and defining environmental objectives;
phase 2 — developing effective environmental strategies;
phase 3 — implementing environmental strategies and integrating them into efficient resource management;
phase 4 — ensuring accountability of environmental strategies.

Researching the state of the environment is part of phase 1. Reporting on the state of the environment is important to ensure accountability of environmental strategies and to provide objective measures of environmental performance and progress towards achieving ESD.

Aims of the report

As the first comprehensive survey of Queensland's environment, this report aims to establish a continuing information base for developing sound environmental strategies and management and for assessing the sustainability of development in Queensland. It attempts to:

- identify existing knowledge on the state of the environment, including the main socioeconomic pressures affecting the environment;
- identify key indicators and data requirements for long-term monitoring;
- identify gaps in the available information;
- develop an appropriate reporting methodology;
- provide trend information on environmental quality and condition;
- create a system for tracking progress in environmental management and providing direction for policy development;
- evaluate the efficiency and effectiveness of environmental strategies implemented to achieve ESD.

The report is designed for use by decision makers, planners and policy analysts in the private sector and government at the local, State and Commonwealth levels. Community groups, students and the public generally should also find the report a valuable resource.

Components of the report

The report has three components, published as separate documents:

- an executive summary;
- an unabridged report discussing the state of the environment in detail (this publication); and
- a report, subtitled *Implementing the legislation*, assessing the efficiency and effectiveness of environmental strategies implemented to achieve the objectives of the *Environmental Protection Act 1994* and the *Coastal Protection and Management Act 1995*.

Environmental themes of the report

The report is broad in scope, examining a range of physical, social and cultural elements of the environment, together with environmental resources such as energy, soils and forests. Its eight substantive chapters explore: the atmosphere, land, inland waters, the coastal zone, energy resources, biodiversity, human settlements and cultural heritage. This wide range of subjects derives from the broad definition of the environment provided in the EP Act:

'"Environment" includes —

(a) ecosystems and their constituent parts, including people and communities; and

(b) all natural and physical resources; and
(c) the qualities and characteristics of locations, places and areas, however large or small, that contribute to their biological diversity and integrity, intrinsic or attributed scientific value or interest, amenity, harmony and sense of community; and
(d) the social, economic, aesthetic and cultural conditions that affect, or are affected by, things mentioned in paragraphs (a) to (c).'

Links between chapters

Although the eight environmental themes are treated separately in individual chapters, many themes and subjects are interrelated. Most subjects are discussed largely within a single chapter in order to avoid undue duplication. However, certain material can logically be discussed in more than one chapter: for example, land clearing and its effects on biodiversity, land resources and water quality are discussed in several chapters. Care has been taken to identify links and provide cross-references.

Pressure-state-response framework

The report uses the 'pressure-state-response' (PSR) framework developed by the OECD. The PSR framework is based on the concept of causality: that is, human activities exert **pressures** on the environment and change its **state** or condition. Society **responds** to this changed state by various actions, policies and programs that directly affect the state of the environment or influence those human activities that exert pressure on the environment.

The information within chapters is treated under the headings 'Pressure', 'State' and 'Response'.

Summaries are provided in the form of 'key issues and findings' at the front of each chapter and in the executive summary.

Figure 1-2 Environmental themes within the eight substantive chapters are discussed under the headings 'Pressure', 'State' and 'Response'. A summary of key issues and findings is also presented within each chapter.

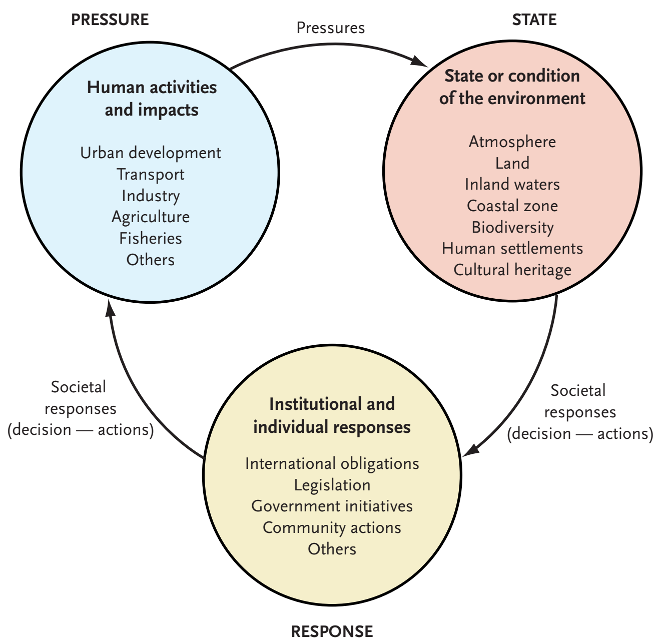

Figure 1-1 The pressure-state-response model
(Source: OECD)

Environmental indicators

This report focuses on environmental indicators to characterise environmental conditions and pressures. An indicator is a physical, chemical, biological or socioeconomic measurement that provides a numerical indication of some aspect of an environmental issue.

The main criteria for selection of the indicators were that they be capable of summarising information important for the assessment of a particular issue, and that they be measurable over the long term so that trends can be identified. Indicators chosen for reporting are listed at the beginning of each chapter.

The indicators are used in discussion of pressure and state issues, but not in discussion of responses. The available response indicators tended to be limited and provided a disjointed picture of levels of response activities. Instead, an overview of the fabric of policy, legislation and strategy at the Commonwealth, State and local levels was provided. The effectiveness of responses is best deduced through changes to environmental pressure and state indicators.

Lack of data in many areas of the report has been a major problem. Data are not available for many of the indicators selected by the working groups. These indicators are, however, listed in the chapters, as an important function of this report is to identify information gaps that need to be filled to ensure effective environmental management.

Report preparation

The report was compiled by expert working groups established for each chapter. Members included research scientists, academics, government professionals and industry experts. The members of the working groups are listed at the beginning of each chapter.

Each chapter was drafted by a principal author (usually the chairperson of the relevant working group) and reviewed by the respective working groups. Final drafts were reviewed by external expert referees (also noted at the beginning of each chapter) and relevant Queensland Government departments.

The EPA gratefully acknowledges the efforts of all authors, working group members and referees, without whose expertise and time preparation of this report would not have been possible.

Data acquisition

A large volume of information, drawn from a wide range of sources, was collated, interpreted and used in this report.

Sources are cited throughout the text. Published citations can be found in the reference lists at the end of each chapter. Other sources are generally acknowledged by the use of organisational abbreviations. Abbreviations are explained in the glossary at the rear of the report. Data that appear without an acknowledgement or citation were provided by the EPA, QPWS and/or members of the working group.

Future directions for state of the environment reporting

As this report is the first of its kind for Queensland, the EPA is conscious that there is wide scope for improvement. The EPA is keen to receive readers' views on whether the report meets their needs and their suggestions for future reports. (A survey form accompanies the report.)

Arid dunefields, tropical rainforests and coral reefs are examples of the great diversity of land and marine environments found in Queensland.

The estuarine crocodile (*Crocodylus porosus*), one of over 400 species of reptiles recorded in Queensland

QUEENSLAND AT A GLANCE

Queensland's land resources lie between the latitudes 10ºS and 29ºS and the longitudes 138ºE and 153ºE. The total land area is 172.8 million hectares; of this, 54 percent is classified as tropical. The area within the State's administrative jurisdiction includes numerous coastal islands.

The mainland coastline extends about 6000 km, and features 1165 offshore islands and cays. The Great Barrier Reef, the most significant feature of the State's coastal zone, consists of 3400 separate coral reefs, shoals and other formations and extends more than 2300 km from Bramble Cay to Lady Elliot Island.

The State can be divided into four main landscape regions: the eastern highlands, the western plains, the north-western uplands and the coastal plain. Much of the eastern coastline consists of long, sandy beaches with sand dunes and high sand deposits. Almost the entire eastern coastline is overlooked by the Great Dividing Range, which rises in places to over 1000 m (figure 1-3). By contrast, the Gulf of Carpentaria is surrounded by low-lying plains: during the wet season, sea and land may be difficult to demarcate.

Queensland's soils, like those of the rest of Australia, are often ancient, highly weathered and leached of nutrients. The continent has been geologically stable, suffering little volcanic activity or creation of new land masses, for many millions of years.

Australia's most naturally diverse State, Queensland has 13 terrestrial and 14 marine bioregions, defined on the basis of broad patterns of biological and physical characteristics. These regions support more than 1000 ecosystem types, habitat for approximately 65 percent of Australia's known frog, reptile, bird and mammal species and 47 percent of its vascular plant species.

The State's terrestrial vegetation communities can be grouped into the broad categories of forests (including woodlands), arid shrublands, grasslands, heathlands and wetlands. Distribution is largely determined by soil type, rainfall and temperature. Native forests are

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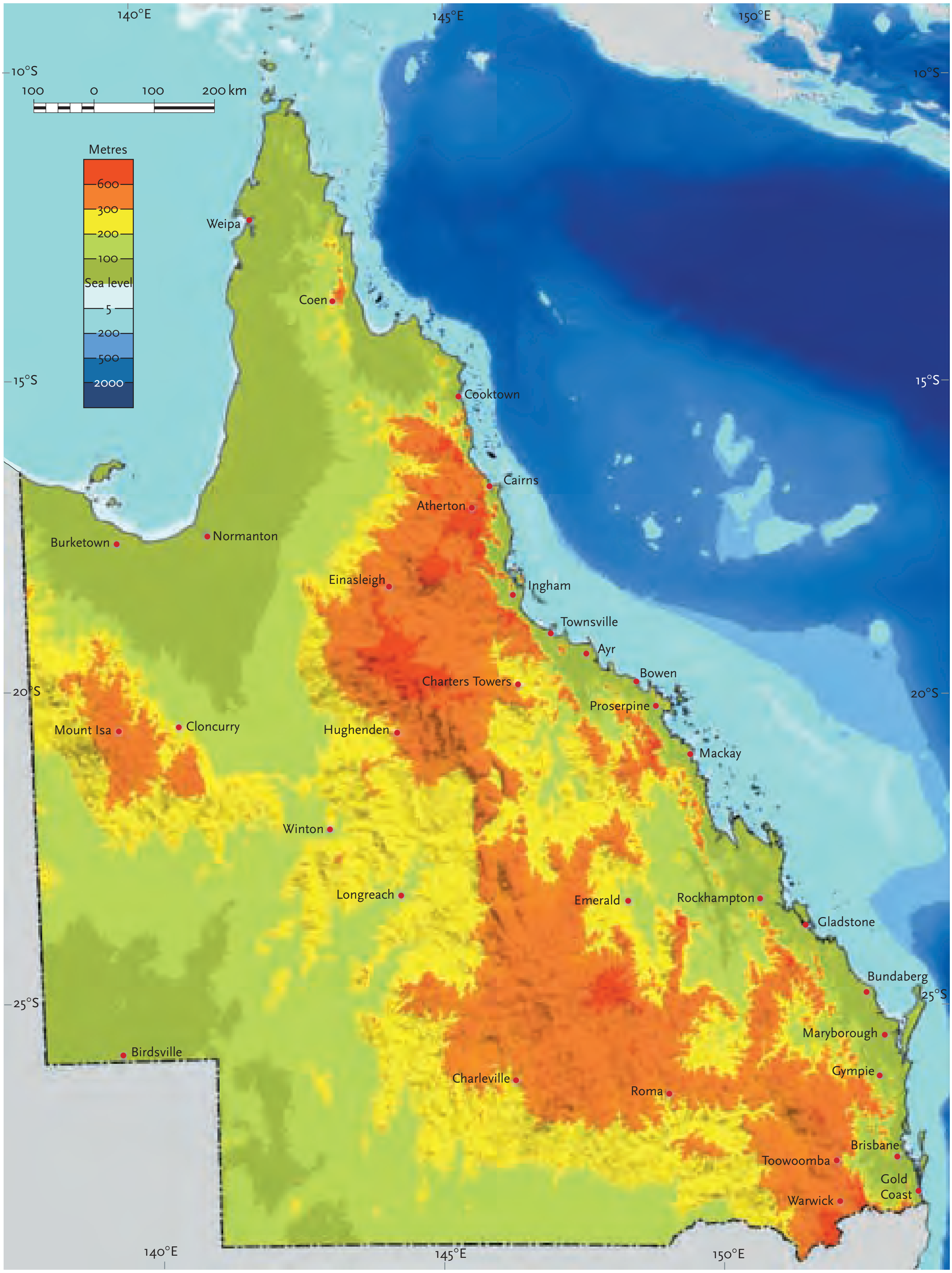

Figure 1-3 Queensland in relief

found over approximately 28 percent of the State, and native grasses over 86 percent, in both open grassland and woodland settings. The coastal zone has over 2 million ha of seagrass, 447 000 ha of saltmarsh and 190 000 ha of mangroves.

Climate

Most of the State north of a line linking Rockhampton, Longreach and Cloncurry has a tropical climate with a summer monsoon and a mild, dry winter with clear skies. The region to the south is subtropical with a warm, humid summer and a comparatively dry winter with clear skies. The inland region west of Longreach and Charleville is subtropical and arid and experiences temperature and rainfall extremes.

Across the State, summer rainfall declines with distance from the coast and winter rainfall declines with distance from the south. Rainfall varies greatly from year to year, strongly influenced by the El Niño Southern Oscillation phenomenon. Seasonal variability is also high, most of the State's rainfall occurring in the summer months. In the Wet Tropics, more than 90 percent of annual rainfall occurs between November and April; the area also has the highest rainfall in Australia. Due to its high relief and coastal location, the Innisfail area receives more than 4000 mm a year. In contrast, Birdsville has the lowest annual average rainfall nationwide, receiving about 200 mm a year.

Queensland is susceptible to harsh climatic conditions, including severe droughts and flooding, frosts, tropical cyclones and violent thunderstorms with damaging winds and hail. Climatic variability has a significant influence on the characteristics of its waters, coastal systems, vegetation and biodiversity and often exacerbates human-induced pressures.

Water resources

Queensland's drainage pattern is controlled mainly by the Great Dividing Range, a loosely arranged chain of mountains, hills and high country running roughly parallel to the east coast. Fresh water is scarce in much of the State, particularly west of the Great Dividing Range. Dry areas are also present along the narrow east coast strip — for example, in the area between Bowen and Townsville where the mountain ranges are low and set back from the coast.

Although mainly dry, Queensland produces 40–45 percent of Australia's runoff while representing only 20 percent of the nation's land area. These proportions highlight not only the aridness of the Australian continent but the seasonal and event nature of much of the rainfall and the large falls received in the relatively small Wet Tropics area.

About 76 percent of the discharge of all Queensland's rivers occurs in sparsely populated catchments that drain to the Gulf of Carpentaria and the Coral Sea north of Mackay. Few inland streams are perennial, most being reduced to dry channels with remnant billabongs in the dry season. High evaporation rates west of the Dividing Range reduce surface water availability even further.

The scarcity and unreliability of rainfall have led to high levels of storage and diversion of surface water from rivers and storages and extraction of ground water from artesian sources to meet human needs.

Land and sea

Queensland's variety of landforms, forest and mineral resources and vegetation provides a wide range of economic uses, cultural values and intrinsic environmental benefits. Grazing of beef cattle and sheep is the primary land use over about 87 percent of the State; crops account for about 2 percent. Protected areas including national parks occupy about 4 percent, while managed forests and timber reserves occupy about 2.5 percent. The remainder of the land is used for services, housing, industry and mining activities.

Coastal waters also provide a wide range of cultural values and economic uses: various recreational and tourism activities, commercial shipping and fishing, a growing aquaculture industry, and, in some areas, wastewater disposal. Fisheries on the southern and central coast have been harvested for many years, while those of the more remote northern Great Barrier Reef Region and the Gulf of Carpentaria have been developed only over the past three decades. Marine parks cover approximately 38 percent of coastal waters, although most of this area is managed for multiple uses rather than providing complete protection.

The most evident impact of European settlement has been clearing of native vegetation to make way for other land uses, particularly grazing. Almost half of Queensland's woody ecosystems have been cleared since European settlement, and clearing continues. Clearing has contributed to soil loss and degradation in many areas.

About three-quarters of Queensland's forest cover is woodland. Closed forests are confined mainly to coastal areas and parts of southern inland Queensland. Most of the State's forest resource is native forest (99.6 percent). About 2.4 million ha of the

Queensland's natural environment supports a wide range of land and sea uses which provide many social, cultural and economic benefits to Queenslanders.

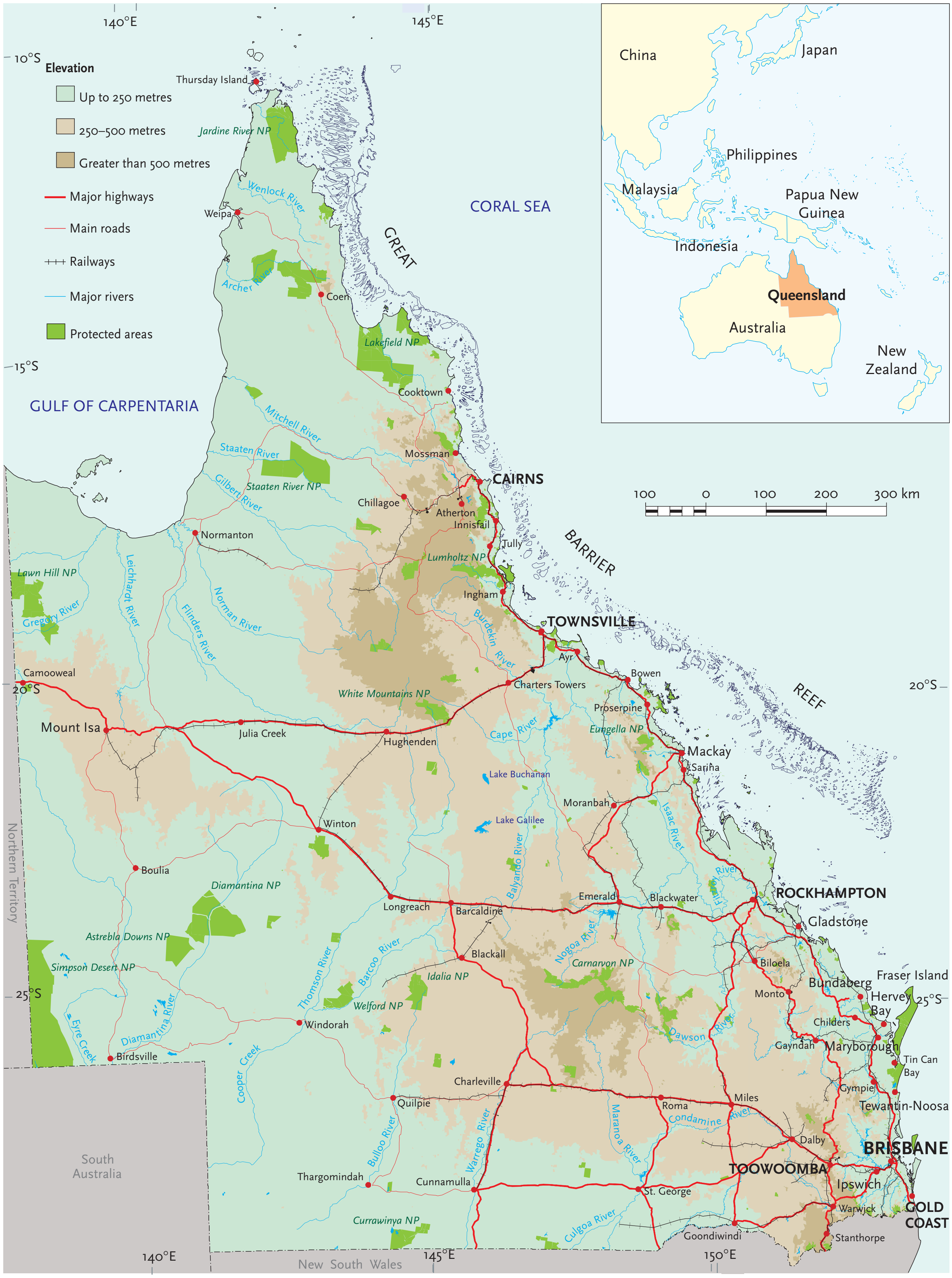

Figure 1-4 Queensland's major urban centres, transport routes and physical features

8.0 million ha of Crown reserves are used for commercial forest operations.

The State has extensive mineral deposits. The Carpentaria–Mount Isa region in Queensland's north-west contains the major base metal deposits (particularly copper, lead, zinc and silver). The north and east of the State also contain a variety of deposits, including the majority of Queensland's gold and some base metals. Large bauxite deposits occur on Cape York Peninsula. The largest coal deposits are located in the Bowen Basin, which extends almost 500 km south from Collinsville. Queensland has extensive resources of most minerals currently mined, with the exception of mineral and silica sands.

Human settlements

Queensland's average population density is very low —1.97 people/km^2 — but the majority of the population resides in the south-east. In 1996, 80.7 percent of Queenslanders lived in cities or urban areas. Population is concentrated on the coast where rainfall tends to be more frequent and reliable, the beaches provide lifestyle and recreational opportunities and, historically, ports provided access in the early days of European settlement. West of the Great Dividing Range, population centres are small and scattered. Settlements in Queensland are well served by an extensive road network supported by a rail network serving the east coast and major inland centres (figure 1-4).

The State's population increased by 27 percent between 1986 and 1996. Population increase is focused on established urban centres, particularly in south-east Queensland and on the coast in cities such as Townsville, Gladstone and Cairns.

Environmental management

Queensland's environmental values and natural resources are shared by all Queenslanders. As a consequence, all sectors of the community — government, industry, commerce, agriculture and each and every individual — have responsibility for environment protection.

All three spheres of government — Commonwealth, State and local — have roles in environmental management and recent years have seen increasing levels of cooperation and resource-sharing between the spheres. The Commonwealth Department of Environment and Heritage focuses on issues of national environmental and cultural heritage significance. At the State level, the Environmental Protection Agency is the lead agency for all environmental management matters in Queensland, but many other government departments also have significant roles. Local governments also have extensive powers and responsibilities and play an important role in helping communities achieve economic, social and environmental outcomes. In particular, they provide water, sewerage and cleansing services and are responsible for land use planning, building control and waste management.

Governments are increasingly consulting and seeking participation from the private sector and the community in their planning, policy development and programs. Many environment protection responses and activities exist outside government. Ecologically sustainable development needs to be addressed globally, nationally, regionally and individually. Community and government responsibilities and responses to individual environmental issues are outlined in the following chapters of this report.

CHAPTER 2

QUEENSLAND'S ATMOSPHERE

Atmosphere

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Contents

KEY ISSUES AND FINDINGS

Queensland's air quality meets national air quality standards with only infrequent exceptions at certain times and places. The potential for air pollution in the State is limited by a low and scattered population and the existence of few major industrialised centres. The south-east Queensland airshed contains Australia's fastest growing region, supporting about 1.9 million people, or 57 percent of the State's population.

Major air pollutants affecting tropospheric air quality are suspended particles, nitrogen oxides, volatile organic compounds (VOCs), sulfur dioxide and carbon monoxide. The major sources of these air pollutants are motor vehicles and power stations, with the Brisbane and Gladstone airsheds being the most affected. Continued population growth and even greater reliance on motor vehicles in urban areas threaten tropospheric air quality.

Queensland's climate is subject to the influence of the greenhouse effect and global warming, with discernible changes now being detected in the temperature and rainfall monitoring record.

- Net greenhouse gas emissions for Australia in 1996 were estimated at 419 million tonnes of carbon dioxide equivalent. Australia's rate of emissions growth is one of the highest in the world, with emissions projected to increase by 28 percent over 1990 levels by the Kyoto target date of 2008. Queensland emissions in 1995 were 83.5 Mt CO_2 equivalent, approximately 21 percent of the national total; emissions have increased by 19 percent since 1990 (land use change excepted). Emissions associated with stationary energy (primarily electricity generation) and transport collectively accounted for 66 percent of total emissions.
- Total stratospheric ozone for winter and summer at middle and high latitudes in both hemispheres showed significant declines between 1978 and 1991. No trends of significance have been observed in the tropics. Stratospheric ozone over Queensland appears relatively stable but normal levels might not return until bans on ozone-depleting substances take full effect.
- Queensland has one of the highest naturally occurring UV-B surface exposures in the world. The relative UV trend for Queensland increased by 3.2 percent per decade between 1979 and 1992. For tropical Queensland the increase was 3.8 percent, suggesting increasing exposure to potentially harmful UV rays.
- Severe rainfall deficits occurred in eastern Queensland during the 1990s. In central and north-east Queensland, rainfall for 1991–95 was the lowest on record.
- The Brisbane air quality index between February 1993 and August 1996 showed that 2 percent of days had a high pollution level and 9 percent had a medium pollution level. At high levels the maximum acceptable pollution concentration has been exceeded. Light-scattering particles are major contributors to unacceptable air quality in Brisbane.
- The frequency of low-visibility days in Brisbane has decreased since 1986; the decrease coincides with the closure of metropolitan coal-fired power stations and the ban on domestic open fires and backyard incinerators in 1987. Increases in 1993–96 are attributable to bushfires and hazard-reduction burning.
- Ozone concentrations in urban centres in excess of specified levels showed considerable variation but no clear trends in south-east Queensland between 1978 and 1997. This is despite increases in traffic volume.
- Brisbane is believed to have the greatest potential for photochemical smog of any major Australian city due to a combination of topographical, geographical and meteorological factors.
- Total suspended particle emissions resulting from human activities in south-east Queensland in 1993 were estimated at 22 000 tonnes. Sixty-five percent came from industrial sources, primarily coalmining, and 18 percent from motor vehicle emissions. The number of days for which the 24-hour average PM_{10} exceeded specified levels has been decreasing in south-east Queensland in recent years. Concentrations of inhalable particles (diameter <10 micrometres) exceeded specified levels in Brisbane on fewer than 5 days in 1997.
- An estimated 70 percent of emissions of nitrogen oxides (NO_x) in south-east Queensland are from motor vehicles. Levels of nitrogen dioxide in south-east Queensland have not exceeded the NHMRC goal since 1978. No discernible trend exists, despite increases in traffic volume, suggesting that emission controls for motor vehicles are matching increases in vehicle numbers.
- New sources of VOCs are estimated at 84 000 tonnes a year in south-east Queensland (52 percent from motor vehicles, 21 percent from commercial sources and 16 percent from industrial sources) based on 1993 data. Biogenic emissions accounted for about 148 000 tonnes.
- Sulfur dioxide concentrations are very low in urban areas throughout Australia, including south-east Queensland, due to the use of low-sulfur fuels and the siting of coal-fired power stations away from urban areas. About one-third of Australia's emissions of sulfur dioxide originate from the combined emissions from the copper and lead smelters of Mount Isa, which are among the largest point sources of sulfur dioxide in the world. Operating at full capacity, their combined sulfur dioxide output is estimated at 975 000 tonnes a year. Mount Isa recorded some days above the NHMRC and ANZECC guidelines between 1980 and 1995. Despite Gladstone's extensive industrial operations, levels of sulfur dioxide rarely exceed 0.04 ppm, 20 percent of the NHMRC goal.
- In 1993 carbon monoxide (CO) emissions from motor vehicles were estimated to be 33 000 tonnes, about 20 percent of Queensland's total CO emissions for that year. In urban airsheds motor vehicle emissions contribute about 83 percent of total carbon monoxide levels.
- Motor vehicle emissions account for 90 percent of atmospheric lead in urban areas, except for those near mineral

smelting operations. Since the introduction of more stringent vehicle emission limits and compulsory use of unleaded petrol (under Australian design rule ADR37) in 1986, the use of leaded petrol has been declining. Lead emissions decreased from about 2200 tonnes in 1985–86 to 400 tonnes in 1995–96.

- The introduction of unleaded petrol in 1986 and reductions in the lead content of leaded fuel produced a strongly decreasing trend in lead levels monitored at several Brisbane sites. Airborne lead levels in south-east Queensland are now consistently below the current NEPM goal of 0.5 $\mu g/m^3$.
- The National Greenhouse Response Strategy 1998 aims to limit net greenhouse gas emissions to meet international commitments. It makes provision for the States and Territories to develop implementation plans. These plans will articulate how implementation will be achieved in the respective jurisdictions. The Queensland Government is currently preparing a Queensland Greenhouse Response Strategy to reduce greenhouse gas emissions.
- The Australian Greenhouse Office is the Commonwealth lead agency overseeing the development and implementation of national greenhouse policy and actions. The Greenhouse Challenge program is a cooperative effort of Australian industry and the Commonwealth Government to reduce greenhouse emissions through voluntary industry action.
- A range of Queensland Government initiatives is responding to air quality issues. The South East Queensland Regional Air Quality Strategy (SEQRAQS) is intended to deal with those aspects of air quality in south-east Queensland which have regionally significant effects on the environmental values of human health and wellbeing, ecological sustainability and amenity, including visibility. The focus of this strategy is on those pollutants which contribute to regional pollution levels.
- The Integrated Regional Transport Plan (IRTP) seeks a transport system in south-east Queensland which moves passengers and freight efficiently, supports economic development, and reduces car dependency. The IRTP has targets and associated actions to counter undesirable trends in transport activity.

Griffith University (AES)

Fog can form in sheltered valleys on cool winter mornings.

Pressure

Climate

Total greenhouse gas emissions
Sulfur dioxide emission levels
Stratospheric ozone
Stratospheric ozone depletion

Tropospheric air quality

Suspended particle emissions
Nitrogen oxide emissions
Volatile organic compound emissions
Sulfur dioxide emissions
Carbon monoxide emissions
Lead emissions
Fluoride emissions
Weather conditions

State

Climate

Maximum temperature
Minimum temperature
Number of days less than 10°C
Number of days greater than 30°C
Rainfall
Number of rain days
Number of cyclones
Number of strong wind days
Number of thunder days

Stratospheric ozone

Stratospheric ozone concentration across Australia

Tropospheric air quality

Brisbane air quality index
Visibility
Suspended particles (PM_{10})
Nitrogen oxides
Volatile organic compound emissions
Ozone
Sulfur dioxide
Carbon monoxide
Lead
Air toxics

INTRODUCTION

INTRODUCTION

'Beautiful one day, perfect the next.' This advertising slogan presents Queensland to tourists as a land of blue skies and bright sunshine. What exactly is beautiful and perfect depends on your point of view. For some it is sunshine; for some it is rain. Whatever the preference, our climate and our very existence depend on the atmosphere — a sensitive envelope of gases which surrounds our planet.

The atmosphere is the air we breathe. We can survive without food for weeks. We can survive without water for days. Yet without air to breathe we cannot survive for more than a few minutes. The atmosphere also maintains our environment within tolerable temperature ranges, smoothing the extremes of night and day and summer and winter. The atmosphere protects us from harmful solar radiation yet is transparent to beneficial solar radiation enabling vision and photosynthesis. However, the atmosphere is not an inexhaustible reservoir of air, but a slender skin (less than one percent of the Earth's diameter) subject to increasing influence from human activities. Changes in the composition of the atmosphere inevitably will lead to changes in the aesthetic and life-supporting characteristics of this essential resource.

The purpose of this chapter is to document the current state of Queensland's atmospheric resources and the pressures on those resources. Values attributed to our atmosphere are identified and indicators to measure trends and changes resulting from human activity are described. Indicators are presented in terms of human pressures on the resource and the current state of the resource including seasonal and longer-term and geographic variation. The responses of government, industry, commerce and the community to issues affecting the condition of the atmosphere are also discussed.

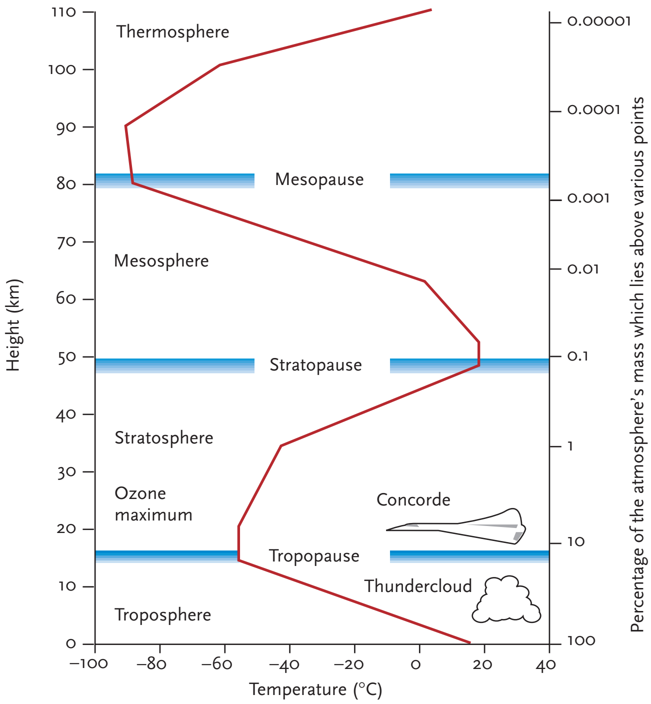


Figure 2-1 Temperature profile of the atmosphere at different altitudes

Queensland's climate is examined on a statewide basis. However, greenhouse and climate change issues are discussed from a global perspective. Stratospheric ozone is also discussed in a global context, but with some local input. Tropospheric air quality issues are considered from a regional airshed perspective, with particular emphasis on the south-east Queensland airshed.

SCOPE

The scope of this chapter relates to the atmosphere above Queensland (troposphere and stratosphere) and, where appropriate, the global climate system. It does not extend to the air environment indoors, or other circumstances to which the *Workplace Health and Safety Act 1995* applies. The atmosphere is discussed in the context of the impact of human activities on air quality and on the climate system, and the current state (condition) of air quality and climate.

DESCRIPTION OF THE ATMOSPHERE

Structure

The atmosphere is a highly dynamic, complex and interactive system of gases and airborne solid and liquid particles which surrounds the Earth. It plays a major role in the global energy balance system and through its chemical and physical properties is able to protect and sustain life on this planet.

The atmosphere is structured vertically into distinct layers. The lower atmosphere comprises the troposphere (0–15 km in height) and stratosphere (approximately 15–50 km). The upper atmosphere (>50 km) comprises the mesosphere, the thermosphere and the exosphere (above the top layer). Layers of the atmosphere are distinguishable by the temperature profile shown in figure 2-1.

Figure 2-2 shows the pressure profile of the lower atmosphere and concentrations of gases in the air. Air pressure at a point represents the mass of air above that point and is a function of the concentration of gas molecules and temperature.

The troposphere contains about 90 percent of the mass of the atmosphere and is the only layer which is highly mixed. Most emissions caused by humans and most internal chemical interactions and exchanges with the biosphere and Earth's surface take place in this layer. Gases and aerosols also regularly enter the stratosphere from the troposphere and upper atmosphere.

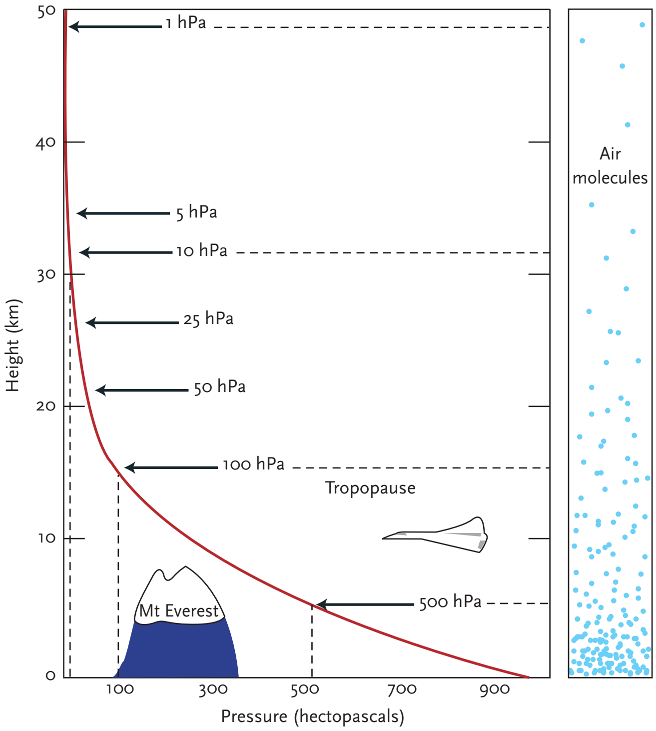


Figure 2-2 Pressure profile of the lower atmosphere at different altitudes

Composition

The composition of the atmosphere is given in table 2-1. Concentrations of major constituents remain relatively constant, whereas trace gases and aerosols are subject to change due to natural emissions and those caused by humans.

Circulation patterns

Air in the atmosphere is circulated by the climate system, an interactive system of physical processes driven primarily by differences in incoming solar radiation at different latitudes. The system's main components are the atmosphere, ocean, biosphere, cryosphere and lithosphere.

The most rapid changes in atmospheric conditions occur in the region near the Earth's surface where we live — in the troposphere. Thermal adjustment of the troposphere occurs over periods of days to weeks, while the stratosphere and upper atmosphere respond more slowly. Components of the biosphere such as terrestrial vegetation and phytoplankton in the upper ocean influence climate on time scales ranging from seasons to decades. Adjustments in the lithosphere (continental land masses) and the cryosphere (continental ice sheets, sea ice, glaciers, snow cover and permafrost zones) occur on all time scales.

Solar radiation is the major external driving force of the climate system. The amount of solar radiation reaching the Earth varies with changes in solar flux due to solar flares, and with the changing distance to the sun due to the Earth's elliptical orbit. Part of this incident radiation is reflected by the atmosphere and by the Earth's surface. The proportion reflected varies with cloud cover, suspended particles in the atmosphere, and surface reflectivity. Most solar radiation is absorbed by the Earth's surface and re-radiated into space as long-wave infrared radiation (terrestrial radiation). The balance between incoming and outgoing radiation maintains the overall energy system of the planet.

The Earth's nearly spherical shape means that more intense solar radiation is received on the tropical region, the surface with the least angle to the Sun. This results in net heating in the tropics and net cooling at the poles, which in turn generate thermally driven circulations in the atmosphere and the oceans. These have a tendency to carry warm air and water from the equator to the poles and cool air and water from the poles to the equator.

As the Earth rotates on its axis, warm equatorial air accelerates rapidly eastward as it moves closer to the axis of rotation. On reaching middle latitudes this produces steep pressure gradients which cause the north–south circulation to break down into characteristic wave patterns and eddies. The general circulation pattern produced features high and low pressure cells underlying a meandering mid-latitude westerly jetstream and meridional circulation near the equator.

Table 2-1 Constituents of the atmosphere and their residence times

Constituent gas	Mean concentration (%v/v)	Mean residence time	Estimated change/year (%)
Nitrogen (N_2)	78	1×10^{6} years	*
Oxygen (O_2)	21	1×10^{3} years	*
Argon (Ar)	0.9	–	*
Water vapour (H_2O)	variable: 0 to 3	8 to 10 days	*
Carbon dioxide (CO_2)	35×10^{-3}	50 to 200 years	+0.4
Methane (CH_4)	17×10^{-5}	7 to 10 years	+1 (decreasing to 0.6)
Hydrogen (H_2)	6×10^{-5}	–	+0.6
Nitrous oxide (N_2O)	33×10^{-6}	130 years	+0.3
Carbon monoxide (CO)	4×10^{-6} to 20×10^{-6}	0.4 year	+1 to 2
Tropospheric ozone (O_3)	1×10^{-6} to 1×10^{-5}	weeks to months	1.5
Stratospheric ozone (O_3)	1×10^{-5} to 5×10^{-5}	months	–0.5
Volatile organic compounds (VOCs)	1×10^{-5} to 1×10^{-4}	–	*
Sulfur dioxide (SO_2)	1×10^{-7} to 5×10^{-5}	3 days	*
Nitrogen oxides (NO_x)	1×10^{-8} to 5×10^{-5}	3 days	*
Ammonia (NH_3)	1×10^{-8} to 1×10^{-6}	3 days	*
Perfluorocarbons (CFCs)	1×10^{-7}	50 to 150 years	+5 to 10
Peroxyacetyl nitrates (PANs)	1×10^{-7} to 5×10^{-6}	*	*

* Data not provided

(Source: EEA 1995)

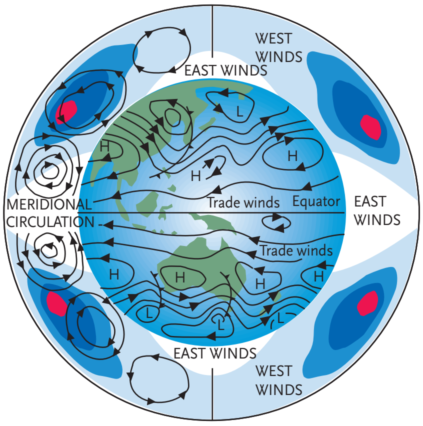


Figure 2-3 Large-scale atmospheric circulation patterns
(Source: BoM)

Earth's ecosystems have evolved and adapted to natural climatic variability. Changes to the climate system caused by human interference must therefore remain within the bounds that the most sensitive life forms can tolerate if the natural ecological balance is to be maintained.

The relatively short time scale of climatic records and the inherent variability of the climate system create difficulties in evaluating trends and determining whether a particular climatic event is within the range of natural variability or is due to human influence. Palaeobiological studies covering the last 100 000 years have shown the temporary nature of existing climatic environments at particular locations (McGlone et al. 1996). Reconstructions of palaeoclimatologies have highlighted the limited experience that is actually provided by the last 100 years of instrument records.

Environmental resource components and values

While the atmosphere can be regarded as a single resource, for the purposes of this report the individual components — climate, stratospheric ozone layer and tropospheric air quality — are identified. The state of these resource components and the pressures affecting them are discussed separately.

The environmental values of the air environment to be enhanced or protected under the *Environmental Protection (Air) Policy 1997* are the qualities of the air environment that are conducive to life, health and the wellbeing of humans.

Queensland's climate

The Bureau of Meteorology has defined three major climate regions over Queensland. Most of the State north of a line linking Rockhampton, Longreach and Cloncurry has a tropical climate with a summer monsoon and a mild, dry winter with clear skies. The inland region west of Longreach and Charleville is subtropical and arid with temperature and rainfall extremes. The rest of the State is subtropical with a warm, humid summer and a fairly dry winter with clear skies.

Across the State, summer rainfall declines with distance from the coast. Winter rainfall declines with distance from the south. Local factors such as proximity to the coast, altitude and topographic features also modify climatic conditions to produce the spatial variability evident in Queensland. Seasonal variability is also high, with most of the State's rainfall occurring in the warmer summer months.

Solar radiation is the main driving force of the climate system.

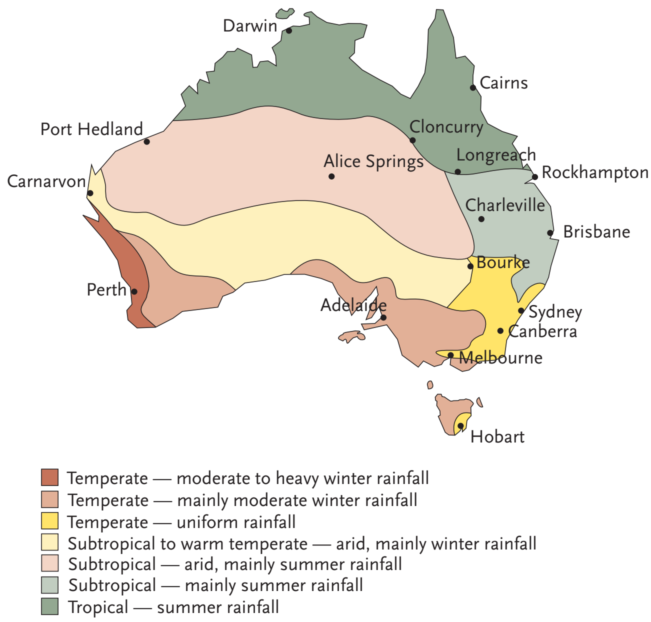


Figure 2-4 Australia's climate regions
(Source: BoM)

Rainfall

Queensland's rainfall is highly variable from year to year. The major influence is the El Niño Southern Oscillation (ENSO) phenomenon. (See box on page 2.11.) Under El Niño conditions, the Southern Oscillation Index (SOI) is strongly negative and below-average rainfall is likely in Queensland. In some locations, such as north-east Queensland, the chance of severe drought (less than 60 percent of average summer rainfall) doubles in El Niño years. Under the reverse La Niña conditions, the SOI is strongly positive and Queensland is likely to experience above-average rainfall with associated flooding. Different regions in Queensland differ in the strength of the correlation between rainfall and the SOI, and the time of year when these correlations are strongest. The strongest correlation is observed on the Darling Downs. As figure 2-5 demonstrates, on a statewide basis average rainfall varies with the SOI with reasonable consistency.

Examination of fluorescence bands in coral sampled at the mouth of the Burdekin River was used to estimate rainfall variability between 1735 and 1980 (Lough 1991). The study showed that 1902 was the driest year in 245 years of record. Drier and wetter 10-year and 30-year periods occurred in the nineteenth century than have been experienced since 1900.

Temperature

Air temperature varies widely across Queensland and is influenced by several factors. Higher temperatures are experienced in the tropical north due to greater intensity of solar radiation. The cooling influence of the sea leads to lower temperatures in coastal areas than inland. Air temperature also decreases with altitude, resulting in lower temperatures in areas such as the Granite Belt and the Atherton Tableland. Figure 2-8 shows the range of temperature extremes for summer and winter across the State.

Trace gases in the atmosphere which absorb the long-wave infrared radiation emitted from the Earth's surface produce the so-called 'greenhouse effect' which maintains the planet's equilibrium temperature. Increased concentrations of these gases and the introduction of new radiatively active gases produce an enhanced greenhouse effect (see box on page 2.17), leading to a higher equilibrium temperature.

Drought is more likely during the El Niño phase of the southern oscillation.

Severe storm events associated with tropical cyclones are a regular occurrence in Queensland.

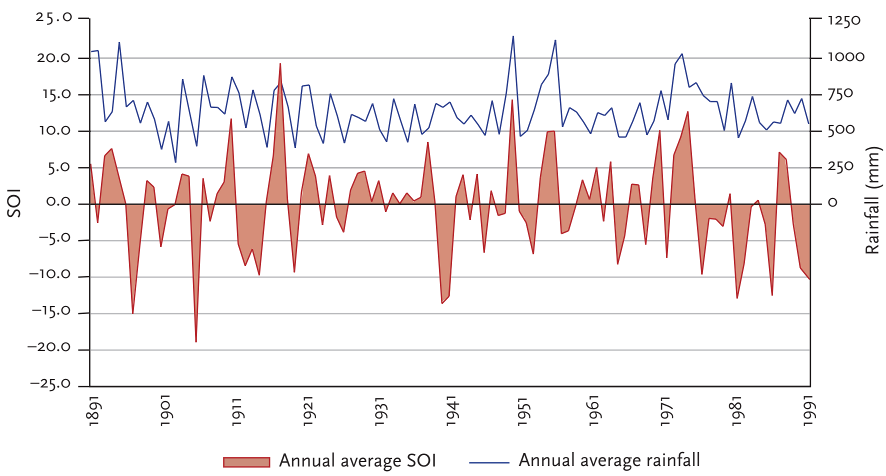


Figure 2-5 Annual average Southern Oscillation Index (SOI) and annual average rainfall. Under El Niño conditions the SOI is strongly negative and below-average rainfall is likely in Queensland. During the La Niña phase, the SOI is strongly positive and Queensland is likely to experience above-average rainfall with associated flooding.
(Source: BoM)

El Niño Southern Oscillation (ENSO) phenomenon

El Niño is a Spanish term, meaning 'the Christ child'. It is used by fishers on the north-west coast of South America to describe the arrival, often near Christmas, of warm ocean currents off the coast of Ecuador and Peru. These currents devastate the usually abundant anchovy fishery. The El Niño current is a reflection of large-scale interactions between the atmosphere and the oceans. The term El Niño is now used widely to describe the circulation of warm water across the eastern Pacific Ocean and the accompanying changes in atmospheric circulation which result in changes to global weather patterns.

Under normal circulation conditions, cold ocean currents move from the Antarctic northward along the west coast of South America. The east–west atmospheric pressure gradient across the Pacific Ocean causes an upwelling of cold, deep-ocean water off the Peruvian coast. The cold water then flows west in the tropics and is heated by the sun. These conditions result in Pacific Ocean temperatures 3°–8°C higher off the Australian coast than off South America. Easterly trade winds moving along the equator bring warm, moist air toward northern Australia and Indonesia, where it rises to high levels in the atmosphere over the warm seas. The rising air cools, producing low air pressures, cumulonimbus clouds and rain. The air then moves eastward at high altitude before sinking over the eastern Pacific Ocean and producing a high pressure system of dry air as it warms. This atmospheric circulation is known as the Walker circulation (figure 2-6).

Under El Niño conditions, the difference in Pacific Ocean temperatures between the Australian and South American coasts diminishes and the Walker circulation and trade winds weaken. The rising of moist air occurs over the central Pacific, resulting in less rain for eastern and northern Australia (figure 2-7).

The southern oscillation was originally defined to describe a tendency for atmospheric pressure over the Pacific Ocean to increase when pressure over the Indian Ocean decreased and vice versa. It is now used to describe large changes in the Walker circulation associated with the pattern of tropical Pacific Ocean surface temperatures.

The Southern Oscillation Index (SOI) is a simple measure of the strength and phase of the southern oscillation, indicating the condition of the Walker circulation. The SOI is the difference in air pressure between Darwin, on the eastern edge of the Indian Ocean, and Tahiti in the central Pacific. Under normal conditions the SOI is close to zero. In the El Niño phase of the southern oscillation, the SOI is strongly negative. When the SOI is strongly positive, the southern oscillation is in the anti-El Niño, or La Niña, phase and higher-than-usual rainfall is probable in eastern and northern Australia.

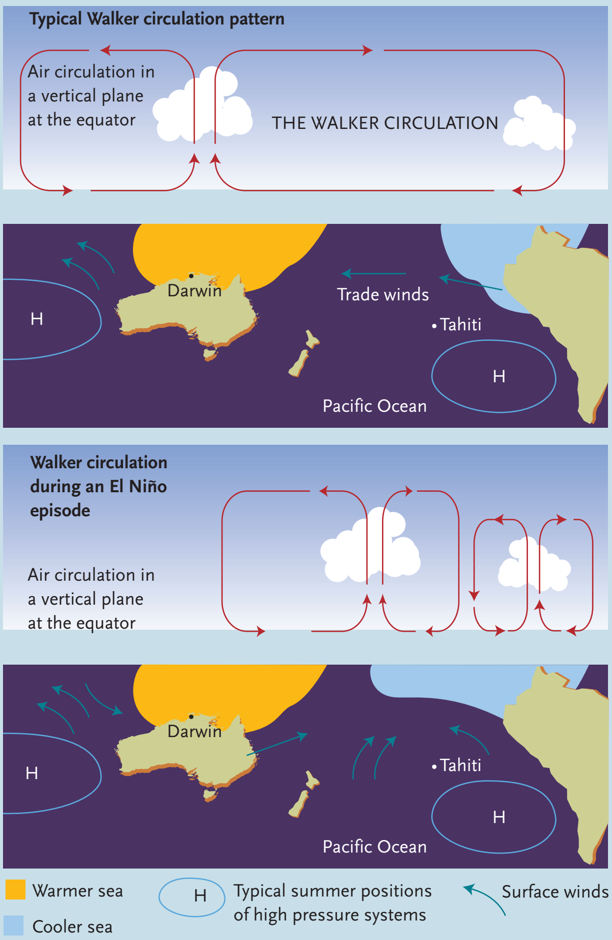


Figure 2-6 Walker circulation under normal and under El Niño conditions
(Source: BoM)

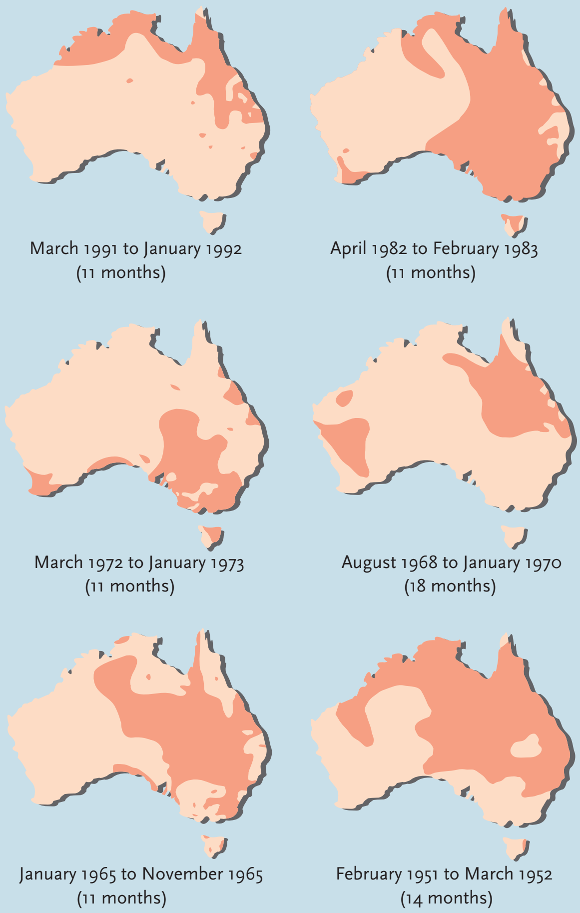
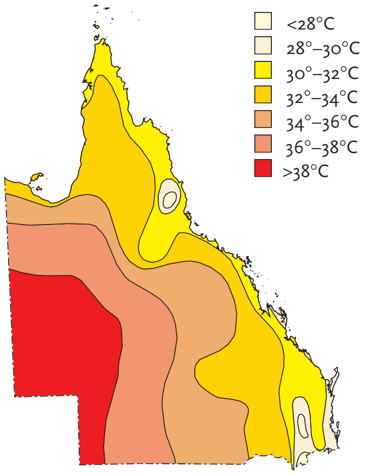
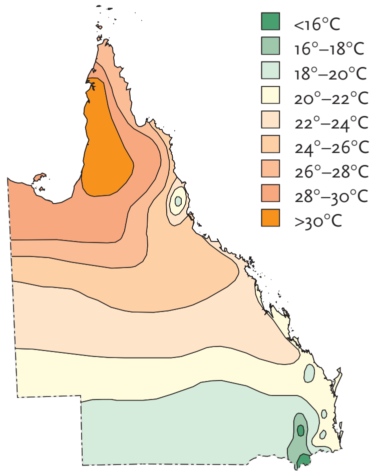


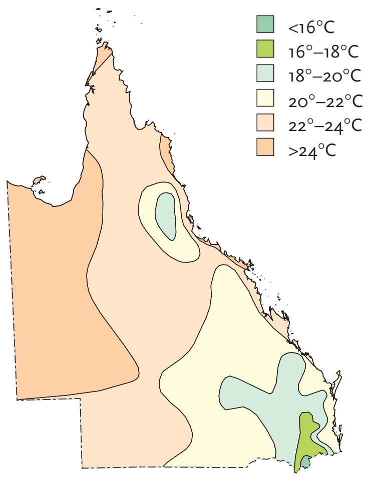
Figure 2-7 El Niño-related drought areas (shaded darker) in Australia since 1951
(Source: BoM)



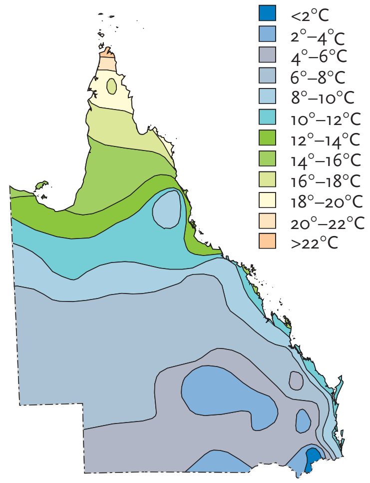
Average maximum temperatures in January



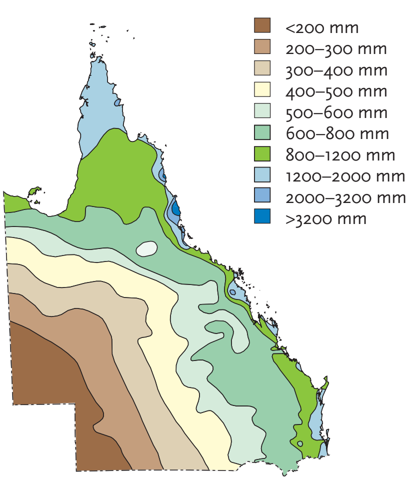
Average maximum temperatures in July



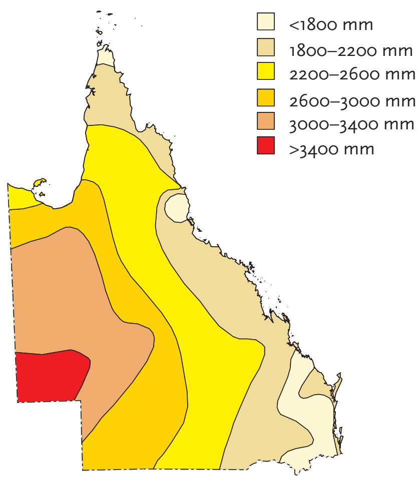
Average minimum temperatures in January



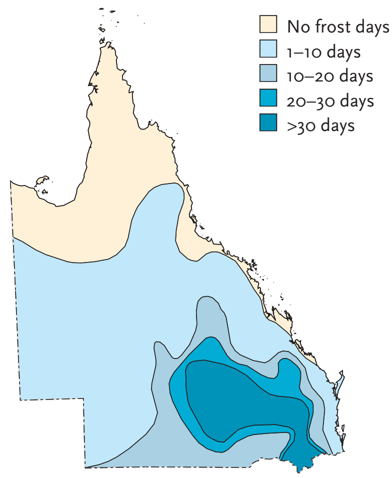
Average minimum temperatures in July



Median annual rainfall, all years of record to 1992



Average annual evaporation



Average annual number of frost days

Figure 2-8 Selected aspects of Queensland's climate
(Source: BoM)

Rainbows are caused by the refraction and reflection of sunlight by water droplets.

Climatic extremes

Queensland is susceptible to extremes of weather conditions, ranging from severe drought to severe floods associated with tropical cyclones. The formation of tropical cyclones in the Australian region occurs over the waters of the Timor Sea, Arafura Sea, Gulf of Carpentaria and Coral Sea.

Cyclones forming off the east coast of Queensland often move south-west before crossing the coastline or curving to the south-east, although they can take erratic and unpredictable paths. Under El Niño conditions, cyclones in the Pacific tend to form well east of the Queensland coast. Under La Niña conditions, more cyclones can be expected to cross the Queensland coast.

Frosts and thunderstorms with hail occur mainly in south-east Queensland, with other areas experiencing these conditions infrequently. The occurrence of drought or flooding in Queensland is strongly associated with the SOI. Based on knowledge of the climatic mechanisms involved, forecast systems for seasonal rainfall and frost have been developed using the SOI (Nicholls and Kariko 1993; Stone and Auliciems 1992; Stone et al. 1996).

Stratospheric ozone layer

Ozone (a compound consisting of three oxygen atoms bonded together) is formed in the stratosphere, with highest concentrations occurring 25 km above the Earth. Ozone absorbs terrestrial infrared radiation and solar UV radiation, causing an increase in temperature with increased ozone concentration. Consequently, in the stratosphere, containing the ozone layer, temperature increases with altitude (see figure 2-1).

The amount of ozone in the stratosphere varies over different parts of the globe. Stratospheric ozone is produced mainly in the tropics because of the higher intensity of solar radiation there. It is transported to higher latitudes by large-scale atmospheric circulation during the winter to spring months.

Ozone is a very reactive gas. The total amount of ozone in the stratosphere reflects the state of the dynamic equilibrium between the formation and destruction of ozone. The natural equilibrium concentrations of ozone have been established over very long time scales. However, in recent decades the introduction to the atmosphere of human-made pollutants, particularly those containing chlorine, has increased the rate of ozone destruction and threatens to change the equilibrium.

The ozone layer is an important atmospheric resource and its destruction has important consequences for the environment. The temperature profile of the atmosphere could change, with consequent changes in air circulation and rainfall patterns. Ozone depletion would also result in more solar UV radiation reaching the Earth's surface. Such radiation is known to be detrimental to living cells and some materials.

Tropospheric air quality

The troposphere is in direct contact with the surface of the Earth and interacts intimately with terrestrial life forms, materials and structures. It supports the life, health and well-being of humans and other organisms by providing oxygen and is therefore a most fundamental resource. It also allows transmission of the visible light spectrum, enabling sight. The relatively inert nature of the component gases gives longevity to the aesthetic appearance and useful attributes of buildings.

The troposphere comprises nitrogen (78 percent), oxygen (21 percent), argon (0.9 percent) and trace gases and

Frost in Girraween National Park, south-east Queensland

Bushfires produce considerable amounts of photochemical precursors and suspended particles.

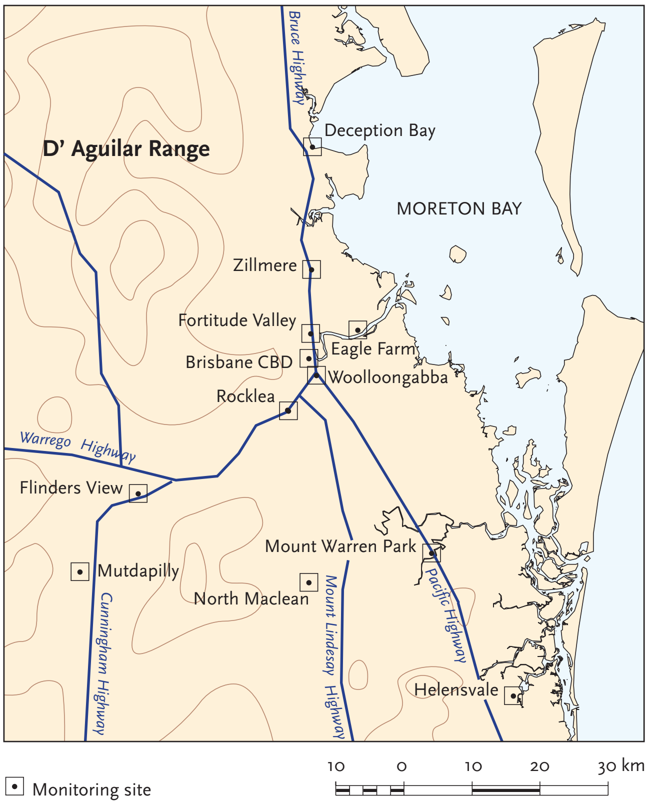


Figure 2-9 Key part of the south-east Queensland airshed, showing locations of major air quality monitoring sites in 1998

aerosols (0.1 percent) (table 2-1.) The trace gases and aerosols contain all the pollutants of interest from an air quality perspective. Breathing, absorbing or swallowing toxic pollutants affects the health of humans and other life forms. Buildings and structures can be corroded or soiled. Pleasant local surroundings can be degraded through reduced visibility or nuisance from smoke, dust and odour.

Tropospheric air quality is a major issue with respect to Queensland's major urban and industrial airsheds, particularly south-east Queensland and Gladstone.

South-east Queensland airshed

The south-east Queensland airshed is centred on Brisbane and extends from Gatton in the west to the Sunshine Coast in the north and the Gold Coast in the south. In 1995 this area contained 1.86 million people, 57 percent of the State's population. It is Australia's fastest growing region, and its population is expected to grow by another million by the year 2011.

The region has a small industrial base but very extensive residential development along the coastal strip. Its major economic activities are light industry and the commercial and

An aerial photo looking towards Brisbane's CBD shows the effect of a temperature inversion. This occurs when a layer of cold air traps warmer polluted air beneath it.

service sectors. Its population relies heavily on private motor vehicles for transport.

Relatively high temperatures experienced from early spring to late autumn, together with the considerable vegetation cover in the region, result in high levels of biogenic emissions of volatile organic compounds (VOCs) which accelerate the rate of formation of photochemical smog in the intense sunlight.

Bushfires and hazard-reduction burns often occur in spring and early summer, producing a considerable increase in the photochemical precursors nitrogen oxides and hydrocarbons, as well as particles, in the region. The formation of photochemical smog is discussed in more detail in the box on page 2.35.

Increased emissions accompanying future population growth and associated development, combined with the topography and climate, could create a potential for increased photochemical smog levels in the region. Brisbane is believed to have the highest photochemical pollution potential of any major Australian city.

Figure 2-10 Gladstone airshed

Provincial airsheds

Gladstone is a centre of major industrial activity in Queensland. The Gladstone coal-fired power station services a range of industries including aluminium smelting, cement and chemical manufacture. The airshed is defined by the Calliope River Valley and the offshore islands (figure 2-10).

Mount Isa, Rockhampton and Townsville are other provincial centres with major industrial activity. Mount Isa is the site of a large mineral ore smelting operation and its airshed is very extensive because of the combination of climate, topography and the dimensions of the ore smelter. Rockhampton lies about 30 km east of the Stanwell coal-fired power station. The Yabulu nickel processing plant is near Townsville.

Although many people live in and around Cairns, the city has no major industrial activity, so the airshed is not of immediate concern from an air pollution perspective.

Table 2-2 Environmental Protection Agency air monitoring locations and parameters monitored in recent years

Monitoring site	Air quality parameters									Meteorological parameters			
	Total suspended particles	PM_{10}	Visibility-reducing particles	Ozone	Photo-chemical smog	Carbon monoxide	Nitrogen oxides	Sulfur dioxide	Lead	Wind speed	Wind direction	Air temp.	Solar radiation
Deception Bay				✓			✓			✓	✓		
Zillmere				✓			✓			✓	✓		
Eagle Farm		✓	✓				✓	✓	✓	✓	✓	✓	
Fortitude Valley	✓					✓			✓	✓	✓		
Brisbane CBD		✓	✓	✓		✓	✓	✓		✓	✓		
Woolloongabba	✓	✓							✓				
Rocklea		✓	✓	✓	✓		✓		✓	✓	✓	✓	✓
Darra		✓							✓				
Mount Warren Park				✓			✓			✓	✓		
North Maclean				✓			✓			✓	✓		
Flinders View			✓	✓			✓	✓		✓	✓	✓	
Mutdapilly				✓			✓			✓	✓		
Barney Point (Gladstone)		✓	✓				✓	✓		✓	✓	✓	✓
South Gladstone							✓			✓	✓		
Clinton		✓											
Targinie			✓				✓	✓		✓	✓		
Parkhurst (Rockhampton)	✓												
Old Glenmore Estate	✓												
Mirani			✓							✓	✓		
South Townsville		✓											
Garbutt		✓											
Earlville (Cairns)	✓												
Menzies (Mount Isa)								✓		✓	✓		

Table 2-3 Summary of ambient air quality guidelines and standards

Pollutant	Averaging time	Maximum concentration (except as noted) EPP Air	NHMRC/ ANZECC	NEPM	WHO[d]	Victorian EPA[e]
Ozone (ppm)	1 hour	0.098	0.10[a]	0.10[a]	0.08	0.12
	4 hours	0.079		0.08		
	8 hours				0.06[g]	0.05
	24 hours	0.03				
	100 days of a growing season	0.03				
Nitrogen dioxide (ppm)	1 hour	0.16	0.16[c]	0.12[a]	0.11	0.15
	4 hours	0.046				
	24 hours					0.06
	1 year	0.01		0.03[a]	0.021	
Particles						
— as TSP (µg/m^3)	1 year	90	90			
— as PM$_{10}$ (µg/m^3)	24 hours	150		50[b]		
— as PM$_{10}$ (µg/m^3)	1 year	50				
— visibility-reducing (km local visual distance)	1 hour	20				20
Sulfur dioxide (ppm)	10 min	0.25	0.25		0.175	
	1 hour	0.20	0.20[a]	0.20[a]		0.17
	24 hours	0.04		0.08[a]	0.044	0.06
	1 year	0.02	0.02	0.02	0.02	
Carbon monoxide (ppm)	15 min				90	
	30 min				50	
	1 hour					30
	8 hours	8	9[a]	9[a]	10	10
Lead as TSP (µg/m^3)	3 months	1.5[f]	1.5			1.5
Lead (µg/m^3)	1 year			0.50	0.50	

a allowed to be exceeded one day a year
b allowed to be exceeded five days a year
c allowed to be exceeded one day a month
d WHO guidelines are converted from weight:volume ratios to ppm using standard conversion factors at 0°C
e acceptable level
f 90 days average
g proposed
EPP Air = *Environmental Protection (Air) Policy 1997*
NHMRC = National Health and Medical Research Council
ANZECC = Australian and New Zealand Environment and Conservation Council
NEPM = National Environment Protection Measure
WHO = World Health Organization
EPA = Environmental Protection Agency

Pressure

PRESSURE

Climate

The planet's energy balance and the global climate are affected by:
- greenhouse gases, especially carbon dioxide, methane and nitrous oxide;
- atmospheric aerosols, especially sulfates derived from fossil fuel, biomass burning and other sources; and
- halocarbons affecting stratospheric ozone.

Human activity is changing the concentrations of atmospheric gases and aerosols. Such changes have the potential to alter the global climate system.

Greenhouse gases

Indicator

Total greenhouse gas emissions

Human activities such as the burning of fossil fuels, land clearing and agriculture are increasing the atmospheric concentrations of greenhouse gases and aerosols. Aerosols — microscopic airborne particles — tend to cool the atmosphere. Together, greenhouse gases and aerosols affect climate-related parameters such as temperature, precipitation and sea level. Many greenhouse gases remain in the atmosphere for many years, whereas aerosols are very short-lived.

In 1996, Australia's net greenhouse gas emissions totalled the equivalent of 419 million tonnes (Mt) of carbon dioxide. On a per capita basis, Australia's emissions are the third highest in the world. Australia's rate of emissions growth is one of the highest in the world, with emissions projected to increase by 28 percent over 1990 levels by the Kyoto target date of 2008 unless significant abatement action is taken.

Queensland emissions in 1995 were 83.5 Mt CO_2 equivalent, approximately 21 percent of national emissions. Queensland's per capita emissions are higher than those of other States and Territories due to the size of the mining, minerals processing and agricultural sectors. The 1995 level represented a 19 percent increase from 1990 (land use change excepted). Emissions associated with stationary energy (primarily electricity generation) and transport are largely responsible for the increase in emissions over this period and collectively are responsible for the majority of emissions (figure 2-11). Net CO_2 emissions from the land use change and the forestry sector, associated largely with land clearing, were estimated at 44.6 Mt in 1995, the largest of any sector. However, estimates of emissions from this sector remain uncertain and further work is required to verify emission trends.

Greenhouse effect

The 'greenhouse effect' is a natural feature vital to life on Earth. Incoming solar radiation warms the Earth's surface which in turn emits infrared radiation. Water vapour and other gases such as carbon dioxide, methane and nitrous oxide then absorb some of this re-radiation, trapping heat in the atmosphere. These 'greenhouse gases' thus warm the atmosphere to maintain the Earth's global mean temperature at just over 15°C. Without this natural effect, the global mean temperature would be about 33°C lower (–18°C) and life as we know it would not exist.

Enhanced greenhouse effect

Since the industrial revolution, atmospheric concentrations of a number of greenhouse gases have increased significantly: carbon dioxide by 30 percent, methane by 145 percent and nitrous oxide by 115 percent (IPCC 1996). Although these gases occur naturally, their increasing concentrations can be attributed to human activities, largely the burning of fossil fuels, land use change and agriculture. Halocarbons, which are not natural constituents of the atmosphere, have also been released into it. These are powerful greenhouse gases and include chlorofluorocarbons (CFCs), which are responsible for ozone depletion.

As a result of increasing concentrations of greenhouse gases, more infrared radiation is expected to be trapped in the atmosphere, potentially causing significant warming and other changes to the planet's climate. The phenomenon is properly called the 'enhanced greenhouse effect' though it is more commonly referred to as the 'greenhouse effect'. Other terms used to describe the effect include 'global warming' and 'climate change'. Human-related emissions of the three main greenhouse gases since pre-industrial times have contributed about four-fifths of the enhanced greenhouse effect, with carbon dioxide accounting for 60 percent and methane for 15 percent (IPCC 1996).

Radiative forcing and global warming potentials

Radiative forcing is defined as the change in the net balance of radiation at the top of the troposphere due to a change in atmospheric composition (Manning et al. 1996). Increases in atmospheric greenhouse gas concentrations are increasing the radiative forcing of the atmosphere, causing the planet's climate to warm.

Greenhouse gases vary in their capacity to add to the radiative forcing of the atmosphere. The global warming potential (GWP) of each gas takes into account its atmospheric lifetime and its ability to absorb radiation. The direct GWP is calculated by comparing it with the radiative forcing resulting from the emission of 1 kg of carbon dioxide over a certain time. Methane also has an indirect effect due to its interaction with NO_x which leads to the formation of ozone, a significant greenhouse gas.

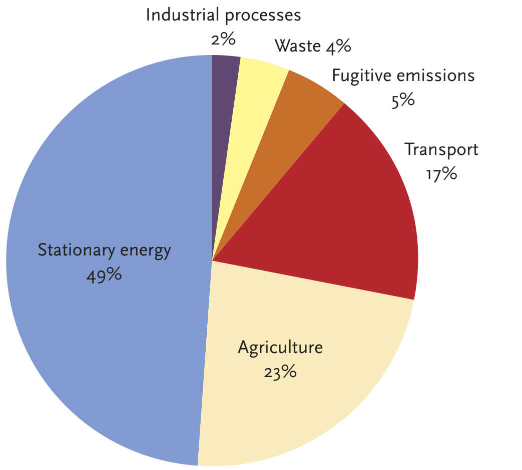


Figure 2-11 Contribution to total CO_2 equivalent emissions by sector (excluding land clearing and forestry), Queensland, 1995

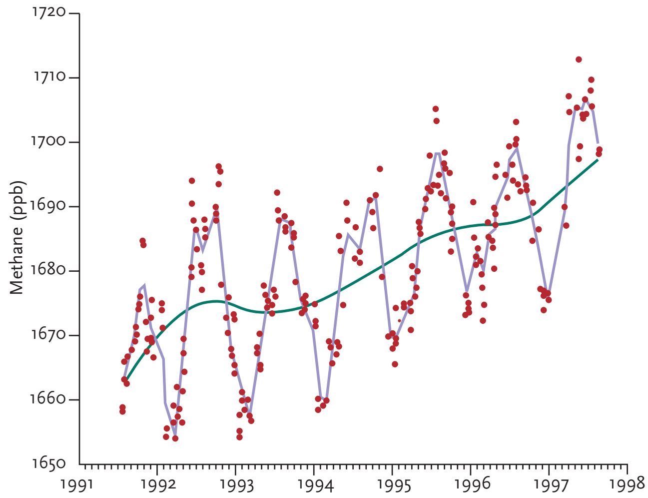


Figure 2-13 The annual atmospheric methane record in the marine boundary layer at Cape Ferguson
(Source: CSIRO Division of Atmospheric Research)

Carbon dioxide

Measurements of ice cores taken in Antarctica and Greenland indicate that global atmospheric concentrations of carbon dioxide have increased significantly since pre-industrial times, from 280 ppm in 1800 to 315 ppm in 1957 and to 358 ppm in 1994. Concentration continues to increase by about 1.5 ppm a year (IPCC 1996). This is mainly a result of fossil fuel burning. A similar recent pattern of change is evident in tropical Queensland (figure 2-12).

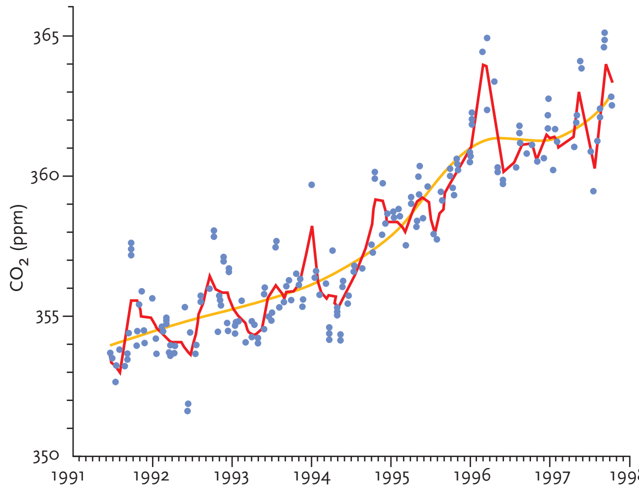


Figure 2-12 The annual atmospheric carbon dioxide record in the marine boundary layer at Cape Ferguson, near Townsville, Queensland
(Source: CSIRO Division of Atmospheric Research)

Methane

Methane is a significant greenhouse gas with a global warming potential (see box on page 2.17) of 21 over 100 years (IPCC 1996). Atmospheric concentrations have increased since pre-industrial times from about 700 ppb to more than 1700 ppb. Sources include agriculture, waste disposal and losses from coal seams during mining (IPCC 1996). Before the late 1970s, the rate of increase was as high as 20 ppb a year. Then followed a marked slow-down in the annual growth rate, with a stop in 1992. Increases resumed in 1993 and concentrations are now rising at around 8 ppb per year. Recent patterns in methane concentration (figure 2-13) highlight the seasonal variation as well as the overall increase.

Nitrous oxide

Nitrous oxide is emitted from many human activities including fertiliser applications, decomposition of animal wastes, industrial chemical production and biomass burning. While emissions are relatively small, nitrous oxide is considered a major greenhouse gas due to its capacity to absorb infrared radiation and its long atmospheric life (see table 2-1).

Analysis of ice core records indicates that atmospheric concentrations of nitrous oxide increased from around 275 ppb in pre-industrial times to around 312 ppb in 1994 (IPCC 1996). There appears to be an accelerating increase in nitrous oxide concentrations in tropical Queensland in recent years (figure 2-14).

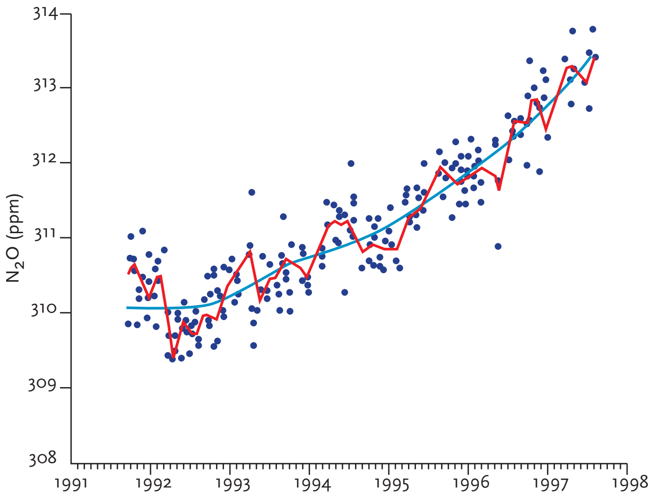


Figure 2-14 The annual atmospheric nitrous oxide record in the marine boundary layer at Cape Ferguson
(Source: CSIRO Division of Atmospheric Research)

Halocarbons

Halocarbons are carbon compounds containing bromine, chlorine, fluorine or iodine. Many halocarbons are effective greenhouse gases. Those containing bromine and chlorine (chlorofluorocarbons, or CFCs, and hydrochlorofluorocarbons, or HFCs) also deplete ozone. Under the terms of the 1987 Montreal Protocol and subsequent amendments, those halocarbons responsible for ozone depletion are being phased out of production. As a result, concentrations of some ozone-depleting halocarbons are beginning to stabilise in the atmosphere and should begin to decline in the decades ahead.

At the same time, atmospheric concentrations of other halocarbons not covered by the Montreal Protocol, including perfluorocarbons (PFCs) and HFCs, are continuing to increase. PFCs and HFCs are potent greenhouse gases, having global warming potentials ranging from 140 to 11 700 over a 100-year time horizon (IPCC 1996). Figure 2-15 shows trends in halocarbon concentrations.

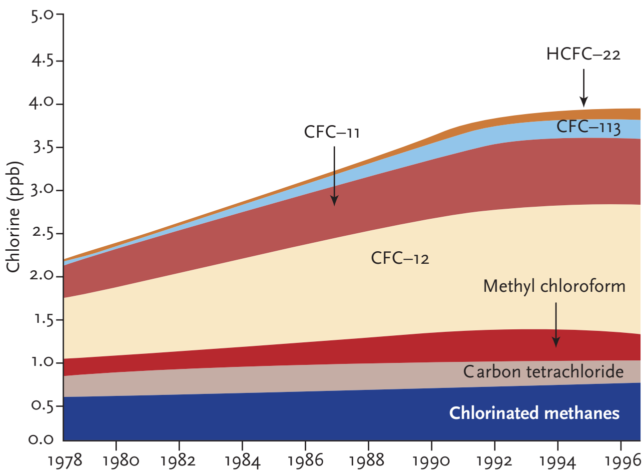


Figure 2-15 Total annual atmospheric chlorine concentration based on measurements of ozone-depleting gases at Cape Grim, Tasmania. Chlorocarbon concentrations have been multiplied by the number of chlorine atoms per molecule to yield the effective chlorine concentration contributed by each species.
(Source: CSIRO Division of Atmospheric Research)

Aerosols

Indicator
Sulfur dioxide emission levels

Atmospheric aerosols — most commonly, sulfate particles formed from sulfur dioxide emissions — can reflect incoming solar radiation and effectively reduce the solar input to the global energy system. The concentration of sulfate particles in the atmosphere is an indicator of pressure on the balance of radiative energy. Increases in atmospheric sulfates are thought to have reduced the effect that increases in greenhouse gases would otherwise have had on the global climate system.

Data are not available for sulfate particles and therefore sulfur dioxide emissions are used as a surrogate. Sulfur dioxide emissions in Queensland are discussed in the section 'Tropospheric air quality'.

STRATOSPHERIC OZONE

Indicator
Stratospheric ozone depletion

Evidence of stratospheric ozone layer change has been observed over the Antarctic region since the early 1980s. A 'hole' with up to 60 percent less ozone than usual now forms over Antarctica. Reduced ozone levels extend over southern Australia.

Chlorofluorocarbons have been used widely in the developed world as refrigerants, aerosol propellants, foam-blowing agents and solvents. The inert nature of CFCs makes them extremely stable in the tropospheric environment, with atmospheric lifetimes of 50–150 years. CFCs take about five years to move to the stratosphere. Once the CFC molecule is above the main body of the ozone layer, intense solar UV radiation disrupts it, releasing free chlorine atoms. These then react with ozone, destroying the ozone molecule but conserving the chlorine atom to react with and destroy more ozone.

Ozone depletion in the stratosphere could change the temperature profile and large-scale air circulations of the atmosphere, causing changes in regional climate. Details of ozone-depleting chemicals and a trend of increasing concentrations are shown in figure 2-15.

A one-percent decrease in stratospheric ozone concentrations has been estimated to lead to a 2.3 percent increase in the incidence of skin cancer (UNEP 1991) and an increase in the incidence of cataracts (see box 'Ultraviolet radiation' on page 2.20). However, these effects can be mitigated in humans by changed behaviour to reduce exposure to the sun.

UV-B radiation can penetrate short distances into clear water, which renders photosynthetic marine organisms susceptible to detrimental effects including reduced growth rates. The consequences for fish stocks and biodiversity are therefore potentially very significant.

The relative UV trend for Queensland between 1979 and 1992 shows a net increase in UV radiation. The trend for tropical Queensland (north of 20°S) is slightly higher (Udelhofen, P., pers. comm.).

Because the migration of ozone-depleting chemicals to the stratosphere is slow, measurements of these chemicals in well-mixed air are most relevant as indicators of pressure on stratospheric ozone. Figure 2-15 shows the trend of total atmospheric chlorine based on measurements of ozone-depleting gases from the baseline air pollution monitoring station at Cape Grim, Tasmania. These measurements are the background concentrations in the atmosphere of the Southern Hemisphere.

Measurements of ozone-depleting gases indicate that tropospheric chlorine concentrations have peaked and are decreasing, and stratospheric chlorine concentrations appear to be at a peak. Stratospheric ozone damage is expected to decline during the next 20–30 years (CSIRO 1996).

Since international conventions limited the use of CFCs, their manufacture and consumption have declined significantly. However, large quantities of CFCs remain in refrigerators and air conditioners manufactured before CFC use was restricted.

Ultraviolet radiation

For convenience in discussion, solar UV radiation is divided into three ranges of wavelength: UV-A (315–400 nanometres, or nm), UV-B (280–315 nm) and UV-C (100–280 nm). The atmosphere is relatively transparent to UV-A, which comprises nearly all the UV radiation reaching the Earth. Ozone in the stratosphere absorbs most UV-B radiation. Oxygen in the atmosphere absorbs UV-C radiation.

Average UV-B surface exposure increases towards the equator because of the combined effect of lower ozone concentrations over tropical regions and variations in sun zenith angle. The Southern Hemisphere is exposed to a higher intensity of solar radiation during the southern summer than the Northern Hemisphere is during the northern summer. This is due to variation in the distance to the Sun with the Earth's elliptical orbit. For these reasons, Queensland has one of the highest UV-B surface exposures in the world.

UV-B radiation has detrimental effects on the health of plants and animals. Exposure of skin can result in sunburn, the formation of skin cancers, premature ageing of the skin and suppression of the immune system. Exposure of the eyes to UV-B radiation can result in formation of cataracts and loss of vision. Plants, too, are adversely affected by UV-B radiation. It causes breakdown of some plant hormones and of chlorophyll, the chemical required for photosynthesis. Different behavioural, structural and biochemical features make some species more susceptible to UV-B radiation than others.

Tropospheric air quality

The development of air pollution problems in Queensland is limited by the State's dispersed population and low number of industrial centres by world standards. In addition, sites of major industrial activity are usually separated from the largest population centres, reducing the exposure of human populations to atmospheric pollutants.

Suspended particles

Indicator

Suspended particle emissions

The air we breathe includes particles we can see in the form of dust and smoke and others we cannot see. The term 'total suspended particles' (TSPs) means all particles from 50 micrometres (μm) to the smallest (0.1 μm). Particles less than 10 μm (PM_{10}) and particles less than 2.5 μm ($PM_{2.5}$) are of greatest concern in terms of human health because they are inhaled deeply into the lungs. In south-east Queensland, annual particle emissions from human sources are estimated at 22 000 tonnes. Industrial sources account for 65 percent of the emissions, about half of which come from the coalmining industry. A further 18 percent is attributed to motor vehicle emissions. Burning biomass including wildfires, controlled hazard-reduction fires and agricultural fires can also be a significant source of suspended particulate matter.

Estimated TSP emissions, calculated from fuel consumption data using emission factors from south-east Queensland (QDEH 1995), are given in figure 2-16. The data used do not include emissions from motor vehicles or biomass burning, which are possibly important sources. TSP emissions from motor vehicles are not directly related to fuel consumption due to variation in emission control devices and patterns of use. TSP emissions from motor vehicles are estimated at 4000 tonnes, less than 2 percent of the total in figure 2-16. Data are not available on emissions from biomass burning.

Acid deposition

Sulfur compounds are emitted to the atmosphere from natural and human-made sources. Natural sources include decomposing organic matter, both marine and terrestrial, and volcanic eruptions. Human-caused emissions are usually in the form of sulfur dioxide from fossil fuel combustion and smelting of mineral sulfide ores. Sulfur dioxide is readily oxidised in the atmosphere to form sulfate, which becomes sulfuric acid when dissolved in water.

Nitrogen oxides also have natural and human-made sources. Nitrogen-fixing bacteria in soils, lightning and natural fires all produce emissions of nitrogen oxides. All human-caused combustion activities where air is used as the oxidant — most significantly, fossil fuel and biomass combustion — produce nitrogen oxide emissions. Nitrogen oxides tend to be oxidised to nitrogen dioxide in the atmosphere, and this forms nitric acid when dissolved in water.

Sulfur dioxide and nitrogen dioxide tend to dissolve in the droplets of water which make up clouds, forming the corresponding acids which then produce acid rain. When water droplets are not available in the atmosphere, the oxides of nitrogen and sulfur may fall to the Earth's surface as dry particles which become acid when moisture is present on the ground.

The environmental effect of acid deposition depends on many factors, including soil type and available moisture in the environment. The critical load, or maximum input which can be tolerated without harmful effects, has been estimated for Australian soil types on a continent-wide basis (Chartres et al. 1995). In general terms, soils with pH>4.5 that experience low rainfall have a high critical load. Many soils with a sandy texture have a low critical load.

Acid deposition in North America and Europe has led to significant environmental damage. The accumulation of acids decreases soil pH, enabling the release of aluminium from the soil matrix, which causes disease and death in many plants. Acidification of water bodies has occurred to such an extent in some areas of North America and Scandinavia that lakes are too acidic to support fish life.

In Australia, acidification of soils from agricultural activity is more significant than atmospheric deposition of acids. However, considerable areas of soil in humid regions could be susceptible to acidification from industrial emissions (Chartres et al. 1995). Acidification of water bodies from acid deposition is not known to have occurred in Australia.

Health effects of common air pollutants

Suspended particles, particularly those less than 10 µm in diameter, can cause increased morbidity and mortality, and impaired lung function, although the mechanism of action is not well known.

Nitrogen dioxide damages lung tissue, decreasing respiratory function and interfering with bronchial clearance mechanisms, resulting in increased susceptibility to respiratory infection and asthma.

Ozone irritates mucous membranes in the eyes, nose, throat and lungs. It also produces increases in airway reactivity and decreases lung function in healthy people, especially during exercise.

Sulfur dioxide aggravates pre-existing lung conditions such as chronic bronchitis and asthma, causing impaired pulmonary function and increased morbidity and mortality. It irritates nerve endings in the air passages, producing an irritant cough and increased mucous secretion and increased susceptibility to respiratory infection.

Carbon monoxide forms a stable complex with haemoglobin in red blood cells, reducing the ability of the blood to transport oxygen from the lungs throughout the body. The resulting oxygen deficiency can impair or damage tissues such as the brain, nerves and heart muscle which require large amounts of oxygen to function normally.

Lead in suspended particles is readily absorbed by the body through the lungs and the gut, and at high concentrations causes impaired liver and kidney functions and neurological damage. More importantly, low concentrations of lead in children from before birth to early school age impair the maturation of nerve cells, causing reduced intellectual development and psychological dysfunction.

Benzene is carcinogenic, causing acute myeloid leukaemia. It also causes bone marrow depression, leading to aplastic anaemia (WHO 1993).

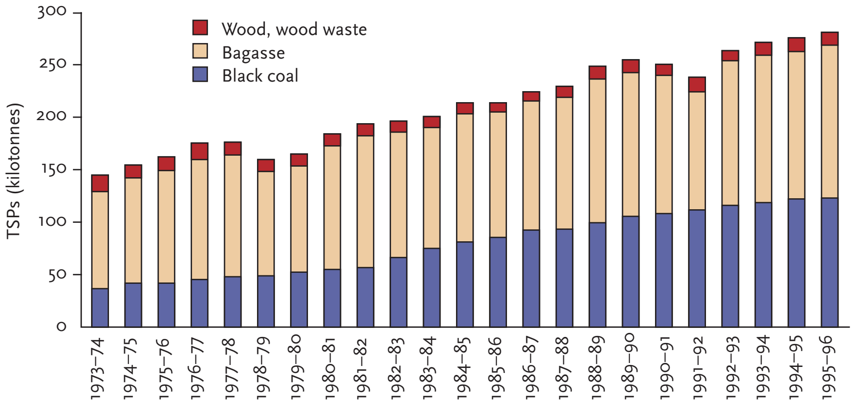


Figure 2-16 Estimated annual total suspended particle (TSP) emissions from fuel consumption at stationary sources in Queensland, 1973–74 to 1995–96

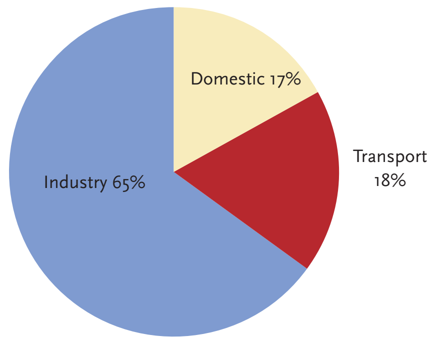


Figure 2-17 Particle emissions by source category in south-east Queensland in 1993

Encroachment of residential and urban districts on industrial zones can increase human exposure to air pollutants.

Nitrogen oxides

Indicator

Nitrogen oxide emissions

Nitrogen oxides (NO_X) are formed when air is heated to high temperatures such as in a flame. Any combustion process which uses air as the oxidant will generate nitrogen oxides as a by-product.

The major source of nitrogen oxide emissions in urban areas is motor vehicle emissions, which accounted for 70 percent of total NO_X emissions in the South East Queensland Air Emissions Inventory (QDEH 1995). Industries such as coal-fired power stations are also a major source of NO_X, although they tend to be located away from urban areas and use tall stacks to enhance dispersion. Burning biomass can also be a significant source of NO_X.

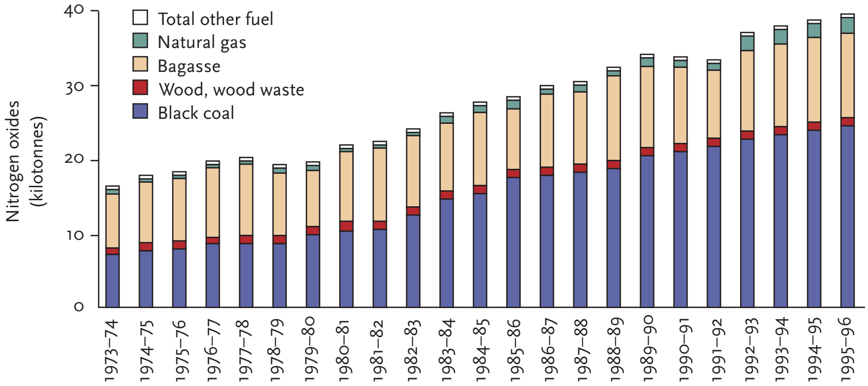


Figure 2-18 Estimated annual emissions of nitrogen oxides from fuel consumption at stationary sources in Queensland, 1973–74 to 1995–96

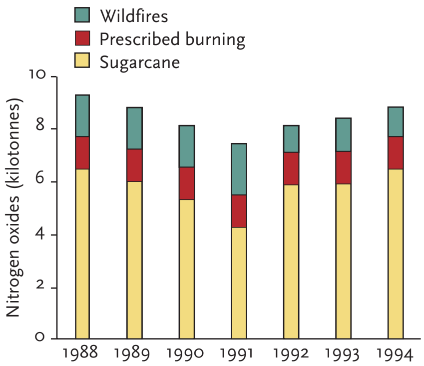


Figure 2-19 Estimated annual emissions of nitrogen oxides from burning biomass in Queensland, 1988–94. In Queensland, nitrogen oxide emissions are precursors to photochemical oxidant formation.

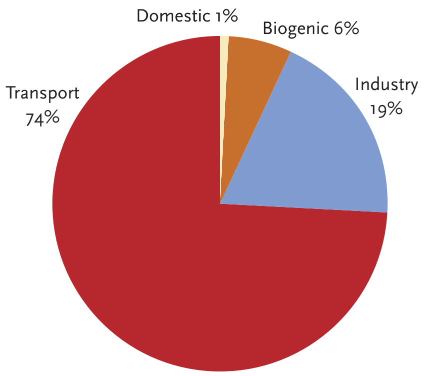


Figure 2-20 Emissions of nitrogen oxides by source category in south-east Queensland in 1993

Estimates of NO_X emissions are given in figure 2-18. Data do not include emissions from motor vehicles or biomass burning, which are possibly the most important sources. NO_X emissions from motor vehicles are not directly related to fuel consumption due to variation in emission control devices and patterns of use. Nitrogen dioxide levels in south-east Queensland change from year to year; the changes show no obvious correlations with traffic volume. Levels of NO_2 in south-east Queensland are below those of Perth and well below those of Sydney and Melbourne. Levels in Gladstone are below the NHMRC and ANZECC guideline.

The National Greenhouse Gas Inventory has estimated NO_X emissions from biomass burning. Using the same methodology, emissions from wildfires, prescribed burning and sugarcane burning have been estimated. Data in figure 2-19 add approximately 20 percent to stationary source emissions.

Transport accounts for almost three-quarters of all NO_X emissions in south-east Queensland (figure 2-20). The average age of Queensland's registered motor vehicles is about 10 years. If government fleets are excluded, the average age is estimated at 14 years. Design changes including cleaner emissions can take years to have measurable effects, so transport is likely to remain a major source of NO_X in the future.

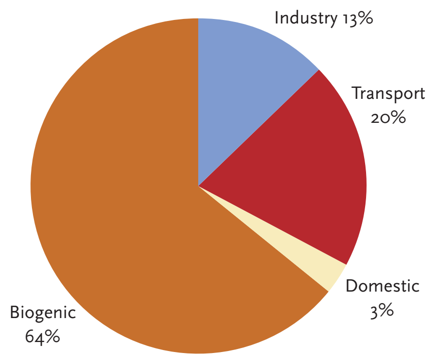


Figure 2-21 Emissions of volatile organic compounds by source category in south-east Queensland in 1993

Volatile organic compounds

Indicator

Volatile organic compound emissions

Volatile organic compounds (VOCs) react with nitrogen oxides in the presence of sunlight to produce photochemical oxidants. VOC emissions from human sources are dominated by motor vehicle emissions. However, industrial emissions tend to be more concentrated and have a significant local influence. Burning biomass can also be a significant source of VOCs.

In south-east Queensland, human-related emissions of VOCs are estimated at 84 000 tonnes a year based on 1993 data. Biogenic emissions for the same period are estimated at 148 000 tonnes, almost two-thirds of total emissions (figure 2-21). Biogenic emissions may have been underestimated due to limitations in availability of data (Riese 1996).

Estimated VOC emissions from fuel use data, using emission factors from the South East Queensland Air Emissions Inventory (QDEH 1995), are presented in figure 2-22. The figure does not include emissions from motor vehicles or biomass burning, which are possibly important sources. VOC emissions from motor vehicles are not directly related to fuel use, due to variation in emission control devices and patterns of use. The South East Queensland Air Emissions Inventory estimated VOC emissions from motor vehicles to be 43 kilotonnes in 1993, which adds about 20 percent to the total for that year.

The National Greenhouse Gas Inventory has estimated VOC emissions from biomass burning. Using the same methodology, emissions from bushfires, prescribed burning and sugarcane burning have been estimated. Data in figure 2-23 add about 10 percent to stationary source emissions.

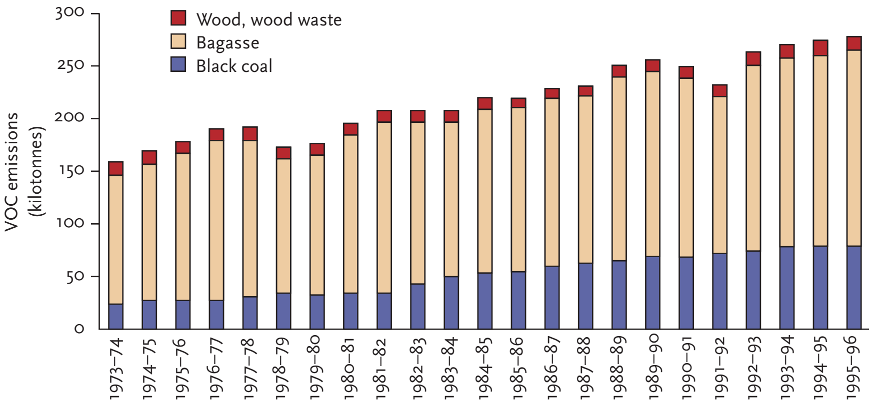


Figure 2-22 Estimated annual VOC emissions from fuel consumption at stationary sources in Queensland, 1973–74 to 1995–96

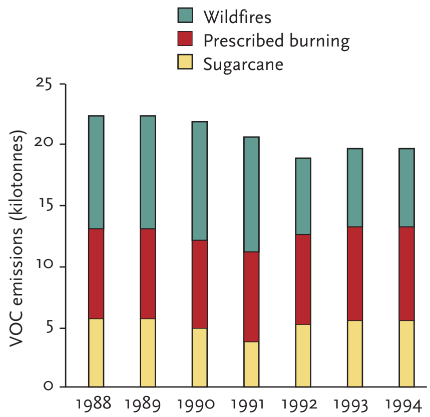


Figure 2-23 Estimated annual VOC emissions from burning biomass in Queensland, 1988–94

Griffith University (AES)

Cane fires are a significant source of suspended particles.

Sulfur dioxide

Indicator
Sulfur dioxide emissions

Sources of sulfur dioxide are primarily smelting industries and combustion of fossil fuel. The copper and lead smelters at Mount Isa combined are among the largest point sources of sulfur dioxide in the world, producing about one-third of Australia's emissions and more than half as much as is emitted in the whole of Japan (Rosser and Gilmour 1994). The smelters are operated with feedback from a network of 10 ambient sulfur dioxide monitoring stations in the urban areas of Mount Isa. Production is reduced when emissions are found to be affecting air quality.

Estimated annual emissions of sulfur dioxide in Queensland for the period 1985–86 to 1995–96 are given in figure 2-24. With both Mount Isa smelters operating at full capacity, a total of 975 000 tonnes of sulfur dioxide would be emitted in a year.

Black coal is the major fossil fuel contributing to sulfur dioxide emissions in Queensland. Estimates of sulfur dioxide emissions from fuel use have been calculated from ABARE data and are presented in figure 2-25.

Emissions of sulfur dioxide from transport fuel use remain low relative to total emissions, as shown in figure 2-26. The increasing trend in the use of black coal, due to an increasing demand for electricity, is reflected in emission estimates. Coal-fired power stations in Queensland generally use coals with low sulfur content and sulfur dioxide emissions are comparatively low, even for Queensland's largest stations at Gladstone (1680 MW), Tarong (1400 MW) and Stanwell (1050 MW). Smaller sulfur dioxide sources of local relevance are oil refineries and coal-fired power stations in other areas.

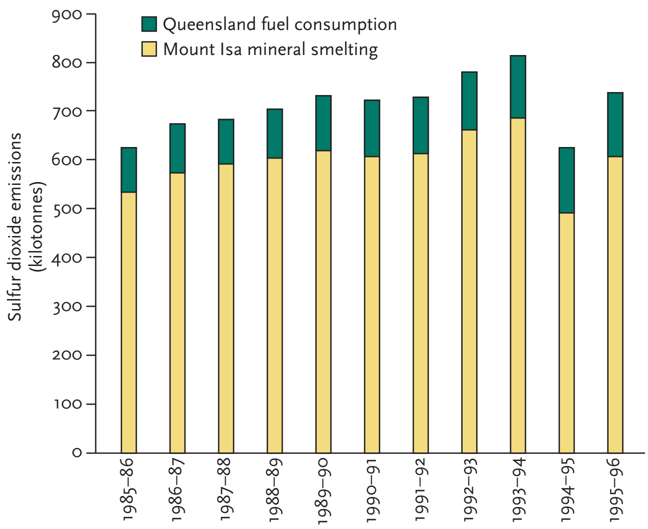


Figure 2-24 Estimated annual sulfur dioxide emissions in Queensland, 1985–86 to 1995–96. Mount Isa mineral smelting estimates are based on published production data for the smelters and the sulfur content of concentrate determined for 1994–95 (Teague, J., MIM, pers. comm.). Fossil fuel estimates are based on ABARE fuel consumption data for Queensland and sulfur content of fuels. Black coal, used mainly for electricity generation, is the greatest contributor of sulfur dioxide from fossil fuel. Sulfur dioxide emissions from both sources are tending to increase. The decrease in estimated emissions from Mount Isa in 1994–95 and 1995–96 is due to lost production during industrial disputes.

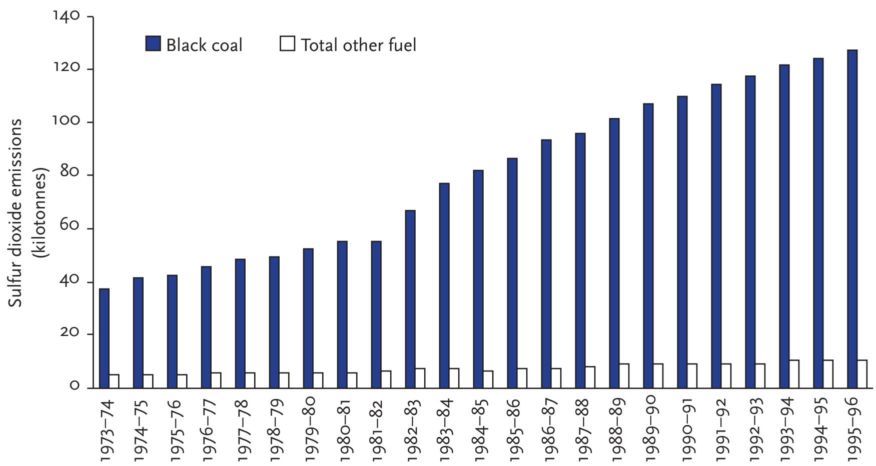


Figure 2-25 Annual sulfur dioxide emissions from fuel consumption in Queensland, 1973–74 to 1995–96. In south-east Queensland, emissions are dominated by industrial sources, which contribute 90 percent of total emissions; motor vehicle emissions contribute the remainder. The industries responsible for most emissions are petrochemical refining, power generation and asphalt manufacture. Tall stacks are used to disperse sulfur dioxide and decrease the potential for adverse effects on ground-level air quality.

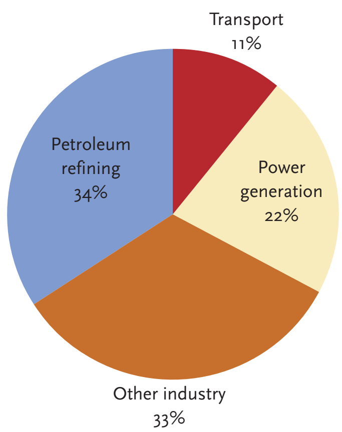


Figure 2-26 Sulfur dioxide emissions by source category in south-east Queensland in 1993

Carbon monoxide

Indicator
Carbon monoxide emissions

Carbon monoxide (CO) is produced from the incomplete combustion of carbon-based fuels. Motor vehicles are the main source of carbon monoxide in urban airsheds, contributing 83 percent of total emissions according to the South East Queensland Air Emissions Inventory (QDEH 1995). Statewide CO emissions are given in figure 2-27.

Emissions from motor vehicles are not directly related to fuel consumption due to variation in emission control devices and patterns of use. In 1993, the South East Queensland Air Emissions Inventory estimated emissions from motor vehicles to be 33 000 tonnes, about 20 percent of the total for Queensland for that year.

The National Greenhouse Gas Inventory has estimated carbon monoxide emissions from biomass burning. Using the same methodology, estimates of emissions from bushfires, prescribed burning and sugarcane burning have been calculated. The data in figure 2-28 add approximately 10 percent to the stationary source emissions, but transport remains the major source of carbon monoxide.

Lead

Indicator
Lead emissions

Generally, motor vehicle emissions are the major source of atmospheric lead in urban areas, accounting for approximately 90 percent of all lead emissions in those areas. The remainder comes from industry. Exceptions occur near mineral smelting operations such as Mount Isa where industrial emissions dominate.

Australian design rule ADR37, introduced in 1986, tightened vehicle emission limits and made compulsory the use of unleaded petrol in new motor vehicles. ADR70, introduced in 1995–96, limited particle, hydrocarbon and nitrogen oxide emissions from diesel-fuelled vehicles. ADR37/01 took effect in 1997, further tightening the limits for emissions from petrol-fuelled vehicles.

Since the introduction of ADR37 in 1986, the use of leaded petrol has been declining. In addition, a voluntary program was initiated by government and the oil industry to reduce the lead content of leaded petrol from 0.84 g/L before 1991 to 0.2 g/L from 1996, and this has greatly accelerated the reduction of lead emissions to the atmosphere.

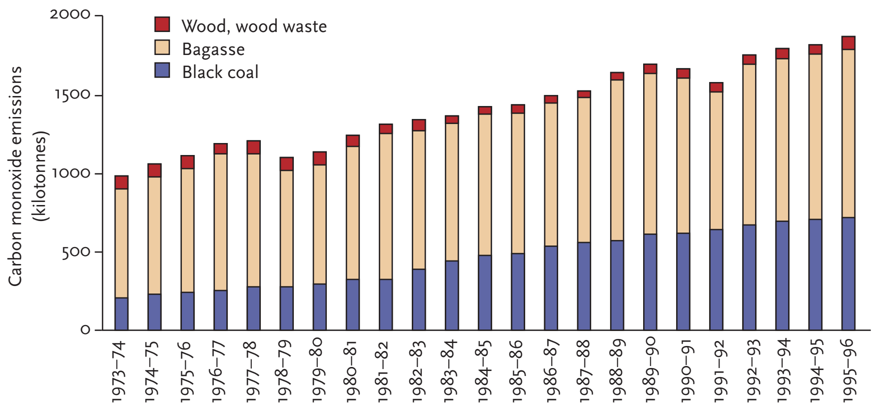


Figure 2-27 Estimated annual carbon monoxide emissions from fuel consumption at stationary sources in Queensland, 1973–74 to 1995–96, excluding motor vehicles and biomass burning

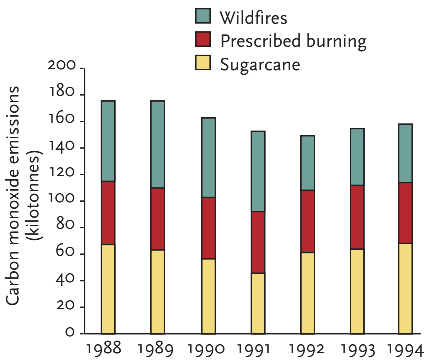


Figure 2-28 Estimated annual carbon monoxide emissions from biomass burning in Queensland, 1988–94

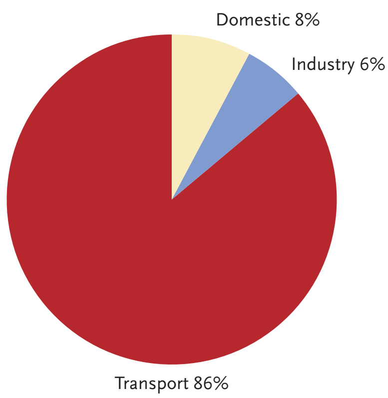


Figure 2-29 Carbon monoxide emissions by source category in south-east Queensland in 1993

Motor vehicles are a major source of carbon monoxide and lead emissions in urban centres.

Estimated lead emissions, calculated from ABARE fuel consumption figures and the agreed lead content of leaded petrol, are given in figure 2-30.

Fluoride

Indicator
Fluoride emissions

Hydrogen fluoride is one of the most toxic atmospheric trace gases, affecting plants at one-thousandth of the concentration of sulfur dioxide that causes injury. Emissions of this gas in Queensland are very localised, being associated with aluminium production, superphosphate manufacture, and brick and glass firing. Efficient techniques are available in several industries to capture and recycle gaseous fluoride, so that emissions to the atmosphere are limited in quantity and geographic distribution.

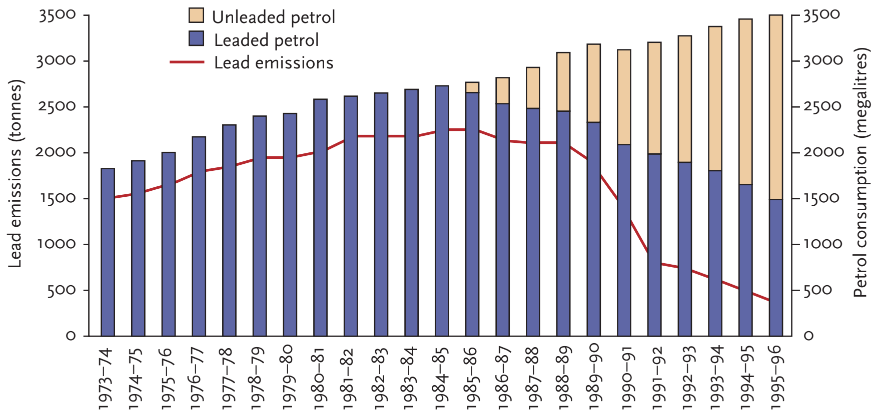


Figure 2-30 Estimated annual lead emissions from and petrol consumption by motor vehicles in Queensland, 1973–74 to 1995–96

Weather conditions

Indicator
Weather conditions

The concentration of pollutants in the air is a function not only of the amount emitted but also of the extent of dilution by dispersion throughout the atmosphere. Variation in weather conditions generally has a greater influence on the day-to-day pollutant concentrations in an airshed than variation in emissions. Under stable, non-dispersive conditions, pollutants tend not to be transported far from the source or diluted. Instead, they accumulate and are recirculated in the airshed.

A windfield study of south-east Queensland by the Queensland Department of Environment and Heritage in 1993 identified weather conditions for typical photochemical smog event days in summer and winter. A mathematical model was used to simulate the transport, dispersion and transformation of pollution in the region. The study showed that high photochemical pollution days are associated with hot, still conditions under the influence of light north-westerly winds in summer, and very light winds in winter and spring. Monitoring data confirmed predictions of recirculation of pollutants in the airshed, although recirculation was sensitive to small changes in conditions. Trajectories of morning and afternoon emissions are sensitive to source location and winds, due to areas of stagnation associated with light winds.

Griffith University (AES)

Weather conditions influence day-to-day pollutant concentrations through dispersion and transportation of pollutants away from their sources.

CLIMATE

Indicators

Maximum temperature

Minimum temperature

Number of days less than 10ºC

Number of days greater than 30ºC

Rainfall

Number of rain days

Number of cyclones

Number of strong wind days

Number of thunder days

'Climate' is the statistical description of the state of the atmosphere (rainfall, temperature, cloudiness, wind, evaporation etc.) over periods of time significantly longer than the lifetimes of individual weather-producing systems that affect it. For climatic data to be meaningful, weather variables must be described in terms of the averages, extremes, ranges, standard deviations and frequency distributions of the individual weather elements. Generally, the climate of a place or region consists of a range of conditions occurring over time. Historically, a 30-year time period has been taken to approximate what is assumed to be a stable, long-term regime, 'the normal climate'. In recent years, however, the concept of a normal climate has become all but obsolete.

'Natural climate variability' describes climate variations due to fluctuations in the solar constant, the orbital conditions of the Earth or some other natural phenomenon. Variation from month to month, or from one averaging period to the next, or from place to place, gives rise to the 'climatic variability' which exists inherently in the climate system.

'Climate change' is a term linked to recent trends which are believed to result from human interference in the natural radiative properties of the atmosphere, due to increased greenhouse gas emissions.

In Australia, information about climate comes from an extensive weather observation network operated throughout the country by the Bureau of Meteorology. Upper-air meteorological observation stations provide data on wind speed and direction, temperature and humidity up to an altitude of about 20 km.

Willy-willy at Windorah

The Bureau also operates radar tracking systems to detect winds and rain, providing an invaluable component of the Australian tropical cyclone warning system. Australian meteorologists make extensive use of data from Japan's Geostationary Meteorological Satellite and the US NOAA series of polar orbiting satellites.

Twenty meteorological stations have been selected as climate reference stations to detect any change in Queensland's climate. These are Thursday Island, Weipa, Burketown, Mount Isa, Richmond, Cairns, Townsville, Mackay, Longreach, Winton, Birdsville, Rockhampton, Gladstone, Amberley, Tewantin, Miles, St George, Charleville, Thargomindah and Willis Island. All stations have at least 30 years of consistent, continuous weather records.

The Bureau of Meteorology has compiled averaged annual rainfall and mean temperature extremes for Queensland (figures 2-31 and 2-32)(Lavery et al. 1997; Torok and Nicholls 1996). Data from climate reference stations in each of the State's three climatic regions have been selected to provide examples of trends in other climate variables. These do not necessarily represent trends for the climatic region as a whole, but are indicative of local variation in climate. The sites are Richmond and Cairns in the tropical north, Amberley and Rockhampton in the subtropical south-east, and Birdsville in the arid subtropical west.

Rainfall

Rainfall deficits (amounts less than mean average rainfalls) occurred in eastern Queensland during the 1990s. Rainfalls for 1991–95 at stations in central and north-eastern Queensland were the lowest on record. (At most stations records have been kept for more than 100 years.)

Between 1991 and 1995 the following worst-on-record rainfall deficits in eastern Queensland were recorded:

- 1.87 metres fell in five years three months in Toowoomba (the amount normally expected in two years) — this was the greatest deficit since records began in 1870;
- 2.8 metres fell in four years five months in Townsville (normally 2.4 years) — the greatest deficit since records began in 1871;
- 1.4 metres fell in four years five months in Charters Towers (normally 2.2 years) — the greatest deficit since records began in 1882;
- 1.4 metres fell in five years three months in Toogoolawah (normally 1.6 years) — the greatest deficit since records began in 1909;
- 1.7 metres fell in four years five months in Beaudesert (normally 1.8 years) — the greatest deficit since records began in 1893;
- 1.3 metres fell in four years five months in Gatton (normally 1.7 years) — the greatest deficit since records began in 1895; and
- Brisbane City had a record 64 days without rain between 24 July and 26 September 1991.

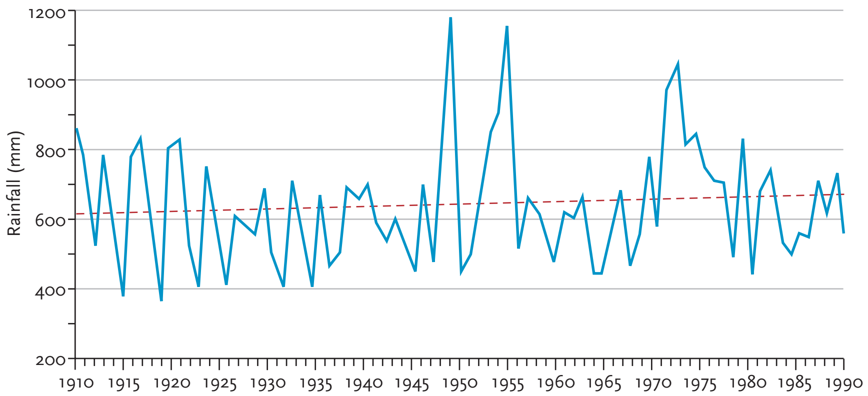


Figure 2-31 Averaged annual rainfall for Queensland, 1910–90. The increasing trend is small relative to the annual variation, and might not be significant.

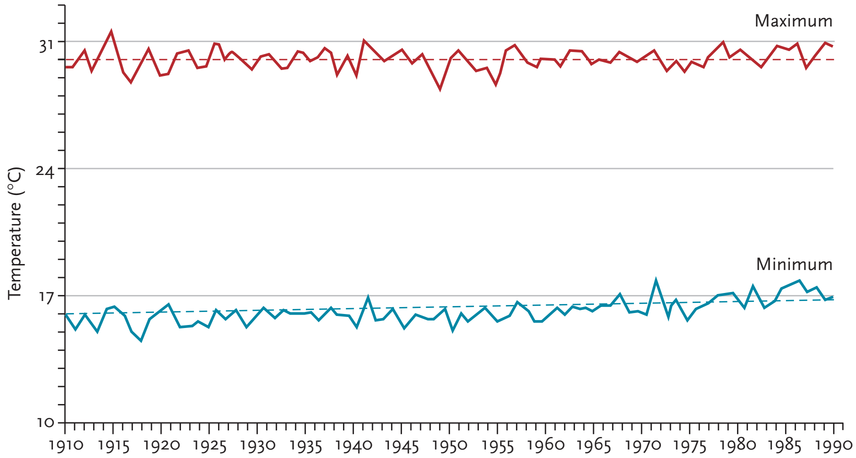


Figure 2-32 Averaged annual mean maximum and minimum temperatures for Queensland, 1910–91
(Source: BoM)

Temperature

Trends in the frequency of frosts have been investigated at several locations in Queensland (Emerald, Biloela, Roma, Dalby, Goondiwindi, Charleville) and New South Wales (Tamworth, Dubbo, Moree) where high-quality, long-term, daily data were available (Stone et al. 1996).

Fewer frosts were observed recently for Emerald, Biloela, Roma, Dalby, Goondiwindi and Tamworth. A trend towards an earlier last date of frost was observed for Emerald, Biloela, Roma, Goondiwindi and Tamworth. Figure 2-32 shows a trend of increasing minimum temperature with no change in maximum temperature.

Climatic extremes

Cyclones are a feature of climate in the Queensland region (all Queensland, the Gulf of Carpentaria and waters east to 160°E). Cyclones nearing or crossing the coast can result in severe wind, high rainfall and flooding (figure 2-33).

Snow is rarely seen in south-east Queensland. However, substantial falls can occur, as this photograph taken at Girraween National Park in June 1985 demonstrates.

Relationships between the number of cyclones and other weather features under El Niño and under La Niña conditions are discussed in the introduction to this chapter, under 'Queensland's climate'. (See also Evans and Allan 1992; Puotinen et al. 1997.)

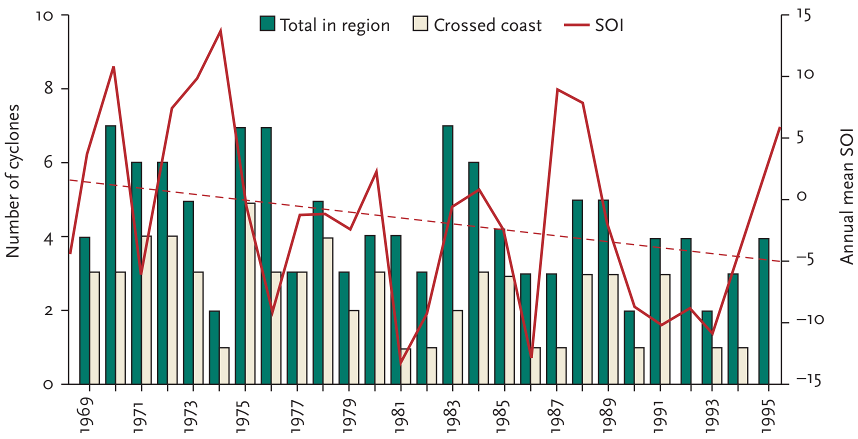


Figure 2-33 Annual number of cyclones occurring in the Queensland region, number crossing the Queensland coast, trend in total cyclones, and annual mean SOI for the period 1969–95
(Source: BoM)

STRATOSPHERIC OZONE

Indicator
Stratospheric ozone concentration across Australia

Ozone depletion

Figure 2-34 gives data from the total ozone mapping spectrometer on the NASA Nimbus 7 satellite from November 1978 to March 1991. This shows significant declines in total column ozone for winter and summer at middle and high latitudes in both hemispheres. No statistically significant trends have been observed in the tropics. With the exception of Cape York Peninsula north of Cooktown, Queensland lies in the 15º–35ºS zone.

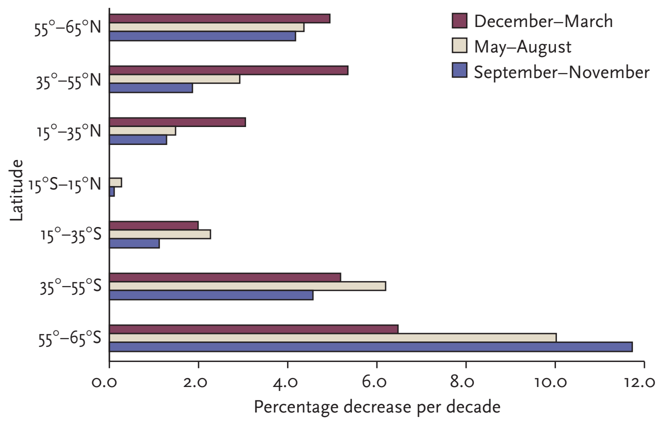


Figure 2-34 Percentage 10-year decrease in global ozone by latitude zone for three periods of the year based on 1978–91 data

Total column ozone above Brisbane Airport has been monitored since February 1985. Three to five measurements are made daily, using a Dobson spectrophotometer. One ozone-sonde balloon flight is made each week. Figure 2-35 shows that, while variations are substantial from season to season and year to year, no long-term trend is obvious.

UV radiation

Australian Radiation Laboratories operates a network of 16 UV radiation monitoring stations in Australia and Antarctica, including four sites in Queensland — Brisbane, Toowoomba, Mackay and Townsville. The relative

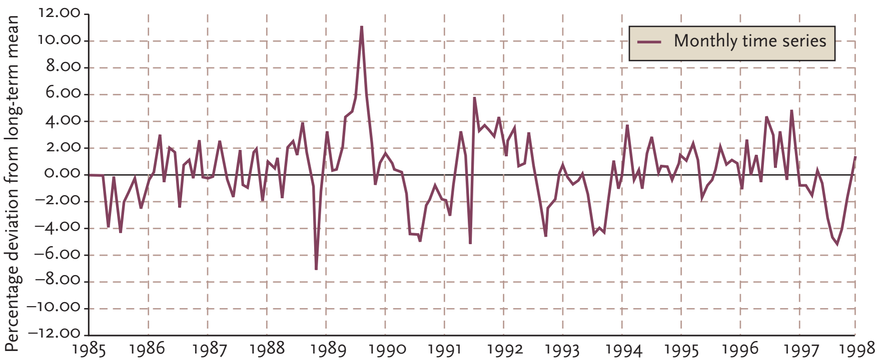


Figure 2-35 Time series of seasonally normalised monthly mean total ozone anomalies (percentage deviations from the long-term monthly mean) for Brisbane, 1985–97
(Courtesy of Philip Shinkfield, Cooperative Research Centre for Southern Hemisphere Meteorology)

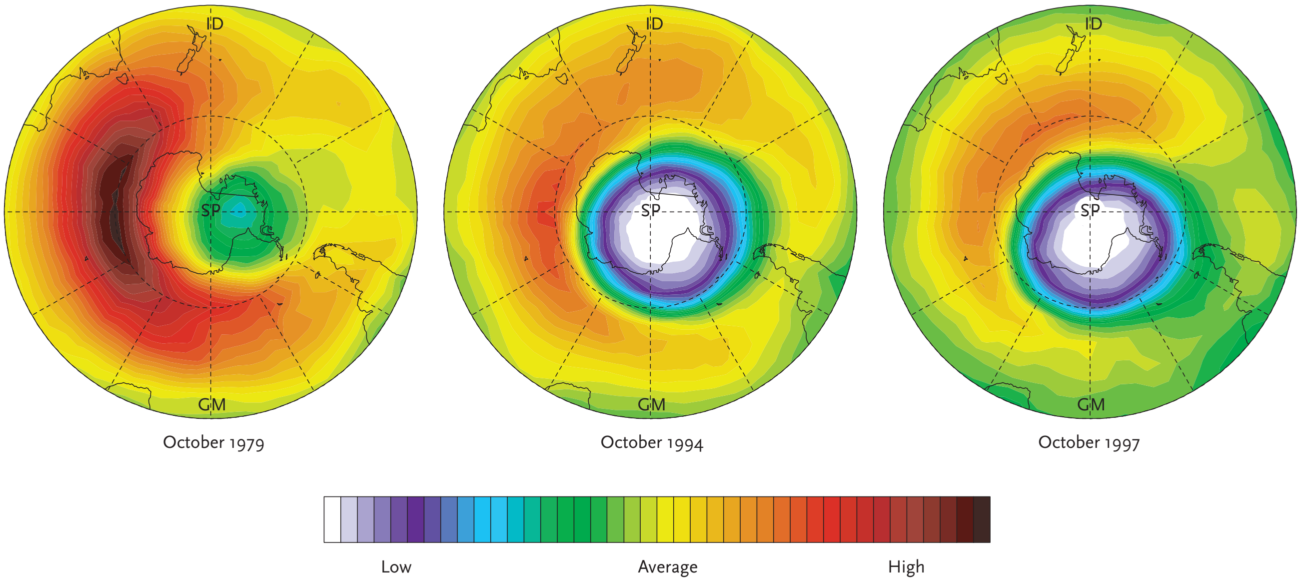


Figure 2-36 October mean ozone distribution over the Southern Hemisphere in 1979, 1994 and 1997, showing the extent of springtime Antarctic ozone depletion reached in recent years. During winter, temperatures fall below –80°C in the highly isolated polar stratosphere, triggering a chain of chemical reactions that lead to rapid ozone destruction and the formation of the springtime ozone hole (coloured white and blue). Between Antarctica and Australia, a crescent-shaped ozone 'mountain' (coloured black and red) has been eroded away by processes that are still being investigated. (SP — South Pole; ID — International Date Line; GM — Greenwich Meridian)
(Courtesy of Dr Roger Atkinson, Cooperative Research Centre for Southern Hemisphere Meteorology)

UV trend for Queensland, based on data collected by NASA between 1979 and 1992, shows an increase of 3.2 percent (±3.5 percent) per decade from the climatological averaged value of 4677 J/m^2. The trend for tropical Queensland (north of 20°S) shows an increase of 3.8 percent (±2.8 percent) per decade from the averaged value of 5132 J/m^2 (Udelhofen, P., pers. comm.).The high variation in UV radiation measurements is due to the inherent difficulties in calibrating detectors and to variation in cloud cover from year to year. These introduce variation in measured UV which is much greater than that expected from stratospheric ozone depletion.

As biological effects such as erythema (skin inflammation) vary with UV radiation wavelength, radiation count data are expressed in terms of the minimum erythemal dose (MED) required to produce erythema in people with fair skin. Figure 2-37 shows national data for 1991 at seven monitoring stations, including Brisbane (Roy et al. 1995). This shows the variation in UV with season and location.

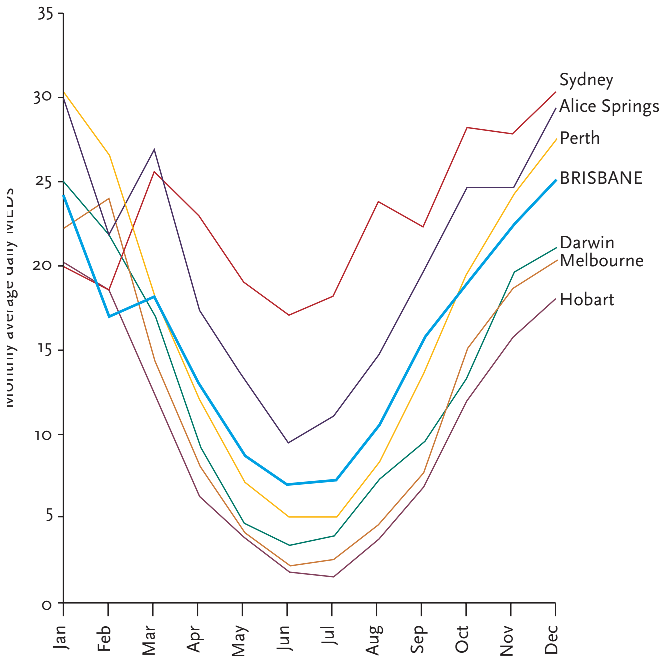


Figure 2-37 Monthly average radiation in minimum erythemal dose (MED) for seven Australian cities, 1991
(Source: Roy et al. 1995)

Although no longer used in most aerosol sprays, CFCs are very stable in the atmosphere and may persist for 50–100 years.

Indicators

Brisbane air quality index
Visibility
Suspended particles (PM_{10})
Nitrogen oxides
Volatile organic compound emissions
Ozone
Sulfur dioxide
Carbon monoxide
Lead
Air toxics

Brisbane air quality index

In considering the state of tropospheric air quality in Queensland, the quality of air in Brisbane is used as a benchmark.

The Environmental Protection Agency (EPA) provides a daily air quality summary for Brisbane. This takes the form of a time series plot of a half-hourly average air quality index each working day between 6 a.m. and 4 p.m.

Each half-hour value of the air quality index is a measure of the photochemical index or the particulate index, whichever is greater. It is calculated from measurements of photochemical oxidants (as ozone) and light scattering by particles at Brisbane metropolitan multiparameter air monitoring stations. The photochemical index is calculated as 50 times the ratio of the maximum measured half-hourly average to the ANZECC guideline of 0.10 ppm. The particulate index is calculated as 50 times the ratio of the mean measured half-hourly average light scattering coefficient to the maximum desirable level (2.35×10^{-4}, equivalent to a local visual distance of 20 km, Victorian EPA standard).

Photochemical oxidants are secondary pollutants which are formed slowly in the atmosphere by the exposure of nitrogen oxides and reactive hydrocarbons to sunlight. Polluted air from the metropolitan area is usually transported by winds to surrounding areas before the photochemical oxidants have developed. Elevated concentrations of photochemical oxidants are usually detected in metropolitan areas only when weather conditions such as stable temperature inversions and mesoscale eddies cause polluted air to be trapped or recirculated. When those conditions occur for several days at a time, the photochemical index usually peaks in the medium range. The photochemical index has peaked in the high range only once since the index was first calculated in February 1993.

Particles with diameters 0.7–2.5 µm interact with light, resulting in scatter. Smoke contains large numbers of such particles and has a large impact on visual air quality.

The Brisbane air quality index has a value of 50 when one of these pollutants is at the threshold of the national goal (ozone) or maximum desirable level (particulates). For ease of interpretation, the scale for the index is divided into three ranges — low (<25), medium (25–50) and high (>50). A low value means levels of both pollutants are less than half the guideline. A medium value means levels of both pollutants are less than the guideline, but at least one pollutant is greater than half the guideline. A high value means that at least one pollutant has exceeded the guideline.

When the maximum index value is in the low range, the dominant indicator is usually photochemical oxidants. The particulate index is usually dominant when the air quality index is in the medium range, and nearly always dominant when it is in the high range. The high range indicates that the maximum acceptable pollutant level has been exceeded. It can be concluded that light-scattering particles are the most significant contributor to events of unacceptable air quality in Brisbane.

South-east Queensland graziers commonly burn pastures in spring to promote rapid growth of new grass when the first summer rain comes. Similarly, forest managers undertake hazard-reduction burning to reduce the risk of severe bushfire damage occurring under extreme weather conditions. Consequently, the south-east Queensland airshed is routinely subjected to significant emissions of smoke under non-dispersive conditions, causing the particulate index to increase.

The significance of these practices is evident in figure 2-38, which indicates the causes attributed by EPA officers to the air quality index ratings. The data in figure 2-38 are conservative, as a cause is not always identified. However, at most times when the index has been high, fires have been identified as the cause.

Visibility

Visibility is principally an amenity-based air quality objective, important because it has a direct impact on an area's image. No NHMRC standard has been set for visibility and no national standard is proposed.

Local visual distance is one of the most readily perceived indicators of air quality. Particles in the size range

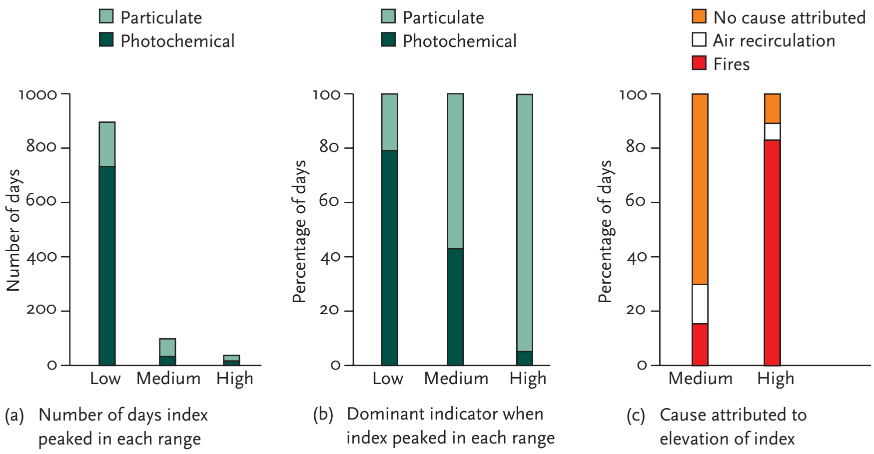


Figure 2-38 Analysis of the Brisbane air quality index, February 1993 to August 1996

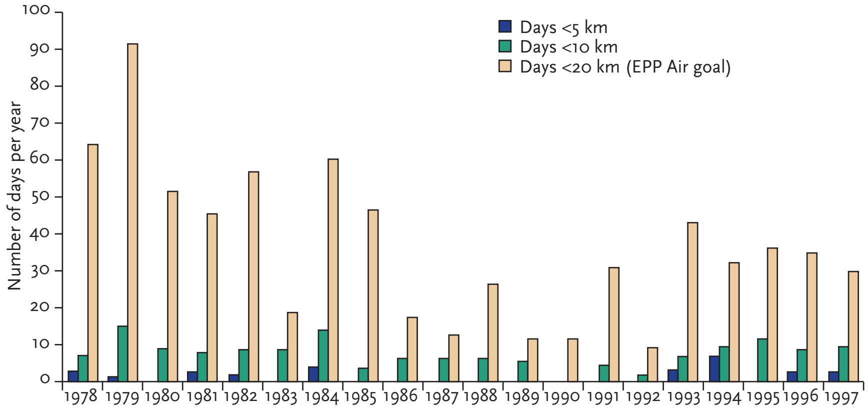


Figure 2-39 Number of days during the year when one-hour visibility readings at air monitoring stations in the Brisbane area were below specified levels, 1978–97

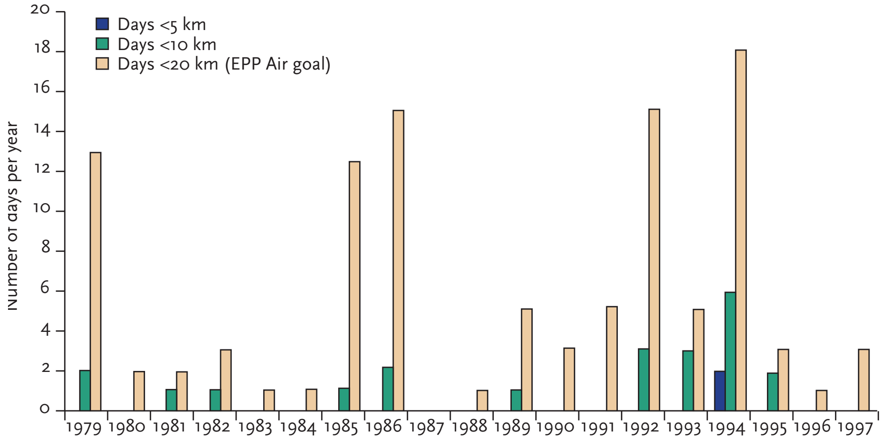


Figure 2-40 Number of days during the year when one-hour visibility in Gladstone was below specified levels, 1979–97

0.7–2.5 µm scatter visible light. Haze occurs to different extents due to the concentration of such particles suspended in the air. Visibility is expected to exceed 20 km under clean air conditions. The most common sources of light-scattering particles are those originating from combustion (burning) processes, including motor vehicles, coal-fired power stations, incinerators and burning vegetation.

Light scattering by particles has been monitored in Brisbane since 1978. Figure 2-39 shows the number of days per year between 1978 and 1997 when the local visual distance fell below 5 km, 10 km and 20 km, due to light-scattering particles. A decrease in the frequency of days when visibility was below specified levels is evident after 1986. This coincides with the closure of metropolitan coal-fired power stations and the Brisbane City Council ban on domestic open fires and backyard incinerators in 1987. The increase in 1993–96 is attributed to dry conditions, bushfires and the practice of hazard-reduction burning in bushland and softwood plantations in the surrounding area.

Figure 2-40 shows equivalent data for Gladstone, where light scattering by particles has been monitored since 1979. A range of major industrial sources, including a coal-fired power station, emit light-scattering particles in Gladstone. The apparent increasing trend is attributed to bushfires and burning off in a succession of dry years, particularly 1994.

Bushfires are a source of light-scattering particles.

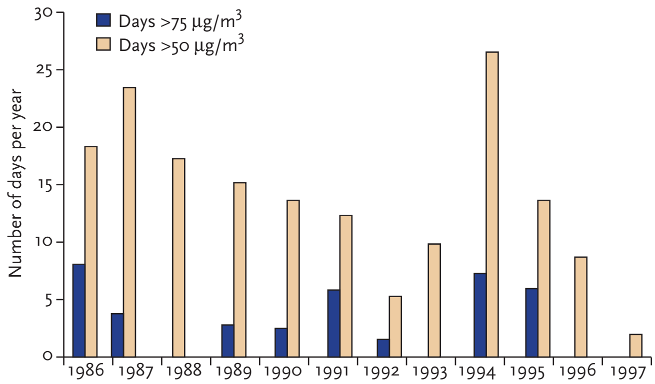


Figure 2-41 Number of days during the year when the 24-hour average PM_{10} concentrations exceeded specified levels in south-east Queensland, 1986–97 (There were no days when the EPP Air goal of 150 µg/m^3 was exceeded.)

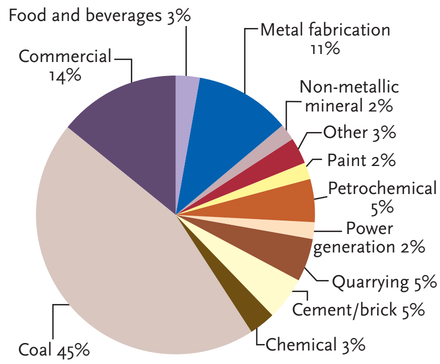


Figure 2-43 Percentage of point source particle emissions by industry sector in south-east Queensland, 1993

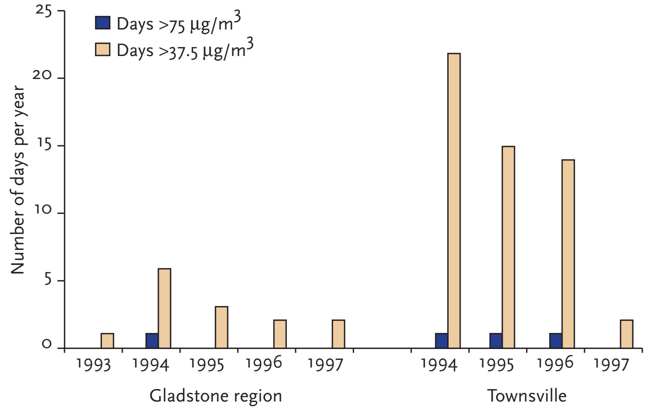


Figure 2-42 Number of days during the year when the 24-hour average PM_{10} concentrations exceeded specified levels in Gladstone, 1993–97, and Townsville, 1994–97 (no days above the EPP Air goal of 150 µg/m^3)

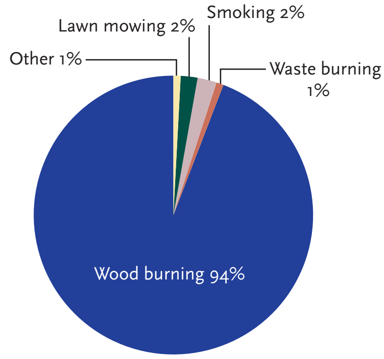


Figure 2-44 Estimated particle emissions from domestic activities in south-east Queensland, 1993

Suspended particles

Measurement of inhalable particles (those with diameters less than 10 µm) is considered a better reflection of the impact of particle emissions on health than the full range of total suspended particles (TSPs). Figure 2-41 shows the frequency, since monitoring began in 1986, of days when specified concentrations of particles with diameters less than 10 µm (PM_{10}) were exceeded in south-east Queensland. Care should be taken in interpreting the data because measurements before 1995 were not continuous, but taken over a 24-hour period each six days. The sources of particles are the same as for those that affect visibility, and the data show similar trends. Tighter emission controls for new diesel vehicles might continue the long-term trend of reduced particle emissions from motor vehicles. The contributions from bushfires and hazard-reduction burning are unpredictable, but are likely to influence particle levels substantially in Brisbane and surrounding areas.

PM_{10} concentrations have been monitored in Gladstone only since 1993 and in Townsville only since 1994 (figure 2-42). Levels for 1994 and 1995 are higher than for other years, due to dry conditions and consequent bushfires, burning off and dust. Levels in Townsville fell in 1997 because of wetter conditions and closure of an industry that had caused local dust near one monitoring site.

Dust from industrial activities adds suspended particles to local airsheds.

Forested areas in south-east Queensland are thought to be significant biogenic sources of VOCs.

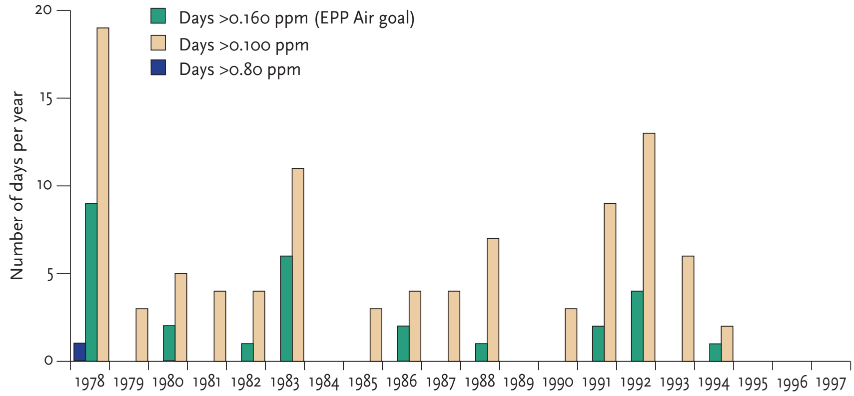


Figure 2-45 Number of days during the year when the one-hour NO_2 concentration exceeded specified levels in south-east Queensland, 1978–97. Long-term levels are below the the EPP Air goal, tending to remain below 0.08 ppm.

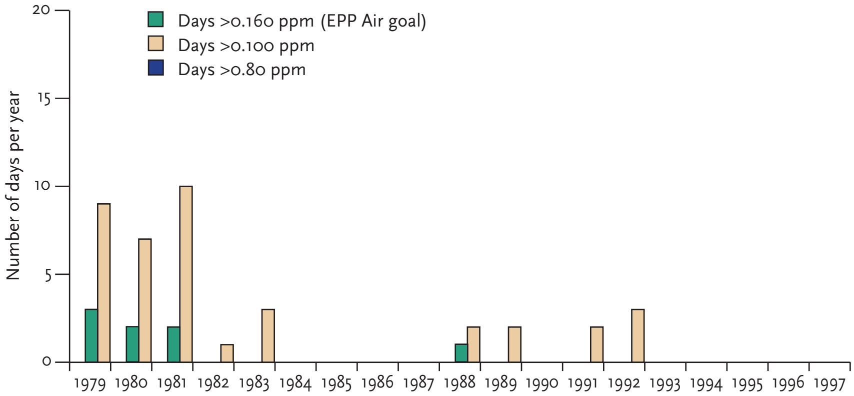


Figure 2-46 Number of days during the year when the one-hour NO_2 concentration exceeded specified levels in Gladstone, 1979–97. Compared with south-east Queensland, the data reflect fewer motor vehicles and fewer other combustion sources in the Gladstone area.

Nitrogen oxides

Motor vehicles are the major source of nitrogen oxides in urban airsheds. Nitrogen dioxide is formed through the reaction of nitric oxide with ozone and is itself a photochemical smog precursor, ultimately producing increased ozone.

The south-east Queensland ambient air monitoring network was expanded in 1993–95 and nitrogen oxide monitors were established outside the Brisbane metropolitan area. Monitoring indicates that the concentrations of nitrogen dioxide at downwind sites in the region do not exceed those measured at metropolitan sites.

Guideline values for nitrogen dioxide (NO_2) are based on human health effects. The NHMRC goal is a one-hour average of 0.16 ppm, not to be exceeded on more than one day a month. This goal has not been exceeded since 1978.

Figures 2-45 and 2-46 show the number of days a year when concentrations in south-east Queensland and Gladstone exceeded specified levels. The data show considerable variation from year to year but no discernible trends, despite increases in traffic volume. This suggests that advances in emission controls for motor vehicles are keeping pace with increases in vehicle numbers.

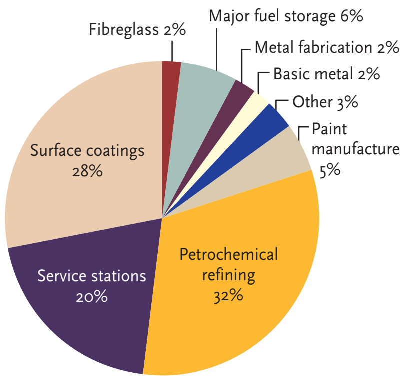


Figure 2-47 Estimated proportions of point-source VOC emissions by industry sector in south-east Queensland, 1993

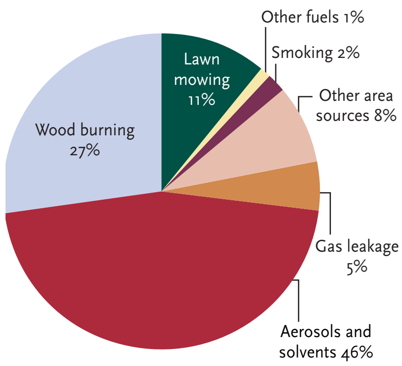


Figure 2-48 Estimated proportions of VOC emissions from domestic activities in south-east Queensland, 1993

Volatile organic compounds

Monitoring data for volatile organic compounds (VOCs) are extremely limited so clear trends cannot be determined (see figures 2-47 and 2-48). For example, biogenic sources of VOCs are reputed to be substantial in south-east Queensland, largely resulting from vegetation growth. Because VOCs control the rate of smog formation, they can contribute significantly to overall smog levels. This occurs particularly if a large emission source is close to a source of nitrogen oxides.

Ozone

In 1995 the NHMRC reduced its guideline for ozone from a one-hour average of 0.12 ppm to 0.10 ppm and introduced a four-hour average goal of 0.08 ppm. Figure 2-50 shows the number of times four-hour average concentrations in south-east Queensland exceeded specified levels. The data show considerable variation from year to year but no discernible trends, despite increases in traffic volume in the region.

Weather conditions appear to be the major influence on ozone concentrations. The concentration of ozone depends on the balance between the speed of ozone production and the rate at which the polluted air is dispersed. Under conditions of strong sunlight and poor dispersion, or recirculation of polluted air back to the source, higher concentrations of ozone are expected.

The formation of ozone from its precursors typically takes several hours. The highest concentrations of ozone are therefore expected to occur downwind of the precursor source. The 1993–95 expansion of the ambient air monitoring network with ozone monitors

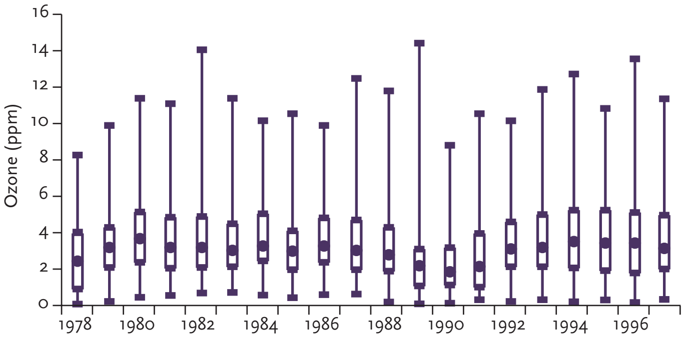


Figure 2-49 Daily maximum one-hour ozone concentration for south-east Queensland, 1978–97 — maxima and minima, 10th and 90th percentiles and medians

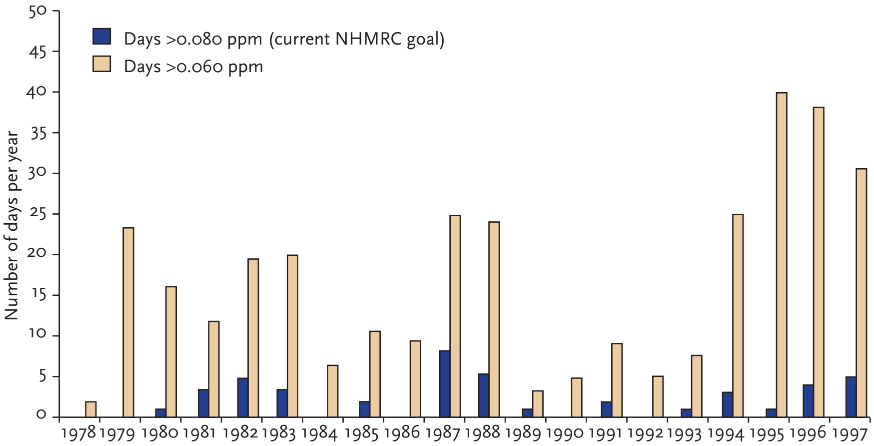


Figure 2-50 Number of days during the year when the four-hour average ozone concentration exceeded specified levels in south-east Queensland, 1978–97

Photochemical smog

In the presence of sunlight, hydrocarbons and nitrogen oxides react to form a complex mixture of pollutants known as photochemical smog. The major constituents of the smog are ozone and suspended particles. Other components include peroxyacylnitrates, aldehydes, ketones and nitrogen oxides (NO_x), which are present in the reaction mixture largely as nitrogen dioxide.

Apart from the health effects of photochemical oxidants and suspended particles, photochemical smog causes haze. This reduces the local visual distance and if nitrogen dioxide is present in high enough concentrations the haze can appear brown. Photochemical smog production is generally limited by the amount of sunlight available or the amount of NO_x present. In Queensland it is usually limited by NO_x due to the abundant sunlight.

The sources of the precursors to photochemical smog formation are generally combustion products originating from motor vehicles, coal-fired power stations and industrial boilers. However, biogenic emissions such as burning vegetation are important sources of reactive hydrocarbons. Motor vehicles are generally the most important source of NO_x in urban areas.

The reactions that produce photochemical smog occur over several hours, and during this time polluted air can be transported to areas remote from the source. This can result in rural areas far from an urban source being exposed to the highest levels of pollutants.

Photochemical oxidants are harmful to health because they decrease lung function. They accelerate ageing of materials such as rubber and some plastics, and are toxic to many plants. The major effect in plants is leaf injury, but crops can have decreased yields and the growth rates of tree seedlings can be reduced without visible injury.

Researchers believe Brisbane has the greatest potential for smog of any major Australian city, for the following reasons:

- Brisbane is in a basin-shaped airshed.
- Its location at about 27°S on the eastern side of a continent results in:
  - — many hours of sunshine,
  - — many days under the influence of stationary or slow-moving high pressure weather cells, and
  - — extended periods, particularly mornings, with little or no wind.
- Early spring to late autumn days have relatively high temperatures.
- The region has an extensive vegetation cover, resulting in high levels of biogenic emissions of reactive volatile organic compounds.
- Many regional land managers practise burning off:
  - — to encourage summer grass growth,
  - — to complete land clearing, or
  - — to reduce the fuel levels for any bushfires.
- Local offshore breezes at night and onshore sea breezes in the day often result in repeated recirculation of pollutants in the airshed rather than dispersion over the ocean in the normal west-to-east movement of weather influences.
- A layer of cold air sometimes traps polluted warmer air below it in a temperature inversion.
- South-east Queensland continues to attract more people, with more motor vehicles used over greater distances and more power use.

outside the Brisbane area has resulted in recordings of more days with ozone levels in excess of 0.08 ppm. Levels exceeding guideline values have almost always been associated with bushfires, a source of photochemical precursors, under weather conditions conducive to photochemical smog formation.

Sulfur dioxide

Sulfur dioxide concentrations in south-east Queensland are very low by world standards. This is typical of Australian urban areas due to the use of low-sulfur fuels and the siting of coal-fired power stations away from urban centres. Annual frequencies of one-hour average concentrations exceeding specified values are presented in figure 2-51. The data indicate that the sulfur dioxide concentration rarely exceeds 0.04 ppm, 20 percent of the NHMRC goal. Since this monitoring began at Ipswich in 1993, no significant concentrations have been detected, despite the proximity of Swanbank power station.

Sulfur dioxide levels monitored in and around Gladstone (figure 2-52) are noticeably higher than those of south-east Queensland because of that city's extensive industrial operations. Levels are still within national standards.

Sulfur dioxide levels monitored in Mount Isa (figure 2-53) are considerably higher than those of Gladstone and south-east Queensland, with some days above the ANZECC guideline. Declines in 1995 were the result of smelter production cutbacks.

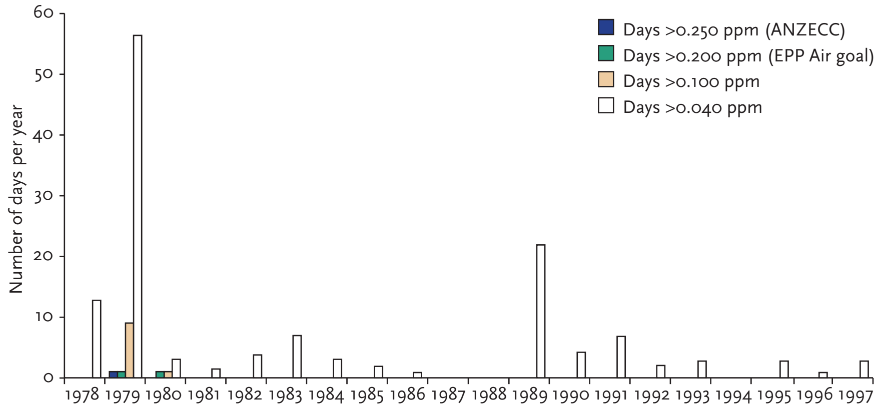


Figure 2-51 Number of days during the year when the one-hour sulfur dioxide concentration exceeded specified levels in south-east Queensland, 1978–97. Levels have declined sharply in recent years, to well below the EPP Air goal of 0.200 ppm.

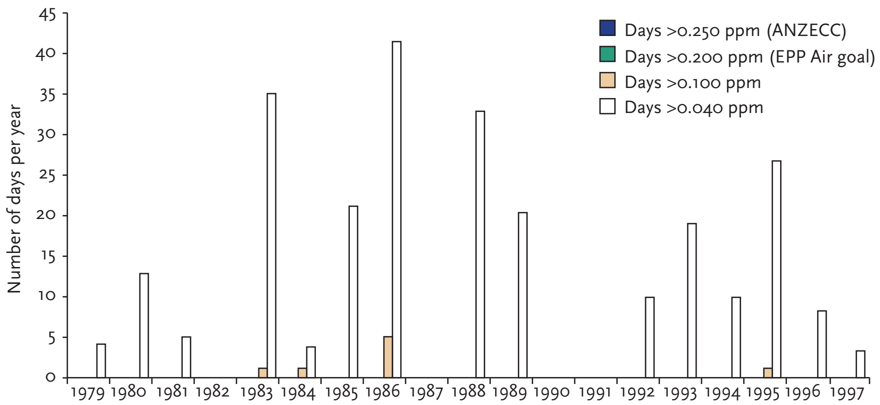


Figure 2-52 Number of days during the year when the one-hour sulfur dioxide concentration exceeded specified levels in Gladstone, 1979–97

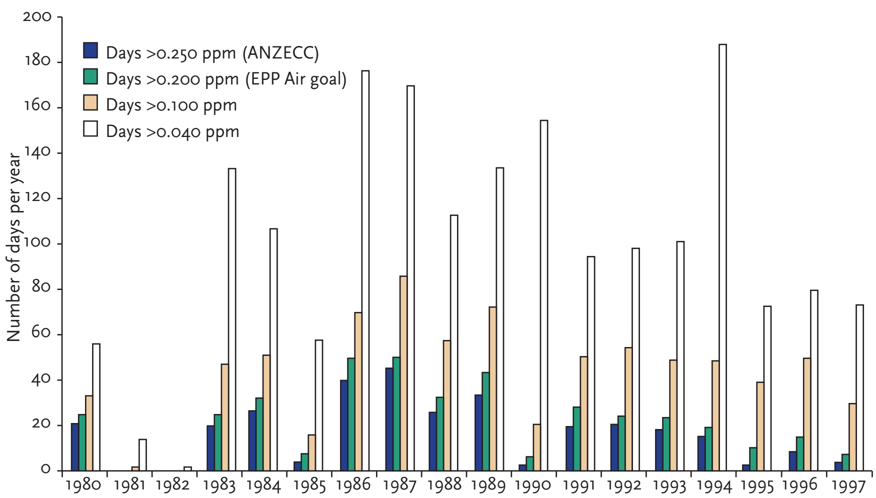


Figure 2-53 Number of days during the year when the one-hour sulfur dioxide concentration exceeded specified levels in Mount Isa, 1980–97

Carbon monoxide

Long-term monitoring of carbon monoxide in Queensland has been conducted only at Fortitude Valley, Brisbane. This is adjacent to a major traffic corridor carrying approximately 50 000 vehicles a day. Figure 2-54 shows a strongly reducing trend in the annual frequency of carbon monoxide concentrations exceeding specified values. The number of days when concentrations exceeded the 9 ppm NHMRC/ANZECC goal declined markedly in 1983 when traffic flow conditions at the site improved. The introduction of catalytic converters for emission control in new motor vehicles has produced a gradual decrease in carbon monoxide concentrations since 1986. Despite increased vehicle numbers, emission controls have brought about a reduction in emissions. More stringent emission controls introduced recently should ensure that this trend continues.

The relationship between air pollution levels and traffic volumes near major roads in Brisbane was studied in 1994–96 (figure 2-55). The highest carbon monoxide concentration occurred on Ipswich Road, Woolloongabba, in July–August 1994. The level was well below the NHMRC/ANZECC goal, however.

Lead

In urban areas more than 90 percent of lead emissions typically come from motor vehicles. Consequently, the highest concentrations of lead in air occur adjacent to traffic corridors. Lead concentrations have been monitored at several sites in Brisbane since 1980.

The EPP Air goal is expressed as a 90-day moving average concentration of 1.5 µg/m³. Figure 2-56 shows data from monitoring sites at Woolloongabba, a high-traffic site, and Rocklea, a more typical urban site. The difference in lead levels at the sites reflects the lower traffic volume and greater distance from the sampler to the road at Rocklea.

Data clearly show the seasonal trend in lead levels, with higher levels occurring in winter due to poor dispersion. The data also show a strongly decreasing trend in lead concentrations, particularly at Woolloongabba. The introduction of unleaded petrol in 1986 has produced a gradual decrease in lead emissions as consumption of leaded fuel has declined (see figure 2-56).

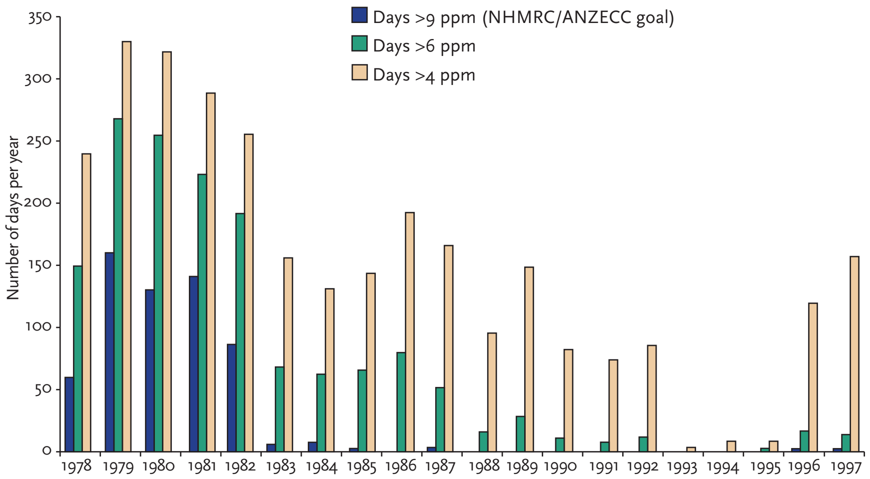


Figure 2-54 Number of days during the year when the eight-hour carbon monoxide concentration exceeded specified levels at Fortitude Valley, Brisbane, 1978–97

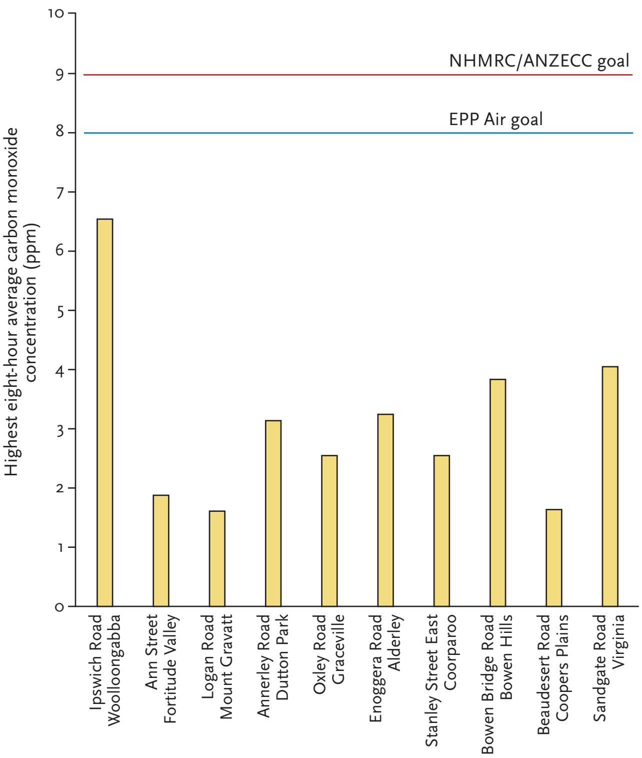


Figure 2-55 Highest eight-hour average of carbon monoxide concentrations at ten Brisbane roadside sites, 1994–96. The NHMRC/ANZECC and EPP Air goals were not exceeded during the study.

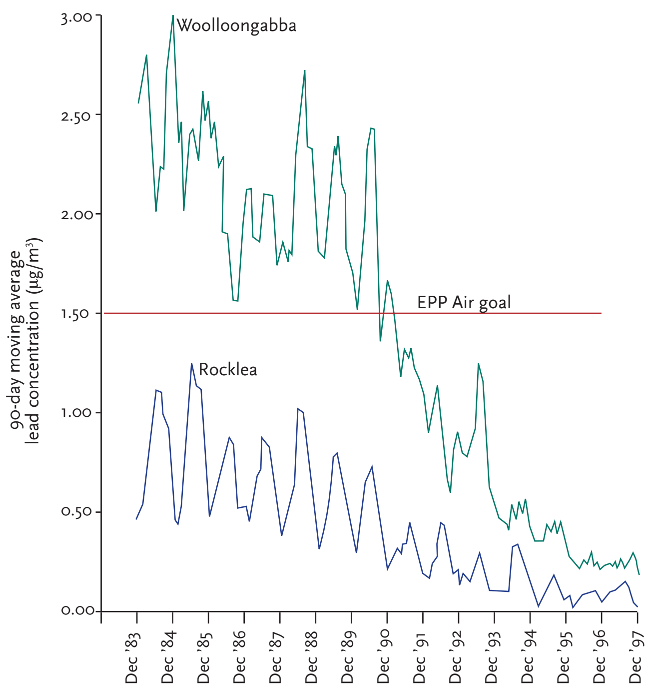


Figure 2-56 Trends in airborne lead levels at two Brisbane monitoring sites, 1983–97

The most significant contributions to the decreasing trend have been a series of reductions in the lead content of leaded fuel. In 1991 the lead content of leaded petrol in metropolitan areas was reduced from 0.84 g/L to 0.4 g/L, with further reductions to 0.3 g/L in 1994 and 0.2 g/L in 1996. Airborne lead levels in south-east Queensland are now consistently below the current guideline value and also below the NEPM goal of 0.5 μg/m^3. Because of this clear trend, lead is not measured in other areas.

Air toxics

In 1988, concentrations of air toxics were measured in three residential areas of Brisbane with significant nearby industries. Analysis showed that aromatic and chlorinated solvents were evident at Acacia Ridge, combined emissions from solvent reclaiming and chemical manufacture were dominant at Wynnum North, and motor vehicle emissions were dominant at Pinkenba. Measurements at Lytton, adjacent to Brisbane's two oil refineries, in 1992 resulted in means of 16.8 μg/m^3 of benzene, 40.3 μg/m^3 of toluene, 11.6 μg/m^3 of xylene and 9.2 μg/m^3 of formaldehyde.

Polycyclic aromatic hydrocarbons (PAHs) in the air of Brisbane were measured in 1994–95 as part of a Queensland Department of Environment and Heritage motor vehicle emissions study. Means for all PAHs for the four sites ranged from 35 ng/m^3 (Dutton Park) to 123 ng/m^3 (Woolloongabba). Means for benzo(a)pyrene ranged from 0.14 ng/m^3 (Mount Gravatt) to 1.54 ng/m^3 (Woolloongabba). The highest levels were at sites close to busy roads, suggesting that vehicle emissions were the major source (Müller et al. 1996).

RESPONSE

This section briefly reviews the current responses to the pressures on Queensland's atmosphere and its state. A range of significant international agreements and conventions, Commonwealth and State legislation, policies and strategies, and local government and industry initiatives collectively influence the management of Queensland's atmosphere.

These responses are designed to protect, restore and enhance Queensland's air environment, following their adoption by industry, commerce and the community. Responses are generally specific to and targeted at the major issues of climate change, ozone and air quality.

CLIMATE

International agreements

The Intergovernmental Panel on Climate Change (IPCC), the pre-eminent scientific body established to advise world governments on climate change science, has prepared two reports which summarise the status of scientific understanding of climate change. The First Assessment Report, released in 1990, was instrumental in the decision of the United Nations to prepare the Framework Convention on Climate Change (FCCC). The findings of the IPCC 1996 Second Assessment ultimately led to the development of the Kyoto Protocol (see box on page 2.39). A Third Assessment Report, due to be completed in 2000, will review the most recent climate data.

National policy context

In 1992 the Council of Australian Governments endorsed the National Greenhouse Response Strategy (NGRS). This decision was driven by the need for Australia to meet its obligations under the terms of the FCCC. A review of the 1992 NGRS found that it had been largely ineffective due to an absence of commitment by jurisdictions to achieve implementation. As a consequence, in November 1998 a new National Greenhouse Strategy was launched (AGO 1998) to help Australia meet its international obligations under the FCCC. The Commonwealth and all States and Territories will contribute to the national effort to reduce greenhouse gas emissions.

The measures outlined in the NGS fall into three areas:

- enhancing knowledge of greenhouse sources and sinks and continuing research into climate change science and abatement and adaptation strategies;
- limiting greenhouse gas emissions through energy market reforms, efficient transport and sustainable urban planning, enhancing greenhouse sinks through sustainable forestry and vegetation management, and fostering the adoption of best practice industrial processes and waste management; and
- laying the foundation for adaptation for climate change.

The measures are to be pursued through a series of eight action modules. Each module includes a range of measures to be implemented, with 85 in total across all modules. The NGS includes both ongoing and new measures and integrates greenhouse into other major policy initiatives, such as the Natural Heritage Trust. Scope exists for governments to pursue different measures using different policy mechanisms. The 1998 NGS makes provision for the States and Territories to develop implementation plans. These plans will articulate how implementation will be achieved in the respective jurisdictions. Reports on progress in implementing the NGS will be prepared biennially, with the first due in late 2000.

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Kyoto Protocol

Background

In response to concerns about the adverse effects of greenhouse emissions, the Kyoto Conference on Climate Change took place in December 1997. Under the 'Kyoto Protocol' to the Framework Convention on Climate Change, developed countries have agreed to reduce their greenhouse gas emissions by an average of 5.2 percent below 1990 levels by 2008–12. The Protocol is the first international treaty to impose legally binding restrictions on emissions of greenhouse gases.

Australia agreed to limit its growth in emissions to 8 percent above 1990 levels. This reflects our above-average population growth rate and the greenhouse-intensive nature of our economy and exports. Only two other countries were allowed to increase emissions: Iceland (10 percent) and Norway (1 percent).

Key features of the Protocol

- Six categories of greenhouse gases are identified: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6).
- Coverage of sources and sinks is comprehensive.
- Flexibility mechanisms are included, enabling countries to approach their emissions abatement task in a cost-effective way. These mechanisms include the trading of greenhouse gas emission entitlements and the establishment of a 'clean development' mechanism to help developing countries reduce emissions through joint projects with developed countries.

Participation

Becoming a party to the Protocol is a two-step process. The first step is for developed countries to sign the Protocol; the second step is ratification. The Protocol is legally binding on individual nations once each government completes ratification.

While Australia, along with other countries, has signed the Protocol, the Protocol does not take effect until it is ratified by 55 participating parties to the Convention.

Ratification of the Protocol is likely to take some time. In part, this is because international negotiations are continuing on implementation issues which have important implications for individual countries, and the outcomes of these negotiations are not yet clear.

The strategy will be reviewed in 2002, or earlier if international developments make it necessary.

The Australian Greenhouse Office, a Commonwealth Government agency, was established as the lead agency to oversee the development and implementation of national greenhouse policy and actions. One action has been the implementation of the Greenhouse Challenge.

The Greenhouse Challenge is a cooperative effort of Australian industry and the Commonwealth Government to reduce greenhouse emissions through voluntary industry action. Participation in the Challenge is through cooperative agreements between the Government and industry participants. The objective of these agreements is for industry to abate its greenhouse emissions, mainly by improving efficiency in energy use and processing. By August 1998, 116 enterprises had signed cooperative agreements and a further 152 had made a commitment to do so.

Queensland policy context

Queensland implementation of the 1992 National Greenhouse Response Strategy and the 1995 Queensland Greenhouse Response Strategy has been limited and measures have had little impact on emissions. Due to recent national and international policy developments, it is intended that a new Queensland Greenhouse Response Strategy be developed. Government coordination on greenhouse matters is currently managed by the Queensland Greenhouse Taskforce, which is made up of representatives from various government departments. The Taskforce provides a focus within government for greenhouse matters and provides coordinated advice to government.

Stratospheric ozone

International responses

Since 1975 the Global Ozone Research and Monitoring Project, coordinated by the World Meteorological Organization, has collected all data from Australian and international ozone monitoring networks at the World Ozone Data Centre in Toronto, Canada, where the data are available to the scientific community worldwide.

In 1977 a United Nations Environment Programme (UNEP) meeting of experts adopted the World Plan of Action on the Ozone Layer.

In 1985 the Vienna Convention for Protection of the Ozone Layer was established as a result of international concern about ozone depletion after discovery of the seasonal occurrence of the Antarctic ozone hole.

In 1987 UNEP adopted the Montreal Protocol on Substances that Deplete the Ozone Layer, introducing a number of measures and a timetable for action regulating the release of the most common CFCs to the environment. The Protocol was signed by the European Economic Community and 32 countries, including Australia, which together were responsible for 82 percent of CFC consumption worldwide.

In 1990 the London Convention amended the Montreal Protocol terms to accelerate the reduction of CFC emissions, and require a total phasing-out of their use. More ozone-depleting substances were added to the list, including additional CFCs, halons, carbon tetrachloride and methyl chloroform.

In 1992 the Copenhagen Convention amended the Montreal Protocol to further accelerate the phasing-out, and added hydrochlorofluorocarbons, hydrobromofluorocarbons and methyl bromide to the list of ozone-depleting substances. One hundred and forty-eight countries have now agreed to the Protocol and its amendments.

National and State policies

The Commonwealth Parliament passed the Ozone Protection Act in 1989 to implement the Montreal Protocol requirements and to control selected end uses of CFCs.

The Queensland Government also used legislation to minimise emission of CFCs through control of their manufacture, sale, use and disposal. Currently this is achieved through the *Environmental Protection Regulation 1998*.

In Australia the terms of the Protocol have been met in accordance with the agreed schedule, in some cases exceeding minimum requirements. The national halon recovery program to collect and destroy halon 1211 and 1301 goes beyond the Montreal Protocol by destroying existing stocks. More than 1800 tonnes of the estimated 2000-tonne surplus had been collected by January 1999.

Daily forecasts of UV-B radiation intensity are provided to the media by the Bureau of Meteorology. Using a global computer model which predicts stratospheric ozone concentrations, the Bureau calculates the corresponding UV radiation intensity at any point on the ground in Australia. This value is converted to an index representing the potential maximum UV-B intensity. A second value takes into account the amount of cloud cover expected in the middle of the day. Both values are considered when forecasts are made. Index forecasts in four ranges — moderate (<3), high (3–6), very high (7–9) and extreme (>9) — allow people to make informed decisions about the level of sun protection required on a given day in order to avoid the potential harmful effects of this UV radiation.

TROPOSPHERIC AIR QUALITY

National

The National Environment Protection Council (NEPC) was created by Commonwealth legislation to establish National Environment Protection Measures (NEPMs) to protect the environment. However, as each State and Territory has responsibility for the environment under the Australian Constitution, complementary legislation is required in each jurisdiction to establish a legal requirement to implement the NEPMs. The *National Environment Protection Council (Queensland) Act 1994* was the first complementary legislation to be passed. Members of the NEPC are Ministers (not necessarily Environment Ministers) nominated by each participating Commonwealth, State and Territory government.

National Environment Protection Measures (NEPMs) are developed by the NEPC to outline agreed national objectives for protecting particular aspects of the environment. Each government is responsible for implementation of NEPMs in its own jurisdiction. NEPMs consist of a combination of:

- goals — desirable future outcomes for environmental quality;
- standards — mandatory values of a quantifiable characteristic of environmental quality to be achieved;
- protocols — procedures to be followed to determine whether a standard or goal is being met; and
- guidelines — outlines of how standards or goals might be achieved or environmental problems addressed.

In June 1998 the NEPM for Ambient Air Quality was released. With the goal to protect human health and well-being, ambient air quality standards and monitoring and reporting protocols were established for carbon monoxide, nitrogen dioxide, photochemical oxidants, sulfur dioxide, lead and particles.

National Pollutant Inventory (NPI)

In February 1998 the NEPM for the National Pollutant Inventory (NPI) was released. From 1 July 1998, larger Australian industrial facilities were required to estimate and report annually their emissions of the chemicals listed on the NPI. This information, along with estimates of emissions from facilities using less than the specified amount of chemicals listed and from mobile sources, such as motor vehicles and aircraft, will be publicly available via the Internet. Information explaining where the substances listed on the NPI are emitted from, what they are used for, and the risks to human health and the environment associated with them will be included on the database. Media attention and social pressure will be focused on emitters to manage or reduce their emissions, as occurs in the United States. It is expected that data from the first NPI reporting year will be publicly available in early 2000.

EPA staff member installing air quality monitoring equipment in Brisbane

The Airwatch educational program, launched in 1998, aims to involve students in air quality issues.

Independent Inquiry into Urban Air Pollution

The Commonwealth Government commissioned an inquiry into the state of urban air quality, with a view to minimising air pollution in Australian cities and towns. The inquiry identified trends in the six criteria pollutants shown in table 2-4. It also identified management options and strategies for controlling emissions and reducing pollution levels in the medium to long term. The Australian Academy of Technological Sciences and Engineering reported the findings to the Minister for Environment in November 1997 (AATSE 1997). The report draws attention to the influence of urban design and urban form on air quality, and gives evidence of this. The role of indoor air quality is also highlighted; the report notes that although most people spend the majority of their time indoors there are no national guidelines or standards for the indoor environment.

Australian design rules

The first Australian design rule (ADR) to set emission standards for new motor vehicles sold in Australia was ADR27, introduced in 1974 (table 2-5). Limits were set for hydrocarbon, carbon monoxide, nitrogen oxides and evaporative emissions from petrol-fuelled passenger vehicles. ADR37, introduced in 1986, tightened the limits and made compulsory the use of unleaded petrol. ADR37/01 took effect in 1997, further tightening the limits for emissions from petrol-fuelled vehicles. ADR37/02 is a proposed standard (AATSE 1997).

ADR70 in 1995–96 limited particle, hydrocarbon and nitrogen oxide emissions from diesel-fuelled vehicles (table 2-6).

Table 2-4 Air quality indicators and goals of the *Environmental Protection (Air) Policy 1998*

	Air quality goal	
Air quality indicator	**Measure**	**Averaging time**
Particles (as PM_{10})	150 $\mu g/m^3$	24 hours
	50 $\mu g/m^3$	1 year
Nitrogen dioxide	0.16 ppm	1 hour
Ozone	0.1 ppm	1 hour
	0.08 ppm	4 hours
Carbon monoxide	8 ppm	8 hours
Sulfur dioxide	0.2 ppm	1 hour
	0.02 ppm	1 year
Lead	1.5 $\mu g/m^3$	3 months

This standard is similar to an earlier European standard, a benchmark world standard. While a new Euro standard was implemented, however, an equivalent Australian one was not.

Queensland

Environmental Protection Act 1994

The *Environmental Protection Act 1994* creates a general environmental duty for everybody not to cause environmental harm, including environmental harm from air pollution. The Act identifies activities that have the potential to cause environmental harm and requires that such activities not be carried out without an environmental authority from the appropriate administering authority.

State Government departments and local governments report annually on environmental authorities issued, cancelled, suspended and refused for environmentally relevant activities, many of which relate to air quality. In 1996–97, 6739 licences and 756 approvals were issued; 794 authorities were cancelled or suspended; 39 applications were refused; and 2437 complaints involving air quality were received.

The Act covers ozone-depleting substances including refrigerants, controlled substances such as solvents and dry-cleaning equipment, plastic foam manufacture, and halon and other fire-extinguishing systems. It also covers conditions on selling, buying, handling, use and reclaiming of controlled substances, and lists ozone-depleting substances.

Environmental Protection (Air) Policy 1997

The *Environmental Protection (Air) Policy 1997*, commonly known as the EPP Air, took effect on 1 February 1998. It identifies environmental values to be enhanced or protected, specifies air quality indicators and goals to protect environmental values, and provides a framework for making consistent and fair decisions about managing the air environment. It also involves the community in achieving air quality goals that best protect Queensland's air environment. The values are the qualities of the air environment that are conducive to suitability for the life, health and wellbeing of humans. They do not apply to air environments in workplaces or indoors.

The EPP Air provides that solid fuel burners for use in residential premises cannot be sold unless they comply with Australian Standard 4013. No structure, exhaust system or

Table 2-5 Petrol-fuelled vehicle emission standards

Standard	HC		CO		NO_x		Evaporation	
	(g/km)	% change	(g/km)	% change	(g/km)	% change	(g/test)	% change
ADR27 (1974)	2.1		24.2		1.9		6	
ADR37 (1986)	0.93	−56	9.3	−62	1.93	2	2	−67
ADR37/01 (1997)	0.26	−72	2.1	−77	0.63	−67	2	0
ADR37/02* (2004)	0.08	−31	1	−47	0.2	−31	na	

* proposed

Table 2-6 Heavy-duty diesel vehicle emission standards

Standard	HC		CO		NO_x		Particles	
	(g/kW h)	% change	(g/kW h)	% change	(g/kW h)	% change	(g/kW h)	% change
Euro 1 (1992)	1.1		4.5		8		0.36	
Aust ADR70 (1995–96)								
Euro 2 (1995)	1.1	0	4	−11	7	−12.5	0.15	−58

air inlet system, or any part involved in the combustion process may be modified or altered in any material way. The Environmental Protection Agency has produced brochures about buying and installing the right heater and how to use a wood heater to minimise emissions of smoke, soot and chemicals.

South East Queensland Regional Air Quality Strategy (SEQRAQS)

In 1992, the Queensland Government formed a group to develop a strategy to maintain and improve air quality in south-east Queensland. The group began gathering information and reviewed the historical air quality monitoring data set to identify air quality trends. Weather patterns associated with events of high pollution were modelled to predict pollution transport throughout the region and identify areas which should be monitored. The air quality monitoring network was increased from three to ten continuously operating multiparameter monitoring stations. An inventory of air emissions for the region was compiled and predictions were made for future emissions. A computer model was developed to simulate transport, dispersion and transformation of emissions and predict future pollutant levels.

A draft strategy for managing air quality in south-east Queensland was published in March 1998 for further public consultation. The South East Queensland Regional Air Quality Strategy (SEQRAQS) is intended to address those aspects of air quality which have regionally significant effects on the environmental values of human health and wellbeing, ecological sustainability and amenity, including visibility. Its focus is on those pollutants which contribute to regional pollution levels, although the need to develop strategies to deal with particular local issues is also recognised.

The strategy focuses on issues of air pollution relevant to the region. Therefore recommended actions relate only to this area, although it is recognised that in some cases air pollution problems affect far wider areas and can best be addressed by statewide or even national actions. The SEQRAQS region comprises 18 local government areas extending from Noosa south to Beaudesert and the Gold Coast, and from the Moreton Bay islands west to Toowoomba, an area of approximately 22 500 km^2.

SEQRAQS is intended to complement other regional initiatives such as the SEQ 2001 Regional Framework for Growth Management, the 1997 Integrated Regional Transport Plan for south-east Queensland (IRTP), the South-East Queensland Economic Development Study and the Gateway Ports Area Strategy.

AirCare

In March 1998, as part of an AirCare project to reduce air pollution caused by vehicles, Queensland Transport established a smoky vehicle telephone hotline for reporting vehicles seen emitting excessive continuous exhaust smoke over 10 seconds or more. Warning letters and defect notices are issued and owners can be asked to present vehicles for inspection. Penalties apply to owners who do not comply with defect notices. At the same time, the Department began a trial program of vehicle emissions testing. This program, known as the OVERT program (on-road vehicle emission random test), is testing mainly light vehicles manufactured between 1972 and 1993. The test procedure does not measure all emissions, but it does indicate those vehicles whose emissions could be improved by servicing and repairs.

Strategic planning

Air quality has become a common element in strategies and plans developed by various Queensland Government and local government agencies, and by industry, for industrial and other land use expansion in south-east Queensland, Gladstone and Townsville. Atmospheric dispersion models have been developed for the south-east Queensland, Gladstone and Townsville airsheds to simulate transport of pollutants from proposed new sources and to predict their potential influence (figures 2-57, 2-58 and 2-59).

In 1997, the agreement between the Queensland Government and Mount Isa Mines Limited was amended. The amendment sets air quality management objectives for Mount Isa and requires a panel assessment study to investigate and report to Parliament on changes to management practices to achieve continuing improvement in air quality in Mount Isa. Operation of a sulfuric acid plant planned for Mount Isa would result in an 80 percent reduction in sulfur dioxide emissions.

Integrated Regional Transport Plan (IRTP)

Transport activity generates around 70 percent of air pollution in the SEQRAQS region. Studies undertaken for the IRTP show that if current trends in regional population growth and transport use continue, there will be significant growth in transport activity which has the potential to severely reduce air quality, even allowing for advances in vehicle emissions technology.

This 25-year plan, approved in 1997, seeks a transport system in south-east Queensland which moves passengers and

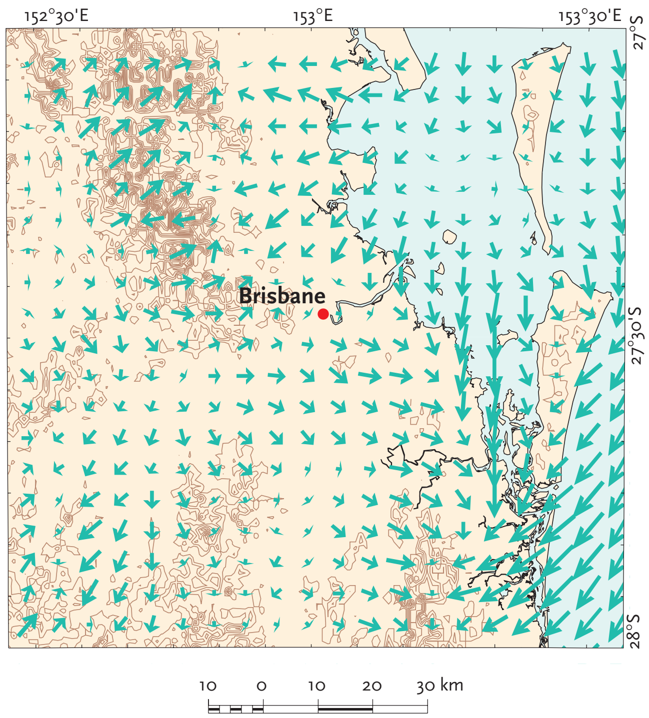

Figure 2-57 Modelled winds and movement of pollutants emitted during the morning from around Brisbane on a summer day. The Lagrangian Atmospheric Dispersion Model (LADM), developed by CSIRO, predicts the detailed three-dimensional winds, turbulent mixing and dispersion of pollutants in the course of a day.

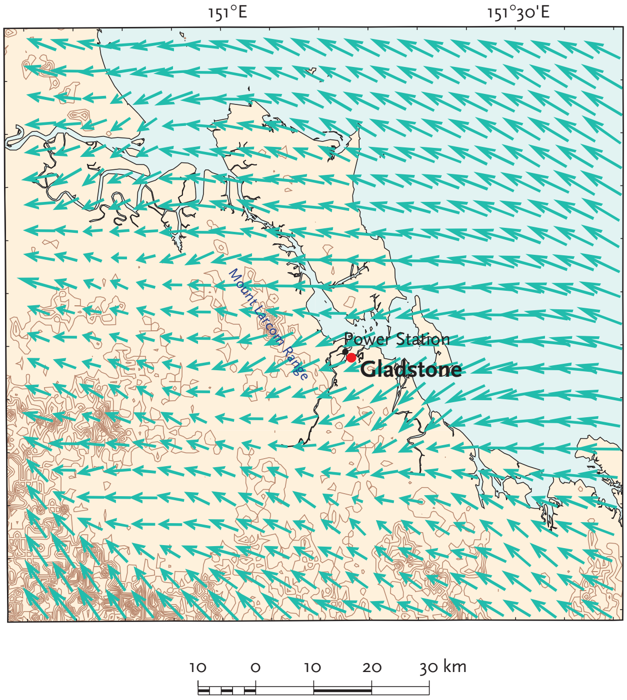

Figure 2-58 Lagrangian Atmospheric Dispersion Model of the Gladstone area at 9 a.m. on a typical summer day, showing emissions from the city moving up the coast, with elevated emissions from the power station travelling to the west of Mount Larcom

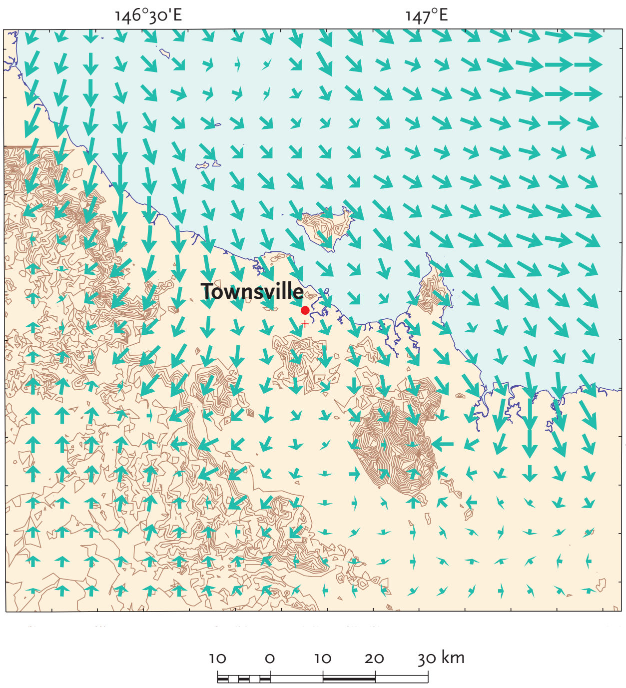

Figure 2-59 Langrangian Atmospheric Dispersion Model of the Townsville area at 11 a.m. on a typical summer day, with the modelled sea breeze already moved inland 8 km to Mount Stuart. Pollutants emitted from the city during the morning are steered around the mountain and are caught in upslope winds over Mount Elliot to the south-east.

freight efficiently, supports economic development, and reduces car dependency. The IRTP has targets and associated actions to change these trends in transport activity. Key objectives for air quality include a major shift to using public transport, and more walking, cycling and shared vehicle use, without increasing personal average weekday vehicle kilometres travelled. Even if these targets are achieved, the number of trips made by private vehicle is still expected to grow by 51 percent between 1992 and 2011 with consequent increases in impacts on air quality, unless appropriate management actions are undertaken.

Cleaner production

Cleaner industrial production is promoted in Queensland by the Queensland Cleaner Production Taskforce Association (QCPTA) and the Environmental Protection Agency. In 1997, the Department of Environment and Heritage and QCPTA presented seminars on the economic and environmental benefits to industry of cleaner production. The Department commissioned The University of Queensland to find local examples (15 cleaner production case studies) of industry adopting cleaner production practices. Examples of industry reducing or eliminating air contaminants are:

- combustion of methane generated at Logan City Council's Browns Plains landfill, leading, through electricity sales, to a reduction in carbon dioxide equivalents of 20 000 tonnes a year;
- reduced emissions of insecticides through improved pest management at the Gayndah Packers Co-operative Association Limited facility (Gaypak) at Gayndah, with a significant reduction (around 75 percent) in chemical use in the Central Burnett region; and
- reduced emission of airborne chemicals through use of biological management at the Palm Meadows Golf Course at the Gold Coast.

Local government

Brisbane City Council's Air Quality Strategy is designed to protect air quality in Brisbane and the surrounding region. Initiatives within the Strategy focus on regional actions, education, transport, industry and energy consumption.

The Strategy and a clean air campaign are linked with TravelSmart and Brisbane 2011, the Council's strategic documents for transport and land use planning respectively.

Monitoring

Climate

The Bureau of Meteorology network and resources continue to provide extensive information about atmospheric conditions from the ground to the stratosphere. This information provides the basis for weather forecasts, warnings, extended forecasts and seasonal outlooks for land and sea. The information is also used to compile monthly, annual, 10-year and other reports which are analysed for trends. Indications of any climate change for parts or all of Queensland will come from these analyses through the Bureau of Meteorology Research Centre, Melbourne, and in published form. Some patterns shown by the southern oscillation have been noted, but periods vary greatly. Computer modelling of regional climate scenarios is not developed to the extent that it can provide accurate, detailed predictions.

Ambient air monitoring

The Environmental Protection Agency (EPA) has been monitoring air quality in south-east Queensland since 1978. Information from regional monitoring stations has been used to identify current and long-term trends. The EPA publishes monthly bulletins reporting results of ambient air monitoring in south-east Queensland and Gladstone. It also publishes annual summaries and trend reports for Queensland.

While traditional methods measure air quality at one point only, the EPA is also using differential optical absorption spectroscopy to measure pollutants over a distance. Concentrations of near-ground ozone, sulfur dioxide, nitrogen oxides, benzene, toluene and xylene can be measured continuously.

Industry codes of practice

Codes of practice that include management of air emissions are being developed by industry associations in close cooperation with the EPA.

The sugar industry in Queensland is moving toward green harvesting of sugarcane to reduce the emission of air pollutants by pre- and post-harvest burning. Figure 2-60 shows the proportion of the Queensland sugar crop green harvested since 1988.

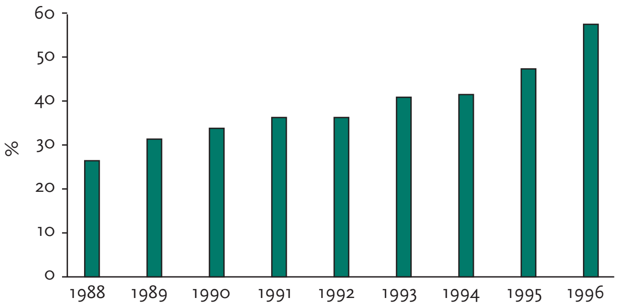

Figure 2-60 Percentage of sugarcane green harvested in Queensland, 1988–96

Community education

In 1998, the Department of Environment and Heritage launched a major environmental education program, Airwatch, to help schools investigate and take action on air quality and air pollution. The Airwatch kit provides background information on air quality and air pollution, and individual and group activities for collecting and evaluating information about local airsheds. The program uses an action research approach. It allows research findings to be fed into action, and the outcomes of action to be fed back into research.

ACKNOWLEDGEMENTS

This chapter was produced through the efforts of many people. The Environmental Protection Agency acknowledges in particular the help of Dr Greg McKeon, Wayne Hall and Neil Flood, Department of Natural Resources; Barry Gordon, Bureau of Meteorology Regional Office, Brisbane; Edward Kleverlaan; Division of Atmospheric Research, CSIRO, Melbourne; Dr Phil Morgan, formerly of the Department of Environment and Heritage; and Environmental Protection Agency staff including Dr Don Neale and Dr Peter Nimmo.

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CHAPTER 3

QUEENSLAND'S LAND

Land

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Contents

Key Issues and Findings

Queensland hosts a wide range of land use activities. The dominant land use is agriculture, principally grazing which occupies some 150 million hectares of the State's total land area of 172.8 million hectares. Cropping is undertaken on 2.7 million hectares. Land uses occupying the remainder of the land include protected areas, forestry, infrastructure, housing, industry and mining.

Cultivation and grazing practices since European settlement have greatly altered the landscape known by Aboriginal people. Substantial areas have been cleared of native vegetation, giving way to introduced pastures, cropping, industry, urban development and mining. In some cases, inappropriate land use practices have caused the degradation of land, vegetation and biodiversity and appear to be unsustainable. Land restoration activities are often difficult, long term and very expensive.

- Population and economic growth inevitably place pressures on the State's land resources. Queensland's population increased by 2.5 percent a year between 1991 and 1996 and continues to grow rapidly.
- Vegetation clearing is a significant pressure on land and soil resources in Queensland. Almost 35 percent of the State, including the larger part of the State's most productive and accessible land, has been cleared since European settlement. Between 1991 and 1995, land clearing occurred at an estimated rate of 285 000 hectares a year. Clearing can accelerate erosion and can increase the risk of salinisation.
- Legislation is in place to regulate clearing of native vegetation on leasehold land. A Broadscale Tree Clearing Policy and associated Local Tree Clearing Guidelines under the *Land Act 1994* came into effect in late 1997. Local governments can use vegetation protection orders and development control plans to protect vegetation on freehold land.
- Cropping has contributed to soil degradation, particularly accelerated erosion, soil fertility decline and soil structure decline. Cropping area in Queensland has steadily increased: 2.7 million hectares were cropped in 1996–97. Practices still causing problems in some areas are bare-surface cropping, fallowing, excessive tillage, compaction by traffic use, overuse of fertilisers and irrigation.
- Overgrazing has contributed to the decline in pasture quantity and quality, particularly during dry seasons. The introduction of plants for grazing has been responsible for some of Queensland's noxious plant species. Livestock also cause significant damage through soil erosion and compaction.
- Urbanisation, particularly in the south-east, precludes land from other productive land uses, including agriculture. During 1994 and 1995 more than 16 500 hectares of agricultural land were subdivided for urban housing. Pressures on prime natural and agricultural land are particularly intense in the Sunshine Coast and Cairns areas. A State planning policy (*Development and Conservation of Agricultural Land*) aims to protect good-quality agricultural land.
- Soil erosion by water affects 80 percent of Queensland's 3.3 million hectares of cultivated land (crops and sown pastures), adding substantial costs to production. Bare-fallowed and overgrazed land is particularly prone to water erosion. Coastal sloping lands around Cairns and Mackay and in the Sunshine Coast hinterland have an extremely high erosion risk. There has been wide adoption of soil conservation measures across Queensland.
- Wind erosion rates appear to have accelerated in the south-west and north-west of the State partly as a result of rural land use practices.
- Soil fertility decline is most severe in soil used for intensive cropping due to removal of significant amounts of nutrients by high-yielding crops, and loss of organic matter through tillage and erosion. The worst affected areas include 350 000 hectares in the Darling Downs and the Burnett regions.
- Soil structure decline is found to some degree in all cropping soils but soils at greatest risk are under cropping with either irrigation or high rainfall and high levels of tillage. About 14 percent of the State's cropping lands are at very high risk of decline. The cotton, grain and oilseed industries are widely adopting practices to reduce soil structure decline; the sugarcane and horticulture industries are doing so to a lesser extent.
- Soil salinity resulting from rising watertables, mostly associated with clearing of deep-rooted vegetation and irrigation, is a concern in many parts of coastal and inland Queensland. An estimated 14 000 hectares is seriously degraded by dryland salinity. Almost half of the State's cleared area is on land highly susceptible to dryland salinity. The total area of land affected by irrigation salinity is comparatively small, an estimated 1500 hectares.
- Soil acidification is accelerated by various agricultural activities including product removal and the use of ammonia-based nitrogen fertilisers. Crops causing the highest rates of acidification are pineapples, bananas, sugarcane and pasture hay. More than 720 000 hectares of coastal land is classed as highly or very highly susceptible to acidification.
- Native pastures occur on 149 million hectares, or 86 percent of the State. Most native pasture communities have suffered widespread deterioration — only 42 percent of native pastures remains in a desirable condition due to changes in pasture composition and surface soil characteristics.
- Major noxious plants infesting large areas of Queensland include rubber vine (34.6 million hectares), prickly acacia (more than 6.6 million hectares), parthenium weed (17.5 million hectares) and mesquite (500 000 hectares). Woody weed invasion affects all Queensland pasture areas, approximately 48 percent of grazing lands having a medium or high degree of invasion. Noxious plants are becoming established at the rate of one or two new species each year.
- Feral populations of 19 species of introduced mammals have established in Queensland. Effects on the land

include damage to grazing land, crops, soil and water bodies, leading to accelerated soil erosion, pasture decline and woody weed invasion. Feral animals also compete with stock and native animals for food and habitat.

- Legislative measures for controlling noxious species are in place. Financial incentives available to landholders include subsidy programs, tax rebates and reduced interest rates. Biological control agents for the control of some weeds have had some success, and research into new agents continues. Community groups and local governments are active in the control and management of woody weeds and feral animals.
- Landcare, a national program in which land managers, industry and government work together for sustainable management, is one of the most significant programs for arresting land degradation and promoting sustainable land use practices. The signature component of the National Landcare Program, now funded by the Natural Heritage Trust, is its community groups. Recent years have seen a large increase in the number of Landcare groups in Queensland.
- Forests cover approximately 49 million hectares, or 28 percent of Queensland, although about 75 percent of this cover is relatively sparse forest. Fifty-eight percent of total forest cover is publicly owned, with 8.0 million hectares on Crown Reserves and 20.7 million on leasehold land. Only about 2.4 million hectares of Crown Reserves are used for commercial forest operations.
- Most of the State's forest resource is native forest (99.6 percent). Plantation forests cover only a small area but supply 61 percent of timber consumed in the State. The worldwide supply of timber is expected to decrease over the next 20 years, providing both pressures and opportunities for Queensland forestry, particularly the need for new timber plantations on private land.
- The need for sustainable forestry management has been recognised in the National Forest Policy. The first Regional Forest Agreement between the Commonwealth and State Governments for the Southeast Queensland bioregion is in preparation. Management of State forests has been split between agencies to separate commercial and custodial functions. Crown foresters calculate sustainable yields for native forests and develop detailed harvesting plans that include environment protection measures.
- The total area of mining leases in Queensland is 1.1 million hectares. The land directly disturbed by mining on these leases is approximately 73 000 hectares. About 23 000 hectares of previously disturbed land had been rehabilitated by mid-1998. The area disturbed by abandoned minesites is not known but is relatively small.
- The Queensland Government is developing a draft environmental protection policy for the mining and petroleum industries. Environmental Management Overview Strategies for the environmental protection and rehabilitation of disturbed land are required for all holders of a mining lease. Since 1985, about $14 million has been spent on rehabilitating abandoned sites.
- Responses to land issues require cooperation from a wide range of stakeholders, regional and holistic approaches, and a long-term sustainability focus. Across the State, landholders are adopting best practice management, but to achieve ecological sustainability, more incentives, more information and education on sustainable practices are needed.

INDICATORS

Pressure

Vegetation clearance

Rate of vegetation clearance

Agriculture

Area under bare-surface production systems

Extent of cropping and sown pasture activities

Grazing pressures

Actual stocking rates compared to carrying capacity

Area of cultivated land with high rates of application of ammonia-based nitrogen fertilisers

Fertiliser use

Agricultural chemicals use

Compliance with maximum residue limits and maximum permitted concentrations in agricultural produce

Irrigated area

Source of irrigation water

Proportion of introduced pasture species that become noxious weeds

Urbanisation

Population and economic growth

Residential dwelling approvals

Number of landfill sites

Introduced plants and animals

Number of introduced and naturalised plant species

Number of introduced animal species

Forestry

Processed timber consumption

Proportion of processed timber harvested from plantations/native forests

Harvest as a proportion of sustainable yield

Mining

Production of principal metallic minerals and fuel minerals

Numbers of operating mines, quarries, mining leases and exploration permits

State

Erosion

Water erosion hazard ratings

Rate of soil loss from water erosion (tonnes/hectare/year)

Frequency of occurrence of dust events (Dust Storm Index)

Difference between measured wind erosion rates and rates predicted by climatic conditions (Accelerated Erosion Index)

Area affected by soil mass movement

Soil fertility and structure

Soil fertility levels

Area affected by soil structure decline

Salinity

Area of land affected by dryland salinity

Area of land affected by irrigation salinity

Acidity

Area of cropping land with naturally acidic surface soil or with high rates of acidification

Native pasture decline

Area of native pasture species recognised as being in a desirable condition

Noxious plants and feral animals

Number, density and distribution of noxious plant species

Percentage of grazing lands affected by woody weeds

Number of established feral animal species and their distribution

Contaminated land

Numbers of low-risk and high-risk sites on registers

Number of potentially UXO-contaminated sites

Loss of land to urban uses

New allotments for housing

Agricultural land subdivided for urban housing

Forest resources

Area of State-owned/privately owned forests

Area of native/plantation forests

Forest area harvested/not harvested

Mining disturbance

Cumulative areas of land disturbance and rehabilitation

Number of abandoned minesites

Introduction

INTRODUCTION

This chapter examines the main environmental issues associated with Queensland's land resources. Like water and air, land is an essential resource. Land:

- is fundamental in sustaining ecological processes;
- supports native ecosystems and maintains biodiversity;
- supports food, fibre and mineral production, contributing to Queensland's economic wealth;
- provides living space;
- supports recreational activities;
- preserves geological, historical and evolutionary information and materials; and
- has spiritual, inspirational, scientific, cultural and educational value.

Queensland's landscape has changed greatly since European settlement. Cultivation and grazing practices have altered the landscape known by Aboriginal people. Substantial tracts of land have been cleared of native vegetation. Native forests and rangeland pastures have declined in area, giving way to introduced pastures, forest plantations, cropping, industry, tourist and urban developments, and mining. In many instances, inappropriate land use and cultural practices have caused the degradation of land and vegetation resources, and appear to be unsustainable. Land restoration activities are often difficult, long term and very expensive.

Scope

This chapter takes a broad view of land resources, discussing soils, vegetation and land use issues. Major environmental issues arising from the use of land resources in Queensland include soil degradation, vegetation clearing, native pasture decline, noxious plants and feral animals, loss of agricultural land and native habitat, and contaminated land. The use of two of the State's key resources, forests and minerals, is also briefly discussed.

Land resources in this chapter are described, depending on context, in various units including catchments, bioregions, agricultural areas, statistical divisions and local government areas.

Agricultural years for ABS statistics cited in this chapter generally cover the 12 months to 31 March.

Background

Queensland's land resources

Queensland's land resources lie between the latitudes 10ºS and 29ºS and the longitudes 138ºE and 153ºE. The area within the State's administrative jurisdiction includes numerous coastal islands. Queensland's total land area is 172.8 million hectares, of which 54 percent is classified as tropical.

The State can be divided into four main landscape regions: the eastern highlands, the western plains, the north-western uplands and the coastal plain. The first three regions broadly correspond to three geological groups: the Tasman geosyncline, which extends almost the length of eastern Queensland; the Great Artesian Basin, covering nearly two-thirds of inland Queensland; and the ancient Precambrian shield, exposed in the north-west and north. Much of the eastern coastline consists of long, sandy beaches with sand dunes and high sand deposits.

Queensland's soils, like those of the rest of Australia, are often ancient, highly weathered and leached of nutrients. The continent has been geologically stable, with little volcanic activity or creation of new land masses for many millions of years. However, limited volcanic action about 25 million years ago produced soils suitable for cultivation in south-east Queensland, around Mackay and in the Atherton Tableland region. Floodplains and deltas of rivers such as the Burnett and the Burdekin also contain agricultural soils.

Vegetation

Queensland's vegetation types can be grouped into the broad categories of forests (including woodlands), arid shrublands, grasslands, heathlands and wetlands. Distribution is largely determined by soil type, rainfall and temperature. Chapter 7, 'Biodiversity', describes vegetation types in detail.

Broad forest types include open eucalypt, dense eucalypt, melaleuca, rainforest, mangrove, cypress pine and banksia. About 50 percent of Australia's total forest area is in Queensland. Currently, native forests cover 49 million hectares, or approximately 28 percent of the State. Most is classed as woodland (36 million hectares); 3 million hectares is classed as closed forest and 10 million hectares as open forest (NFI 1998).

Eucalypt open forests or woodlands cover 65 percent of the total forest area and occur on relatively infertile soils in low-rainfall areas. Rainforests, covering 5 percent of the total forest area and 72 percent of Australia's total rainforest area, occur as warm temperate and subtropical rainforests in the south-east and as tropical rainforest in the north. Cypress pine forests occur in south and central Queensland, mainly on relatively infertile, coarse-textured soils.

Queensland has about ten main types of woodlands, most with mixed species rather than a single species. Woodlands have been cleared extensively for cropping and grazing. Broad shrubland types include mulga (*Acacia aneura*), gidgee (*Acacia cambagei*) and spinifex (*Triodia* spp.).

Native pastures occur on 149 million hectares, or 86 percent of the State. Native grasses occur in grassland and woodland settings and are commonly used for livestock grazing. Nineteen local native pasture communities have been recognised in the State (figure 3-20). These are made up of 46 localised areas of distinctive pasture communities named local pasture units (LPUs). Of the 19 native pasture communities, the

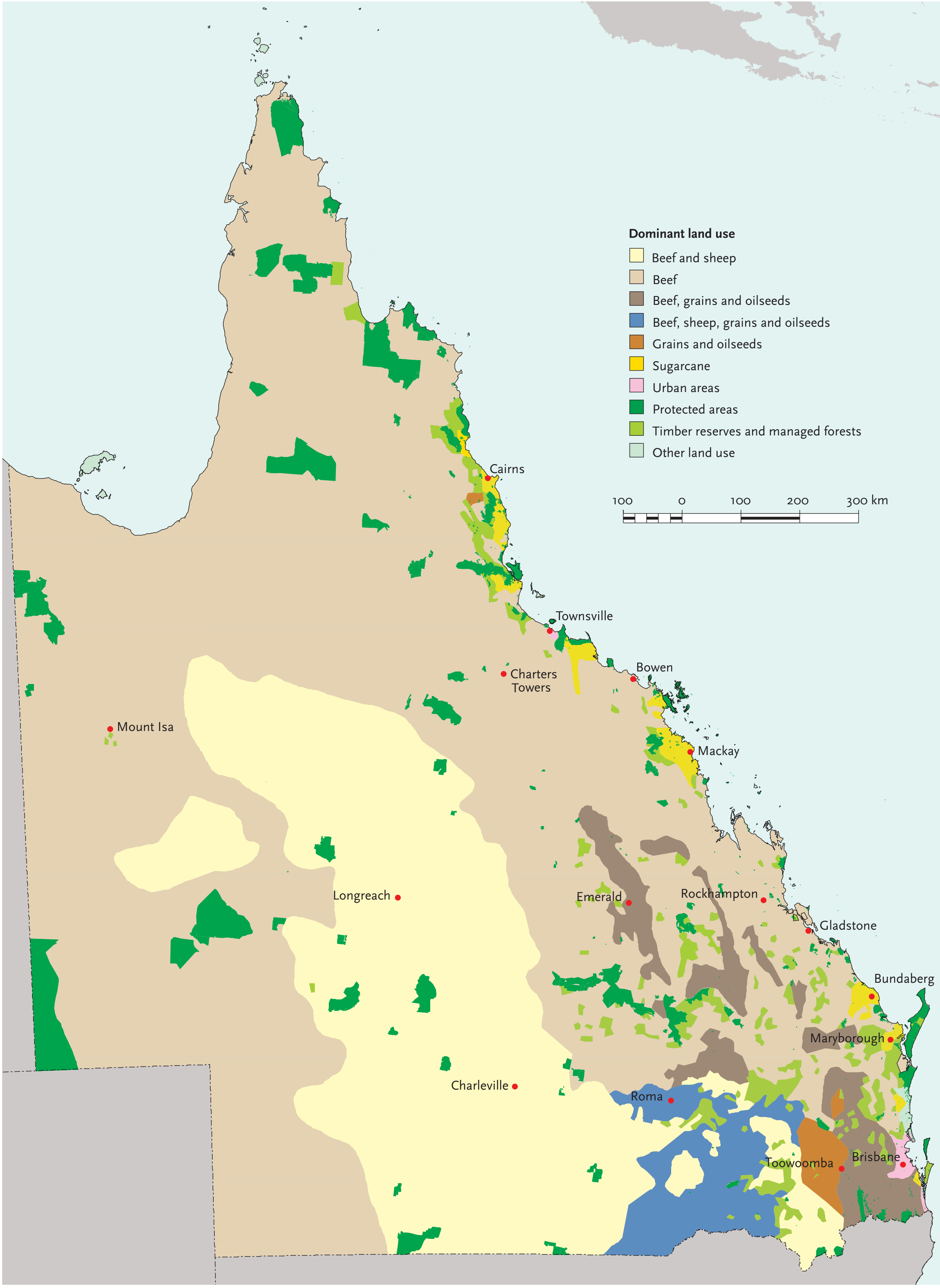

Figure 3-1 Dominant land uses in Queensland
(Source: DNR)

Aristida-Bothriochloa community occupies a larger area than all others — about 30 million hectares. The mulga (annual shortgrass) pasture community, at 600 000 hectares, occupies the smallest area.

An additional 5.6 million hectares (1994 figures) is sown to 'improved' pasture species, mostly from Africa and South America (ABS 1998a). 'Improved' pastures generally have higher nutritional value. They are located mainly in south-east and eastern coastal regions.

Coastal heathlands typically occur on poorly drained, infertile soils. Coastal heathlands and related vegetation have been cleared extensively, especially in south-east Queensland.

Wetlands include lakes, mangroves, saline coastal flats and intertidal flats and areas subject to seasonal inundation along rivers and creek banks.

Land use

Queensland hosts a wide range of land use activities. Food and fibre production (grazing and cropping) is the dominant use: agricultural establishments occupy some 150 million hectares of the State's total land area of 172.8 million hectares (ABS 1999). Protected areas including national parks and nature reserves occupy about 4 percent, while managed forests and timber reserves occupy 2.5 percent. The remainder of the land is used for services, housing, industry and mining activities (figure 3-1).

Cropping and grazing

The diversity of Queensland's soil types and climate has made possible a wide range of valuable agricultural industries. Sugarcane farming and intensive horticulture are carried out in the high-rainfall areas of the coastal zone and Atherton Tableland or where adequate irrigation water supplies are available. Large areas of grain and introduced pastures are found on the Darling Downs and Central Highlands. Cotton is produced primarily under irrigated conditions and is therefore grown close to major dams or rivers in central and southern Queensland.

In March 1996, Queensland had 32 186 agricultural establishments covering 149.7 million hectares (ABS 1998a). The number decreased to 30 987 establishments in March 1997 over an increased area (151.1 million hectares), continuing the downward trend in establishment numbers of recent years (ABS 1999).

Sugarcane is one of Queensland's main crops, ranking third in area after wheat and grain sorghum crops. Cultivation is intense and crops are often irrigated.

Table 3-1 Area occupied and gross value of major crops in Queensland in 1995–96 and 1996–97

Crop	Area ('000 ha)		Gross value ($m)	
	1995–96	1996–97	1995–96	1996–97
Sugarcane	359	371	1117	1112
Grain sorghum	597	424	226	179
Wheat	627	980	147	422
Barley	168	na	39	67
Cotton	120	129	337	409
Peanuts	20	23	28	34
Sunflowers	46	96	27	na
Vegetables	32	na	437	448
Bananas	5	6	178	141
Mangoes	na	na	60	55
Mandarins	na	na	47	57
Pineapples	3	3	36	39
Tobacco	2	na	27	29
Total all crops	**2394**	**2685**	**3110**	**3509**

(Sources: ABS 1998a, 1998b, 1999)

Table 3-2 Gross value of Queensland's agricultural commodities ($m)

Commodity	1993–94	1994–95	1995–96	1996–97
Crops	2543	2970	3244	3509
Livestock	2124	1916	1552	1614
Livestock products	513	580	575	554
Total	**5180**	**5466**	**5370**	**5677**

(Sources: ABS 1998a, 1999)

In 1996–97, the area of land under crops (excluding pastures and grasses) was 2.7 million hectares (ABS 1999). Cropping area fluctuates from year to year, but peaked in 1985–86 at 3.3 million hectares. Table 3-1 gives land areas and gross value of major crops as estimated by the ABS from information provided by landholders. Note that while sugarcane accounts for 38 percent of the total gross value of crops, it is grown on only 15 percent of the total cropping area. Another estimate of cropping areas has been obtained by analysis of satellite images taken between 1988 and 1995: the total area of broadacre crops (grains, cotton, oilseed and forage crops) in Queensland was estimated at approximately 2.7 million hectares and that of sugarcane at 450 000 hectares (Kuhnell and Danaher 1996).

It is estimated that approximately 150 million hectares, or 87 percent of Queensland's land area, supports sheep and cattle; this is about 60 times the area used for cropping (Burrows et al. 1988). The last ABS estimate of area of land used for livestock in Queensland, 159 million hectares, was made in 1981 (ABS 1998a). More recent information on estimated livestock numbers, provided to the ABS by landholders, is available. Numbers fluctuate according to commodity prices and seasonal conditions. Cattle numbers in Queensland increased annually by between 6 and 15 percent in the early 1970s and reached a peak of 11.5 million in 1977. Over the next 10 years, numbers steadily declined to a low of 9.5 million in 1989, then gradually increased to 10.4 million in 1997. Sheep numbers peaked in 1990 at 17.4 million, then declined to 10.5 million in 1997 (ABS 1998a, 1998b, 1999).

Table 3-2 gives the gross value of agricultural commodities produced in Queensland. In 1996–97, crop production contributed 62 percent, while livestock contributed 28 percent and livestock products 10 percent. The value of crop production has increased in significance compared to livestock and livestock products in recent years.

National parks and State forests

The 7.1 million hectares devoted to protected areas, including national parks, are important in preserving Queensland's biodiversity. Protected areas also have economic, aesthetic, educational, scientific and recreational values. The value in monetary terms of national parks is difficult to estimate, but it has been estimated that visitors to Queensland national parks spend more than $600 million annually in association with their visits. This has a total direct and indirect output effect in the Queensland economy of around $1.2 billion (Kinhill Economics 1998).

A further 4.3 million hectares are under State forest and timber reserve tenure. About 2.4 million hectares are used for commercial forest operations.

The direct turnover of the Queensland forest industry (including plantation forests and forests outside State tenure, which provide about 60 and 25 percent of all processed timber respectively) is estimated to be $1.7 billion. The forest industry is concentrated in the Brisbane–Moreton, Wide Bay–Burnett, Darling Downs, Fitzroy and Mackay regions (DPI 1998).

Mining

The total area of mining leases (1.1 million hectares) is only 0.6 percent of the State's land area. Major mineral deposits are described on page 3.28 and shown in figure 3-10. Table 3-3 gives the value of minerals produced in Queensland. In 1996–97, coal contributed 64 percent.

Minerals are the major export income earner for Queensland (ABS 1999). The major mineral exports for 1997–98 were black coal ($5.48 billion), copper ($517 million) and gold ($462 million). Queensland is the largest coal exporter in the world (DME 1998a; DME, unpub. 1999).

Table 3-3 Value, at mine, of minerals produced in Queensland ($m)

Commodity	1993–94	1994–95	1995–96	1996–97
Metal ores	1583	1646	1906	1725
Coal	3317	3339	3688	3947
Oil and gas	234	301	342	355
Other non-metal ores, including clays and limestone	136	147	134	101
Total	**5270**	**5434**	**6070**	**6127**

(Sources: ABS 1998a, 1999)

Land tenure

In the Australian Federation, a State's interests in land are derived from two sources: the sovereign power by which the State Government exercises authority to legislate on behalf of the people; and the proprietorial power by which the State, acting as landlord, allocates property rights by means of tenure.

Table 3-4 Land tenure in Queensland at June 1997

Tenure	Area ('000 ha)	Percentage of State
Leasehold	115 347	66.8
Freeholding lease	16 318	9.4
Freehold	28 680	16.6
Protected areas	6 927	4.0
State forests, timber reserves	4 257	2.5
Other State land	1 171	0.7
Total	**172 700**	**100**

(Source: DNR)

The State owns or leases out a large part of Queensland: Crown land, leasehold land and freeholding leases cover 83.4 percent of the State. A freeholding lease is a lease which is in the process of being converted to freehold (that is, to private ownership of land). Leasehold conveys property rights of lower status than freehold — for example, the Crown retains the rights to timber on some leasehold land. Freehold rights are not absolute, however: for example, mineral rights are reserved by the Crown. The State can potentially use the leasehold system to achieve public interest outcomes, such as influencing patterns of land settlement or fostering sustainable land management principles.

Property interests in the land tenure system are protected under the *Land Act 1994*; a land registry holds ownership information. Land is leased, sold or reserved with reference to equity principles and the interests of clients and stakeholders. Stakeholders include Aboriginal and Torres Strait Islander peoples, trustees of State trust land, industry groups, land professionals, financial institutions, individuals, community interest groups and all levels of government. Table 3-4 summarises land tenure in Queensland at June 1997.

Queensland's land resources are subject to a wide variety of land uses which impose a complex range of pressures, many of them interrelated. Both urbanisation and agriculture exert pressures to clear vegetation, which can result in increased erosion and dryland salinity. Exotic species can take greater hold where land has been cleared or eroded, or where weather conditions are favourable to them. Some land degradation conditions themselves act as pressures: erosion results from land clearing, poor agricultural practices and weather, but in turn contributes to declines in soil fertility and structure. Even some remedial responses can become pressures if mismanaged: fertiliser use is a positive response to soil fertility decline but overuse can have negative impacts on land and water quality.

Queensland experiences periodic drought which can affect land resources for long periods.

Table 3-5 provides an overview of relationships between past and present pressures on land and soil resources and their resultant state, or condition. Many of these pressures also lead to loss of natural habitat and degraded air and water quality. These issues are discussed in detail in other chapters.

UNDERLYING PRESSURES

Weather and climate

Climate has a significant effect on land and soil resources. The landscape we know has been shaped by water, ice and wind, by biological activity and by heat and cold over long periods. Human activities have magnified the impact of these forces on land and soil resources. For example, rates of water, wind and mass movement erosion have risen markedly as land has been cleared of vegetation, cropped or overgrazed. Heavy grazing

Table 3-5 Overview of relationships between pressures on and condition of land resources

Pressure	Resulting condition if pressures are poorly managed
Underlying pressures: — weather and climate — population growth — economic pressures	Underlie and/or exacerbate many of the following pressures
Vegetation clearance	Degraded soils, particularly: — erosion — dryland salinity Spread of noxious species (can lead to degraded soils) Increased grass cover
Agriculture: — bare-surface production systems — intensive cultivation — grazing and associated fire regimes — application of fertilisers and agricultural chemicals — irrigation — introduction of exotic species	Vegetation clearance Erosion (can lead to loss of soil fertility and structure) Soil fertility decline Soil structure decline Irrigation salinity Acidification Land contamination Noxious plants and animals (can lead to native pasture decline and erosion) Native pasture decline Contaminated land
Urbanisation	Vegetation clearance Loss of productive land Land contamination from wastes
Introduced plants and animals	Noxious plants and feral animals (can lead to native pasture decline and erosion)
Forestry operations	Depletion of forest resources Erosion and chemical contamination of soils
Mining	Depletion of mineral resources Disturbed land Land contamination from wastes

has magnified the effects of drought on pasture condition (see 'Grazing' below).

Queensland's climate is subtropical to tropical. Rainfall and rainfall intensity vary widely across the State and within and between seasons. Parts of the State are subject to climatic extremes such as storms, cyclones and extended droughts. Broad climatic patterns, seasonal weather conditions, climatic extremes and climate change all have the potential to affect land resources.

Broad climatic conditions such as extended wet or dry periods affect vegetation cover, fire regimes and the spread of feral populations. Seasonal weather conditions determine in part the extent of green vegetation cover, which in turn affects levels of erosion (see box 'Seasonal vegetation cover and erosion'). Climatic extremes such as drought and flood have a particularly significant effect. For example, a study on the Darling Downs found that 70 percent of water erosion measured over 14 years was due to six storms (Freebairn and Wockner 1991). Many of the major climate extremes have been associated with El Niño or La Niña events as part of the El Niño Southern Oscillation (ENSO) phenomenon (Taylor and Tulloch 1985; McKeon et al. 1990).

There is evidence that in recent decades the State has not been exposed to the full range of possible climatic extremes. Stream flow and rainfall patterns have been reconstructed for periods before recording began in around 1880, using fluorescence bands in corals at the mouth of major river catchments such as the Burdekin River (Lough 1991). A reconstruction dating back to 1735 suggests that there were wetter and drier decades and thirty-year periods in the eighteenth and nineteenth centuries than in the twentieth century. The extreme drought year of 1902 was the driest of the 245 years of the study (1735 to 1980).

The high variability of rainfall between areas and from season to season and year to year in Queensland makes it difficult to describe pressures and land condition in general terms and to prescribe appropriate management strategies. For example, decisions on vegetation clearing and stocking rates in the past were sometimes made without consideration of climate variability or with a poor understanding of it. Learning to understand and adapt to climate variability is important in land resources management in Queensland.

The expectation of climate change occurring with global warming as a result of the enhanced greenhouse effect is also an important climatic factor (see chapter 2, 'Atmosphere'). Current climate change scenarios predict significant effects on Queensland's rainfall, although the direction of change may differ in different areas (Hall et al. 1998).

Similarly, the effect on climate extremes is uncertain. The recent and likely future behaviour of ENSO under global warming is the subject of considerable debate (Allan et al. 1996; McKeon et al. 1998) and has major implications for much of Queensland (Suppiah et al. 1998). The Southern Oscillation Index (SOI) is a commonly used measure of ENSO behaviour and provides a record back to the 1870s. The period 1976–99 had more El Niño periods of consistently negative SOI (1977, 1982, 1987, 1991–95, 1997) than La Niña periods of consistently positive SOI (1988, 1996, 1998). There is as yet no consensus amongst climatologists on whether this ENSO behaviour is due to global warming or to natural variability.

Any long-term variation in the behaviour of ENSO may have important implications for land management in the future. For example, episodes of vegetation regeneration in western New South Wales and Queensland from deteriorating and degraded conditions have involved sequences of favourable above-average rainfall years, often in association with La Niña events, in the mid-1950s and early 1970s (Condon 1986; Tothill and Gillies 1992). The importance of the La Niña phase for this regeneration, or the cessation of pasture deterioration, is only just beginning to be appreciated. Any future reduction of La Niña frequency is likely to reduce the opportunity for resource regeneration. There is a need for continuing monitoring and prediction of ENSO behaviour.

Population growth

Population growth underlies most of the pressures discussed below. Population growth creates demands for housing, services, transport, food production, water supply, forest products and mineral resources. Population growth also results in intensification of activities such as vegetation clearance, agricultural production, urban development and introduction of exotic species, raising the risk of damaging effects.

In June 1997 Queensland's estimated population was 3.4 million; it is expected to reach between 5.8 and 6.5 million by 2040. The State's population grew by an average of 2.3 percent a year between 1992 and 1997 (ABS 1999). Although highly urbanised, Queensland's population is more decentralised than those of the other mainland States. The tourist population also requires land for accommodation, food, transport and services. Details of population and tourism growth rates can be found in chapter 8, 'Human settlements'.

Economic pressures

Several underlying economic pressures contribute to and exacerbate land degradation in Queensland. These include the State's export orientation, decreasing real commodity prices, inflation, the cost–price squeeze, non-viable property sizes, increasing debt and market failure in the property market. Many of these pressures are interrelated.

While exports are a valuable component of the State's economy, Queensland's net export orientation imposes additional demands on the State's land resources. In 1997–98 , the State exported $22.6 billion of products to other States and other countries. Foreign exports earned $16 billion; these included coal ($5.5 billion), other mineral products ($3.3 billion), meat products ($1.6 billion), and sugar, cotton and cereals (ABS 1999).

Cost–price squeezes occur when the real cost of inputs rises but the real price received for commodities falls. Non-viable property sizes are a result of a combination of decreasing real prices for commodities and inappropriate land allocation policies of the past. Rising debt resulting from cost–price squeezes, non-viable property sizes, prolonged drought and other factors intensifies pressure on the land to provide an economic return and thus increases the risk of degradation.

Market failure can contribute to degradation if land degradation on a property is not truly reflected in the value of the property. If buyers have insufficient knowledge of the symptoms and effects of degradation, degraded and non-degraded properties may sell for similar prices. Again, if the demand for land is greater than the supply of land, market failure can occur. In these cases, landholders who knowingly or unknowingly degrade the land do not incur the full cost of degradation. In 1998, DNR began a study with Natural

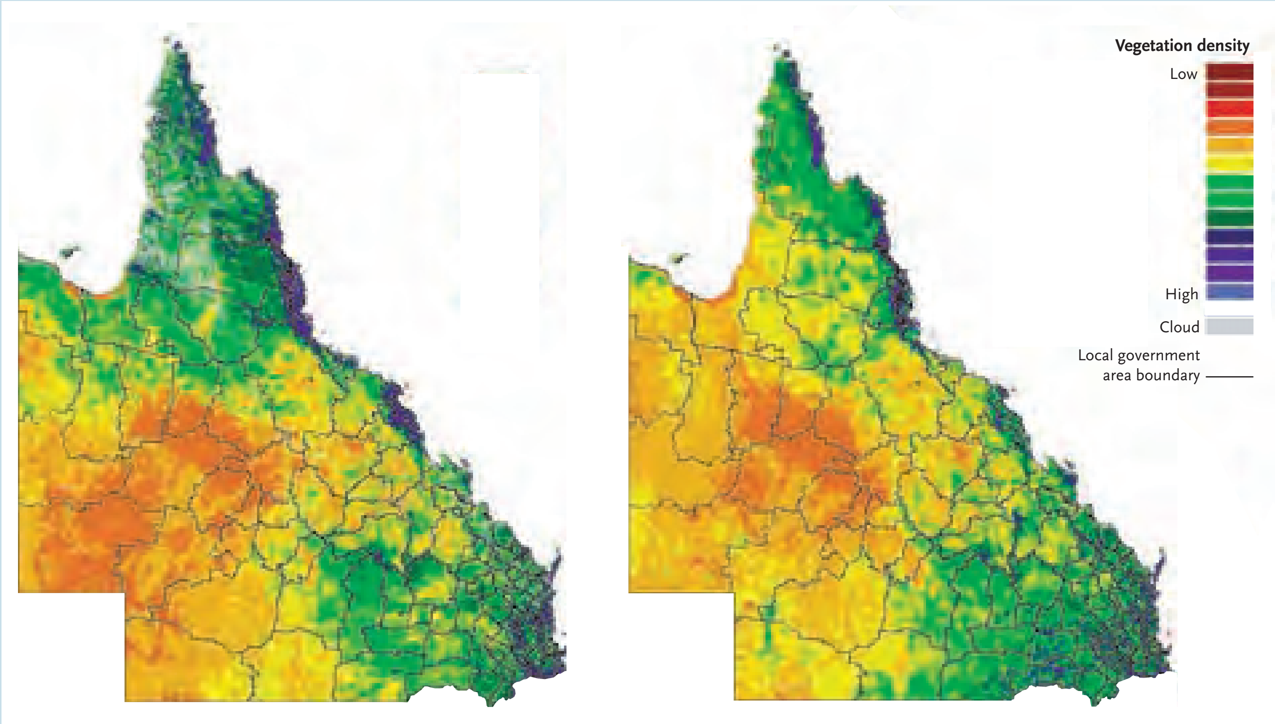

Figure 3-2 Green vegetation density in Queensland, 9–22 March 1996 and 7–20 September 1996
(Source: DNR Climate Impacts and Spatial Systems)

Vegetative cover often declines during dry seasons, leaving the land surface exposed and susceptible to high soil loss from storm events. Fifty percent of vegetation cover can reduce erosion by 90 percent. Even 30 percent of vegetation cover can reduce water erosion by 70 percent.

The potential for water erosion increases significantly in Queensland during the wet season, from November to March. Maintaining a protective groundcover of vegetation and/or plant residues is especially important at this time, when there may be high-intensity rainfall.

The presence of trees, shrubs and grasses also protects soils from wind erosion. Because most wind erosion occurs during the dry season (May to October), cover is significant.

Figure 3-2 uses NOAA (National Oceanographic Atmospheric Administration) satellite data to show green vegetation cover in two periods in 1996. These images need conservative interpretation as they provide only a qualitative indication of seasonal plant growth as a result of rainfall, not an overall picture of vegetation resources or trends. The images show green cover and exclude dry or dead plant residue, which is also useful for erosion control. Note that not all green cover is necessarily of high quality: thick areas of woody weeds will have a high level of green cover.

Figure 3-2 shows that in March 1996, during the wet season, Queensland's central, south-western and western parts had low green vegetation densities compared with coastal and south-eastern parts. The September 1996 image shows the density of green cover during the dry season, the critical time for wind erosion. Both soil moisture and vegetation cover are low during September. All areas (with the exception of the south-east and north-east portions) had relatively low densities of green cover, possibly also reflecting the accumulated impact of drought conditions in the first half of the decade.

The effect of the seasonal conditions on wind erosion is illustrated in the average monthly number of dust storm days in Queensland. Wind erosion is highly seasonal in Queensland, being most prevalent late in the dry season and early in the wet season. The onset of the wind erosion season in September is related to the low level of soil moisture (and thus green vegetation cover) and the high wind energy associated with the easterly passage of frontal systems across Queensland. There is an average of four dust storm days per month in October, November and December whereas there is fewer than one per month in March, April, May and June (figure 3-3).

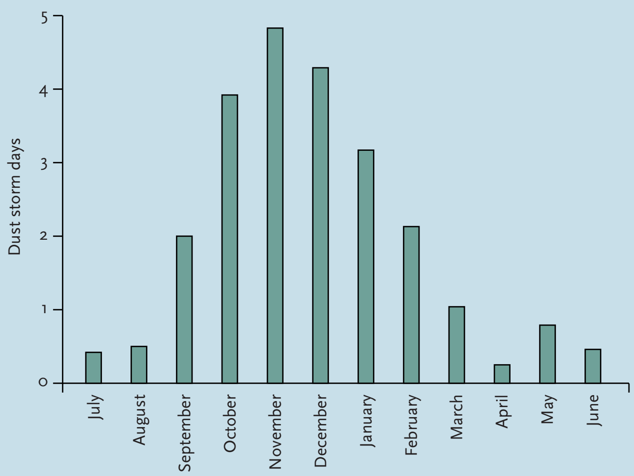

Figure 3-3 Average number of dust storm days per month for Queensland, 1973–96

Heritage Trust funding to determine whether property valuation can be used as an incentive to encourage sustainable management and off-park conservation.

In recognition of the pressures placed on rural Queensland by drought, low commodity prices and deterioration in natural resources, the State Government has implemented a rural revival program in two regions: the Desert Uplands and the south-west mulga lands around Charleville.

VEGETATION CLEARANCE

Indicator

Rate of vegetation clearance

Since European settlement, land has been cleared of natural vegetation, for grazing in particular but also for cropping, forestry, mining and urbanisation. Assessment of the historical extent of clearing is difficult because the nature of vegetation cover at the time of European settlement is uncertain. Some studies, based on paintings by early settlers and soil analyses, suggest that much of the central and south-west Queensland landscape before European settlement may have been open woodlands and grasslands with scattered mature trees, created by Aboriginal fire regimes featuring frequent fires (Pyne 1991; Burrows et al. 1998). It is thought that these grasslands have been extensively invaded by woody plants over the past 150 years as a result of reduced frequency of fire and increased grazing pressures (Noble 1997) or of climate fluctuations (Fensham 1998). It is uncertain whether vegetation clearance has been of regrowth that has occurred since European settlement or of original tree cover. Others suggest that the evidence for the open woodland scenario should be treated with caution and that woodlands were more extensive than suggested.

With this uncertainty, it has been estimated that at European settlement about 117 million hectares of Queensland (68 percent of the total land area) supported woody ecosystems (Scanlon and Turner 1995) and approximately half has now been cleared of native vegetation. Danaher et al. (1992) estimated that the area of wooded vegetation in Queensland in 1992 was 76 million hectares.

The larger part of land considered fertile, arable or suitable for introduced pasture and forestry has been cleared and other large areas have been cleared for urbanisation, mining and other purposes. Land clearing was encouraged through government-sponsored settlement schemes for pastoral and agricultural development. The largest of these was the Fitzroy Basin (Brigalow) Development Scheme in central Queensland, which operated from 1962 until 1976. It hastened the clearing of 1.8 million hectares of native bushland for the cultivation of introduced pastures, grains, oilseeds and fodder crops. Clearing has also been extensive in the Mulga Lands and in south-east Queensland. In the heavily populated SEQ 2001 area (2 250 000 ha centred around Brisbane), 64 percent of all bushland was cleared between 1820 and 1987 and a further 1 percent was cleared in the period 1987–94 (Catterall et al. 1997).

Clearing in Queensland continues on a significant scale. A CSIRO study to map the type, severity and extent of land cover disturbance using Landsat satellite imagery estimated that about 3 million hectares of native vegetation (almost 2 percent of Queensland) were cleared between 1983 and 1993 (DEST 1995).

The Statewide Landcover and Trees Study (SLATS) undertaken by DNR provides an estimate of tree clearing using Landsat satellite imagery. Preliminary estimates published in 1997 indicated that the average rate of tree clearing in Queensland in 1991–95 was 262 000 hectares a year (0.15 percent of the land area of Queensland each year), or 259 000 hectares if clearing in State forests is excluded (DNR 1997a). More recent estimates indicate that the overall figure for 1991–95 was closer to 285 000 hectares a year (Danaher, T., pers. comm.). About 55 percent of the clearing occurred on leasehold land, 42 percent on freehold land and the remaining 3 percent on Crown land. Almost 54 percent of all clearing in 1991–95 occurred in the Brigalow Belt bioregion (DNR 1997a). Figure 3-4 shows the most recent estimates of rates of clearing across the State. The box 'Land use changes in the Maroochy River catchment' (page 3.44) provides an example of recent clearing rates.

Preliminary SLATS data suggest that the rate of clearing overall declined by approximately 21 percent between 1988–91 and 1991–95, although clearing in the Southeast Queensland bioregion may have accelerated. Regrowth might be occurring in central Queensland at a rate that is 43 percent of the clearing rate, although this estimate has a high degree of uncertainty (DNR 1997a).

The link between clearing and loss of biodiversity is clear, as discussed in chapter 7, but poorly managed clearing practices can also have adverse effects on land quality. Poorly managed tree clearing, particularly on erodible soils such as vertisols

DNR

Land clearance for urban development (left) and agricultural purposes (right) continues on a significant scale in Queensland.

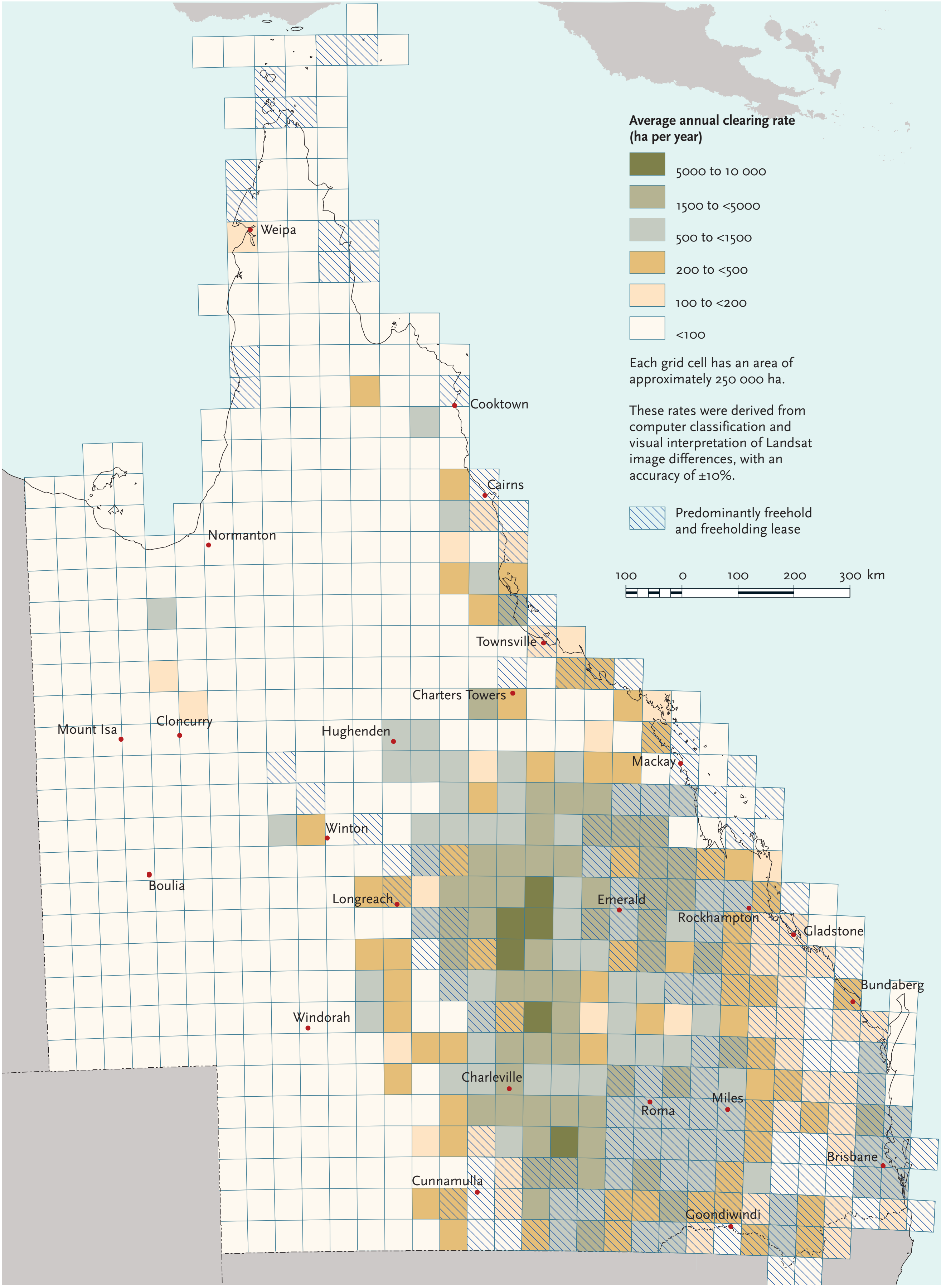

Figure 3-4 Average annual clearing rate, Queensland, 1991–95, by 30' × 30' (latitude/longitude) grid cell. The Queensland average was 285 000 ha per year.
(Source: DNR)

and on sloping land, along ridges or along stream banks, has contributed to water erosion and soil mass movement in parts of Queensland. Trees also protect land from wind erosion, reducing wind speeds and evaporation rates. Erosion rates cannot be related directly to rates of tree clearing as factors such as rainfall patterns, soil types, slopes and level of remaining or replacement cover are significant. Cover is the most important management factor. In some cases where trees are replaced by grass cover, the grass may provide better erosion protection than trees and no or patchy grass. Cover levels of more than 30 percent appear to be critical for erosion control (Freebairn et al. 1991; Wylie 1993). Statewide data that link rates of clearing to recorded erosion rates are not available, but see pages 3.30–3.32 for an analysis of the accelerating effects of land use on wind erosion.

Clearing of deep-rooted vegetation has been linked to the development of dryland salinity in other States, particularly in the Murray–Darling Basin and in south-west Western Australia. However, susceptibility to dryland salinity is generally low in Queensland. Landscapes at risk from salinity have a particular combination of geology, groundwater levels, rainfall, land use and soil type features (for example, see box 'Dalrymple Shire — grazing in Queensland's tropical rangelands'). For salinity to appear in the landscape, there needs to be a significant increase in deep drainage as a result of land use change. In many parts of Queensland, the clearance of native vegetation for pasture production has not significantly increased deep drainage due to predominantly summer rainfall and heavy clay soils, so the risk of salinity is low. A higher risk could be associated with vegetation clearance on freely draining soil types where rainfall exceeds evaporation potential for several months of the year. Establishment of cropping and irrigation systems poses a much greater risk for the development of watertable salinity.

AGRICULTURE

Agriculture exerts a wide range of pressures on land resources. Cropping practices such as bare-surface production, frequent cultivation and overuse of fertilisers, pesticides and other farm chemicals can have detrimental impacts on land resources through soil fertility and structure decline, erosion, salinity, acidification and contamination.

Grazing is the most extensive land use in Queensland. More than two-thirds of agricultural establishments in Queensland carry livestock, most running cattle or sheep or both (ABS 1999). Overgrazing, especially during dry seasons, can cause a decline in pasture quantity and quality, and lead to replacement of preferred and/or native species with unpalatable and noxious species. Livestock can also cause significant damage through soil erosion and compaction, the contamination of water bodies and the spread of weeds.

Agricultural activities can exert a wide range of pressures on soil resources (Pumicestone catchment).

Bare-surface production systems

Indicator

Area under bare-surface production systems

Bare-surface production systems, in both cropping and grazing, are those where soils are left bare of vegetation and exposed at some time during the production cycle, for example by ploughing after harvest. Poorly managed bare-surface production systems can contribute to soil losses through erosion. Bare-surface production systems include crops such as grains, oilseeds, fodder crops and sugarcane, and grazing if it is so intensive that cover is removed.

In eastern areas of the Darling Downs, where soils are highly erodible, soil losses from water erosion on cultivated land with inadequate erosion protection have been measured at between 30 and 50 tonnes per hectare per year, depending on slope and rainfall intensity. This is equivalent to an annual loss of 3–5 mm of topsoil. In extreme cases, where soil was devoid of cover and no contour banks had been constructed, up to 300 tonnes/hectare of soil movement was measured after major storms (Freebairn and Wockner 1991). In sloping canelands in wet tropical areas of north Queensland, losses of 150 tonnes per hectare per year in cultivated soils were measured (compared with less than 15 tonnes per hectare in soils that were not tilled) (Prove 1991). As discussed in the 'Response' section, widespread adoption of conservation measures has greatly reduced erosion potential across the State.

Bare-surface production systems can also contribute to wind erosion losses, particularly where the soil is left bare of vegetation for long periods and protective soil crusts are disrupted.

As landholders' practices differ, a total figure for the area of bare-surface production systems is not available with current data sets. Table 3-1 shows the area under specific crops. Figure 3-11 uses a predictive model to show erosion hazard for broadacre crops and sugarcane lands in Queensland under two possible stubble management systems (see page 3.29 for discussion).

Intensive cultivation

Indicator

Extent of cropping and sown pasture activities

Poorly managed intensive cultivation contributes to declining soil fertility and structure and soil acidification.

Soil fertility declines when the quantity of nutrients lost exceeds the amount generated naturally, acquired from erosion elsewhere or added artificially. Most cultivated and pastoral areas are subject to declining soil fertility as a consequence of the long-term removal of nutrients in harvested products or grazed plants and through the erosion, leaching and runoff of dissolved nutrients, but soil fertility decline is most severe in soil used for intensive cropping.

Soil structure decline is also mainly a problem of soils used for intensive cultivation. The main causal factors are high water content of the soil at the time of cultivation (the most significant factor), high machinery load and traction, and use of deep tillage. The main regions affected are those used for grain, oilseeds, sugar, horticulture, and vegetable crops. The degree of soil structure decline varies between cropping industries. Soil structure decline affects clay soils more than loamy and sandy soils because clay soils retain water longer.

Recent surveys of the extent and status of soil structural decline in Queensland's cropping lands found that all cropped soils exhibit some degree of structural decline, the problem being most serious in high-intensity production systems (McGarry 1997).

Agricultural activities and processes that cause soil acidification are:

- removal of large amounts of plant material and produce (which are alkaline);
- use of ammonia-based nitrogen fertilisers;
- leaching of nitrate nitrogen out of the root zone;
- accumulation of animal manure and urine in soils; and
- excessive irrigation (or high rainfall) on naturally acidic soils.

Intensive ploughing of soils over long periods can lead to soil structure decline.

These agricultural processes occur mainly in the coastal zone. The first two carry the highest risk of acidification.

Because levels of soil fertility and structure decline and acidification depend on farming practices, the area of land under sown pastures and crops in Queensland is only a broad indicator of the potential extent of degradation (figure 3-5). In 1994, 5.6 million hectares were under sown pasture; the area is increasing at the rate of about 300 000 hectares a year. Cropping area has increased steadily since about 1880. By 1900, cropping occupied about 100 000 hectares; it reached 1 million hectares in the 1950s, 2 million hectares in the 1970s, and 3 million hectares in the 1980s. The area under crops peaked in 1986 and has declined since: 2.7 million hectares were cropped in 1996–97. It is not known whether the land no longer cropped has been allowed to revegetate with native vegetation or lies fallow (ABS 1998a).

Grazing

Indicators

Grazing pressures

Actual stocking rates compared to carrying capacity

In Queensland, grazing for meat and wool production, based mainly on native pastures, is the major land use (Lloyd and Burrows 1988). The history of Australia's rangelands includes major degradation episodes resulting in loss of pasture productivity and financial hardship for graziers (Carter et al. 1999). A major cause of these degradation episodes has been inappropriate management of stocking rates, burning, and pest and weed control. Extreme climate variability has amplified the effects of poor management decisions.

High grazing pressure results in reduced soil surface protection from erosion, reduced infiltration capacity, greater loss of desirable perennial grasses, reduced frequency of burning and increased competitiveness of undesirable trees and shrubs (Tothill and Gillies 1992). From an agricultural perspective, low grazing pressure is essential to maintain the productivity and condition of the resource base.

Queensland's pasture species include tropical species found throughout the world as well as uniquely Australian flora such as spinifex pastures. The vegetation communities of most of Queensland's rangelands at the time of European settlement (1860s) were the result of Aboriginal fire management and light grazing by soft-footed macropods. The State's grazed rangelands occur across a very wide range of climates, from <250 mm of annual rainfall to >1000 mm (O'Rourke et al. 1992). Soils also vary widely in texture, structure and fertility. As a result, native pastures vary widely in terms of plant and animal production, in sensitivity to grazing pressure and in the impact of overgrazing on pasture productivity, soil erosion, weed invasion and pasture composition (Tothill and Gillies 1992).

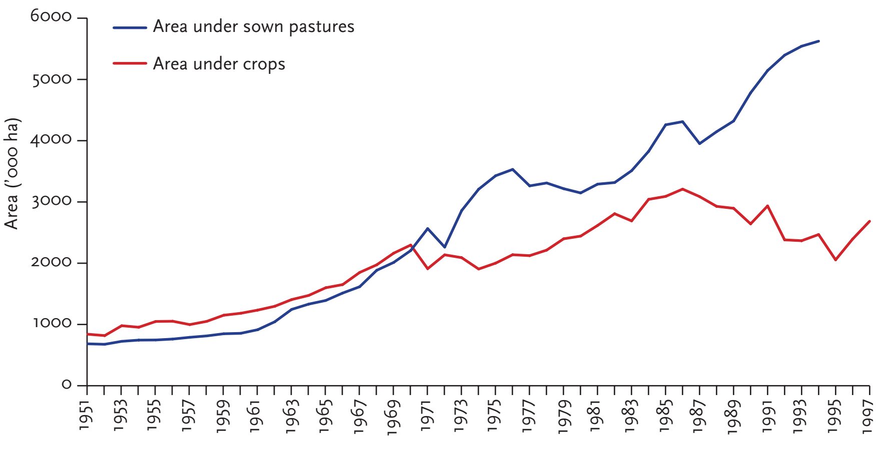

Figure 3-5 Area under sown pastures and area under crops in Queensland, 1951–97. The last year of data reported by the ABS on area under sown pastures was 1994. *(Sources: ABS 1996a, 1999)*

Because of these variations, it is not easy to quantify the impact of grazing pressure across the State. Figures 3-6

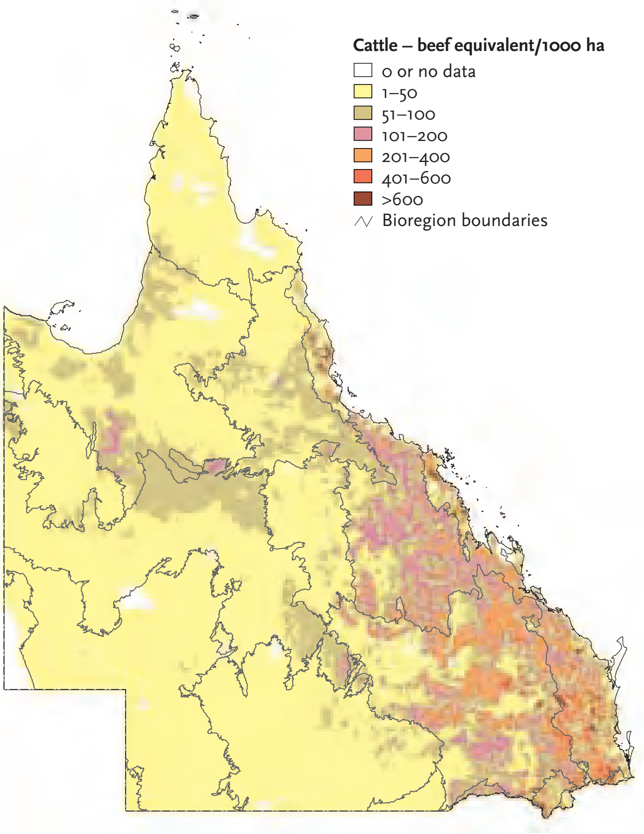

Figure 3-6 Beef cattle grazing pressure in Queensland in the year to March 1994, based on a standard equivalent of a 400 kg steer
(Source: DNR)

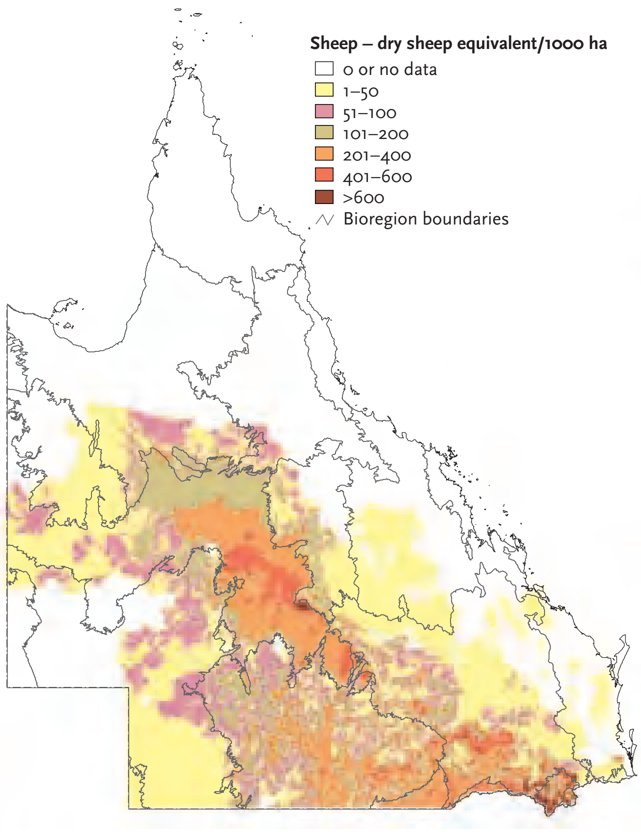

Figure 3-7 Sheep grazing pressure in Queensland in the year to March 1994, based on a standard equivalent of a 50 kg dry sheep
(Source: DNR)

and 3-7 show estimated grazing pressure in Queensland for beef and sheep in the year to March 1994 in terms of beef and dry sheep 'equivalents'. Beef and dry sheep equivalents (DSEs) are the total weight of animals in an area divided by the normal weight of a single animal (usually taken as 400 kg for beef and 50 kg for dry sheep). However, these figures do not provide any indication of the varying capacity of the rangelands to sustain grazing pressures.

Recent research has been directed at evaluating grazing pressure by combining grazier experience with measurements of pasture productivity (Hall et al. 1998; Johnston et al. 1999). In this research, estimates of 'safe' carrying capacity for specific areas or benchmark properties have been combined with simulated or modelled pasture growth (averaged over 30 years) to calculate safe levels of pasture use. Across Queensland's grazing lands, estimated safe pasture use, expressed as a ratio of animal intake per hectare to average long-term pasture growth per hectare, ranged from 6 percent to 30 percent (Hall et al. 1998). Estimates were highly correlated with climatic and nutritional indices of animal production (Johnston et al. 1996a, 1996b; Hall et al. 1998). The box 'Carrying-capacity assessments in south-west Queensland' provides an example of use of this approach.

If potential problems can be overcome, this approach, which has the advantage of incorporating variations in climate,

Carrying-capacity assessments in south-west Queensland

An approach to estimate 'safe' carrying capacity for properties in south-west Queensland is being applied in a DPI project (Johnston et al. 1996a, 1996b) in response to grazier and government initiatives aimed at shaping a more sustainable grazing industry (Warrego Graziers Association 1988; QDL 1993). A total of 217 properties — that is, 37 percent of the properties in the Murweh, Paroo, Quilpie, Bulloo and Barcoo shires and 45 percent of the area of the shires — volunteered to participate in objective carrying-capacity assessments from 1994 to 1998.

Properties involved ranged greatly in size (from 2376 ha to 866 949 ha) and estimated carrying capacity (from 9 DSE/km² to 305 DSE/km²). Where property livestock figures were available, stocking ranged from 9.4 DSE/km² to 334 DSE/km².

On 165 properties, the owner/manager provided his or her own estimates of long-term carrying capacities, derived either from records or from experience. Sixty-six percent of these estimates were within 10 percent of the assessed carrying capacity. On 23 percent of properties, the assessed carrying capacity was 10 percent or more below that nominated by the owner, and on 11 percent of properties it was 10 percent or more above that nominated by the owner.

The impact of the project on participants was assessed in 1998. One-third of the sixty producers surveyed indicated that they had made some change to their management practices following assessment. Two-thirds of those making changes believed they had seen some improvement in pasture condition since implementing the changes.

This case study provides an example of problems imposed by vegetation clearing and intensified land use in tropical rangeland catchments.

Dalrymple Shire is in the upper catchment of the Burdekin River and covers 6 885 000 hectares (figure 3-8). It is bounded by the Great Dividing Range in the west and by a chain of coastal ranges in the east. More than 90 percent of the shire is used for beef production.

While there is wide variation in the condition of Dalrymple Shire's soils and pastures, recent studies agree that pasture decline, erosion, woody weeds and, potentially, salinity are major problems in the shire (Mortiss 1995; De Corte et al. 1994; Hinton 1993).

The best available data on resource condition are from a recent land survey by Rogers et al. (1997), which provides a snapshot of land condition between 1991 and 1993 based on more than 200 visited sites (table 3-6). Widespread signs of soil erosion were found on each of the seven major geological landscapes. Exotic weeds were prevalent on several landscapes, with rubber vine particularly abundant. Spread of two species of the native currant bush was considered a serious problem in most landscapes.

Salinity was identified as a significant emerging issue. Many soils had moderate levels of soluble salts, resulting in salinity problems where shallow watertables had developed in areas of extensive clearing. Groundwater and landscape features indicate that further areas are at risk if clearing continues.

Most of the land condition problems are the result of a century of grazing pressure on vulnerable land forms and pasture types, on infertile and erodible soils and on properties of inadequate size.

High beef prices in the early 1970s encouraged graziers to increase the size of herds. A slump in prices from 1974 to 1978 coincided with above-average rainfall, so that graziers maintained high stocking rates. They failed to reduce grazing pressure during the 1980s when rainfall was below average, causing pasture degradation. Pressland and McKeon (1992) found that stocking rates in the shire between 1976 and 1986 were double the estimates of safe beef equivalents.

Technical developments have also exacerbated the pressure on native pastures. *Bos indicus* cattle introduced during the 1960s are more drought-hardy and better foragers than British breeds.

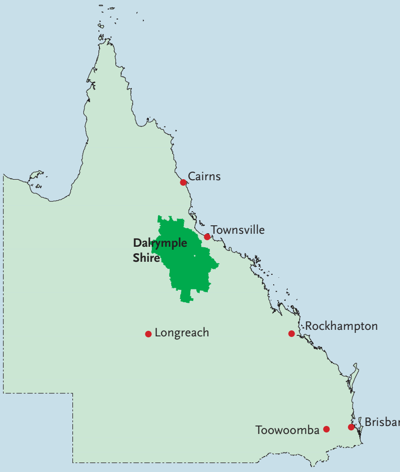

Figure 3-8 Location of Dalrymple Shire

The practice of supplementary feeding with non-protein nitrogen during the dry season encourages animals to forage on dry standing feed. This puts additional pressure on tufted grasses, reducing their ability to grow rapidly after the first rains of the wet season. The combined effect of greater cattle numbers and high dry-matter intake contributed to a 50 percent increase in dry-season grazing pressure between 1965 and 1970.

Studies have proposed responses to these problems:

- Improved property planning and management are needed to achieve a better balance between available feed and stock numbers (Mortiss 1995). The key to sound pasture management is appropriate stocking rates (Hynes et al. 1996).
- Fire regimes should be used as a pasture management tool, particularly in above-average rainfall years (Hynes et al. 1996).
- Cooperative arrangements with neighbouring properties are essential for management of fire regimes and woody weed control (Hynes et al. 1996; Landsberg et al. 1998). Another potential area of cooperation is the development of a voluntary code of grazing practice for Dalrymple Shire (Mortiss 1995).
- There should be better investigation, dissemination and/or use of information, particularly relating to seasonal forecasts, risk management techniques, the signs of declining pastures and fertility, and the technology and economics of land clearing (Mortiss 1995).

Local producer groups (such as the Balfes Creek Catchment Group and the Rural Advance Movement) are responding to many of these suggestions.

One grazier in Dalrymple Shire has reported in detail on management changes initiated in 1987 to increase the sustainability of his cattle property (Landsberg et al. 1998). From 1979 to 1986, high stocking rates on the property had resulted in feed shortages during drought periods and lack of opportunities for pasture burning to control weeds. During the transition to sustainable management practices (1987 to 1991), stock numbers were reduced by approximately 50 percent. From 1992 to 1995, in a very low rainfall period, improved pasture condition allowed an increase in stock numbers to about 67 percent of the previous high number. In contrast, most cattle properties in north-east Queensland were forced to markedly reduce stock numbers during this period. Landsberg reports that the benefits of reducing stocking rates in line with sustainable management principles were improved animal performance per head, lower production costs, better land condition and 'more sleep at night'. Johnston et al. (1999) suggest that the recent willingness of graziers to publicly debate grazing management issues, as in this example, indicates a positive move towards achieving sustainable management on grazing lands.

Table 3-6 Land condition of survey sites in Dalrymple Shire, 1997

Geological landscape	Percentage of shire area	Percentage of sites affected by erosion	Percentage of sites with exotic weeds	Percentage of sites with low grass basal area (<1.5%)
Alluvial	9	40	22	37
Basalt	13	25	17	21
Cainozoic	34	50	10	34
Granodiorite	7	56	61	4
Igneous rock	14	44	26	25
Metamorphic rock	7	65	5	37
Sedimentary rock	16	70	7	51

(Source: Rogers et al. 1997)

could be used to develop a statewide indicator of grazing pressures. Potential problems include inaccurate reporting of domestic stock numbers, difficulties in estimating pressures from native and feral animals, variations between modelled and measured pasture growth (Carter et al. 1999) and changes to condition of native pastures.

Native and introduced herbivores also add grazing pressure and this is difficult to estimate. Recent studies in south-west Queensland suggest that non-domestic herbivores contribute 30–40 percent of total grazing pressure (Pahl, L., pers. comm.). The drilling of many new artesian bores in the last two decades has not only increased the extent and continuity of grazing pressure but also allowed native animals to multiply greatly in previously waterless areas (James et al. 1996). Very few areas of pastoral rangeland are further than 10 km from sources of water (Landsberg et al. 1997).

An underlying problem is the structure of the grazing industry: many enterprises are too small to provide sufficient scope for reducing grazing pressure in dry periods. The decline in prices received for wool and beef over the past 30 years has resulted in marginal economic viability for many grazing enterprises (Gramshaw 1995). Small property sizes are likely to exacerbate the problems of marginal economics, preventing the use of lower stocking rates in some cases.

Changes to fire regimes since European settlement may also have contributed to pressures on native pastures (Burrows 1995). Change in the frequency, season and intensity of fires, made to support grazing needs, combined with the effects of grazing itself, has shifted the balance between grass and woody plants to favour the growth of woody weeds and other intractable weeds such as rubber vine.

Rates of erosion are generally lower on grazed land than on cultivated land (Elliott et al. 1996) but they have been significant where there has been overclearing and/or overgrazing. Loss of cover in semi-arid regions of Queensland due to grazing pressure leaves soil exposed to heavy rains and may result in water erosion (McIvor et al. 1995). Estimates of cover levels required to reduce surface runoff range from 20 percent (see, for example, Miles 1993) to greater than 80 percent (Lang 1979), depending on grazing pressure and seasonal and physical conditions.

Groundcover, including grasses, shrubs, gibber and cryptogamic crusts, is critical in providing protection against wind erosion in the drier west of the State. According to Leys (1992), approximately 50 percent groundcover is required to prevent wind erosion in rangelands. Overgrazing reduces groundcover which, in turn, leads to reduced seed reserves and less plant cover, further increasing the erosion risk. These effects are exacerbated where grazing pressure is maintained for extended periods into drought. Erosion in the arid interior is believed to result from grazing regimes on soils of moderate to high erodibility (SCARM 1998). See 'State' section for an analysis of the accelerating effects of land use on wind erosion: this analysis indicates that overgrazing is contributing to wind erosion in the Thargomindah–Charleville region in the south-west of the State and in the Urandangi–Mt Isa–Croydon region in the north-west.

In south-west Queensland grasslands, stocking has also been found to damage cryptogamic soil crusts, particularly around waterholes (Hodgins and Rogers 1997). Cryptogamic crusts are communities of organisms such as cyanobacteria, algae, fungi and lichens which form on surfaces with low cover of vascular plants. They help prevent erosion, assist in plant germination and contribute to soil fertility.

More than 70 percent of Queensland's State forests are currently under grazing occupation. The impacts on forest health of grazing in multiple-use forest areas, a common practice in Queensland, are not fully understood. In some circumstances, feral and native animals may affect forest health through excessive browsing, leading to soil compaction, erosion and spread of weeds. Conversely, controlled grazing may have benefits in reducing fire hazard and controlling unwanted vegetation (NFI 1998). No quantitative information about the impact of grazing on native forests in Queensland exists (Kelly 1998).

Grazing pressure in Queensland's semi-arid areas can be exacerbated by high stocking rates, poor pasture management and drought.

Fertilisers and agricultural chemicals

Indicators

Area of cultivated land with high rates of application of ammonia-based nitrogen fertilisers

Fertiliser use

Agricultural chemicals use

Compliance with maximum residue limits and maximum permitted concentrations in agricultural produce

Fertilisers

Inappropriate or excessive use of fertilisers can contribute to soil acidification and fertility problems.

Soil acidification rates differ according to crops and cropping practices. Soils used for growing sugarcane, bananas, heavily fertilised horticultural crops (such as pineapples) and nitrogen-fertilised grass pastures experience the greatest rates of acidification. Acidification rates are lowest under tobacco and relatively low under table grapes and summer cropping systems such as soybeans, maize and peanuts (Moody and Aitken 1997).

The use of ammonia-based nitrogen fertilisers provides a useful indicator of potential soil acidification. Average nitrogen use of four production systems — sugarcane, bananas, pineapples and pasture hay — is 200 kg/hectare/year or more (table 3-7). Most of the area under these crops, which totals 405 000 hectares, will experience high rates of acidification unless an appropriate liming strategy is implemented (Moody and Aitken 1995).

The overuse of fertilisers can also lead to a build-up of nutrients which can affect soil fertility (as well as polluting waterways, as discussed in chapters 4, 'Inland waters', and 5, 'Coastal zone'). Some problems appearing in Queensland's intensive cropping systems are a result of fertiliser overuse. For example, work by the Cooperative Research Centre for Sustainable Sugar Production in Townsville confirmed overuse of the fertiliser phosphorus in around 80 percent of Queensland sugarcane farms with a cropping history of 10 years or more. In contrast, potassium is not accumulating and cane farming may be depleting soil mineral reserves (DNR 1998). Fertiliser use in pineapple and banana plantations can also be excessive.

Table 3-7 Area of cultivation on naturally acidic soils in Queensland under high nitrogen (N) fertiliser input

Agricultural system	Area ('000 ha)	Average N application (kg/ha/year)	Average yield (tonnes fresh weight/ha)
Sugarcane	320	200	75
Tropical/subtropical tree crops	15	20	26
Other tree crops	7	120	45
Bananas	6	300	28
Pineapples	6	400	100
Vines	2	100	15
Vegetables	9	65	40
Field crops	87	40	4
Pasture hay for intensive livestock	33	>250	–
	40	<250	–

(Source: Moody and Aitken 1995)

Fertiliser use can provide an indication of potential pressure on land, but there is no direct relationship between use levels and contamination levels as much of the fertiliser is used by plants or broken down. Details of fertiliser use in Queensland are shown in 'Response: Maintaining soil fertility'.

Agricultural chemicals

Agricultural chemicals used in Queensland include biocides (insecticides, herbicides, fungicides), defoliants, soil improvers and growth promoters. Problems resulting from incorrect use include soil and water pollution, land and product contamination, and human health concerns arising from handling of chemicals and consumption of produce. The persistence of insecticides in soils ranges from a few days for some organophosphates such as malathion and parathion to more than five years for some chlorinated hydrocarbons. Similarly, the persistence of herbicides ranges from a few weeks for 2,4-D to several months for atrazine and propazine.

Cattle and sheep dipping sites present serious soil contamination problems. Amitraz, cypermethrin and chlorofenvinphos are common active chemical ingredients used in dips. These chemicals can contaminate the land in the vicinity of the dip and can damage soils by eliminating beneficial soil organisms and plants. Surface runoff, windblown dust and soil erosion can distribute the chemicals over wider areas.

Little information on chemical use is currently available. Table 3-8 provides ABS data for Queensland and Australia for 1991–92.

Aerial spraying of pesticides

Table 3-8 Chemical use by area and volume of application, 1991–92

Chemicals	Queensland	Australia
Herbicides		
'000 ha	1 108	14 880
tonnes	270	2 380
Insecticides		
'000 ha	346	3 117
tonnes	227	690
Fungicides		
'000 ha	103	813
tonnes	462	1 618

(Source: ABS 1996b)

As in the case of fertilisers, use levels do not relate directly to contamination of land and vegetation resources. Cost-effective indicators of environmental contamination from agricultural chemicals are difficult to find. One set of data that is available, although at the national level only, is compliance with standards for chemical residues in agricultural produce. The levels at which maximum residue limits (MRLs) and maximum permitted concentrations (MPCs) are set are directed at protecting human health and so compliance data are not necessarily a good indicator of the effects of residues on broader environmental health (Hamblin 1998). Moreover, some chemicals tested are used in feed or post-harvest in storage, so that only the produce to be consumed is at risk of contamination, not land and vegetation resources. Nevertheless, compliance rates can provide limited information on the bioavailability of some chemicals in the environment and the likelihood of accumulation of contaminants in plants and animals.

The National Residue Survey (NRS) is undertaken annually by the Bureau of Resource Sciences. Samples of raw food produced in Australia are tested for residues of a wide range of chemicals used in the production of food, including insecticides, fungicides, preservatives, antibiotics, anthelmintics (used to control parasitic worms) and hormonal growth promotants. The NRS conducts randomised and targeted programs, each involving a similar number of samples.

Table 3-9 summarises NRS results on chemical residues in selected agricultural products for the whole of Australia for 1997 and indicates that the misuse of agricultural chemicals is low. Of the 68 over-MPC results for metals, 53 were for the essential micronutrients copper, zinc and selenium, 12 were for cadmium, 2 were for mercury and 1 was for lead. Meat samples from all species other than pigs had a compliance rate of over 99.9 percent for agricultural and veterinary chemicals. Most non-compliance in meat samples from pigs was the result of antimicrobial residues (BRS 1998).

Persistent organochlorines such as DDT, dieldrin, heptachlor, BHC and HCB have not been available for use on livestock since the 1970s, but may still be present in soil and may be ingested by cattle. High levels of compliance with MRLs for organochlorine residues have been observed over the last six years (BRS 1997). In 1997, of 5895 meat samples and 2215 grain samples tested, only one sample was above the MRL (dieldrin in a cattle sample).

Similar high levels of compliance are found for organophosphates, with only one detection above the MRL in the meat samples (chlorpyrifos) and 18 in the grain samples. Most (15) were due to dichlorvos, a pesticide registered for use for cereal grain protection and disinfestation, which degrades rapidly. Residues probably indicate an excessive rate of application of the pesticide (BRS 1998).

Table 3-9 Summary of 1997 National Residue Survey results for major commodity groups

Commodity group	No. of samples collected	No. of analyses	Over MRL/MPC*	
			Chemical residues	Metals
Cattle	9 964	14 596	4	22
Sheep	5 717	7 959	2	27
Pigs	2 793	3 567	38	10
Horses	455	762	1	na
Poultry	436	514	0	0
Camels	62	94	0	9
Other meat species	504	1 085	0	na
Eggs	228	298	0	0
Cereal grains	4 989	20 327	7	0
Flour and bran	266	870	3	na
Pulses	395	1 620	[9]	0
Canola	96	408	0	0
Onions	129	1 419	0	0
Nuts	127	671	0	na
Total	**26 161**	**54 190**	**64**	**68**

*Maximum residue limits (MRLs) for foodstuffs in Australia are set out in Standard A14 of the Food Standards Code published by the National Food Authority. Maximum permitted concentration (MPC) refers to acceptable levels of heavy metal or other contamination in foods, not to pesticide levels. MPCs are set out in Standard A12 of the Food Standards Code. na: Metals were not analysed. [ ] indicates the presence of a chemical commodity combination for which there is effectively no MRL.
(Source: BRS 1998)

Farm irrigation in Redland Bay, south-east Queensland

Irrigation

Indicators

Irrigated area

Source of irrigation water

Irrigation can induce irrigation salinity as a result of use of poor-quality water or rising watertables. The incidence of irrigation salinity increases as the area under irrigation increases, although management changes such as drainage systems and cropping practices have minimised impacts (see 'Response' section). There were 403 600 hectares of crops and pasture under irrigation in Queensland during 1996–97 (table 3-10), a 2 percent increase on the previous year (ABS 1998b).

Sources of irrigation water are given in table 3-11. Groundwater generally has higher levels of salinity than surface water supplies. Groundwater is the source of water for about 40 percent of irrigated land.

Table 3-10 Area irrigated in Queensland, 1993–94 and 1996–97

Crop	Irrigated area ('000 ha) 1993–94	1996–97
Cereals	45.3	30.7
Sugarcane	168.1	172.3
Fruit	25.1*	22.5
Grapevines	nr	0.8
Vegetables	27.5	23.4
Pasture	69.8	47.7
Other crops	73.0	106.3
Total	**408.9**	**403.6**

*Includes grapes. nr = not reported in this category. 1995–96 data not reported.
(Sources: ABS 1996a, 1998b)

Table 3-11 Source of irrigation water for crops and pastures, 1993–94

Source of irrigation water	Area irrigated ('000 ha)
Surface water from State irrigation schemes	
Channel and pipeline	96.6
Direct from regulated streams	75.4
Other surface water	
Direct from unregulated streams	34.6
From farm dams	39.1
Underground water supply	
Within State schemes	97.4
Other	65.5
Town or reticulated water supply	**0.3**
Total	**408.9**

(Source: ABS 1996a)

Introduction of exotic agricultural species

Indicator

Proportion of introduced pasture species that become noxious weeds

Agriculture is the source of several noxious weeds (see table 3-14). The grazing industry exerts a strong demand for new pasture species, legumes and fodder trees. In the past, many potential pasture and fodder species were imported and planted in Queensland with little consideration of their pest potential. For example, prickly acacia was introduced to grazing lands in western Queensland in 1890 to provide shade and fodder.

According to Lonsdale (1994), of the 463 non-native pasture plants introduced into northern Australia between 1947 and 1985, only 21 proved useful to agriculture while 60 were later listed as noxious plants. Of the 21 useful plants, 17 later became noxious weeds on non-grazing land, leaving only four species that were useful and did not cause weed problems. Buffel grass, for example, is a desirable introduced plant for grazing but is displacing native grasses in many parts of the State.

URBANISATION

Loss of natural habitats and productive agricultural land due to urbanisation is a prominent land use change issue in Queensland. While this loss reflects the higher value society now places on residential property, in the long term urbanisation of high-yielding agricultural land may reduce the State's capacity to meet human needs for food, fibre and fuel.

Urbanisation has impacts on the quality of land. Construction, now regulated, has historically been equated with significant erosion problems. Disposal of municipal wastes to landfill sites is the most obvious potential land contamination issue, as discussed below. Land can also be contaminated by industrial and transport activities associated with urbanisation.

Loss of land to urban uses

Indicators

Population and economic growth

Residential dwelling approvals

Population and economic growth

Population and economic growth provide broad indicators of pressure on urban and peri-urban land resources. Queensland's population has grown at an average of 2.5 percent a year and its Gross State Product has grown at an average of 4.6 percent a year over the last decade (see details of growth rates in chapter 8, 'Human settlements'). Considerable land resources are needed to accommodate rising population and industrial development.

In particular, as the State's population is highly urbanised, population growth increases demand for urban land. More than 44 percent of Queensland's population lives in the Brisbane Statistical Division. Urban areas in Queensland, especially in the State's south-east, tend to be sprawling or low density, requiring more land than high-density cities. Urban areas are expanding in all Queensland's major population centres, particularly Townsville and Cairns and those in the south-east corner.

In a medium-growth scenario, Queensland's population is expected to reach 5.6 million by 2030, or 2.2 million more than the population in 1997. In about 30 years, urban areas will have to accommodate twice the population they do today or cover twice their present areas, placing pressure on surrounding land resources.

Projected land use changes in south-east Queensland from 1991 to 2011 provide some indication of the scale of this pressure. Increases of 25 percent and 37.2 percent respectively are projected in the land devoted to urban and rural residential purposes (table 3-12).

Table 3-12 Projected land use changes in south-east Queensland, 1991–2011 (based on medium population projections)

Land use	1991 (ha)	Projected for 2011 (ha)	Percentage change
Urban			
Urban residential	61 278	76 608	+25.02
Rural residential	22 712	31 158	+37.19
Urban industrial	6 922	7 875	+13.76
Urban commercial	433	433	0
Other urban	9 811	9 811	0
Total urban	**101 156**	**125 885**	**+24.45**
Rural			
Rural general	581 666	556 943	−4.25
Agriculture	51 146	51 146	0
Rural other	1 281	1 281	0
Total rural	**634 093**	**609 370**	**−3.90**
Undisturbed	79 577	79 577	0

(Source: BCC 1998)

Residential dwelling approvals

Residential dwelling approvals also give an indication of pressures on land resources. Building of detached and semi-detached dwellings generally keeps pace with population growth. In the period 1991–96, an average of 44 128 new dwellings were approved each year in Queensland, most of them in south-east Queensland (table 3-13).

Between 1991 and 1996, the top 20 local government areas (LGAs) in terms of approvals recorded 84.8 percent of the residential development activity in Queensland. This proportion increased to 86.4 percent for 1996–97. With the exception of Brisbane City, these 20 LGAs recorded fewer dwelling approvals in 1996–97 than their average annual figure for the previous five years, reflecting subdued activity. Of all the residential dwellings approved in Queensland between 1991 and 1996, detached houses comprised around 70 percent.

Increasing demand for urban land has meant loss of bushland and agricultural land.

Urban wastes

Indicator

Number of landfill sites

Disposal of solid waste in landfill sites, the main waste disposal method in Queensland, is a pressure on land quality and resources. If landfills are not properly managed, leachates can permeate surrounding soils and water, contaminating them. Odours, gases, litter and noise from transportation and treatment of waste can also cause conflicts with adjacent landholders. Landfills are licensed under the *Environmental Protection Regulation 1998*. Licensing conditions and recycling initiatives seek to minimise the impacts of landfills on the environment.

At July 1998, 2293 landfill sites, including disused and unofficial landfills, were recorded on the Environmental Protection Agency's Environment Management Register. Of the total, 99 were managed landfills, mainly operated by local governments. Chapter 8, 'Human settlements', provides details of waste volumes.

INTRODUCED PLANTS AND ANIMALS

Introduced plants

Indicator

Number of introduced and naturalised plant species

An estimated 50 to 100 new plant species are imported into Queensland each year.

Table 3-13 Residential dwelling approvals in Queensland, top 20 local government areas, 1991–96 and 1996–97

1991–96			1996–97		
Local government area	Average annual dwelling approvals	Percentage share	Local government area	Average annual dwelling approvals	Percentage share
Brisbane City	8520	19.3	Brisbane City	8730	26.4
Gold Coast City	6720	15.2	Gold Coast City	5430	16.4
Maroochy Shire	2460	5.6	Maroochy Shire	1970	5.9
Caboolture Shire	2300	5.2	Cairns City	1540	4.7
Cairns City	2180	4.9	Redland Shire	1330	4.0
Logan City	1930	4.4	Caboolture Shire	1240	3.8
Redland Shire	1740	3.9	Pine Rivers Shire	1210	3.7
Pine Rivers Shire	1370	3.1	Logan City	870	2.6
Ipswich City	1350	3.1	Caloundra City	860	2.6
Caloundra City	1320	3.0	Noosa Shire	810	2.4
Hervey Bay City	1040	2.4	Ipswich City	720	2.2
Noosa Shire	1000	2.3	Mackay City	600	1.8
Beaudesert Shire	870	2.0	Hervey Bay City	540	1.6
Mackay City	870	2.0	Beaudesert Shire	530	1.6
Townsville City	830	1.9	Thuringowa City	460	1.4
Thuringowa City	800	1.8	Townsville City	420	1.3
Toowoomba City	770	1.7	Toowoomba City	410	1.2
Cooloola Shire	460	1.0	Burnett Shire	320	1.0
Burnett Shire	450	1.0	Livingstone Shire	300	0.9
Rockhampton City	440	1.0	Cooloola Shire	280	0.9

(Source: QDLGP 1997, from ABS data)

Introductions of new plant species can be either deliberate or accidental (table 3-14). Deliberate introductions have been mainly for agricultural, horticultural or ornamental purposes. Public demand for non-indigenous ornamental garden plants is a major factor: 34 percent of Queensland's established noxious species, including rubber vine, were originally introduced as garden plants.

The Australian Quarantine and Inspection Service (AQIS) processed 89 applications for permits to import live plant material into Queensland in 1993, an indication of the pressure to introduce additional foreign plant species. These applications involved 933 plant taxa. Plants representing 130 genera were imported under permits issued in Queensland (Panetta et al. 1994).

Hymenachne amplexicaulis, introduced in the 1980s for use in ponded pastures, has spread into native wetlands.

The Commonwealth Plant Introduction (CPI) numbers for 1993 show 1842 introductions covering at least 217 taxa (many of the plants are identified only to genus) (Govaars and Tibbits 1994). This figure includes seeds introduced for use by research agencies. It is likely to represent only a small proportion of the total introductions by commercial nurseries and private individuals.

Accidental introduction occurs in a variety of ways including transport of seeds or plant material in imported/interstate grain and pasture seed, on imported/interstate vehicles and machinery, and on clothes and belongings of interstate/international travellers. The volume of imported products makes accidental introductions difficult to prevent: for example, in 1992–93, Australia had 644 000 inbound freight containers and 5.3 million airline passenger movements (DPIE 1993). Parthenium weed, one of Queensland's worst noxious plants, is an example of an accidental introduction as a result of trade. It was introduced into Queensland through contaminated grass seed imported from Texas in the late 1950s (Csurhes 1995).

Groves (1986) suggested that only five percent of imported plants become naturalised and only 1 to 2 percent of all introductions become noxious. An estimated 1226 introduced plant species have become naturalised in Queensland since European settlement. An additional four to six species become established each year (Specht 1981).

Table 3-14 Mode of introduction of Queensland's established noxious plants

Mode of introduction	Percentage of introductions
Garden ornamental species	34
Accidental introductions such as contaminants in soil and grains	16
Food species	7
Pasture or fodder species	3
Revegetation species	3
Other commercial species	3
Unknown	34

Introduced animals

Indicator

Number of introduced animal species

Since European settlement more than 50 species of vertebrates and an unknown number of invertebrates have been introduced into Queensland. Farm and domestic animals — sheep, cattle, horses, rabbits, hares, foxes, cats, pigs, goats, donkeys, camels, buffalo and many birds — were introduced for food, as beasts of burden, as domestic pets, for pest control and as game to hunt. Accidental introductions also occurred, mostly as 'stowaways'. These included various species of rats, mice, sparrows and other birds. Exotic animals have also been introduced illegally for containment in small private zoos.

An average of one to five additional exotic mammal species are legally introduced into Queensland each year. The demand comes from zoos, circuses, wildlife parks, farmers, research organisations and the public. However, no reports of new mammal species becoming feral in Queensland have been received for about 20 years.

New species are occasionally introduced as potential food or fibre sources or for hunting. Examples are the ostrich, Indian blackjack antelope, deer and alpaca. Once populations increase to commercial size, there is the risk that sufficient numbers might escape to allow feral populations to develop.

Public demand for new pet species exerts a constant pressure that threatens to increase the number of species of feral animals. For example, the Indian palm squirrel has been in demand recently as an unusual pet. This animal has the potential to become a destructive feral animal which could damage tree crops and native vegetation. The meerkat from Africa and non-native rodent species also have high potential to become feral.

Rabbits have devastated enormous areas of grazing land in Queensland. Rabbits have been controlled through a combination of myxoma virus and calicivirus release, poisoning, warren fumigation, shooting, trapping and fencing.

FORESTRY

This section discusses two key environmental aspects of forestry activities: the pressure on the forest resources themselves and the impacts of the forestry process on land resources.

Pressure on forest resources

Indicators

Processed timber consumption

Proportion of processed timber harvested from plantations/native forests

Harvest as a proportion of sustainable yield

In 1993–94, the most recent year for which a full range of forestry data is available, about 2.16 million m^3 of timber were processed in Queensland (DPI 1998):

- plantation logs, most from Crown forests, accounted for 61 percent;
- hardwood logs made up 29 percent of the total (about 60 percent of these harvested from private forests);
- cypress pine accounted for the remaining 10 percent (69 percent of this harvested from Crown forests).

In the early 1980s most timber from Crown lands was harvested from native forests; it is now increasingly harvested from plantations, as shown in figure 3-9. Of all timber produced and consumed in the State from both private and public sources (excluding imports and exports), about 61 percent came from softwood plantations in 1994–95 (DPI 1998). Nevertheless, native timbers have different characteristics from plantation timbers and have an important role to play in a diverse market.

Figure 3-9 Crown timber removals, 1991–92 to 1996–97
(Source: DPI 1997)

Only about 50 percent of sawlogs harvested in Queensland are processed into sawn timber; the rest are veneered, chipped or become waste. About 943 000 m^3 of sawn timber were consumed in Queensland in 1994–95. Most sawn timber consumed was home-grown: only about 30 percent was imported from overseas and interstate. In the same year, Queensland exported about 115 000 m^3 of sawn timber. However, if all forest products are considered (notably paper and paper products), Queensland was a net importer to the value of $287 million in 1994–95 (DPI 1998). Note that under an 'ecological footprint' approach (see chapter 8, 'Human settlements'), the area of forest appropriated by consumption of paper for the average Queensland resident is 0.6 ha.

The worldwide supply of timber is expected to decrease over the next 20 years, providing increasing opportunities for the Queensland forest industry but also potentially placing pressure on forest resources.

In recent years efforts have been made to achieve sustainable yield, that is, the quantity of timber that can be harvested on a non-declining basis from a forest. In 1994–95, the calculated sustainable yield of sawlogs from multiple-use forests was 112 000 m^3 and the actual harvested volume was 111 000 m^3. What the broader concept of ecologically sustainable yield means for harvesting levels is not yet fully understood (NFI 1998).

Little information is available about pressures on privately owned native forests. It is acknowledged, however, that many landholders consider that retaining private forests rather than using the land for urbanisation or agriculture is not economically viable because of long investment periods and/or comparatively low returns. Another issue is pressure from leaseholders to clear native forest resources where the Crown leases the land but retains ownership of the timber on the land (DPI 1998).

Impacts of forestry operations

Logging of forest areas, like clearing of any vegetation, can cause considerable land disturbance when unregulated, increasing soil erosion and soil mass movement by removing surface cover and changing soil hydrology. Logging also removes soil nutrients accumulated in harvest products, eventually resulting in less fertile soil. Estimates of the level of impacts on a statewide basis are not available. In recent years, logging has been regulated in order to minimise such impacts, as discussed in 'Response'.

MINING

Mining in Queensland began with the gold rushes of the 1860s. Activity increased in the early twentieth century when the metallic mineral-bearing region of the north-west was developed. Mining was extended in 1955 when bauxite was discovered on Cape York and expanded further with the development of the coal industry in the 1960s and 1970s (ABS 1998a).

Mining operations can have significant environmental impacts. Unlike forests, minerals are a non-renewable resource. The mining of minerals is thus potentially both a resource use issue and an environmental issue.

Mining of mineral resources

Indicator

Production of principal metallic minerals and fuel minerals

Queensland has extensive mineral deposits (figure 3-10). The Carpentaria–Mount Isa region in the State's north-west contains the major base metal deposits (particularly copper, lead, zinc and silver). The north and east of the State also contain a variety of deposits including the majority of

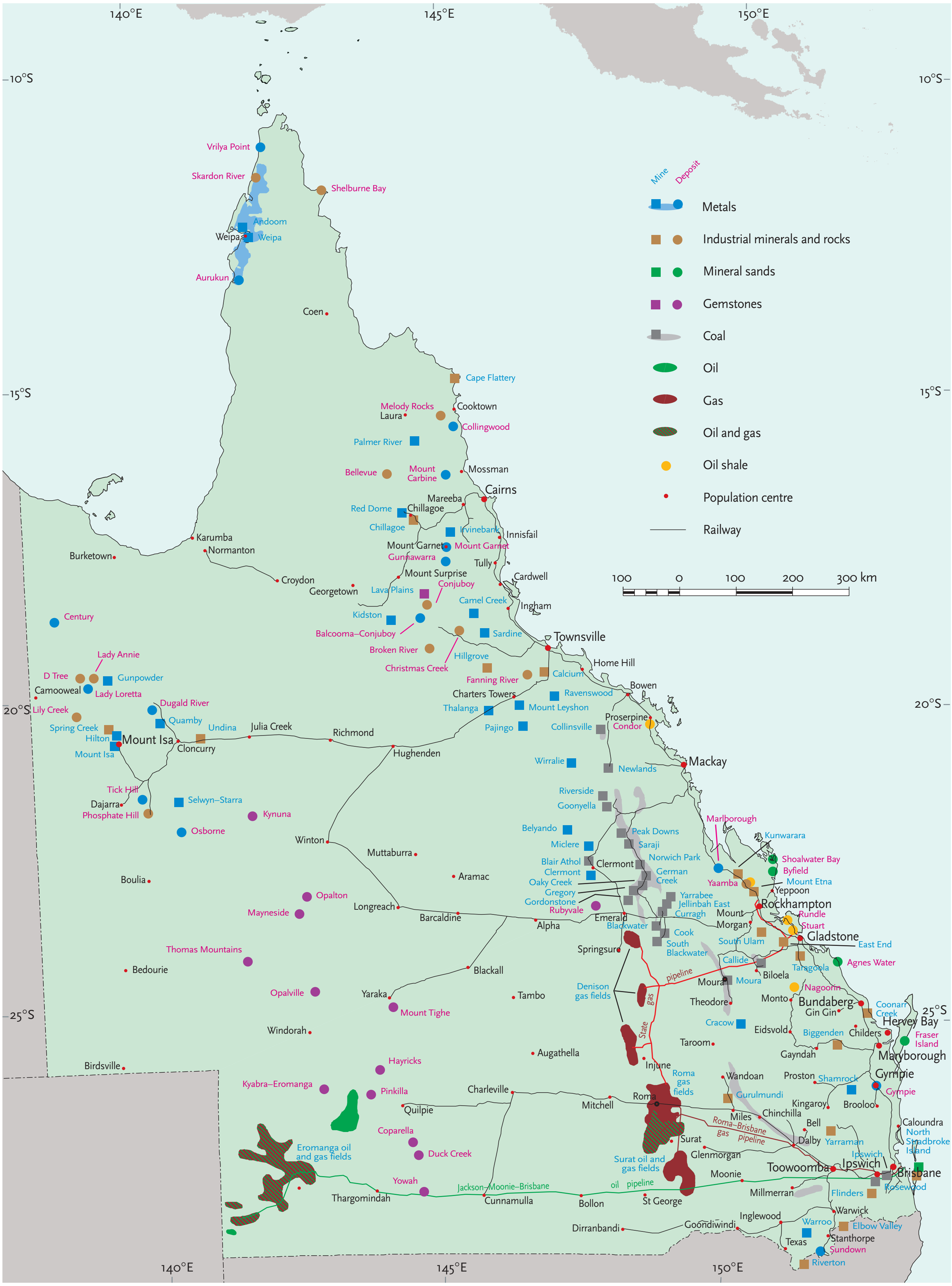

Figure 3-10 Distribution of Queensland's major mineral resources
(Source: DME)

Table 3-15 Production of principal metallic minerals and fuel minerals in Queensland, 1993–94 to 1997–98

Type of mineral	Unit	1993–94	1994–95	1995–96	1996–97	1997–98
Metallic minerals						
Bauxite	'000 tonnes	8 616	9 335	9 179	9 149	9 247
Copper concentrate	'000 tonnes	838	749	1 007	1 069	941
Gold bullion (inc. alluvial gold)	kilograms	44 011	41 770	38 994	39 281	42 679
Lead concentrate	'000 tonnes	413	299	359	320	412
Mineral sands:						
— Titanium minerals	'000 tonnes	204	247	252	121	237
— Zircon	'000 tonnes	51	67	56	37	62
Nickel ore	'000 tonnes	200	222	3	0	0
Tin concentrate	tonnes	79	52	82	125	12
Zinc concentrate	'000 tonnes	525	382	446	411	383
Zinc-lead concentrate	'000 tonnes	95	57	48	9	0
Fuel minerals						
Black coal	'000 tonnes	85 739	94 496	93 763	99 437	105 752
Crude oil	megalitres	936	910	826	805	720
Natural gas condensate	megalitres	172	253	265	197	220
Natural gas	gigalitres	1 616	2 035	2 164	2 107	2 600
Liquefied petroleum gases:						
— Propane	megalitres	150	182	191	173	210
— Butane	megalitres	86	115	118	81	100

(Sources: ABS 1998a; DME 1998b; and data provided by DME)

Queensland's gold and some base metals. Large bauxite deposits occur on Cape York Peninsula. The largest coal deposits are located in the Bowen Basin, which extends almost 500 km south from Collinsville. Other coal deposits include the Tarong, Moreton, Surat, Mulgildie, Laura, Galilee and Callide Basins. Extensive coal deposits in the Surat and Moreton Basins, including the large Wandoan field, remain largely unexploited. Moderate oil and natural gas reserves exist in the Eromanga, Cooper, Surat and Bowen Basins. The State's major coal basins are believed to hold significant volumes of coal-bed methane gas. Queensland has extensive resources of most minerals currently mined, with the exception of mineral and silica sands (DME 1998b).

Table 3-15 shows production of Queensland's principal metallic minerals and fuel minerals.

Mining impacts

Indicator

Numbers of operating mines, quarries, mining leases and exploration permits

Community concern about the impacts of mining on the State's land resources has grown as the number and size of mining projects have increased, particularly where mines are sited in areas valued for their natural habitat or cultural significance. Despite the small proportion of the State used for mining (1.1 million hectares of mining leases), land disturbance by mining can be dramatic during the operational period, particularly when compared to disturbance caused by other land use activities.

The area and type of land disturbance vary according to the type of mineral extracted and the methods employed. Subsurface mining by tunnels and shafts causes less land disturbance than surface mining methods such as open cuts and dredging, which can cause extensive disturbance despite rehabilitation activities. Sandmining, in particular, has historically destroyed extensive areas of vegetation and changed soil profiles and topography although modern methods focus on minimising damage. The major impacts of mining on land resources can occur before, during and after the operational phase, and include:

- vegetation clearance;
- access roads and infrastructure;
- survey lines, drill sites and prospecting/exploration tracks;
- large voids, piles of waste and tailings dams;
- unrehabilitated or poorly restored sites; and
- surface subsidence.

Pollution of air and water and disturbance or destruction of habitats are discussed in other chapters.

The number of mines, leases and quarries indicates the extent of potential pressure on land resources and the number of exploration permits indicates a continuing development of the mining industry (table 3-16). In 1997–98, there were 674 active Exploration Permits (Minerals) in Queensland. This was less than the 967 permits and 1071 permits in 1996–97 and 1995–96 respectively, due largely to native title considerations, declining metal prices and the continuing development of global perspectives by mining corporations (DME 1998b).

Table 3-16 Number of mines, mining leases, quarries, and producers of minerals and petroleum products in Queensland, 1997–98

Mining and quarrying activity	Number
Operating coalmines	30
Potential and committed coalmines (at 30 June 1995)	23
Operating metalliferous mines	49
Metalliferous mining leases*	3229
Quarries	73
Mineral producers	101
Petroleum producers	10
Active Exploration Permits (Minerals)#	674
Mining claims*	1114
Mineral development licences*	119

*At 11 January 1999 #At 5 March 1999
(Sources: DME 1998b and data provided by DME)

STATE

The current status or condition of Queensland's land resources is a product of the pressures of vegetation clearance, agriculture, urbanisation, introduced plants and animals, forestry and mining that have affected the resource over the past 150 years. For many of the land quality issues discussed in this section, there is a lack of baseline data or data consistently collected on a statewide basis. Available data are generally restricted to site-specific assessments or to short-term experimental studies. This makes it difficult to evaluate the relationship between pressures and condition and between responses and condition.

One of the key issues is the condition of Queensland soils: the status of erosion, soil fertility decline, soil structure decline, soil salinity and soil acidification. Noxious plants and feral animals are also significant issues, as their spread is detrimental to the environment and reduces productivity. Several issues surround land use changes, particularly the loss of agricultural land and the development of sites contaminated by past agricultural, industrial, waste disposal and military activities. This section also discusses the status of forest resources and of land disturbed by mining activities.

EROSION

Soil erosion is the detachment and transport of soil by the forces of water, wind or gravity (mass movement). Commonly eroded are the rich, biologically active, topsoil layers that contain organic matter and nutrients.

Water erosion has three characteristic forms. Sheet erosion is the removal of uniform layers of soil by runoff water. Rill erosion occurs where water flows in streamlets rather than evenly, cutting small, well-defined incisions on the land surface. Gully erosion occurs when small streams unite, cutting a channel.

Wind erosion is widespread in the drier parts of Queensland and results in the loss of valuable topsoil and nutrients. The extent of wind erosion depends on climate (especially dryness), weather patterns, soil type, vegetation cover, soil conservation practices and crop production methods.

DNR

Soil erosion by water affects 80 percent of Queensland's cultivated land. The most vulnerable areas are the high-rainfall, steep cropping lands and overgrazed pastoral lands on steeper slopes.

Soil mass movement, also known as landslip, occurs when the inherent strength of soil or weathered rock material is no longer sufficient to support its weight. The result is the sudden movement of soil and rock debris down slopes. The main contributing factors are the excessive clearing of steep slopes, heavy rainfall, and unstable geological and topographical characteristics.

Water erosion

Indicators

Water erosion hazard ratings

Rate of soil loss from water erosion (tonnes/hectare/year)

Virtually all parts of Queensland are affected by water erosion. Water erosion affects an estimated 80 percent of the State's 3.3 million hectares of cultivated land (crops and sown pastures).

No data are available on actual soil losses for the whole of the State. Figure 3-11 shows two erosion scenarios for broadacre crop and sugarcane lands using a predictive model (PERFECT) based on information about rainfall, steepness of terrain, crop water use and groundcover (Littleboy et al. 1989). The key variable is the adoption of conservation farming practices, for which no detailed spatial data are available (see 'Response' section for summarised data). The figure therefore presents scenarios under two management systems: one where stubble is incorporated into the soil and the land is left fallow, and the other where stubble is retained and zero tillage is practised.

Where stubble is incorporated, the areas most at risk from water erosion are in the coastal high-rainfall, steep cropping lands and the wet hinterland areas (>10 tonnes/hectare/year). Even inland, large areas have an erosion hazard rating of 10–50 tonnes/hectare/year. Cropping and cereal lands of the Central Highlands, Dawson–Callide, inland Burnett, Darling Downs and Western Downs are susceptible, as are overgrazed pastoral lands on steeper slopes.

The model indicates that if broadacre and sugarcane farmers practised stubble retention, the risk of soil erosion for much of south-east Queensland and coastal areas north of Mackay would be reduced to negligible levels (<1/tonne/hectare/year). The high-hazard areas around Toowoomba and Warwick would be greatly reduced in size.

The cost of water erosion to landholders and infrastructure providers is substantial. On the Darling Downs, water erosion can add $45 per hectare per year to the cost of production after 10 years of moderate erosion involving the loss of 20 to 40 tonnes of soil per hectare per year. Costs to the community are increased by erosion damage to infrastructure such as

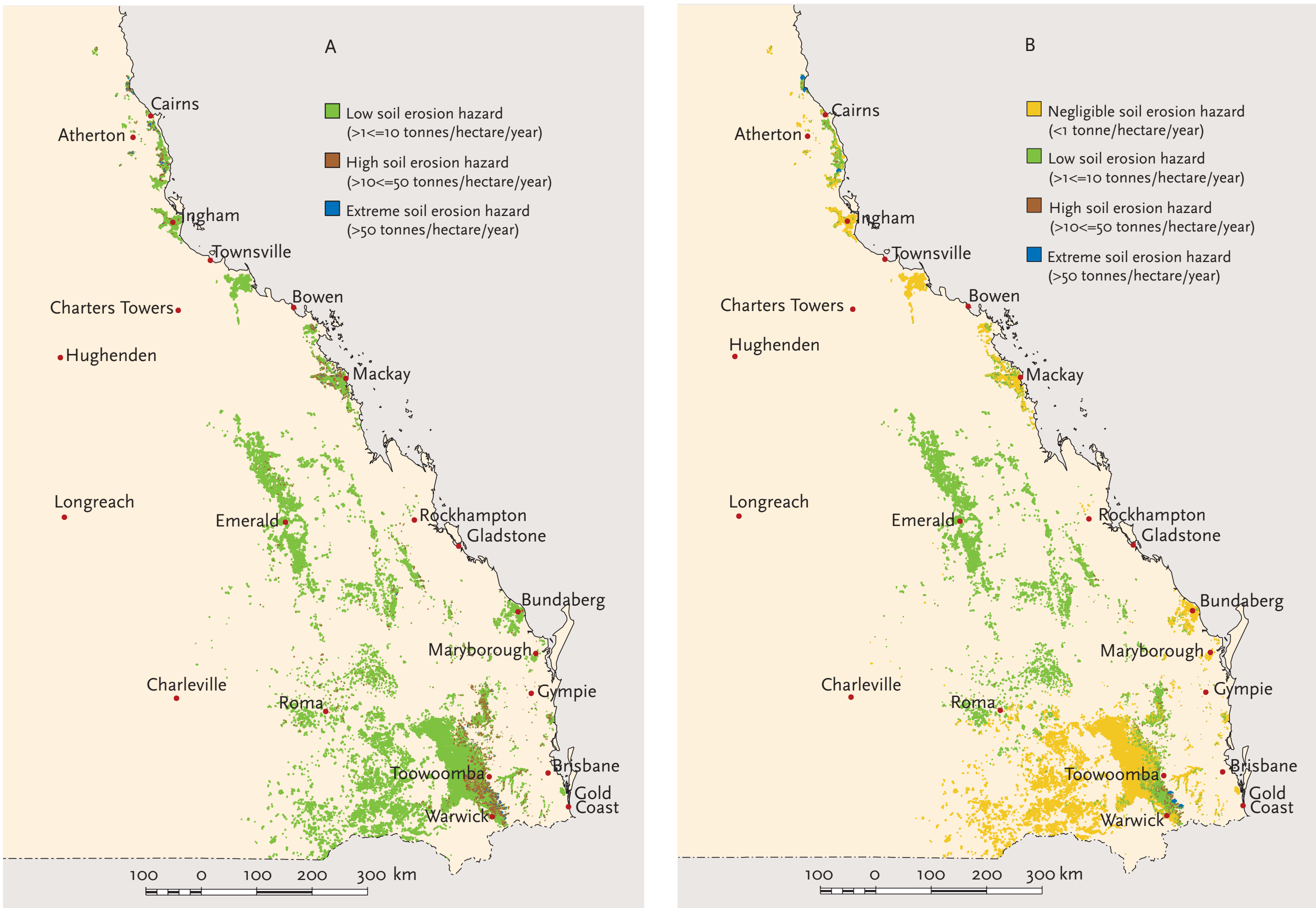

Figure 3-11 Water erosion hazard for broadacre crops and sugarcane under two management systems: A, stubble is incorporated and the land is left fallow, and B, stubble is retained and zero tillage is practised.
(Source: DNR)

roads and railway corridors, pollution of water supplies, and silting of drains, navigation channels and shipping berths. The sum of these costs exceeds $30 million annually.

Wind erosion

Indicators

Frequency of occurrence of dust events (Dust Storm Index)

Difference between measured wind erosion rates and rates predicted by climatic conditions (Accelerated Erosion Index)

The role of wind erosion in land degradation is not widely recognised, largely because it occurs mainly in remote areas where land use intensities and population are low. In addition, the evidence of wind erosion becomes visible only when more than 3 mm of topsoil, or approximately 30 tonnes a hectare, are removed (Kimberlain et al. 1977). Downwind evidence is also subtle. A dust storm in the Channel Country in November 1994 is reported to have transported more than 15 Mt of soil from a large area, yet removed less than 0.4 mm of topsoil, leaving little on-ground evidence of wind erosion (McTainsh et al. 1996). Similarly, a dust storm that passed over Brisbane in 1987 was noticed by few, although it was estimated to have transported between 1.9 and 3.4 Mt of dust off the coast during the event (Knight et al. 1995).

Soil erosion rates are best measured as soil loss per unit area of land but such data are not available for most of Queensland. Broadscale wind erosion rates can be approximated using meteorological data from 20 stations throughout Queensland

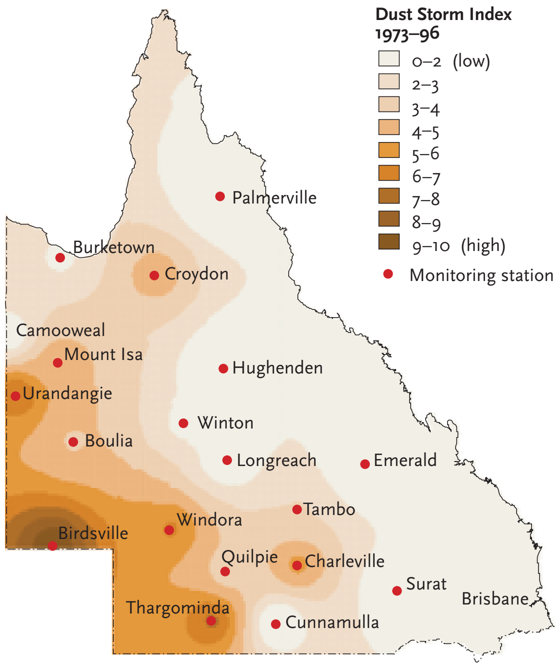

Figure 3-12 Wind erosion in Queensland (1973–96), as measured by the Dust Storm Index (DSI) at 20 meteorological stations

on the frequency of occurrence of dust events (dust storms, local dust events and dust haze). Wind erosion event data can be weighted according to their intensity (severe dust storms are weighted at five times moderate dust storms, and local dust events at one-twentieth) and combined in a Dust Storm Index (DSI). Figure 3-12 shows the pattern of wind erosion in Queensland in the years 1973–96, as measured by the DSI. The figure shows the strong influence of climate on wind erosion: the highest rates are in the arid far south-west of the State, diminishing to the east and north as rainfall increases. However, the Mitchell grasslands around Longreach and Winton have lower wind erosion rates than areas in the same rainfall zone to the south and north.

Effects of rural land use

Wind erosion is the result of complex interactions between natural factors (including rainfall, evaporation, wind conditions, soil erodibility and vegetation cover) and land use factors (including the impacts of agriculture and grazing). The extent to which natural wind erosion rates have been accelerated by rural land use activities is not well understood because of measurement difficulties.

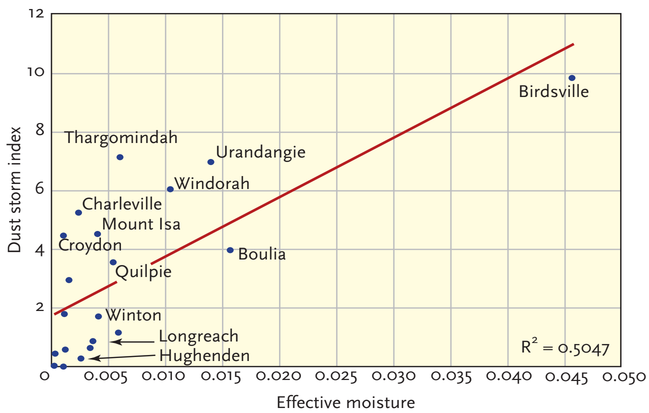

Figure 3-13 The relationship between measured wind erosion rates (DSI) and the Em model at 20 Queensland stations averaged during 1973–96. The regression line defines the wind erosion rates throughout the State that are consistent with the climatic conditions as described by the Em model. This provides a conservative distinction between stations above the line that may be eroding at an accelerated rate and those below the line that may be eroding at, or near, natural erosion rates.

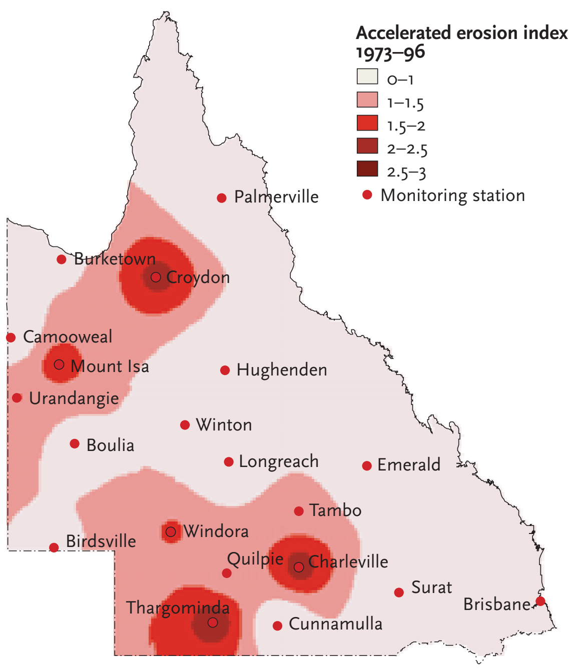

Figure 3-14 Regions within Queensland with an Accelerated Erosion Index (AEI) value above 1 are eroding at a rate higher than that predicted by the Em model, which may reflect stronger wind conditions, erodible soils or the land use activities.

Burgess et al. (1989) developed an effective moisture (Em) model as an indicator of wind erosion under natural conditions, without the impact of land use activities. The Em model uses precipitation and evaporation parameters to estimate effective soil moisture. By comparing the measured Dust Storm Index (DSI) to erosion predicted by the Em model, the component of wind erosion that has been accelerated by land use activities can be estimated. If the measured DSI at a station is higher than that predicted by climatic conditions (as shown in figure 3-13 by the regression line of the relationship between DSI and the Em model for the 20 stations averaged for 1973–96), this is assumed to reflect the influence of factors not measured by the model. These include the two natural factors (wind conditions and soil erodibility), plus land use factors. As DSI values already contain a component of accelerated wind erosion, this methodology tends to understate the real levels of accelerated wind erosion. It is likely, therefore, that stations at and below the regression line still have a component of accelerated wind erosion.

An Accelerated Erosion Index (AEI) can be calculated from the ratio between measured erosion rates (DSI) at a location and rates predicted by the climatic conditions (see SCARM 1998 for details of methodology). If a station data point is above the line (for example Thargomindah), the AEI will be greater than 1 and it can be inferred that the area has accelerated wind erosion. Figure 3-14 shows the spatial pattern of the Accelerated Erosion Index (AEI), which is highest in the south-west and north-west of the State. These high AEI figures are not necessarily due to land use change, as wind conditions and soil erodibility also are factors excluded from the Em model. In areas where these two natural factors cannot explain the high AEI values, land use effects can be inferred. There is some evidence to suggest that strong winds in the south-west and north-west may at least partly explain high AEI values (McTainsh et al. 1998; Kalma et al. 1988).

The main difference between the DSI pattern (figure 3-12) and the AEI pattern (figure 3-14) is in the area around Birdsville, extending into the Channel Country. Although Birdsville has the highest wind erosion rates (DSI) in the State, it has a low AEI value. In addition, the area has moderate to high wind conditions and erodible sandy soils, which would increase wind erosion rates above predicted levels. Therefore, at this level of analysis it appears that the cattle grazing carried out in this region is not causing measurable accelerated wind erosion. Similarly, the low AEI values for the Mitchell grasslands around Longreach–Winton may in part reflect the low to moderate wind conditions there and the relatively low wind erodibility of these cracking clay soils, but they also suggest that grazing in this area may not be having a significant accelerating effect on wind erosion.

In the Thargomindah–Charleville region (south-west) and the Urandangi–Mt Isa–Croydon region (north-west), it is probable that the high AEI values reflect a combination of high wind conditions and land use effects, as the soils are generally of only moderate erodibility. Miles and McTainsh (1994) raised the probability of accelerated wind erosion in the mulga area around Charleville. The area of apparently high accelerated erosion in southern Cape York has been tentatively attributed to overgrazing of erodible local sandy soils (SCARM 1998).

Temporal trend

Figure 3-15 shows the temporal trend of wind erosion rates (total DSI) for Queensland since 1973. While there appears to be a general increase in wind erosion rates through time, shorter-term fluctuations appear to reflect the effects of rainfall. The low erosion rates in the mid-1970s are associated with above-average rainfall (661 mm averaged for all stations 1974–78, compared with 523 mm for 1973–96) and high rates in 1994 are associated with drought conditions (370 mm). The smaller increase in wind erosion during the 1982–83 drought may be because the drought was less severe in Queensland (452 mm).

Changes in AEI values over time are difficult to quantity, because of the small numbers of stations involved in any year. To reduce this problem, the AEI data can be blocked into three time periods: 1974–78 (a period of high rainfall and low wind erosion activity), 1979–85 and 1986–96 (two periods of variable rainfall and moderate wind erosion activity). In 1974–78 only five stations (in the south-west and north-west regions) had AEI values above 1, but four of these had very high values. In the latter two periods, while very high values were much less common, larger numbers of stations (nine and seven respectively) across a greater area had AEI values above 1. Indications in the Birdsville–Channel Country region are that, although AEI values averaged over 1973–96 are low, they are increasing through time. There is a shortage of historical data on changes over time in wind conditions, soil erodibility and land use activities; this makes it difficult to assess their contribution to accelerated wind erosion.

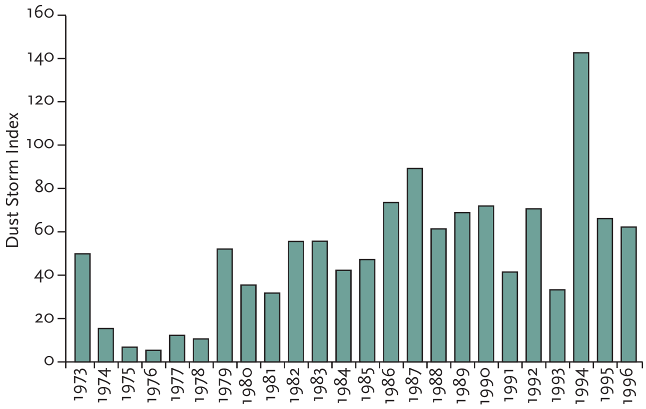

Figure 3-15 Changes in wind erosion, as measured by the Dust Storm Index (DSI), between 1973 and 1996

Soil mass movement

Indicator

Area affected by soil mass movement

Soil mass movement includes sheet erosion and landslips, and occurs primarily on devegetated sloping land in higher-rainfall areas. Land most susceptible to soil mass movement generally has slopes greater than 15 percent and has the characteristics described in the box 'Land prone to soil mass movement'. Regions showing the highest susceptibility are upland areas around Toowoomba and Cairns and steep land around Gympie and along the Border Ranges in the south.

Estimates of the total land area affected by soil mass movement in the State are not available. In the Bremer and Lockyer Valleys west of Brisbane, the known area affected by soil mass movement is 4788 hectares, covering 1222 landslip sites. More than 90 percent of these sites involve cleared areas. In the Murphy's Creek catchment, south-east Queensland, 5000 hectares of land had patchwork slippage totalling 45 000 m^3 (11.7 tonnes/hectare) after a period of extremely heavy rain in January 1974. Again, most of this occurred on cleared land.

SOIL FERTILITY DECLINE

Indicator

Soil fertility levels

Soil fertility is the capacity of soil to provide an adequate and balanced supply of the nutrients necessary for plant growth. It is determined by soil type, plant needs and management practices. Shortages of any nutrient, or a nutrient's presence in amounts sufficient to produce toxicity, will reduce plant growth and hence productivity.

While most cultivated and pastoral areas are subject to declining soil fertility, the incidence of significant soil fertility decline in Queensland is confined mainly to intensively cropped areas. It currently affects the clay soils (vertisols) of the Western Downs, Dawson–Callide, Darling Downs and Central Highlands (particularly in grain-producing areas), the red friable clays (ferrosols) of the Burnett region and the Atherton Tableland, and a variety of coastal soils used for field and horticultural crops including sugarcane. The worst-

Brisbane before (left) and during (right) a major dust storm
(Source: G. McTainsh)

Land prone to soil mass movement

Dissected plateaus or sloping land underlain by horizontal basalt lavas

Basalt soils commonly contain shrinking and swelling clay minerals that increase the risk of failure and slippage in gully heads and flanks. This type of slippage occurs on basalt plateaus around Mount Tamborine, Beechmont, Springbrook, Lamington, the Border Ranges, the Toowoomba escarpment, Mount Mee, Mapleton–Maleny and Buderim. Other basalt plateaus in Queensland exhibit similar problems. Localised slides are known on the Atherton Tableland but are not widespread in this area because plateau dissection is not well advanced.

Dissected slopes underlain by horizontal, interbedded hard and soft sedimentary rocks

Soft sediment layers such as shale and siltstone weather more readily than sandstone or basalt layers, producing weak strata prone to slippage on sloping land. These formations are common in the upper Lockyer Valley, where slopes in the foothills of the Main Range are underlain by interbedded shale, siltstone and sandstone of the upper part of the Marburg subgroup. These slopes have been extensively cleared and there are numerous slippage areas. Similar combinations of geology, clearing and high rainfall occur in several other parts of eastern Queensland.

Deeply weathered rocks in high-rainfall areas

In high-rainfall tropical areas, many rock types weather to considerable depths, producing materials of a soft consistency. This occurs in much of the high-rainfall Wet Tropics area, which is underlain by deeply weathered rocks of the Hodgkinson Formation of Barron River Metamorphics and, to a lesser extent, granites. Instability problems on the Cairns hill slopes have resulted from undercutting colluvium and weathered rock during road and house construction. Similar problems occur in the Mackay hinterland.

Bands of basalt or greenstone in steeply inclined meta-sedimentary strata

Many steeply inclined sequences of sedimentary, meta-sedimentary and volcanic rocks occur between the New South Wales border and Rockhampton. Bands of basalt or greenstone (metamorphosed basalt) within these layers commonly weather to deep soils, producing a potential for sliding, particularly if the balance of forces is changed by clearing. Such a situation occurs in the Mary River valley between Kenilworth and Gympie, where steep slopes have been cleared for agriculture, particularly pineapple growing.

Local moderate to steep slopes on unconsolidated sediments

Interbedded clays and sandstone were deposited in several small basins in eastern Queensland during the Tertiary period. These sediments have remained soft and relatively unconsolidated in flat to undulating topography. In rare cases, where moderate to steep slopes occur, the sediments can fail. A number of failures of this kind have affected houses in Oxley, Brisbane.

affected areas include 350 000 hectares in the Darling Downs and the Burnett region. Parts of these areas have been cultivated for more than 100 years.

The fertility status and risk of decline of Queensland's soils are shown in figure 3-16. The line on the map indicates approximately where climate and fertility conditions affecting fertiliser use change. Fertiliser is used extensively east of the line to maintain fertility; little or no fertiliser is used west of the line (see page 3.51).

Wheat grain protein content can provide an indication of declining soil fertility. Darling Downs soils cleared of brigalow vegetation initially produced wheat of 16–17 percent protein content. However, after 25 years of cropping, protein levels declined to below 11 percent, and after 50 years they were below 9 percent (Dalal et al. 1991). Wheat grain protein content appears to be declining across all grain cropping regions. While grain yields have also declined, the trends are less clear because they are masked by improved cultivars, better weed control, other improved practices, and the expansion of cropping on new lands. Soil nitrogen and phosphorus levels are falling in cereal cropping areas, often necessitating the use of artificial fertilisers and legumes (such as soybeans or lucerne) in rotation.

Soil fertility may be a potential problem in grazing lands as well as cropping areas. McCosker and Winkes (1994) found that much of northern Australia's grazing land was deficient in phosphorus for cattle production. A study of grazing land soil fertility in central and northern Queensland (Ahern et al. 1994) found naturally low levels of phosphorus and sulfur in many areas. Almost half the pasture soils in inland central Queensland (around Gladstone, Rockhampton and Mackay and inland to Clermont) were low in phosphorus. The phosphorus status of north Queensland pasture soils (around Bowen, Townsville, Cairns and Mossman and inland to Georgetown, Charters Towers and Tambo) was even lower. Twenty percent had 'low' or 'very low' levels and almost 55 percent had 'extremely low' levels. Sulfur was 'extremely low' in almost 80 percent of the northern soils. Little information is available on the effects of grazing on these naturally low levels.

Soil structure decline

Indicator

Area affected by soil structure decline

Soil structure decline is the reduction in soil air space, particularly the interconnected spaces around soil aggregates. A sound soil structure provides habitat for soil micro-organisms and facilitates the movement of water, gases and nutrients to plant roots and the penetration of the soil by the roots. Deterioration of soil structure can cause poor germination, reduced root growth, increased susceptibility to plant disease, low water infiltration, waterlogging and increased runoff.

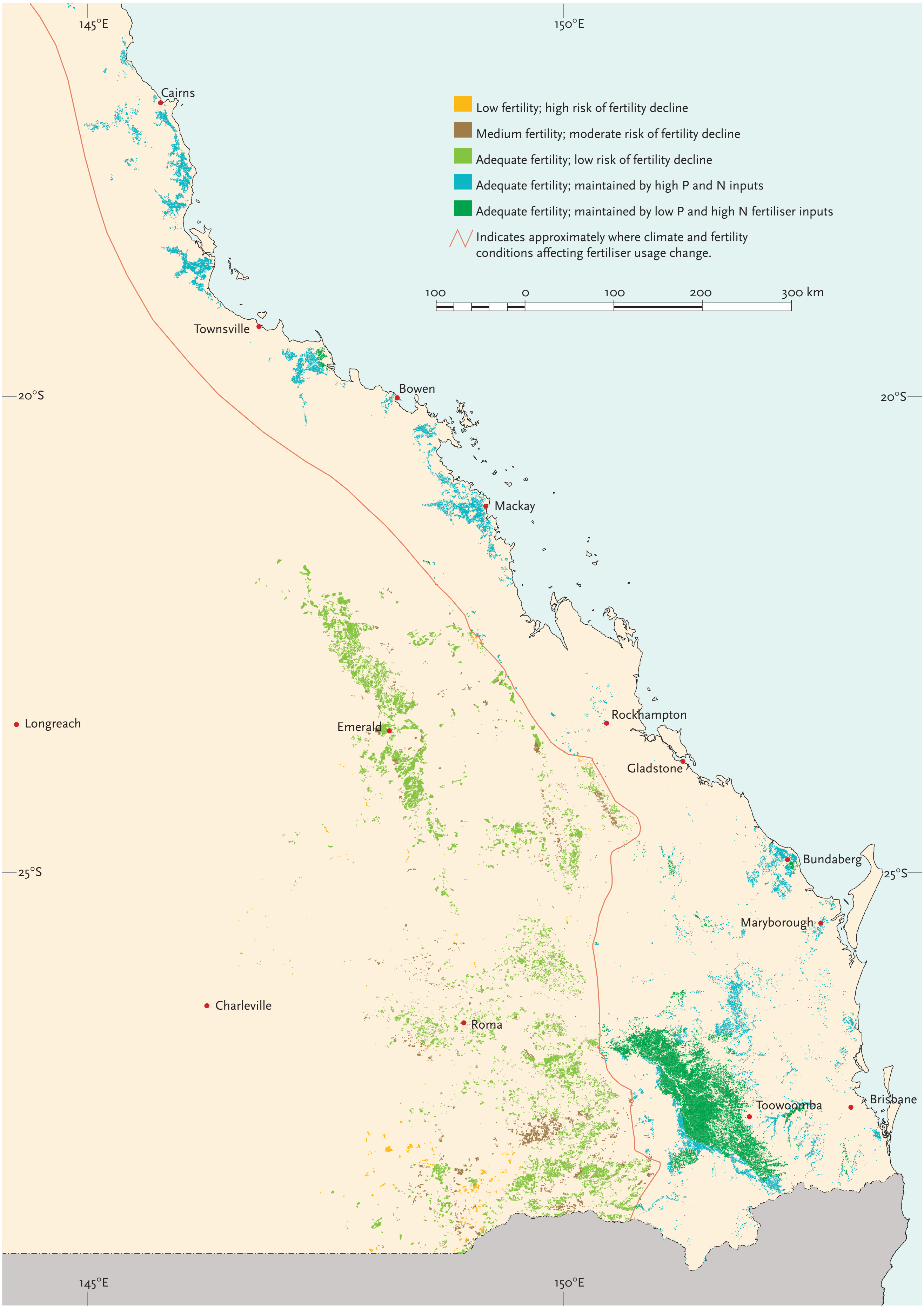

Figure 3-16 Soil fertility of cropping lands in Queensland, 1997
(Source: DNR)

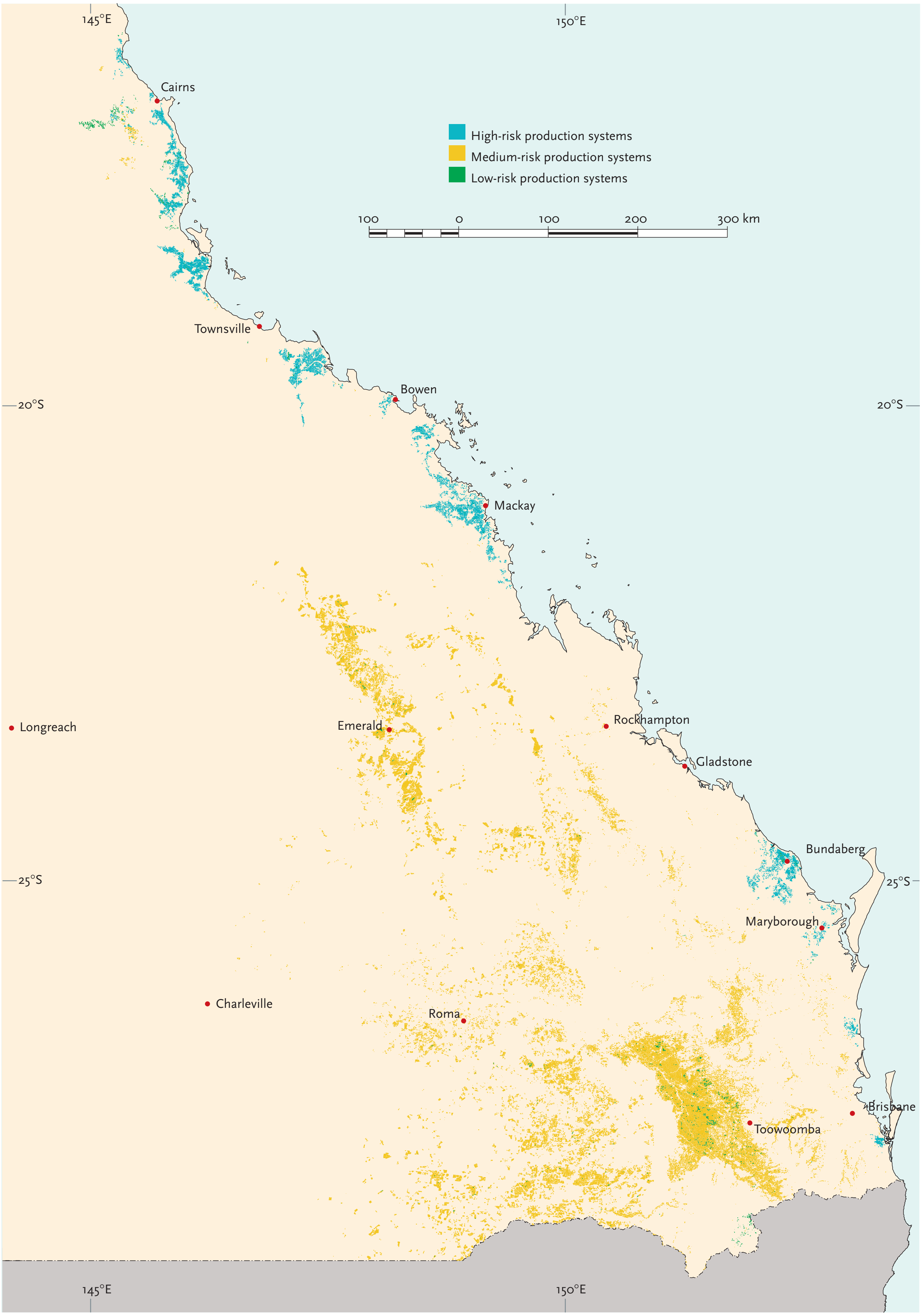

Figure 3-17 Risk of soil structure decline in cropping lands in Queensland, 1997
(Source: DNR)

Table 3-17 Area of cropping land in Queensland affected by soil structure decline, 1997

Category	Characteristics of cropping systems	Area (ha)	Area (%)
A — high risk	Minimum tillage not adopted High potential for wet sowing/harvesting Intense repeated traffic at pre-planting, planting and harvesting No traffic control or retained beds Rotational cropping rare	450 000	14.1
B — medium risk	Wet sowing/harvesting sometimes practised Widespread acceptance and use of minimum tillage Controlled traffic common	2 600 000	81.3
C — low risk	Wet sowing/working/harvesting rare Minimum tillage practised Controlled traffic and retained beds throughout Rotation crops for soil structure repair common	150 000	4.6

Note: 'Controlled traffic' means in-field machinery uses common wheel tracks. 'Retained beds' means cropping beds are used for that purpose only and retained from season to season.
(Source: DNR)

Soil structure decline is found to some degree in all cropping soils (McGarry 1990). The problem is often difficult to assess because it may not be manifest at the soil surface (McGarry 1993). McGarry (1997) observed that as many as 80 percent of cropping farms in south-east and central Queensland were affected. The main regions affected are grain, oilseed, sugar, horticulture and vegetable cropping areas with high rainfall or irrigation, characterised by the use of large tractors and deep tillage.

The risk of soil structure decline in Queensland shown in figure 3-17 has been estimated by examining the characteristics of the cropping systems defined in table 3-17. These include intensive tillage, wet sowing or harvesting, lack of traffic controls and monoculture cropping. About 14 percent of cropping lands are at very high risk of soil structure decline.

The extent of soil structure decline on grazing lands is not known. The problem might be widespread due to repeated trampling by hard-footed domestic animals, especially damaging in moist and wet soils. In addition, soils in grazing areas, such as kandosols and sodosols, are known to possess inherently poor structure and low levels of organic matter, increasing their susceptibility to trampling.

SOIL SALINITY

Indicators

Area of land affected by dryland salinity

Area of land affected by irrigation salinity

Soil salinity involves excessive levels of soluble salts in the root zone. Soils are considered to be highly affected by salinity when electrical conductivity of the saturated soil solution exceeds 4.5 dS/m. However, plants have varying salt tolerances and soil salinity must be considered in the context of the particular crop or vegetation type at risk. There are two types of soil salinity, caused by two common land use activities:

- Dryland salinity is generally caused by rising saline groundwater after clearing of deep-rooted vegetation. Dryland salinity can also be caused by the inappropriate siting of infrastructure such as roads and drainage channels, where these alter local hydrology and promote ponding and rising watertables.
- Irrigation salinity can be caused by irrigation with slightly saline water or by the infiltration of excessive irrigation water to the watertable.

Dryland salinity and irrigation salinity are of increasing concern in Queensland. Severe salinity outbreaks can be identified by the presence of salt crusts, salt seepage sites or extensive areas of land that appears 'naturally' clear of vegetation in areas of otherwise adequate rainfall.

A survey by DNR field staff in 1990 found a total of 14 000 hectares of land estimated to be seriously degraded by dryland salinity. The increased awareness of salinity as an emerging issue for Queensland and increased incidence of saline outbreaks suggest that this figure requires urgent revision. Figure 3-18 shows the distribution of dryland salinity outbreaks in Queensland.

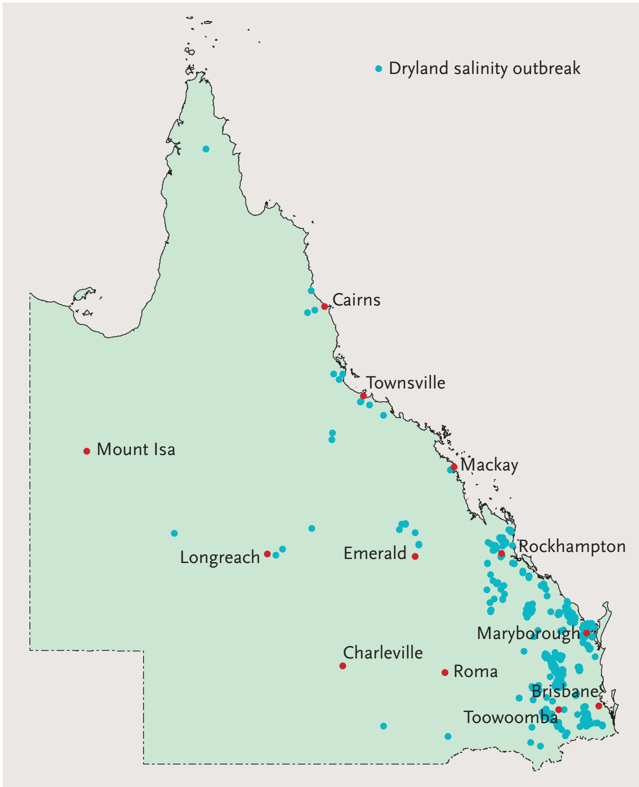

Figure 3-18 Locations of dryland salinity outbreaks in Queensland
(Source: DNR)

The regions identified from the 1990 survey as most affected have annual rainfall ranging from 500 mm to 1500 mm. The problem is most severe in eastern parts near Rockhampton, Bundaberg, Maryborough and Toowoomba and within 200 km of the coast. Dryland salinity also occurs at places on the western slopes of the Great Dividing Range. The Murray–Darling Basin Commission estimated that 1200 ha of land in the Queensland part of the Basin was affected by dryland salinity in 1993, and that the area affected is growing at the rate of 4 percent a year (MDBC 1993). There is insufficient information to make an assessment of the potential for salinity to develop in central, south-west and north Queensland.

The total area of land affected by irrigation salinity is comparatively small, an estimated 1500 hectares. Affected areas are near Emerald, Bundaberg, Maryborough, Mareeba and Townsville.

SOIL ACIDIFICATION

Indicator

Area of cropping land with naturally acidic surface soil or with high rates of acidification

Soil acidification involves a decrease in soil pH over time. Naturally acidic soils in Queensland occur on 74 million hectares, or 43 percent of the State. Strongly acidic soils cover 6.7 million hectares. The most acidic soils lie along the coast and hinterlands in south-east Queensland, the south and central Burnett region, the Mackay coastal strip, the Eungella Tableland, the Wet Tropical Coast, and the Atherton Tableland; these areas have annual rainfalls greater than 500 mm.

A class of naturally acidic soils known as acid sulfate soils occurs in most low-lying coastal areas of Queensland. Acid sulfate soils contain the mineral pyrite (an iron sulfide). When these soils are permanently under the watertable, as in natural wetland conditions, they do not cause problems. However, drainage for uses such as agriculture (particularly sugarcane) or urban development (especially canal estates), causes the pyrite to react with atmospheric oxygen to release sulfuric acid, which damages aquatic ecosystems and corrodes infrastructure. Chapter 5, 'Coastal zone', covers this issue in detail.

Soil acidification on agricultural lands is caused by natural processes and by agricultural and pastoral activities. The rate of decrease in soil pH is determined by the amount of acidity being added to the soil and the soil's pH buffer capacity. The soil's pH buffer capacity, or ability to resist acidification, rises with increasing clay and organic matter content. The main consequence of soil acidification is a reduction in crop or pasture productivity. Figure 3-19 shows the broad pattern of Queensland cropping lands susceptible to acidification. More than 514 000 hectares of cropping land are classed as having a very high susceptibility to acidification, 222 000 hectares as having high susceptibility and 352 000 as having a medium susceptibility.

Native pastures in Queensland are extensively grazed by domestic stock.

NATIVE PASTURE DECLINE

Indicator

Area of native pasture species recognised as being in a desirable condition

Native pasture decline is damage to and replacement of native pastures, usually through overgrazing combined with poor management, drought and changed fire regimes. Native pastures have declined in terms of quality (species composition) and quantity (amount of biomass) since European settlement. Pasture decline is a particular economic and environmental problem for the sheep and beef industries and pastoral communities of the semi-arid and arid areas. In general, data on pasture decline reflect historical rather than contemporary degradation. The rate of pasture decline has declined or halted as a result of attitudinal changes and improvements in management (SCARM 1998).

Weston et al. (1981) evaluated the condition of native pastures and found significant areas of pasture decline. An estimated 29.1 million hectares was considered to have vegetation degradation. While the northern Mitchell grass community was found to be relatively resilient, it was threatened by prickly acacia (*Acacia nilotica*). The southern mulga *Aristida-Bothriochloa*, Mitchell grass and black speargrass communities had areas of serious degradation.

Tothill and Gillies (1992) assessed the condition, productivity and sustainability of these native pasture lands. They concluded that there is widespread deterioration in most native pasture communities, as indicated by undesirable changes in pasture composition and soil surface characteristics. Of the total native pasture area, only 42 percent was described as being in a 'desirably sustainable' condition. Forty-one percent of the area was in a 'deteriorating' condition, and 17 percent was described as 'degraded'. Deteriorating pastures could be returned to a desirable condition through appropriate management. Only the native sorghum, ribbongrass, littoral, Georgina gidgee, Mitchell grass and spinifex pasture communities were found to have 50 percent or more of their area in a desirably sustainable condition. Only 20 percent of the bluegrass (browntop) and mulga (perennial shortgrass) communities are in a desirably sustainable condition. Figure 3-20 shows the native pastures in Queensland with the percentage of area in each in a desirably sustainable condition. Note that 'rainforest' refers to pastures derived from rainforest, and assumes that forests have been cleared. Figure 7-12 in chapter 7, 'Biodiversity', shows the percentage of the larger pasture communities in each rating.

The condition of native grasslands is monitored by DPI and DNR through the QGRAZE network, which provides data on the state of native pastures from more than 400 monitoring sites. By July 1998, 375 sites had had the full array of data

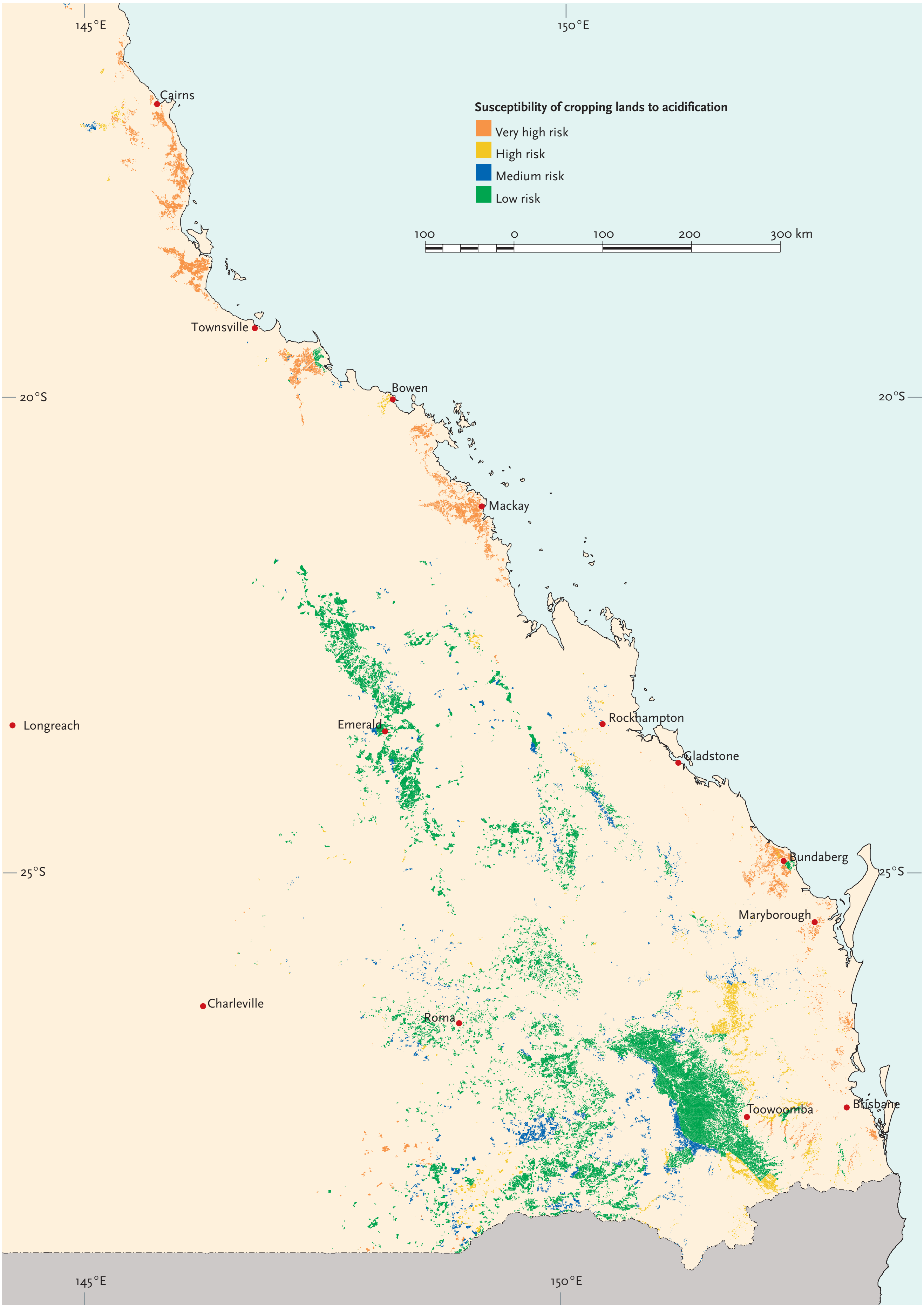

Figure 3-19 Queensland cropping lands susceptible to soil acidification

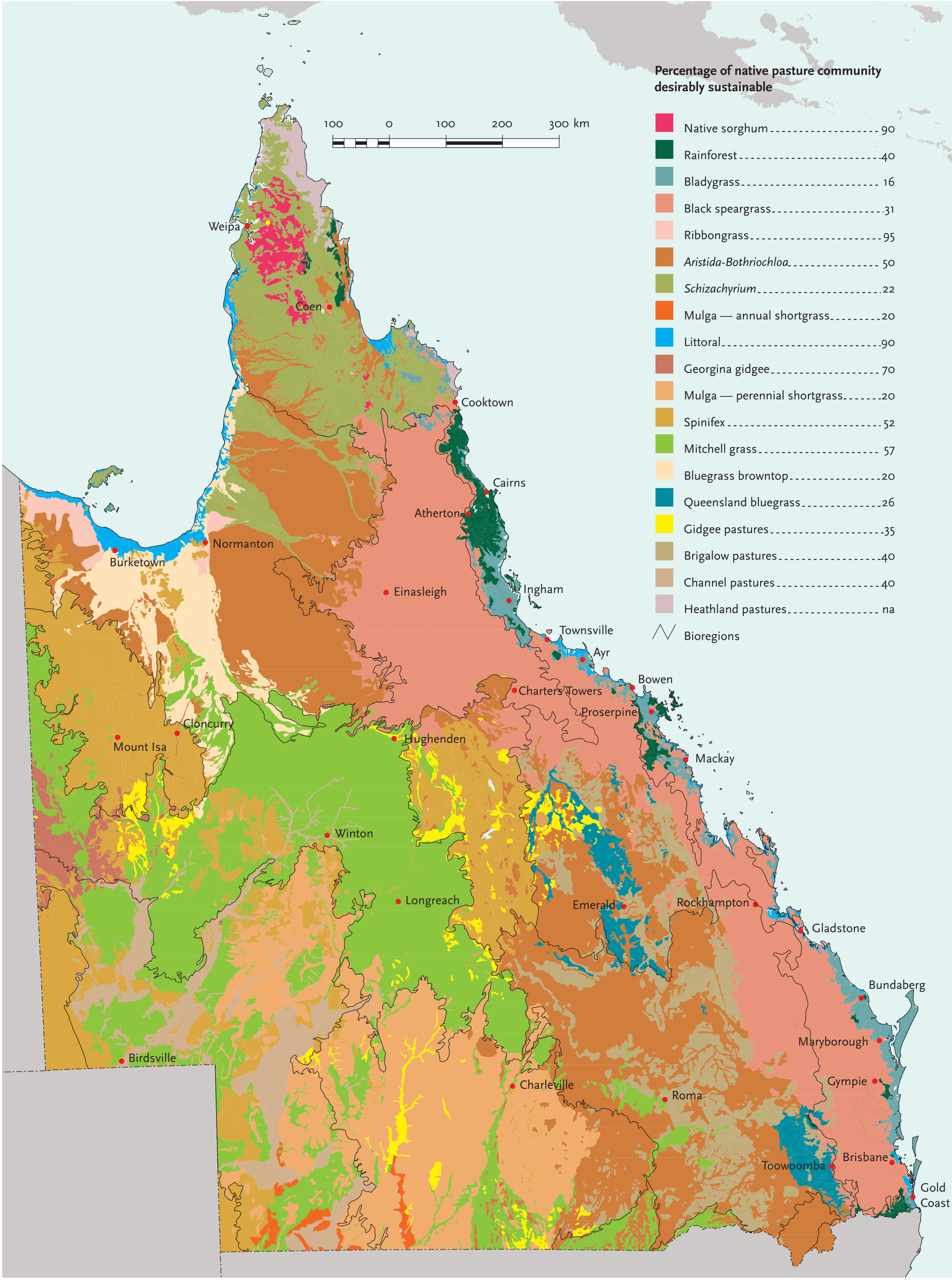

Figure 3-20 Queensland's native pasture communities. The legend specifies the condition of the pasture communities according to Tothill and Gillies (1992).
(Source: DPI)

collected at least once, with a total of 526 data recordings made. Data collected include species composition, groundcover, tree basal area, soil surface condition and pasture yield. In the *Aristida-Bothriochloa* pasture community, the largest of the Queensland pasture communities and one used extensively for grazing, monitoring between 1992 and 1997 at 43 representative sites found that the percentage composition of key perennial species and groundcover had declined. Undesirable perennial grasses declined between 1992 and 1994 but since 1994 have progressively increased. Rainfall was below average from 1992 to 1995, but was above average in 1996 and 1997. Continued monitoring is necessary to determine further changes in species composition (Cliffe, N.O., pers. comm.).

Queensland's grazing lands are subject to high year-to-year variability in rainfall, frosts and humidity and this variability amplifies the pressure of human activities. Palatable perennial grasses, the key forage source for Queensland's wool and beef cattle grazing industries, have declined substantially when drought and heavy use have occurred together (McKeon et al. 1990; Tothill and Gillies 1992; Orr et al. 1993; Orr 1998). Climatic extremes also contribute to changes in species composition in Queensland pastures. For example, climatic extremes have been linked to:

- disappearance and regeneration of Queensland bluegrass (*Dichanthium sericeum*) and perennial Mitchell grass (*Astrebla* spp.) in the Mitchell grasslands in the 1950s and 1980s (Orr and Evenson 1985; Orr 1986);
- invasion and disappearance of black speargrass (*Heteropogon contortus*) in Mitchell grasslands in the 1950s (Bissett 1962); and
- death of perennial Mitchell grass (*Astrebla* spp.) plants in 1987–88 due to drought in north-west Queensland, particularly under heavy grazing (Orr 1998).

It is difficult to discriminate between climatic and human-induced effects. Walker (1988) recommended determining trends in the condition of the pasture resource by comparing conditions after sequences of years with similar climatic conditions.

The quantity and quality of native pastures have declined due to conversion to sown pastures or to crops, particularly wheat, barley, sorghum and cotton. The southern blue grasslands have been converted to crops: only 1 percent of the area remains. Accurate figures for the central blue grasslands are not available, but it is estimated that the area of grassland has been reduced to only 30 percent of its former area. The Mitchell grasslands remain largely unaffected by cultivation, with the exception of the south-eastern part of their range in Queensland where cropping is extensive.

Further, within areas classified as native pasture, there are large areas of naturalised alien grass species. The major naturalised species were conservatively estimated to occupy five million hectares in Queensland in 1990. Cloncurry buffel grass (*Cenchrus pennisetiformus*) is widely naturalised in north-west Queensland, covering an estimated 1.2 million hectares, while Indian bluegrass (*Bothriochloa pertusa*) has replaced the native black speargrass (*Heteropogon contortus*) in parts of coastal and subcoastal north Queensland, estimated at 0.8 million hectares in 1990 (Walker and Weston 1990). The area of naturalised pasture species is now conservatively estimated at 10 million hectares, of which 5 million hectares is buffel grass (Weston, E.J., pers. comm.).

Noxious plants and feral animals

Noxious plants and feral animals are nuisance or harmful species that are detrimental to the environment and/or reduce productivity of the land. They include both native and introduced species. Most, however, are introduced from other countries.

Certain introduced plants are unpalatable or even poisonous to domestic stock and native animals, while others compete strongly with native species or with agricultural plants. In particular, the invasion of pasture lands by woody weeds is a serious form of land degradation in Queensland.

Feral animal species have a negative impact on native species and cause damage to land resources. Many compete with domestic livestock for food, in some cases causing severe overgrazing and soil erosion.

Feral pigs destroy land, particularly along watercourses, and are believed to help spread weeds. They are widely distributed across Queensland, preferring habitat where water and cover are available.

Noxious plants

Indicators

Number, density and distribution of noxious plant species

Percentage of grazing lands affected by woody weeds

The Department of Natural Resources maintains a list of declared plants to be controlled according to the requirements of the *Rural Lands Protection Act 1985*. In 1998, 64 species/genera of plants had been declared noxious, although many troublesome species remain undeclared. The most significant noxious species — rubber vine, prickly acacia, mesquite, parthenium weed and Siam weed — affect large areas in Queensland (table 3-18). The cost of attempting to control noxious plants and the damage they cause is estimated at more than $500 million a year. Introduced exotic plants and their impacts on biodiversity are also discussed in chapter 7, 'Biodiversity'.

Rubber vine is the most significant riparian weed species in Queensland because of its toxicity to livestock, large area of impact, extreme aggressiveness and dense infestations that exclude desirable plants (figure 3-21). Nearly 35 million hectares of Queensland are affected to some extent, and approximately 700 000 hectares are densely infested. Losses to the State's grazing industry due to rubber vine are esti-

Three of the most significant noxious plant species — mesquite (left), parthenium weed (middle) and rubber vine (right) — affecting large areas of Queensland

mated at $10 million a year. It is estimated that up to 20 percent of northern Australia may be susceptible to infestation (Tomley 1995).

Parthenium weed invades native grasslands and has spread to more than 10 percent of Queensland. It is responsible for losses of at least $16.5 million a year, primarily to the grazing and cropping industries.

Prickly acacia, once promoted as a desirable shade and fodder tree, has spread to 6.7 million hectares of the Mitchell grasslands and has the potential to invade two-thirds of the State (figure 3-22) (Kriticos 1997). (See box 'Prickly acacia — a growing threat to the Mitchell grass downs'.)

Many of the noxious species fall into the category of 'woody weeds' — shrubby plants both native and exotic that are a particular problem for grazing in arid and semi-arid areas. The most extensive woody weeds are rubber vine, prickly acacia, parkinsonia, turkey bush, mesquite and groundsel bush, but many more species have the potential to cause problems.

All Queensland pasture areas are affected by woody weed invasion. Approximately 16 percent of grazing lands are categorised as suffering a high degree of invasion, 32 percent a medium degree and 52 percent a low degree. Areas in the high category are located primarily in the Mulga Lands and Mitchell Grass Downs bioregions in the west and south-west. Burrows et al. (1985) studied the vegetation dynamics of mulga lands along two permanent transects. Results indicate a slow but steady increase in the density of most woody weeds in mulga lands.

Table 3-18 Number of local government areas affected by five major noxious plant species in Queensland, 1996

Species	No. of local government areas affected	Total area affected (ha)
Rubber vine (*Cryptostegia grandiflora*)	32	34 600 000
Prickly acacia (*Acacia nilotica* subsp. *indica*)	16	>6 651 000
Mesquite (*Prosopis* spp.)	14	500 000
Parthenium weed (*Parthenium hysterophorus*)	96	17 542 000
Siam weed (*Chomolaena odorata*)	1	<100

(Source: DNR)

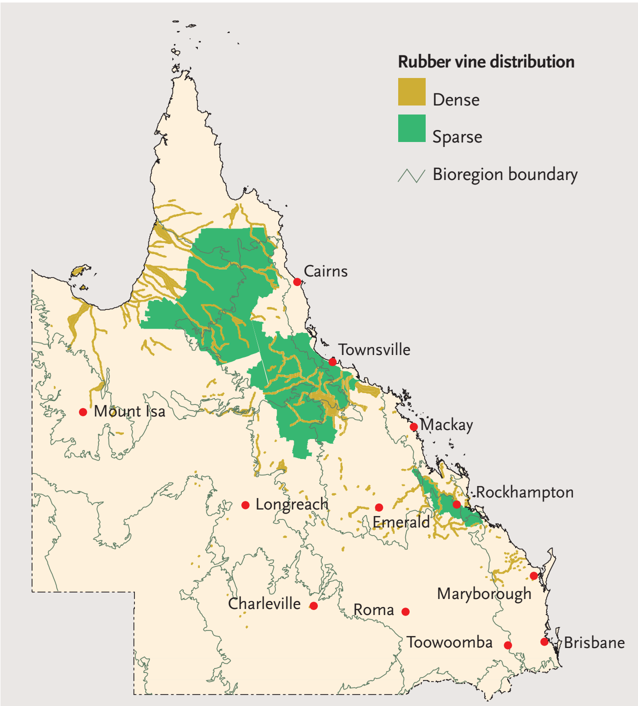

Figure 3-21 Distribution of rubber vine in Queensland, 1987
(Source: DNR)

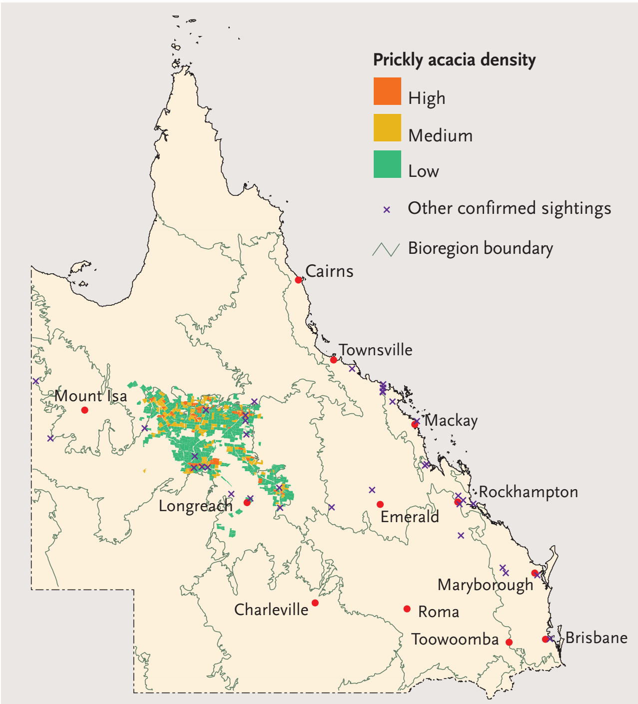

Figure 3-22 Distribution of prickly acacia in Queensland
(Source: DNR)

Prickly acacia — a growing threat to the Mitchell grass downs

Queensland's Mitchell grass downs cover approximately 21.9 million hectares, or 13 percent of the State. They form one of the world's largest remaining areas of natural grassland. This region is dominated by native grasses (primarily several species of *Astrebla*) and is virtually treeless in its natural state. Most of the area is used for grazing sheep and cattle.

Prickly acacia (*Acacia nilotica* subsp. *indica*), a large tree species, was introduced into Queensland from India in the 1890s. It was originally cultivated as a shade and ornamental plant. In 1926 it was promoted by the Department of Agriculture and Stock as a 'useful' shade tree in western Queensland. The tree was also considered a fodder plant. The small number of cultivated specimens planted early this century produced thousands of seeds, which were spread over a vast area by animals and floodwaters.

Prickly acacia competes strongly with native grasses and, in time, can form dense infestations which exclude grasses completely. The loss of pasture grasses under stands of dense prickly acacia translates into a loss of grazing productivity in the order of $5 million a year.

Prickly acacia ranks as one of Queensland's most damaging noxious weeds. It has invaded 6.7 million hectares of the northern Mitchell grass downs pasture community (figure 3-22). It continues to spread into additional areas and has the potential to invade the entire Mitchell grass system. Table 3-19 shows areas infested with prickly acacia in nine western Queensland shires, ranging from only 1 percent of Longreach Shire to 50 percent of Richmond Shire.

The cost of controlling prickly acacia in the nine western shires shown in table 3-19 is estimated at $55.3 million — $45.3 million for initial treatment and $10 million for follow-up. Funds would also be required to conduct follow-up treatment of regrowth and seedlings for a number of years.

Complete eradication of prickly acacia from Queensland is no longer feasible due to the immense area involved. Full eradication of a noxious plant is possible only when it is detected soon after its importation and population development. The further spread of prickly acacia can, however, be controlled provided landholders are aware of the problem, are able to identify the plant and have sufficient resources to prevent it spreading. Various control options, including herbicides and mechanical control, are available. These techniques are often judged by landholders as not cost-effective for controlling extensive infestations, leading to demands for biological control.

DNR has sought host-specific biological control agents for prickly acacia for some time but a satisfactory control agent has not yet been found. Only 6 percent of tested biological control agents ever exert significant control over the target pest. About 20 insect species from Kenya and Pakistan are being tested for their potential as biological control agents for prickly acacia. Four species are undergoing host testing and one, a leaf-feeding beetle, has been successfully mass-reared and released (DNR 1997b). Short-term control continues to rely on an integrated approach involving chemical and mechanical methods.

Table 3-19 Areas infested with prickly acacia in nine western Queensland shires, 1996, based on density estimates from individual properties

Shire	Low density <5% (ha)	Medium density 5–50% (ha)	High density >50% (ha)	Total area (ha)	Percentage of shire infested
Aramac	707 350	114 200	42 130	863 670	37.2
Barcaldine	7 760	19 960	2 220	29 930	3.6
Cloncurry	57 650	–	–	57 650	1.2
Flinders	1 124 220	165 200	109 760	1 399 180	33.6
Ilfracombe	23 280	–	–	23 280	3.5
Longreach	17 740	–	6 650	24 390	1.0
McKinlay	650 800	298 240	67 630	1 016 670	25.0
Richmond	833 740	339 260	180 720	1 353 720	50.3
Winton	1 510 040	293 800	78 720	1 882 570	35.0
Total	**4 932 580**	**1 230 660**	**487 830**	**6 651 060**	**28.4***

*Average of all shires
(Source: DNR)

Feral animals

Indicator

Number of established feral animal species and their distribution

Feral populations of 19 species of introduced mammals have become established in Queensland (table 3-20). The best-known feral species are the larger vertebrates, such as rabbits, pigs, goats and deer. At least one amphibian (the South American cane toad) and several reptiles, birds and fish have also become naturalised. Queensland's most significant feral animals and their impacts are listed in table 3-21.

The distribution of feral species in Queensland is influenced by the availability of suitable habitat. Populations also vary with seasonal conditions, rainfall, control by landholders and commercial harvesting. The latter is particularly important in the case of feral pigs and goats. Rabbit populations vary greatly in response to rainfall and drought and are distributed over vast areas, although the calicivirus introduced recently appears to be rapidly reducing numbers and distribution (see box 'The rabbit: a resilient pest').

Regular mapping of distribution and population density is required to adequately monitor feral animal populations. Limited surveys have been completed for feral species but the data are not comprehensive at this stage. The distribution of the most prominent feral animals is shown in figure 7-10 in chapter 7, 'Biodiversity'.

The cost of damage by feral animals varies from species to species according to social, feeding and breeding habits. Feral pigs alone cause tens of millions of dollars' worth of damage annually in Queensland. Deer appear to have a minor impact, while rabbits have devastated enormous areas of grazing land. The annual cost of rehabilitating land damaged by rabbits, not including the loss of pasture communities, is between $4,000 and $6,000 per hectare. Damage caused by smaller vertebrate feral species such as rats and mice belies their size, amounting to millions of dollars during severe plagues in grain crops and other rural enterprises. These, and other introduced species such as cats and foxes, also adversely affect biodiversity, as discussed in chapter 7, 'Biodiversity'.

Feral goats strip vegetation cover, accelerating erosion processes.

Table 3-20 Feral mammals established in Queensland

Order	No. of species
Artiodactyla (red deer, fallow deer, chital deer, rusa deer, goat, camel, water buffalo, feral cattle, pig)	9
Rodentia (house mouse, black rat, brown rat)	3
Carnivora (domestic dog, European fox, domestic cat)	3
Lagomorpha (European rabbit, European hare)	2
Perissodactyla (horse, donkey)	2
Total	**19**

(Source: DNR)

Table 3-21 Queensland's most significant feral animals

Common name	Major damage
European rabbit*	Damages grazing land. Strips vegetation cover and damages soils, causing erosion and allowing weeds to invade. Competes with native animals for food and burrow space.
Feral pig*	Damages crops (peanuts, corn, sugarcane), fences, irrigation channels and roads. Is a possible vector of exotic diseases. Causes lamb disease and kills young lambs.
European fox*	Kills lambs, fowls.
Feral goat*	Strips vegetation cover, allowing the spread of noxious and unpalatable species. Damages soils and accelerates erosion processes.
Feral horse*	Damages soils and accelerates erosion.
Feral camel*	Damages soils and accelerates erosion. Is a carrier of exotic disease.
Feral donkey*	Damages soils and accelerates erosion.
Red deer	Strips vegetation cover, damages soils and accelerates erosion.
Chital deer	Strips vegetation cover, damages soils and accelerates erosion.
European hare*	Damages grazing land. Is a carrier of exotic disease. Accelerates soil erosion.
Buffalo*	Is a carrier of exotic disease. Damages soils and water bodies.
Cane toad	Competes with native reptiles for food and is poisonous to predatory animals.

*Species declared under the *Rural Lands Protection Act 1985*

CONTAMINATED LAND

Indicators

Numbers of low-risk and high-risk sites on registers

Number of potentially UXO-contaminated sites

Contaminated land contains hazardous substances (such as arsenic, DDT or oil) which might pose a risk to human health or the environment. Land contamination can result from point or diffuse pollution sources and accidental spills. Point sources include municipal, domestic, industrial and mining wastes or residues. Diffuse sources include wastes or residues from agriculture, livestock and forestry. In the past, land was contaminated by activities that were not known to be dangerous at the time, often using chemicals that have since been banned or are now subject to much stricter controls.

At July 1998, 16 122 sites were recorded on the EPA's Environmental Management Register for low-risk sites. Low-risk sites are sites that have been used for an activity likely to cause land contamination or sites that have been shown through a site investigation to have some contamination. At that time, 10 sites were recorded on the Contaminated Land Register as high-risk sites: on these, it was necessary to remediate the land to prevent serious environmental harm.

Some land used for military training during and after World War II has been contaminated with unexploded ordnance (UXO). The main concern related to the presence of UXO is the possibility of injury or death if a UXO item is accidentally detonated. Potential UXO sites are identified by the Commonwealth Department of Defence and reported to affected local governments through the EPA. At July 1998, 9857 lots were identified as being within areas potentially affected by UXO; of those, 72 were recorded on the EPA's Environmental Management Register because detailed investigation by commercial consultants had established that conditions should be imposed on the use of the land.

As part of the EPA's assessment and management strategy, nearly 240 items of UXO have been located and disposed of as a direct result of the investigation and remediation of potentially affected sites by commercial UXO consultants. Hundreds of individual lots of land containing evidence of their previous military use have proven to be uncontaminated. Department of Defence specialists dispose of any UXO items found.

Loss of land to urban uses

Indicators

New allotments for housing

Agricultural land subdivided for urban housing

Rates of land use change are not available for Queensland as a whole, although work is being done to develop methodology using remotely sensed data sets and geographic information systems (see box 'Land use changes in the Maroochy River catchment'). Chapter 5, 'Coastal zone', provides details of change in coastal areas in Queensland.

The rate of subdivision for housing can be used as a measure of land use change for urban development. However, the rate of subdivision does not necessarily reflect changes due to other forms of development.

Geographic coverage of subdivision and agricultural suitability information in digital form is available for only 22 local government areas and only from 1994. Of these, the five highly urbanised local government areas (LGAs) that have the greatest proportions of good-quality agricultural land are Redland Shire (4.81 percent), Brisbane City (2.15 percent), Logan City (1.96 percent), Maroochy Shire (1.87 percent) and Cairns City (1.57 percent) (table 3-28).

Figure 3-23 shows the total area allocated for dwelling construction from agricultural land and other land in the 22 LGAs in 1994 and 1995. The analysis is restricted to land subdivided into lots of between 300 m^2 and 5 ha in size, as allotments of this size are predominantly non-productive in an agricultural sense. Allotments greater than 5 hectares are potentially productive or not seriously or irreversibly disturbed by the presence of dwellings.

In the two years 1994 and 1995, the total area of land converted to residential land use in the 22 LGAs was 16 742 hectares. Of this, 25.8 percent (4280 hectares) was previously good-quality agricultural land. As most of the land being converted is in the coastal belt, this can be compared to the 580 000 hectares of land used for growing cane and small crops in this region. Urbanisation has affected approximately 0.7 percent of the land used for cropping in a two-year period alone.

The most significant losses were in the shires of Noosa (738 hectares), Maroochy (658 hectares), Caboolture (221 hectares), Burnett (214 hectares), Beaudesert (202 hectares) and Redland (186 hectares), and the cities of Brisbane (574 hectares), Mackay (291 hectares), Cairns (275 hectares) and Caloundra (250 hectares). The bulk of this conversion has involved larger allotment subdivisions (that is, from 2500 m^2 up to five hectares), representing rural residential development. Further details can be found in table 3-28.

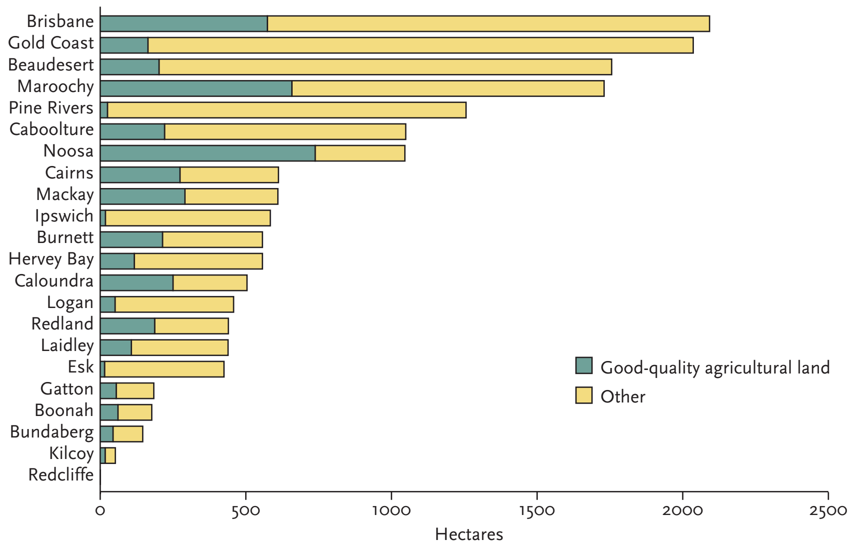

Figure 3-23 Subdivision of land in 22 local government areas in 1994 and 1995 *(Source: QDHLGP)*

Land use changes in the Maroochy River catchment

Urban development is increasing in Queensland's coastal zone, especially in the south-east region. Sustainable use of the coastal zone in the future may depend on accurate monitoring of the nature and rate of land use changes.

The widespread and incremental nature of the impacts of urbanisation (such as loss of habitat, increased erosion and urban runoff) suggests the catchment as the appropriate unit for monitoring and management. Researchers from The University of Queensland are developing a method of plotting the spatial distribution of land use changes in catchments that uses remotely sensed data sets and relies on geographic information systems (Phinn and Stanford 1998). The data are refined by field knowledge and aerial photographs.

The land cover classification scheme developed by the researchers took existing regional vegetation and physiographic classifications and modified them to allow application to satellite image data sets. Spectral bands were selected to distinguish between similar vegetation signals, for example mangroves and upland forest. These classifications were then applied to satellite images to derive land cover maps for 1988 and 1997 and identify changes in the Maroochy and Mooloolah River catchments (figures 3-24 and 3-25). The maps were verified using a sample of control points from aerial photos. Overall, the accuracy of the data is estimated at 75 percent, with higher accuracy for data on developed areas.

The maps for the Maroochy River catchment showed three predominant types of change in the catchment from 1988 to 1997: development of urban areas, increase in the area of forest (possibly due to higher rainfall in the period before 1997), and creation of new areas for crops (mostly sugarcane). The greatest changes in area were from grassland to forest (6000 hectares) and from bare ground to cropping area (4000 hectares). Land was developed mostly in areas that had previously been forest (1200 hectares) and bare ground (1800 hectares).

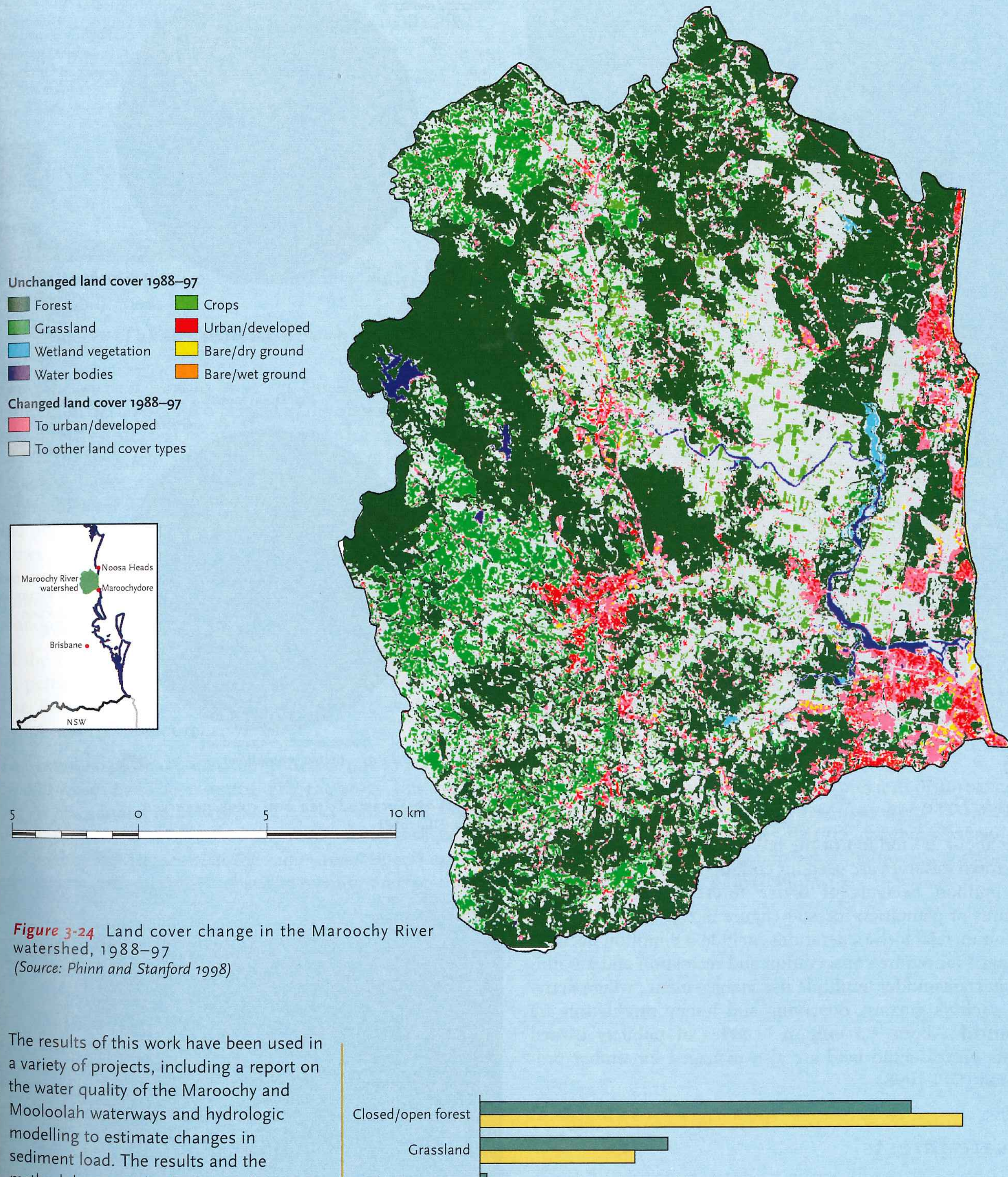

Figure 3-24 Land cover change in the Maroochy River watershed, 1988–97
(Source: Phinn and Stanford 1998)

The results of this work have been used in a variety of projects, including a report on the water quality of the Maroochy and Mooloolah waterways and hydrologic modelling to estimate changes in sediment load. The results and the methodology are also being used to map land cover for the Sunshine Coast area for use by CSIRO's Division of Tropical Agriculture in association with the Cooperative Research Centre for Sustainable Sugar Production in Townsville.

Tools such as this will also be useful for evaluating the success of development controls and considering the implications of proposed development on environmental and water quality conditions.

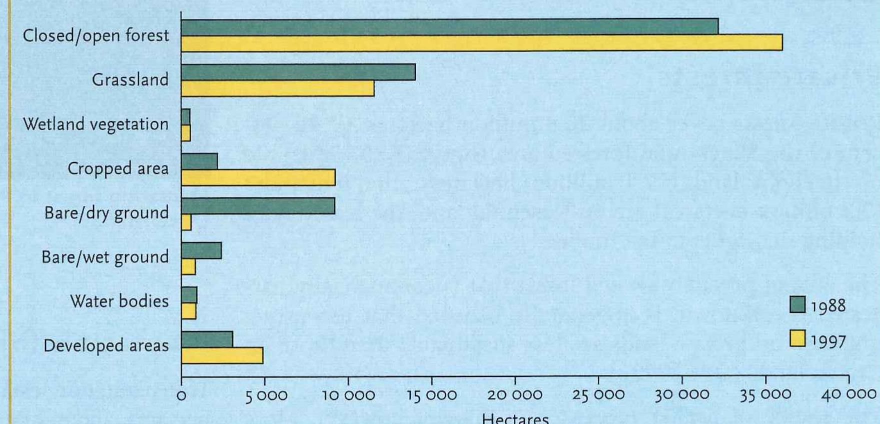

Figure 3-25 Areas of land use categories in the Maroochy River catchment, 1988 and 1997. The difference is net change (includes both losses and gains).

The pressures of urbanisation on prime natural and agricultural land are especially intense in areas such as the Sunshine Coast and the Cairns district (for example see Anstey et al. 1996), with particular impact on canegrowing land. In the period 1980–95, 1.9 percent of canegrowing land in the State was converted to residential land. However, in certain mill areas — for example, Mulgrave (14.8 percent) and Maryborough (7.2 percent) — a higher proportion has been converted. Over the next 20 years, 7.4 percent of canegrowing and cropping land in the Cairns and Sunshine Coast areas is likely to be lost to urban development.

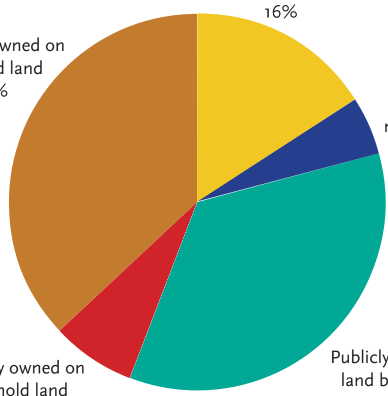

Figure 3-26 Queensland's total forest area
(Source: DPI 1998)

FOREST RESOURCES

Indicators

Area of State-owned/privately owned forests

Area of native/plantation forests

Forest area harvested/not harvested

Forests (including woodland, open forests and closed forests) cover approximately 49 million hectares, or 28 percent of Queensland. About 74 percent of this cover is woodland. Closed forests are confined mainly to coastal areas and parts of southern inland Queensland. Most of the State's forest resource is native forest (99.6 percent) (DPI 1998). The biodiversity status of forests is discussed in chapter 7, 'Biodiversity'.

Fifty-eight percent of the State's forest is publicly owned. Of this, 8.0 million hectares are on Crown Reserves and 20.7 million on leasehold land (figure 3-26).

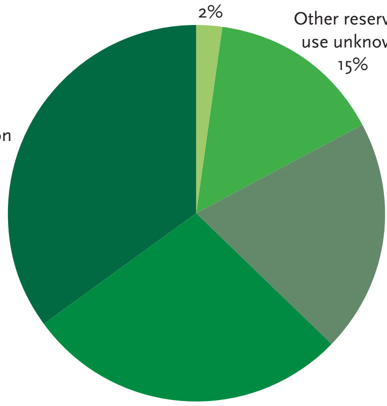

Figure 3-27 Forested area on Crown Reserves
(Source: DPI 1998)

State forests

Only about 2.4 million of the 8.0 million hectares of forests on Crown Reserves are used for commercial forest operations (2.2 million hectares of native forest and 0.18 million hectares of plantation forests) (figure 3-27). Areas not used for commercial forest operations include 2.8 million hectares managed for nature conservation and recreation and 1.6 million hectares under 'multiple use management', where activities such as grazing, quarrying and honey production are permitted. About 2.3 million hectares of publicly owned forests on leasehold land are also managed for timber production (DPI 1998).

Private forests

Private forests cover about 20.4 million hectares, or 42 percent of the State's total forested area (figure 3-26). Most are on freehold land (17.1 million hectares); the remainder (3.3 million hectares) are on leasehold land, the leaseholder holding the rights to the timber.

The area of privately owned forest that is commercially harvested is unknown. It is generally believed that harvesting practices on private lands are less sustainable than those on Crown lands (DPI 1998).

The source of timber processed is known, however. More than one-quarter of processed timber is sourced from private lands. Sixty percent of hardwood processed is from private resources (DPI 1998).

Plantation forest in Pumicestone catchment in south-east Queensland

Plantation forests

The plantation estate comprises slightly less than 200 000 hectares, about 2 percent of Crown Reserves or about 0.4 percent of Queensland's total forest area (figure 3-27). About 90 percent of this (180 000 hectares) is publicly owned. Two-thirds of publicly owned plantations are located in the Wide

Bay–Burnett region, sited close to the State's major population centres and transport facilities. Plantation forests generally are of a single tree species, mostly exotic pines, selected for good growth rates and adaptability to infertile soils (DPI 1998).

Despite this relatively small area, plantations provide the majority of the State's timber (see 'Pressure' section).

MINING DISTURBANCE

Indicators

Cumulative areas of land disturbance and rehabilitation

Number of abandoned minesites

The total area of mining leases in Queensland is currently 1.1 million hectares, or 0.6 percent of the State's land area. The land directly disturbed by mining on these leases is reported to be 73 000 hectares. The undisturbed parts of mining leases comprise buffer zones, areas included because of the linear nature of lease boundaries, prospective mine paths, proven and unproven reserves and non-surface rights to underground mines. Of the 73 000 hectares reported to be disturbed, 26 000 are attributed to mining for metalliferous ore and 46 000 to mining for coal. The additional area of land disturbed on abandoned leases is considered to be relatively small.

Of the 73 000 hectares disturbed, about 23 000 hectares, or 32 percent, had been rehabilitated by 1997 (DME 1998b). The 'Response' section of this chapter describes responsibility for and funding of rehabilitation.

The number of abandoned minesites is not known. In all, 50 000 leases have been issued over the years, but the number of abandoned sites will be far lower than this because many leases were never mined and many old leases have been replaced by new leases over the same area. Mineral explorers are encouraged to reopen abandoned minesites so that not only can new minerals be found but previous disturbance can be rehabilitated as part of the new operation. As a result of these factors, DME estimates that the number of abandoned mines that require significant rehabilitation is possibly less than one hundred (DME 1998b).

Gold mine at Palmer River, north Queensland

RESPONSE

Landholders have the primary role in land resource management, but governments and community groups play a significant part. In the sections below, the responses of Commonwealth and State Governments to land resource issues are discussed. Specific issues, including adoption rates by landholders of sustainable land management practices where data are available, are then discussed in more detail.

The agriculture industry spent an estimated $70.3 million on environmental protection in 1994–95, and $56.2 million in 1995–96. This includes control and prevention of soil and land degradation, protection of waterways from contamination, protection of native plants, animals and habitat, and eradication of plant growth, animals or insects affecting sustainable land use. Queensland spent 1.2 percent of total agricultural turnover on environmental protection in 1994–95, and 0.9 percent in 1995–96, more than any other State. In those years, the industry received $1.5 and $2.0 million in soil conservation grants and subsidies (ABS 1998c). Mining industry expenditure is discussed in 'Managing mining impacts' below.

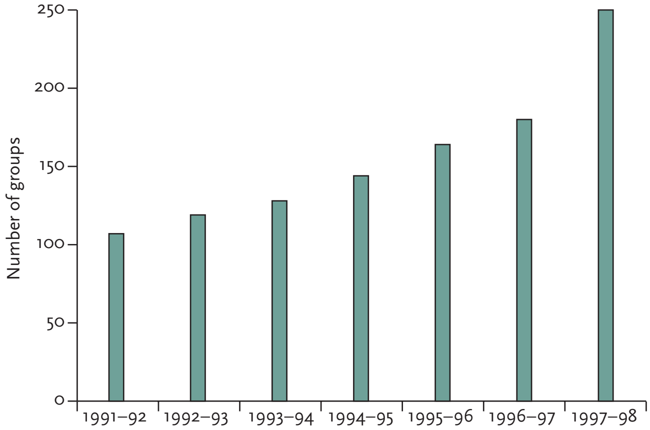

Figure 3-28 Number of Landcare groups in Queensland, 1991–92 to 1997–98. In 1997–98, 170 of these groups were endorsed Landcare groups, and the remaining 80 groups were in related programs.
(Source: DNR)

NATIONAL INITIATIVES

Landcare, a national program in which land managers, industry and governments work together for sustainable management, is one of the most significant programs for arresting land degradation. Landcare was established nationally by the National Farmers' Federation, the Australian Conservation Foundation and the Commonwealth Government in the late 1980s. It is now supported with funding from the Commonwealth Government under the National Landcare Program and coordinated in Queensland by DNR. The 1990s were declared the Decade of Landcare.

The key characteristic of the National Landcare Program is the cooperative work of its community groups. Landcare group members volunteer and work to their own localised agenda, with an emphasis on working together on problems too large for single landholders to handle. Studies show that Landcare group members have significantly higher levels of adoption of better land use management practices than non-members (ABARE 1994). In 1992–93, 3162 Queensland farm businesses (14.8 percent) were actively involved with Landcare, and a further 2472 (11.6 percent) were involved in similar programs (ABS 1996c). Recent years have seen a strong increase in the number of Landcare groups in Queensland (figure 3-28).

DNR

Landcare field day at Yarraman. Community involvement has been the keystone of sustainable land management strategies in Queensland.

The Commonwealth Government's financial involvement with land management solutions increased significantly in May 1997 with the establishment of the Natural Heritage Trust (NHT), which will provide funding of $1.25 billion over six years. The NHT focuses on five main areas: vegetation, rivers, biodiversity, land, and coasts and marine. It includes funding for several land-focused programs including the National Landcare Program, the National Vegetation Initiative (incorporating the Save the Bush and the One Billion Trees programs), Bushcare, the Farm Forestry Program, the National Land and Water Resources Audit, the National Feral Animal Control Strategy and the National Weeds Strategy.

In 1997–98 the National Landcare Program in Queensland received $13,573,000 in funding from the NHT for 243 land and water conservation projects. These included catchment and regional resource management planning; vegetation mapping and planning; development of land capability mapping and suitability frameworks; weed management; soil conservation; pasture and grazing management; rehabilitation of uncontrolled bores and construction of pipelines to replace open bore drains in the Great Artesian Basin; tree planting; and development of best practice guidelines for weed control, irrigation, grazing and soil conservation.

The National Landcare Program also funds courses in property management planning, known as Futureprofit, for landholders. Farm planning helps farmers manage resources more sustainably. Futureprofit has attracted considerable interest: more than 130 workshops were held across the State in 1997–98. A feature of its success has been the close support provided by the major industry groups. A survey in 1992–93 showed that 34.7 percent of Queensland farm businesses had a farm plan of some kind, higher than the national average of 30.6 percent of farmers. Nationally, sugar farmers were the farming group most likely (at 38.2 percent) to have a farm plan, while broadacre farmers also rated highly (ABS 1996c).

Despite these successes, a review of the National Landcare Program in 1997 by the Australian National Audit Office found that after eight years of operation the Commonwealth was unable to indicate in any detail the outcomes that had been achieved (ANAO 1997). It pointed to lack of operational objectives, lack of a comprehensive assessment of needs and lack of an outcome focus. Monitoring review had been variable and there had been a failure to objectively apply the performance indicators and targets originally developed. The ANAO also pointed to a lack of clarity in differentiating between the roles of the Commonwealth and the States.

Research

Another important Commonwealth Government response is the funding of research through CSIRO, the Land and Water Resources Research and Development Corporation and commodity-based research and development corporations funded jointly by farmgate levies and the Commonwealth Government. The Commonwealth Government also provides funds to cooperative research centres in which industry, universities and government organisations undertake collaborative research.

State Government roles

The Department of Natural Resources (DNR), the custodian of natural resources in Queensland, works to support the State's economic growth through the sustainable use, development and management of land, water and native vegetation resources. The Department provides a wide range of monitoring, modelling, research, guidelines and control programs, some of which are discussed in the following sections.

The Department of Primary Industries (DPI), a rural economic development agency, works with industry to increase the profitability of primary industry-based enterprises on a sustainable basis and provides research, extension and regulatory services throughout the State.

A number of government departments, industry organisations, local governments, environment groups and community members participated in developing the Environmental Code of Practice for Agriculture in 1997–98. Codes for individual industries including sugar and horticulture have been completed, and others for the intensive livestock sector are being developed. DNR and DPI also work with individual industry bodies in developing voluntary industry-specific environmental guidelines. By 1997, a five-year Land Management Field Manual project, funded jointly by DNR and the NHT, had produced nine user-friendly manuals aimed at improving landholder and community understanding of local soils and their crop/pasture suitability in Queensland's cropping regions.

Managing vegetation clearance

In Queensland, the clearing of native vegetation on leasehold land is regulated under the *Land Act 1994*. DNR is responsible for managing tree clearing on leasehold and other State lands. Under the Act, the Broadscale Tree Clearing Policy and associated Local Tree Clearing Guidelines came into effect in late 1997. These provide guidance to DNR for assessing applications for permits to clear trees. They apply only to leasehold land on which the State owns the trees and where grazing or agriculture is the primary use (approximately 67 percent of the State).

Clearing on leasehold land requires a permit, the permit being valid for five years. Over the period 1994–96, clearing permits were granted for an annual average of 770 000 hectares. Half of this area was for regrowth, that is, for vegetation that has been cleared in the past five to ten years. In 1998, permits applying to 425 396 hectares were granted; 76 percent of this area was regrowth. Table 3-22 shows the area covered by tree clearing permits for 1998. Permits were issued for large areas of virgin growth in central Queensland, but proportionately more permits for clearing of regrowth were issued in the west and south.

The area for which permits have been issued each year has decreased dramatically since 1994, when permits covering 1 079 800 hectares were issued. The area of land actually cleared (estimated at 285 000 hectares annually from 1991 to 1995) is probably much lower than the area of permits as not all permits granted are acted on.

Other Acts play a part in managing vegetation clearance: the *Nature Conservation Act 1992* partly regulates the removal of native habitat, and the *Water Resources Act 1989* controls the removal of native vegetation in creeks and rivers. Special leases for broadscale tree clearing in forest reserves are administered by DNR under the *Forestry Act 1959*.

At present, the primary regulatory control over activities on private lands, principally urban lands, is through local government. Vegetation protection orders (VPOs) can be issued to protect trees or vegetation of scenic, historic or cultural value, protect river bank stability or prevent land

Table 3-22 Area covered by type of tree clearing permit by DNR region, 1998

Region	Permit for clearing virgin growth (ha)	Permit for clearing regrowth (ha)	Permit for clearing for use as fodder (ha)	Total area (ha)
Central West	55 636	129 258	0	184 894
Metropolitan	2	0	0	2
North	2 388	14 048	0	16 436
South East	484	1 636	0	2 120
South West	33 462	188 482	0	221 944
Total 1998	**91 972**	**333 424**	**0**	**425 396**
Total 1997	**48 206**	**261 777**	**3 000**	**312 983**

'Virgin growth' is timber that has not previously been cleared. 'Regrowth' is timber that has been cleared in the past five to ten years. 'Fodder' is food for livestock.
(Source: DNR)

slippage. Data on VPOs are not available for the State. Brisbane City Council reports that since it introduced its Vegetation Protection Ordinance in 1991, the program has proved effective in protecting large areas of vegetation in the city's outer fringes (BCC 1996). VPOs in Brisbane now cover a total area of 18 250 hectares (BCC 1998). (See also 'Green space' in chapter 8, 'Human settlements'.)

The Queensland Government has recognised the need for a comprehensive system of vegetation management across all tenures, both private and public. It has established a Vegetation Management Advisory Committee to advise on the development of a system to meet ESD objectives and national and international commitments.

Accurate information is an essential aspect of managing vegetation resources. The Statewide Landcover and Trees Study (SLATS) is one of the largest remote-sensing projects carried out in Australia. DNR initiated SLATS in recognition of the need for better information on vegetation in Queensland. It uses Landsat satellite imagery to provide data on land use, vegetation density and extent of land clearing (see 'Pressure' section for data).

Revegetation of stream banks is important for bank stabilisation and prevention of soil erosion.

REDUCING EROSION

Water erosion

In response to the potential and actual damage and costs of soil erosion, soil conservation measures are well established in cropping areas of Queensland. Table 3-23 summarises the extent of implementation of runoff control measures (for example, diversion banks and contour banks) on cropping lands in Queensland, showing increases in use from 1993 to 1996. Implementation has been most common in the central, south and south-east regions but less than 30 percent of erosion-prone land in the north has been treated.

Table 3-23 Extent of implementation of runoff control measures on cropping lands ('000 hectares) by DNR region, 1993–96

Region	Area of cultivation	Area requiring treatment	June 1993	June 1994	June 1995	June 1996
Central	807	802	413	420	425	432
North	367	185	50	50	52	53
South	1670	1414	623	638	707	724
South-east	378	224	174	199	202	202
West	–	–	3	3	3	3
Total	**3223**	**2625**	**1263**	**1310**	**1388**	**1415**

As cover is the most significant factor in reducing erosion, zero tillage or reduced tillage is one of the most successful erosion control measures (Littleboy et al. 1992; Freebairn and Wockner 1991). In the past decade, adoption of reduced or zero tillage by broadacre farmers has increased from 25 percent to 75 percent, with an associated reduction in soil loss from 30 tonnes/hectare/year to 5–8 tonnes/hectare/year. Reduced tillage has also been adopted in the horticulture industry: 60 percent of bean producers in the Gympie district have adopted best practice reduced tillage management (DPI, unpub. 1999).

Retaining stubble or trash rather than burning it or ploughing it in has also been shown to significantly reduce soil losses (Freebairn and Wockner 1991). In sugarcane cropping, trash retention can reduce soil erosion rates to less than 10 tonnes/hectare/year, compared with almost 50 tonnes/hectare/year under trash removal. Recently there have been marked increases in green cane harvesting and trash blanketing in the sugar industry. In the 1998 season, more than 65 percent of the State's cane crop was cut green: close to 100 percent of the crop in most northern areas, 82 percent in central regions, and 56 percent in southern regions (DPI, unpub. 1999).

A 1992 study (Littleboy et al. 1992) found that almost 50 percent of landholders in central Queensland practised stubble mulching to ensure adequate land cover. This compared with less than 20 percent of landholders on the central Darling Downs. About 20 percent of landholders in graincropping areas and almost 60 percent in sugarcane lands had adopted this practice.

Table 3-24 shows the area of land under various stubble disposal techniques in Queensland in 1994–95 and 1995–96. Statewide, only 20 percent of the area of stubble in 1995–96 was mulched. The majority (53.1 percent of land area) was ploughed into the soil. Only 1.5 percent of crop stubble was burnt and 16.4 percent was removed.

Table 3-24 Area under various crop stubble disposal techniques, Queensland ('000 ha)

Stubble disposal technique	1994–95	1995–96
Burnt	49.2	21.9
Removed by grazing, baling or fire harrowing	nc	234.8
Incorporated into soil by ploughing	696.7	762.1
Mulched	147.3	289.1
Left intact (crops sown by direct drilling)	125.2	126.6

nc = not collected
(Source: ABS 1997)

Wind erosion

The extent of responses to the issue of wind erosion is difficult to identify as a result of the generally low level of awareness of the nature of wind erosion and the extent of damage it causes to Queensland's land and soil resources. Tree clearing on leasehold lands must be approved by relevant government agencies (see 'Managing vegetation clearance' above). DNR, DPI and the Commonwealth Government are working to encourage farmers to reduce grazing pressure during drought. Some Landcare groups are also active in projects to reduce wind erosion.

Maintaining soil fertility

The major response to declining soil fertility in Queensland is the use of fertilisers. Artificial fertiliser use in Queensland increased steadily after World War II, rising markedly during the 1960s and 1970s, then stabilising or declining slightly during the 1980s and 1990s. Recently, fertiliser use has stabilised at about 400 000 tonnes a year. This levelling is possibly due to long dry seasons experienced between 1991 and 1996, which reduced both cropping area and the farm income needed to buy fertiliser. In 1995–96, 12 437 agricultural establishments used 409 481 tonnes of artificial fertiliser on 1 523 814 hectares of crops and pastures (0.27 t/ha) (figure 3-29). Compared with 1993–94 figures, this represented an increase of only 0.6 percent in volume of fertiliser used but a 32.3 percent increase in area of application.

Fertiliser use is standard practice in agricultural systems east of the line in figure 3-16 (page 3.34). Little or no fertiliser is consistently applied west of the line. Artificial fertiliser use by region in 1995–96 is shown in table 3-25. The Darling Downs

Figure 3-29 Average fertiliser application rate on intensively cropped lands (1994–95 data were not reported)
(Source: ABS)

Table 3-25 Artificial fertiliser use by region, 1995–96

Region	Amount used (tonnes)	Area treated (ha)	Tonnes/ha
Moreton and Brisbane	33 113	76 068	0.44
Wide Bay–Burnett	52 189	163 033	0.32
Darling Downs	64 586	606 955	0.11
South-West	5 528	49 036	0.11
Fitzroy	16 893	103 741	0.16
Central-West	62	70	0.89
Mackay	77 473	165 757	0.47
Northern	79 256	173 183	0.46
Far North	80 162	185 391	0.43
North-West	220	579	0.38
Queensland	**409 481**	**1 523 814**	**0.27**

(Source: ABS 1997)

Table 3-26 Fertiliser use on agricultural crops in Queensland, 1995

Crop	Superphosphate ('000 tonnes)	Nitrogenous fertiliser ('000 tonnes)	Other fertilisers ('000 tonnes)
Pastures	24.7	21.2	11.1
Wheat	4.4	14.1	3.6
Sugarcane	16.0	88.7	119.3
Other crops	18.1	72.3	46.4
Total	**63.2**	**196.3**	**180.4**

(Source: ABS)

Statistical Division accounted for 40 percent of the total area fertilised in Queensland in 1995–96, but has one of the lowest application rates. Higher application rates are found in the State's northern regions. Nitrogenous fertilisers were the most commonly used form of artificial fertiliser: 207 428 tonnes were applied to 721 138 hectares in 1995–96 (ABS 1998a). Table 3-26 shows fertiliser use on specific crops in 1995.

Despite increasing fertiliser use, in many instances farmers are not supplying sufficient nutrients to replace losses (see 'State: Soil fertility decline'). Many places in Queensland's eastern zone are losing nutrients despite fertilisation efforts, resulting in declining crop quality and yields. Conversely, excessive or inappropriate use of artificial fertilisers in some areas is imposing environmental costs (see 'Pressure: Fertilisers and agricultural chemicals' above).

Reducing soil structure decline

Strategies for preventing soil structure decline are both mechanical (for example, traffic control practices and tillage only when the soil is dry) and biological (for example, rotational cropping and ploughing in green crops). Combining these practices is generally the best way to retain soil structure. The adoption rate and status of three of these strategies in the four major cropping industries are outlined in table 3-27. The cotton and grain and oilseed industries are adopting these approaches widely; the sugarcane and horticulture industries are adopting them to a lesser extent (McGarry 1997).

A number of Landcare groups are developing and using management strategies for reversing soil structure decline.

Table 3-27 Adoption rate and status of cropping management practices for reduction of soil structure decline in Queensland

Cropping industry, adoption rate and status	Minimum tillage	Controlled traffic and retained beds	Rotational cropping
Grain/oilseeds			
Adoption rate	Medium to high	Medium	Not possible due to low soil water availability in fallow
Status	Practice widespread	Practice increasing	—
Irrigated cotton			
Adoption rate	High	High	High
Status	Practice widespread	Practice followed by 80% of the industry	Practice widespread (also green manuring and legume break crops)
Sugarcane			
Adoption rate	Low	Low	Very low
Status	None — routine removal of beds and 'plough-out' to depths of 40 cm or more	None — experimental work being done	None
Horticulture and vegetables			
Adoption rate	Very low	Low to medium	Low
Status	None	Rare	Rare

(Source: Adapted from McGarry 1997)

Training workshops in the identification, repair and control of soil structure decline have been conducted. Several research and development agencies, including the Grain Research and Development Corporation and the Cotton Research and Development Corporation, have developed and tested effective repair and control methods for adoption by farmers.

CONTROLLING SALINITY

Soil salinity usually builds up over long periods and problems might appear long after the causes started. Similarly, management responses rarely produce immediate improvements.

A combination of agronomic solutions (for example, revegetation with deep-rooted plants and appropriate crop selection) and engineering solutions (such as surface or subsurface drainage, groundwater pumping and more efficient irrigation systems) is often required to effectively minimise and potentially reverse the expansion of salinity.

Drainage and groundwater pumping systems to lower groundwater levels have been incorporated into the irrigation infrastructure in the Emerald and Burdekin irrigation areas. However, the increase in salt loads to downstream river systems has not been quantified. Management changes have been made in regions where groundwater quality has deteriorated to the extent that it affects production. For example, farmers reliant on poor-quality groundwater for irrigation in the Lockyer Valley have incorporated salt-tolerant crops such as beetroot into their cropping practices.

Landcare groups are active in salinity programs. The National Landcare Program and the Land and Water Resources Research and Development Corporation (LWRRDC) provide considerable funding for soil salinity control and land reclamation.

REDUCING ACIDIFICATION

Lime and dolomite dusts, which have alkaline pH, can be applied to acidified soils to neutralise acidity. The use of lime in Queensland is increasing (Moody and Aitken 1997). More than 246 000 tonnes were applied in 1995–96, compared with 100 000 tonnes in 1985–86. However, the Standing Committee on Agriculture and Resource Management (SCARM) reports that Australia-wide little attention is being paid to the problem of soil acidification; areas treated are minimal in relation to the potential problem; and investment in remediation or amelioration is negligible. The exception is the wet tropic coasts and subtropical slopes, where lime is heavily applied to relatively small areas under sugarcane, bananas and other high-value crops grown on tropical red soils (SCARM 1998).

Liming is a palliative treatment: prevention of acidification is more important and can be achieved through improved farming practices, including crop husbandry and fertiliser management. Several Landcare groups in Queensland have awareness programs and management strategies for the control of soil acidification.

The LWRRDC has funded several research and development projects on soil acidification through DNR. It is also implementing new national coordination arrangements to increase benefits from Australia's acidification research and extension programs.

RESPONSES TO NATIVE PASTURE DECLINE

SCARM indicators (using ABARE survey data) report on three major practices for sustainable pasture management: in 1995–96 nationally, 73 percent of landholders undertook piping of borewater supplies for stock, 35 percent conducted formal vegetation/pasture monitoring, and 15 percent undertook pitting or opposed disc ploughing to promote soil regeneration or prevent soil degradation. Incidence of these practices decreased sharply from 1992–93 to 1995–96, possibly due to drought (SCARM 1998).

A range of programs and projects is in place to deal with native pasture decline in Queensland. DNR, DPI, CSIRO, the National Landcare Project, the Meat Research Corporation, the CRC for Sustainable Development of Tropical Savannas at James Cook University and The University of Queensland have conducted on-farm projects and/or research into the impacts and control of weeds, fire, drought and feral animals and wildlife.

Since the process of native pasture decline begins with overgrazing, sound management strategies for regulating stocking rate are critical. Where graziers have greatly reduced stock numbers (by 30–50 percent), substantial benefits in resource condition and cash flow have resulted (for example Landsberg et al. 1998). Other reported benefits include reducing the impact of droughts as well as more opportunities for pasture burning to control weeds. DPI, DNR, the National Landcare Program and various research organisations have made significant efforts to overcome overgrazing problems. For example, GRASS Check (Grazier Rangeland Assessment for Self-Sustainability Check) is a system designed by DPI to help primary producers monitor the health of their own pastures. In 1998, a revised GRASS Check manual was published and workshops were run across the State. DPI and the Queensland Beef Industry Institute (QBII) have established long-term stocking rate experiments on properties near Calliope, Injune, Emerald and Charters Towers, examining the effects of a range of stocking rates on the production and stability of native pastures. QBII also maintains major integrated study sites on cattle properties to examine the impacts of management strategies, such as various tree retention rates, on pasture yield.

DPI's 'safe' carrying capacity project mentioned in the box 'Carrying-capacity assessments in south-west Queensland' now includes more than 200 properties covering over 130 000 km^2 of predominantly mulga country. The adoption by producers of sustainable management practices and livestock carrying capacities under this project has considerably reduced impacts on the environment and ensured the future of the area (DPI, unpub. 1999).

In the Mulga Lands Project, DNR and DPI in cooperation with local graziers are aggregating properties in the mulga lands (around Charleville) to reduce grazing pressure. The development of beef cattle feedlots in Queensland has also resulted in a significant reduction in grazing pressures on land affected by droughts.

Because of the contribution of native and feral herbivores to total grazing pressures, control measures for these animals, as discussed in the next section, are essential to complement stocking rate management.

RESPONSES TO NOXIOUS PLANTS AND FERAL ANIMALS

DNR is the lead agency for reducing the impacts of noxious plants and feral animals in Queensland. The Department works closely with and supports other State agencies and local governments. DNR also provides advice on priorities and best practice management to landholders. The Rural Lands Protection Board provides strategic advice to the Minister for Natural Resources on these issues. Local governments are responsible for implementing pest management on their own lands and monitoring and enforcing pest management on other lands. Pest management plans have been implemented by 75 percent of local governments (DNR 1998).

The ABS estimates that expenditure on 'eradication of plant growth, animals or insects affecting sustainable land use' is a significant component of environmental expenditure by Queensland's agricultural industry, comprising 64 percent of expenditure in 1994–95 and 60 percent in 1995–96. These proportions were much higher than the average for Australia, which was 45 percent in 1994–95 and 40 percent in 1995–96 (ABS 1998c).

Noxious plants

While chemical and mechanical control strategies remain important, experience in dealing with noxious plant problems over many years indicates that the three most effective responses are:

- prevention by excluding new weed species from Australia;
- biological control through the release of pests or diseases that target the noxious plant; and
- ecologically sustainable land management regimes involving low grazing pressure combined with regular fire burns to maintain pasture cover and competitiveness.

Recognition of the importance of a coordinated national approach to weed control led to the development in 1997 of the National Weeds Strategy by the Agriculture and Resource Management Council of Australia and New Zealand and the Australian and New Zealand Environment and Conservation Council (ARMCANZ and ANZECC 1997). The strategy aims to prevent the development of new weed problems, reduce the impact of existing weed problems of national significance and provide cost-efficient and effective means to promote national action on weed management. The strategy recognises that the primary responsibility for weed management rests with landholders but that collective action is often necessary where the problem is too large for the individual landholder.

Management of noxious species has a legislative basis in Queensland. Legislative measures include the *Rural Lands Protection Act 1985*, *Agricultural Standards Act 1994*, *Land Act 1994*, *Chemical Usage (Agricultural and Veterinary) Control Act 1988*, *Mineral Resource Act 1989*, *Nature Conservation Act 1992*, *Local Government Act 1993* and *Environmental Protection Act 1994*.

The Rural Lands Protection Act seeks to reduce the rate at which major noxious species colonise new areas and to prevent the introduction of species that pose a serious threat should they become naturalised. Under the Act, plants that warrant enforced control are declared 'noxious'. Landholders are required to control 'declared' plants on their land. A local council can issue a notice to a landowner requiring that declared plants be controlled on that land by a specified date. Local and State Governments are also required to control declared plants on land under their control.

Community awareness and cooperation are, of course, essential in complementing and ensuring effectiveness of strict regulatory control. 'Control' and 'action' groups of landholders for fighting various weeds are established throughout Queensland. Landcare projects have focused on priority weeds, determined through consultative processes including community surveys. DNR's Weedbuster Project delivers weed information to the community and supports the work of local government, Bushcare and other community groups involved in the protection and restoration of native bushland.

The NHT-funded National Weeds Program and DNR's Strategic Weed Eradication and Education Program (SWEEP), partly funded by the NHT, are working to control weeds in the

The rabbit: a resilient pest

The European rabbit (*Oryctolagus cuniculus*) has had a devastating impact on Queensland's vegetation and land resources. The extent of its spread and impact emphasises the need to maintain strict controls over exotic animals that have pest potential in the Australian environment.

In 1859, 24 rabbits were accidentally or intentionally released near Geelong in Victoria. The animals spread rapidly, reaching the Queensland border in 1886. Until 20 years ago, rabbits were found in high densities across much of the southern third of the State, with isolated pockets of high density further north. Few are found north of the Tropic of Capricorn, due to limited rainfall in winter during the rabbit breeding season (Parer 1987).

Although rabbits can have significant effects on vegetation even at low population densities, most damage is caused by the high densities that can rapidly be attained following good rainfall. Dense populations consume a significant proportion of available vegetation and, as rabbits are selective grazers during good conditions, can reduce or destroy desirable pasture species. Australia-wide, the cost of rabbits to primary production (mainly wool) is estimated at $115 million per annum. Loss of plant biomass and cover also removes shade, shelter and food for other fauna such as wombats, bilbies and kangaroos and increases erosion risk.

Rabbits grazing in low densities can also be detrimental during drought when the animals, in their search for diminishing food supplies, eat spinifex seedlings and seed heads, ringbark small trees and reduce woody plants to small leafless stems. This interrupts the germination and establishment cycles of woody perennials (Williams et al. 1995; Lange and Graham 1983).

Rabbits are prohibited animals under the *Rural Lands Protection Act 1985* and control is the responsibility of every landholder. Levies on local councils provide funds for rabbit research and control, and maintenance of the Darling Downs–Moreton rabbit-check fence (shown in figure 3-30) and eradication of rabbits inside its boundaries.

Rabbit populations are difficult to control because of the animals' prodigious reproductive rate. During good seasons in South Australia, rabbits are estimated to reproduce at the rate of 18 000 per hour. Control efforts that are sporadic and uncoordinated yield only short-term relief: effective control requires coordinated and repeated campaigns conducted over large areas.

Strenuous attempts at physical control (shooting, trapping, fencing), chemical control (1080 and pindone poisoning, warren fumigation) and biological control (the release of the myxoma virus in 1950 and the calicivirus in the mid-1990s) have reduced rabbit densities in Queensland to low in most areas. Medium densities remain in two regions in the south (Bulloo Downs and the Stanthorpe–Texas–Inglewood areas) (Berman et al. 1998). A detailed monitoring program has demonstrated that rabbit numbers are now at their lowest for many years and native wildlife and vegetation are already recovering (DNR 1998). Continued action is necessary, however, to prevent resurgence.

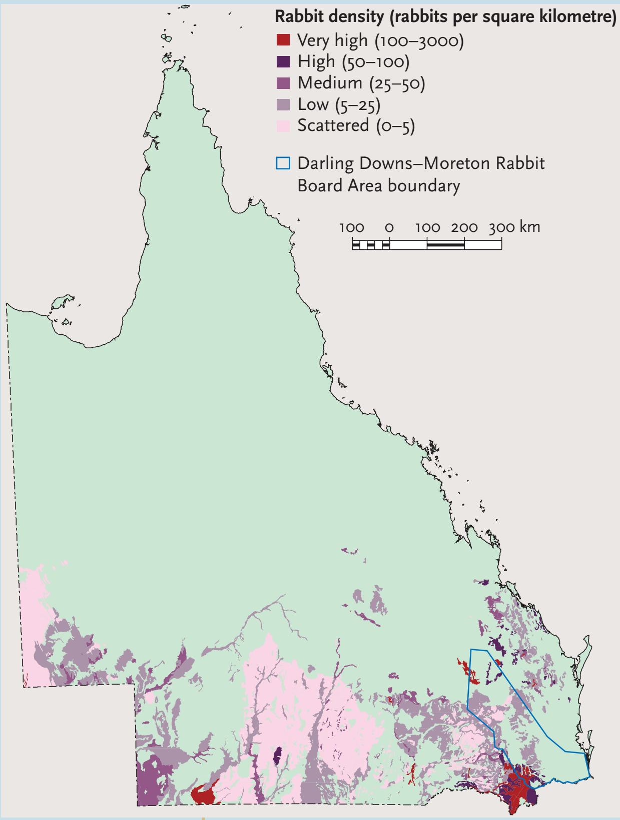

Figure 3-30 Estimated rabbit densities based on suitability of habitat for rabbits, 1999
(Source: DNR)

Estimates of rabbit densities are rough as populations vary considerably over time. Figure 3-30 provides an estimate of rabbit densities based on suitability of soils and landforms for rabbits. As this is a map of suitability of habitat rather than actual densities, some illustrated areas will not have rabbits because they are cultivated or have thick forest on them, precluding rabbit populations. Similarly, the area within the rabbit-check fence is shown as suitable for rabbits although this is a relatively rabbit-free area. With these qualifications, ground truthing indicates that the map generally depicts the distribution and density of rabbits fairly accurately.

State. These programs recorded significant achievements in 1997–98. The extent of the infestations of prickly acacia and rubber vine was mapped. A National Containment Boundary for rubber vine has been established and one for prickly acacia is in development. Rubber vine infestations have been successfully controlled in strategic locations south and west of the National Containment Boundary and particularly in the far western river catchments. Similarly, prickly acacia infestations have been controlled outside the likely National Containment Boundary and in eastward-flowing catchments; infestations likely to spread into the Lake Eyre Basin and Western Gulf river systems have also been controlled.

Biological control agents have assumed an important role in weed management. For example:

- In 1996–97, two seed-feeding beetles that attack mesquite were released into infestations in semi-arid Queensland (DNR 1997b).
- The rubber vine rust (*Maravalia cryptostegiae*) and a moth (*Euclasta whalleyi*), both introduced by DNR, have become widely established on rubber vine in north Queensland, significantly reducing seed production and seed survival (DNR 1998). It is unlikely that these biological control agents, either separately or in combination, will solve the rubber vine problem in Queensland so

research is under way to maximise their impact by integrating their use with fire and herbicides (DNR 1997b).

- Two new agents, a stem-boring weevil and a root-boring moth, are being released against parthenium weed (DNR 1998).
- A bruchid seed-feeding weevil for the control of parkinsonia has established and is spreading at several sites in north and central Queensland. It had destroyed up to 97 percent of seeds at the release sites, two years after its first release (DNR 1998).

Research is an important component of response. DNR conducts research into biological control methods for seven weeds: parthenium weed, lantana, mesquite, rubber vine, prickly acacia, mother-of-millions and sickle pod. DNR has a field station in South Africa as a base for exploration and preliminary testing of potential biological control agents. The NHT has provided funding for research into adaptive management of two Weeds of National Significance, rubber vine and prickly acacia (see also box 'Prickly acacia — a growing threat to the Mitchell grass downs').

Feral animals

As for plants, the legislative basis for management of introduced mammal species causing serious agricultural damage in Queensland is the Rural Lands Protection Act. Pest animals are 'declared' under this Act in various categories depending on the level of control required. Declaration in certain categories makes landowners responsible for control; declaration in other categories makes illegal the introduction, keeping or selling of a species without approval.

Again, a coordinated effort by landholders is the cornerstone of successful management. DNR provides advice to landholders and coordinates control programs. Some Landcare groups in Queensland are active in awareness, education and training programs. Financial incentives such as tax rebates, reduced interest rates and subsidies are extended to landholders for the control of feral animals.

Total eradication of a well-established feral animal is generally not feasible unless the population is small and highly localised. Instead, control programs seek to suppress feral populations to minimise damage. DNR coordinates programs for baiting of pigs, foxes and wild dogs. Control of feral animals in Queensland is focused primarily on declared mammalian feral animals such as pigs and rabbits.

Pigs have been controlled by poisoning, trapping and shooting, but the costs prohibit implementation of effective, sustained control programs. Rabbits have been controlled though a combination of myxoma virus and calicivirus release, poisoning, warren fumigation, shooting, trapping and fencing (see box 'The rabbit: a resilient pest'). The development of a goat meat export industry has seen the feral goat population reduced from 400 000 to less than 120 000 head (DPI, unpub. 1999). Information about the control of some other feral animals can be found in chapter 7, 'Biodiversity'.

The Cooperative Research Centre for Tropical Pest Management and DNR also conduct research in this field. In 1996–97, DNR began a five-year research program into control of mice in crops. Trials on the use of zinc phosphide as a rodenticide on grain crops on the Darling Downs have been successful. The use of the fungus *Metarhizium flavoridae* as a biological control agent for plague locusts is the subject of a five-year study by DNR in collaboration with CSIRO and the Australian Plague Locust Commission (DNR 1997b). A trial of the effectiveness of baiting dingoes in western and northern Queensland indicated that single-property baiting programs may, in fact, increase stock losses, due to the disruption of dingo populations (DNR 1998).

LAND MANAGEMENT IN A VARIABLE CLIMATE

The variability of the Queensland climate makes it difficult to manage land in a sustainable manner. In recent years, systems for forecasting seasonal rainfall and frost have been developed; these systems use the El Niño Southern Oscillation Index, and are based on sound knowledge of the climatic mechanisms involved.

The Queensland Centre for Climate Applications is a joint DPI and DNR initiative that develops and promotes tools for farmers to use, such as seasonal forecasts to enable them to destock ahead of drought, decide when to burn pastures and woodlands, decide to send stock out on agistment, select crop varieties, minimise erosion, and optimise fertiliser application and irrigation to suit predicted climate patterns. The Centre, established in 1998, conducts 'Managing for Climate' workshops for landholders on how to obtain and use climate information and promotes the use of publications and computer-based communication, information and analytical tools.

CONTAMINATED LAND

The object of the *Integrated Planning Act 1997* (IP Act) is to seek ecological sustainability through coordinated planning and management of development. The Act includes provisions to prevent inappropriate rezoning of land that might be contaminated. It requires the investigation of land that has been used for a potentially contaminating activity before development approval is granted.

The *Contaminated Land Act 1991* provided for contaminated land to be properly identified, managed and used safely, and aimed to prevent further contamination. Under the Act, a Contaminated Sites Register was established to record all contaminated land or potentially contaminated sites. On 6 July 1998, the Contaminated Land Act was repealed and its functions were incorporated in the *Environmental Protection Act 1994* (EP Act). This provided for management of contaminated land according to the principles of ecologically sustainable development.

Unexploded ordnance is a particular land contamination problem in Queensland because of the large amount of military training that took place in the State during World War II. As a result of investigations, many previous military sites were declared unaffected and others cleared of unexploded items.

The EP Act adopts the concept of risk management by developing two registers to replace the Contaminated Sites Register. 'Low-risk' sites are recorded on the Environmental Management Register (EMR) and 'risk' sites are recorded on the Contaminated Land Register (CLR).

The EMR records land that has been or is being used for an activity likely to cause land contamination (a 'notifiable activity') and land that has been shown through a site investigation to have some contamination. The principal uses of the EMR are for land use planning and to trigger site investigations when a change in the use of land recorded on the register is proposed.

Where land has been investigated and the EPA is satisfied that action needs to be taken to remediate the land to prevent serious environmental harm, the land is recorded on the CLR.

A site management plan is used to manage land recorded on the EMR where an investigation has found some remaining contamination. The plan aims to minimise the environmental harm that might be caused by the contamination by applying conditions on future land use. It also aims to avoid unnecessary and expensive clean-up of sites when the land can be safely managed for the intended uses under the plan.

Under the EP Act, all local governments are required to notify the EPA of land within their boundaries that has been or is currently used for a notifiable activity, for inclusion on the EMR. Similarly, if the owner or occupier of land becomes aware that a notifiable activity has been or is being carried out on the land, or if the land has been or is being contaminated by a hazardous contaminant, the owner or occupier must notify the EPA.

Since military activities are a Commonwealth Government responsibility, management of unexploded ordnance (UXO) issues largely rests with the Commonwealth. *The Commonwealth Policy on the Management of Land Affected by UXO 1990* aims to protect the public from the hazards of UXO. Although the policy limits the Commonwealth's liabilities and imposes the responsibility and costs for remediation on the landowner, it provides for the Department of Defence to conduct preliminary investigations of suspect UXO areas and to consult with the EPA on sites requiring management.

The Queensland Government's *Strategy for the Assessment and Management of Land Contaminated by UXO* combines provisions of the IP Act and the EP Act to implement procedures for the investigation and safe use of potentially affected land. Negotiations between the Queensland and the Commonwealth Governments continue on procedures and liability for investigating and remediating UXO-affected land and on the implementation of landowner indemnification and public awareness programs.

Landfills, particularly those handling hazardous waste, require management to prevent chemicals entering the environment. Chapter 8, 'Human settlements', provides details of landfill and waste management initiatives.

AGRICULTURAL CHEMICALS

The Queensland Government enacted legislation prohibiting the use of certain organochlorine pesticides (OCPs) in agriculture in 1987. The Commonwealth-funded Queensland Rural Pesticide Recall Program also commenced in 1987 to help rural producers dispose of unwanted farm chemicals.

More significantly, farmers are adopting comprehensive integrated pest management strategies to reduce potential contamination. Integrated pest management covers a wide range of strategies depending on the crop and its pests; they include use of less harmful chemicals, improved delivery methods, targeted timing of application, and avoidance of the use of chemicals by breeding resistant crops, using crop rotations and so on. Examples of integrated pest management strategies adopted in Queensland are described below.

- Since 1995, through application of integrated pest management strategies, apple growers have achieved a 60 percent reduction in total chemical use for pest and disease control with no loss of productivity.
- The development of midge-resistant grain sorghum hybrids has almost eliminated the need for the use of insecticides to control this pest. Previously, more than 50 percent of crops were sprayed.
- The eradication of the papaya fruit fly has meant a reduction in use of chemicals for control, as well as reduced impact on native fruits and berries.
- The cattle and sheep industries have reduced their reliance on chemicals for external parasite control: through the adoption of the 'lice buster' program for lice control in sheep; through the introduction, selection and breeding of cattle for tick resistance to reduce the use of acaricides; and through the use of lures to attract blowflies to reduce flystrike in sheep (DPI, unpub. 1999).

DNR conducts research into pesticide exports into the environment; a current project, in conjunction with Mauritius, is examining pesticide and nutrient exports from sugarcane lands. A Pesticide Input and Environmental Fate Information System is also being developed. It will provide assistance to those designing or interpreting pesticide monitoring programs.

PROTECTING PRIME AGRICULTURAL LAND

There is now wider recognition of the problem of loss of agricultural land to urban development. Policies are being developed to protect the more productive agricultural land from urban disturbance. Queensland's *State Planning Policy 1/92: Development and Conservation of Agricultural Land* identifies good-quality agricultural land as 'a finite national and state resource that must be conserved and managed for the longer term'. This policy introduced a requirement that local

Good-quality agricultural land like this in Redland Bay still exists close to many urban areas, but development pressures have meant much is being lost.

Table 3-28 Subdivision of and protection measures for good-quality agricultural land in 22 local government areas (LGAs)

LGA	Good-quality agricultural land in 1994 and 1995			Adequate protection	
	Total area (ha)	Percentage subdivided	Hectares per dwelling	1994	1996
Beaudesert	51 141	0.39	0.14	*	*
Boonah	29 214	0.21	0.58	*	*
Brisbane	26 640	2.15	0.06	*	*
Bundaberg	3 367	1.31	0.07	*	
Burnett	79 967	0.27	0.26		
Caboolture	15 611	1.42	0.06	*	*
Cairns	17 482	1.57	0.10		*
Caloundra	22 602	1.11	0.18	*	*
Esk	56 091	0.03	0.06		
Gatton	25 602	0.21	0.31		*
Gold Coast	22 635	0.72	0.02	*	*
Hervey Bay	18 483	0.63	0.08		*
Ipswich	35 005	0.05	0.01		
Kilcoy	6 561	0.21	0.23		
Laidley	20 822	0.51	0.18		
Logan	2 607	1.96	0.02		
Mackay	95 160	0.31	0.21	*	*
Maroochy	35 190	1.87	0.24		*
Noosa	52 081	1.42	0.47		
Pine Rivers	8 911	0.28	0.01		
Redcliffe	0	na	0	na	na
Redland	3 885	4.81	0.08		
Total	**629 057**	**0.68**	**0.10**		

*Strategic plans had adequate provisions for protection of agricultural land in these years.
Note that Redcliffe is not a rural area.

governments try to avoid the alienation of productive agricultural land unless it is absolutely necessary in the public interest and alternative sites are unavailable.

To assist in implementation of this policy, in 1993 DNR and QDHLGP published *Planning Guidelines: The Identification of Good Quality Agricultural Land* and in 1997 DNR published *Planning Guidelines: Separating Agricultural and Residential Land Uses*. Local governments are using these guidelines to plan in urban fringe areas and impose appropriate conditions on new residential developments.

Some local government areas (LGAs) have strategic plans with provisions for protecting agricultural land from urban development pressures. At 1 January 1994, eight of the 22 urbanised LGAs discussed on pages 3.44 and 3.46 had adequate provisions for protection of agricultural land in their strategic plans. By 31 August 1996, the number had increased to 11 (table 3-28). The LGAs with higher rates of land conversion largely correspond to those without adequate provisions in strategic plans, with the exception of Boonah, Mackay, Beaudesert and Caloundra. Note that whether or not the issue is addressed in strategic plans, LGAs are obliged to consider agricultural land as a constraint to development under the State Planning Policy mentioned above. Other planning controls such as subdivision provisions in rural zones can also protect agricultural land.

MANAGING FORESTRY RESOURCES

International criteria and indicators for sustainable management of forests have been developed through the Montreal Process, the informal agreement by the Montreal Process Group of countries (currently 12) to work towards the implementation of such a system. Australia is developing a framework of regional indicators based on the Montreal process for use in Australia. The indicators are being tested to determine their applicability to different ecosystems and in order to develop quantitative performance measures.

In 1992 Commonwealth, State and Territory Governments developed a National Forest Policy which sets out broad conservation and industry goals for the management of forests. As well as conservation objectives (see chapter 7, 'Biodiversity'), it includes the negotiation of Regional Forest Agreements (RFAs) between the Commonwealth and State Governments on the long-term management and use of forests in particular regions (see box 'Regional Forest Agreements' in chapter 7, 'Biodiversity'). An assessment of the environmental, social and economic values of the forests of the Southeast Queensland bioregion is nearing completion and could form the basis for an RFA for these forests.

Since 1993–94, management of State forests has been split: DPI is responsible for the commercial management of the forests, while DNR has a custodial role, independently setting and monitoring environmental resource management standards for DPI's forestry activities.

DPI is committed to ensuring that all of its commercial forestry operations are ecologically sustainable. Selective harvesting rather than clear-felling is the standard method of operation in native forests to retain significant forest cover. Sustainable yields for native forests are calculated and the maximum volume of timber to be harvested annually is determined. DPI also develops detailed harvesting plans for every major timber sale and has comprehensive operating procedures that include environmental protection measures.

These include protection of watercourses, prevention of soil erosion, and protection of wildlife and scenic and cultural heritage values. A draft code of practice, developed by DPI, is being reviewed by DNR after trial and consultation. The code includes provisions on building and maintenance of access roads to forests, harvesting procedures, pest, disease and weed control, and the use of chemicals.

The Queensland Government has recognised that future increase in demand needs to be met through privately owned timber plantations and is promoting private forestry development through joint venture sponsorships, enhanced advisory and extension services, expanded research and development and the removal of structural impediments.

The NHT-funded Farm Forestry Program has the goal in Queensland of developing and promoting the adoption of plantation forestry for wood and non-wood products. Projects in 1997–98 included the Farm Forestry Planning project, run by the State Property Management Planning Committee. The project aimed to integrate farm forestry into the property management planning framework across the State. The Noosa and District Landcare group, the North Queensland Timber Cooperative and the Cooloola Treegrowers Cooperative provided demonstrations, extension and marketing advice to landholders interested in commercial plantations. A project of the Queensland Forest Research Institute demonstrated silvicultural systems for farm forestry and promoted the use of native species for biodiversity conservation and carbon sinks. The dry area plantation project run by DNR provided advice to 56 landholders, conducted farm forestry field days and established 47 hectares of farm forestry.

The Industry Commission (IC 1993, 1997) has identified a number of disincentives to landholders' engaging in farm forestry activities that need attention from governments. These include difficulties in separating the ownership of trees and of land, the potential for double taxation of profits, uncertainty about harvesting rights and export controls on unprocessed wood.

MANAGING MINING IMPACTS

The *Mineral Resources Act 1989* introduced requirements for the holder of a mining lease to have in place an approved Environmental Management Overview Strategy (EMOS). An EMOS is an agreement between government and a mining company or leaseholder to carry out environmental protection measures and rehabilitate disturbed land. A Plan of Operations describing how the mine will meet its environmental commitments and an Environmental Audit statement about the plan's consistency with the EMOS are also required. Several incentives, including discounts on security deposits, are offered to those meeting environmental performance requirements. By 1998, 96 percent of mining leases were for projects having an EMOS and meeting at least the basic requirements of environmental management.

DME conducts detailed environmental compliance assessment of mining industry activities. It is expected that each mining and petroleum project will be assessed at least once every five years. Exploration projects where site disturbance has occurred will be assessed at least once during the period of tenure.

The *Mineral Resources Act 1989* and the *Environmental Management for Mining in Queensland Policy*, implemented in 1992, aim to ensure that rehabilitation of minesites is undertaken by leaseholders before a mining lease is terminated or expires. The Act provides for a system of security deposits to cover the cost of rehabilitation. However, some sites were abandoned before the Act and Policy were enforced. The low security deposits previously required, coupled with inflation, have meant that some rehabilitation has been publicly funded in recent years. Since 1985, DME has spent about $14 million on rehabilitating sites at Agricola (via Kenilworth), Charters Towers, Horn Island, Croydon, Herberton, Gympie, Irvinebank and Mount Morgan (DME 1998b).

Rehabilitation of mined areas, like this revegetation at Weipa, is required under law.

A Queensland Criminal Justice Commission inquiry in 1994 into the improper disposal of liquid waste identified the need for a review of the environmental impact and regulation of mining in the State. As a result, the Queensland Government agreed to prepare an Environmental Protection Policy (EPP) for the mining and petroleum industries under the *Environmental Protection Act 1994*. When finalised, the EPP will set out the processes and requirements that will apply to large and small mining and petroleum operations.

The EPP will deal with the rehabilitation of abandoned minesites. It may include a program for:

- conducting an inventory of historic abandoned minesites and progressively rehabilitating those that pose an unacceptable hazard to public health and the environment;
- introducing procedures to reduce the number of developed sites abandoned without adequate financial security to complete rehabilitation; and
- developing an equitable funding facility to allow for necessary rehabilitation of abandoned sites (DME 1997).

In 1999, Cabinet approved proposals for the reform of mining regulation. In future, the EPA will regulate the environmental impacts of mining operations and assess potential impacts of mining proposals and DME will regulate land tenure and resource allocation aspects.

The Queensland mining industry's expenditure on environmental protection, including management of pollutants, land rehabilitation and change to production processes, was $53.6 million in 1993–94 and $79.5 million in 1994–95. About 70 percent of this was current expenditure, which includes personnel and material related to rehabilitation (ABS 1998a). Nationally, about 0.5 percent of total mining industry current expenditure and about 0.7 percent of mining turnover is environment-related (ABS 1998c). Capital expenditure fluctuates from year to year, but a significant proportion relates to land rehabilitation (table 3-29).

Table 3-29 Expenditure on environmental protection by the mining industry, Queensland ($ million)

Expenditure type	1993–94	1994–95
Current	38.8	53.2
Capital:	14.8	26.2
Water, air and solid waste pollutants	5.3	15.1
Land rehabilitation and other pollutants	9.5	9.1
Total	**53.6**	**79.5**
Value at mine	5269.6	5433.5

(Source: ABS 1998a)

Towards sustainable land use

The development and expansion of land-based activities in Queensland during the past 150 years have laid the foundation for the State's economic development. They have also resulted in varying degrees of land degradation, which has not only reduced environmental values but placed economic development at risk by adversely affecting long-term productivity. Land degradation processes in Queensland are well documented. They create significant challenges for landholders, the community and government to reverse the trends and reconcile competing demands for land resources.

The move towards sustainable land use requires adoption of the principles of ecologically sustainable development (ESD) — 'development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends'. The core principles of ESD in the context of land resources are to:

- conserve and maintain biodiversity and life cycles;
- conserve and maintain the quantity and quality of soil, water, air, flora and fauna resources;
- maintain and enhance the productive capacity of land resources;
- minimise environmental and production risks associated with climate variability and market forces;
- maintain and enhance socioeconomic benefits to the community;
- balance intergenerational equity; and
- institute legislative and non-legislative structures conducive to sustainable land use.

An important aspect of successful application of the principles of ESD to land is the active participation of all sectors of society, including the community, industry, landholders, miners, foresters, developers and governments. The need for 'on-ground' solutions is clear, as is the need for communities to work together and through partnerships with local councils and government organisations. To encourage commitment, incentives for ecologically sustainable practices need to be found (IC 1997).

A second important aspect of sustainable management is a holistic view of land, water, air and biodiversity issues in decision making. In recognition of this, the Queensland Government has formed a new Landcare and Catchment Management Council (LCMC) that integrates the previous Queensland Landcare Council and the Catchment Management Coordinating Committee. The council, which met for the first time in November 1997, provides strategic advice to the Minister for Environment, Heritage and Natural Resources on Landcare, catchment management and implementation of the Natural Heritage Trust.

A third important aspect of sustainable management of land is the need for a regional approach to many issues. The LCMC is encouraging communities to develop natural resource management and biodiversity conservation plans at the regional level with the assistance of State agencies. The first natural resource management strategy, for the Queensland Murray–Darling Basin, was endorsed in 1998. The Industry Commission, in its draft report on ecologically sustainable management, recommends the strengthening of community institutions such as catchment management and other regional bodies concerned with natural resource management. The Industry Commission suggests that these bodies should be able, for example, to enter into conservation agreements with landholders, develop and audit local codes of practice and monitor the state of the local environment (IC 1997).

The lack of data at a regional and local level and the lack of coordination and comparability in data collection and dissemination are often cited as barriers to sustainability (IC 1997, SCARM 1998). Significant efforts are being made at all levels of government to improve the situation through state of the environment reporting and development of indicators. SCARM has developed a set of sustainable land management indicators to assess how well Australian agriculture is applying the principles of ecologically sustainable development. A summary report of findings was published in 1998 (SCARM 1998). The report does not attempt to make general statements on the sustainability of agriculture as no agreed method is available to trade off the positive and negative trends between indicators.

Education and the dissemination of environmental knowledge must also follow. The Industry Commission has flagged the need for more research to be directed into developing practical guides to best management practices (IC 1997). SCARM reports that the education levels and farm managerial skills base of Australian farmers are improving and the uptake of sustainable practices is generally increasing, although from a low base (SCARM 1998). This report has provided many examples of landholders being willing to adopt sustainable practices and shift their focus from productivity and short-term economic gains to one of sustainability of production and preservation of environmental assets.

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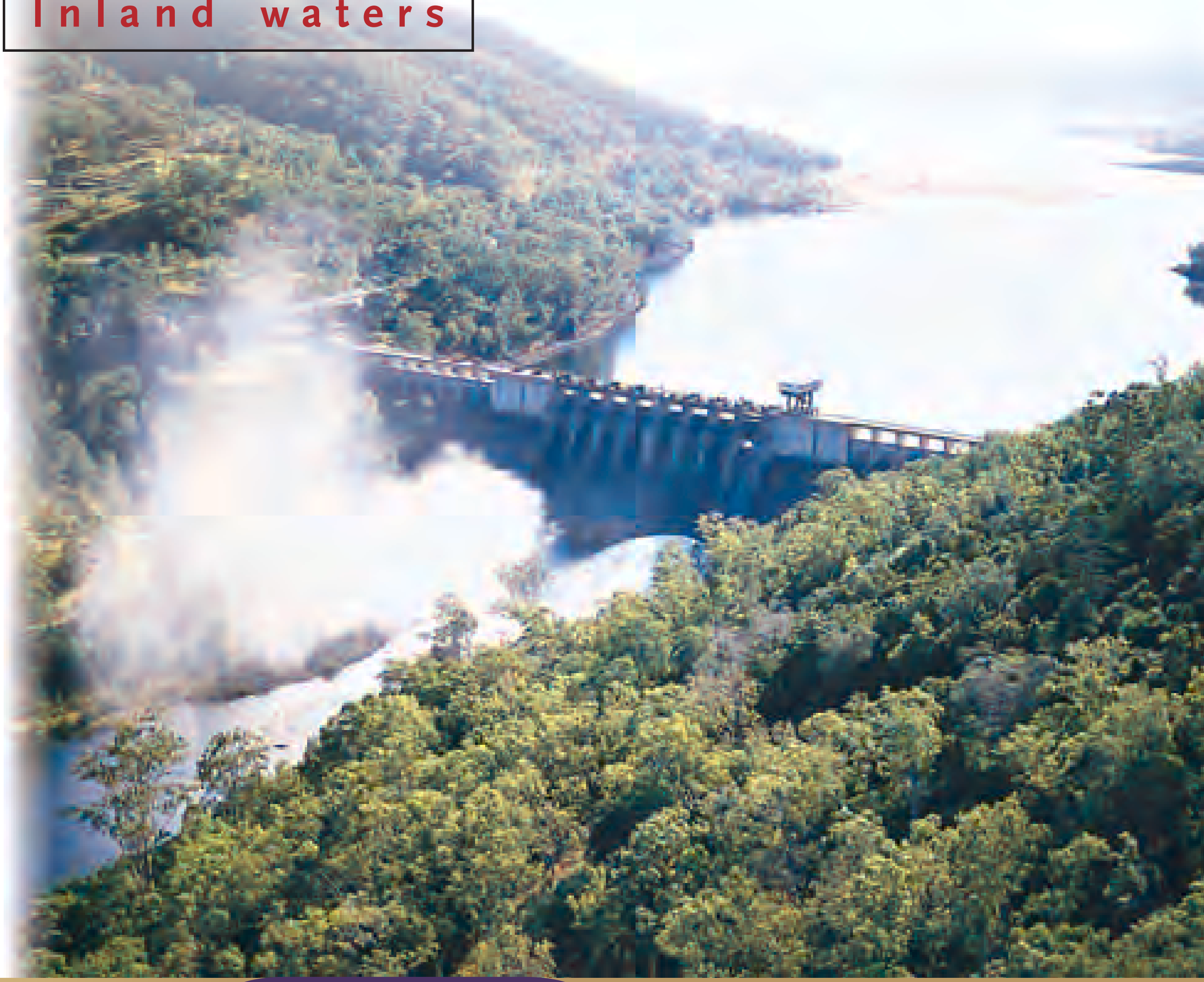
CHAPTER 4

QUEENSLAND'S INLAND WATERS

Inland waters



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Contents

Key issues and findings

Fresh water is one of Queensland's most precious resources. Water supply is often the limiting factor to development in the State, particularly west of the Great Dividing Range. Human activity over the past 200 years has had a very significant impact on both the quality and quantity of Queensland water resources. Most of the State's river systems and aquifers have been adversely affected to some degree.

Rainfall over Queensland is highly variable: the State has both the highest and lowest annual average rainfalls recorded nationwide. Approximately 76 percent of the State's rainfall occurs in sparsely populated catchments that drain to the Gulf of Carpentaria and the Coral Sea north of Mackay.

River runoff tends to be highly episodic, reflecting Queensland's rainfall regime, infrequent flood events accounting for the majority of flow. At other times, fresh water is scarce. Queensland's river systems discharge an estimated 159 million megalitres (ML) annually. Only 6 percent of discharge drains to inland river systems.

Queensland relies heavily on surface water storages. The State receives 40–45 percent of Australia's rainfall runoff, about 2 percent of runoff being captured in dams, weirs, barrages and other surface storages. The combined capacity of the 200 largest artificial storages is approximately 10 million ML.

Annual human consumption of water is an estimated 3 242 000 ML, or more than 3000 litres per person per day. Nearly 80 percent of water withdrawn from storages is used for agriculture, and 65 percent of the total is used for irrigation.

Approximately 7 percent of rainfall infiltrates to underground aquifers. Groundwater use is estimated at 1 400 000 ML annually — about 44 percent of total water consumption. The Great Artesian Basin underlies approximately 65 percent of the State and is the sole source of water for stock and domestic use in many western areas.

The major pressures on inland water resources are excessive surface and groundwater abstraction; loss of riparian vegetation; loss of wetlands; altered flow regimes resulting from dam and barrage construction; increased sediment, nutrient and pesticide inputs from agricultural and urban development; introduced, translocated and nuisance species; hazardous industrial and mining waste discharges; and river modification.

Quantity

- Over-allocation of surface water has led to water abstraction beyond sustainable levels in some catchments, especially in southern Queensland. Abstraction rates which significantly reduce environmental flow requirements can alter aquatic ecosystems, affect the migration of fish and contribute to algal blooms.
- Groundwater abstraction in excess of annual recharge rates has caused watertables to fall below sea level in some coastal aquifers. The result is the intrusion of salt water into freshwater basins. Water withdrawn behind the salt front is unsuitable for irrigation.
- Uncapped bores and open bore drains have resulted in lower groundwater tables and significantly reduced spring flows in some inland areas. About 75 percent of the 240 spring groups in the Great Artesian Basin no longer flow.
- The removal of deep-rooted trees and waterlogging have raised the groundwater table in some areas, bringing salts to the surface. Approximately 14 000 ha of land in Queensland is now salt-affected due to rising groundwater levels.
- Many of Queensland's freshwater wetlands have been extensively modified and destroyed as a result of human activity. Major threats include reclamation for agriculture, flood mitigation and flow improvement works, sedimentation, feral animals and nuisance weeds. At least 80 percent of wetlands in areas affected by intensive agricultural activity and urbanisation have been lost to development. Those that remain are often in poor condition.
- Urban and rural development on floodplains is extensive in Queensland. Flooding may become worse through the loss of flood storage volume through filling for development, acceleration of flows caused by increasing the proportion of impervious surfaces in a catchment, leading to higher peak flows and increased runoff from impervious areas.
- Diversion activities such as dams, weirs and barrages have significantly altered the natural flow regime of many rivers and creeks. This affects sedimentation patterns, the hydrology of floodplains and wetlands, and native plants and animals. Information relating to the amount of water required for environmental flows is largely unavailable.
- River management practices such as river straightening, desnagging and bank stabilisation can increase the volume and rate of flow of affected rivers and streams. This leads to accelerated erosion of waterways and flooding.
- In February 1994 the Council of Australian Governments (COAG) endorsed strategies for the reform of Australia's water industry. These involve water pricing reform, clarification of property rights, allocation of water for the environment, adoption of trading arrangements for water, institutional reform and public consultation and participation.
- The COAG Water Reform Framework also directs that proper assessments be undertaken where dam construction is proposed. The Queensland Government has recently consolidated responsibility for management of environmental impact assessment processes for water infrastructure projects in the Environmental Protection Agency.
- The Department of Natural Resources (DNR) has introduced water management planning (WMP) and water allocation and management planning (WAMP) processes to allocate future water licences using a whole-of-basin approach. Both processes are designed to determine environmental flow requirements.
- In 1989 the Great Artesian Basin Rehabilitation Program was initiated by the Commonwealth and State Governments to repair or plug and replace an estimated 1380

bores flowing uncontrollably. Between 1991 and 1996 more than 175 bores were rehabilitated, saving an estimated 32 000 ML annually.

- WaterWise is an initiative of DNR and local governments designed to reduce the demand for water through public awareness and education campaigns. Several councils have reduced water consumption by 20 percent or more since water conservation campaigns began.

Quality

- Data on the extent of riparian vegetation in Queensland are very limited. Localised studies indicate that the condition of remaining riparian vegetation is poor to very poor, due to factors such as intensive grazing, clearing, erosion and invasion by grasses or exotic species.
- The loss of topsoil through erosion reduces the productivity of agricultural land, while the runoff of soil to surface waters increases turbidity and sedimentation. Agricultural chemicals attached to the soil are also introduced. In the absence of soil conservation measures, soil loss can be in the order of 400 tonnes per hectare per year.
- Catchment runoff has increased in urban areas as the extent of impervious surface areas has grown. The runoff, contaminated by a range of domestic and industrial pollutants, flows into surrounding waterways during storm events and through washing activities. In rural areas soil, agricultural chemicals and animal wastes are common runoff contaminants, especially where riparian buffer strips have been removed. Nutrient runoff contributes to algal and macrophyte blooms.
- Cyanide and heavy metal contamination resulting from acid mine drainage and tailings dams poses a threat to both surface water and groundwater if not properly managed. Derelict minesites and inadequate mine rehabilitation pose a particularly significant threat. More than 50 000 ha of previously mined land requires rehabilitation in Queensland.
- Introduced plants and animals constitute an increasing pressure on inland waters. Eleven species of introduced fish and 20 introduced plants are self-sustaining in Queensland's inland waters.
- Many of the environmental indicators identified in this report are not monitored routinely over extended periods. Water quality data are largely unavailable for most of western Queensland. Detailed monitoring is confined to waterways near major population centres. Data accessibility, coordination and quality assurance are also areas of concern.
- In 1992 the National Water Quality Management Strategy was launched to provide water quality managers with the policy principles required to achieve sustainable use of Australian water resources.
- In 1996 the Commonwealth Government established the Natural Heritage Trust (NHT) to fund projects in five environmental areas: vegetation, rivers, biodiversity, land, and coasts and marine. Key subprograms that have a direct impact on inland waters are the National Rivercare Initiative, the National Landcare Program, Murray–Darling 2001, the Fisheries Action Program and the National Wetlands Program.
- The National Land and Water Audit has been funded under the Natural Heritage Trust to provide the first comprehensive appraisal of the environmental, social and economic costs of land and water degradation in Australia.
- In 1997 the Landcare and Catchment Management Council (LCMC) was formed to provide strategic advice to the Minister for Natural Resources on landcare and catchment management in Queensland. It also serves as the link between community organisations devoted to landcare and catchment issues and the State Government. The LCMC is responsible for providing advice and strategic direction for the operation, management, administration, monitoring and evaluation of the NHT in Queensland.

PRESSURE

Development: land clearing and reclamation of wetlands by sector

Percentage of total catchment area developed for agricultural, industrial, mining or urban sectors

Area of additional land cleared each year by catchment

Changes in developed land use

Changes in area of riparian vegetation as a percentage of total riparian zone by catchment

Area of wetlands lost to development

Percentage of protected area by catchment

Diversion: dams, weirs and barrages; water supply and power generation for agriculture, industry, mining or urban sectors

Total percentage of flow diverted by catchment and division

Total storage volume per person by catchment, by division and statewide

Extraction: the withdrawal of water by each sector

Water withdrawal by agricultural, industrial, mining and urban sectors

Water withdrawal for irrigation by crop type

Water withdrawal by industry type

Total water withdrawal as a percentage of average annual runoff

Total water withdrawal per person

Percentage of water withdrawn from groundwater and surface waters

Quantity of water withdrawn by major groundwater system

Recharge of major groundwater systems

Changes to groundwater table

Incidents: accidents and dumping

Reported incidents where hazardous materials were spilled or dumped per year

Introduced, translocated and nuisance species

Proportion of catchments affected by introduced or nuisance species by species

Incidence of introduced and nuisance species

Reported number of algal occurrences for report period by catchment

Pollution by sector

Agriculture

Tonnes of nitrogen and phosphorus fertilisers used by catchment or region

Tonnes of nitrogen and phosphorus fertilisers used by crop type

Tonnes of pesticides used by catchment or region

Tonnes of pesticides used by crop type

Industry

Units/tonnes of product by industry type

Total volume of waste produced by industry type

Mining

Tonnes of ore produced annually by mining type

Tonnes of overburden produced annually by mining type

Tonnes of tailings produced annually by mining type

Area of open-cut mining by catchment

Number of licensed dredging operations

PRESSURE (continued)

Urbanisation

Volume of sewage effluent discharged to inland waters

Volume of sewage effluent discharged to inland waters per person

Percentage of total sewage effluent discharged to inland waters

Percentage of population served by sewage treatment plants

Percentage of treatment plants with primary, secondary or tertiary levels of treatment

Megalitres of sewage per person by urban area

Megalitres of sewage effluent released to inland waters with primary, secondary or tertiary levels of treatment

Megalitres of stormwater runoff by urban area

Tonnes of suspended solids in stormwater runoff by urban area

Percentage of impervious surface area by urban area

Tonnes of solid waste produced by urban area

Tonnes of regulated waste by broad category by urban area

Recreation

Number of boats using freshwater recreational areas

Number of visitors to freshwater recreational areas

Estimated freshwater fish catch by recreational fishers

Number of fish stocking programs

River modification: dredging, desnagging and channelising; removal of sediment, bank stabilisation and river modification by sector

Number of river modification projects

Tonnes of sediment removed from river, wetland or floodplain

Area/length of river, wetland or floodplain affected by river modification

Length of river modified as a percentage of total length managed by each river improvement trust

STATE

Water quantity: storage (surface and groundwater), annual runoff

Total water storage capacity

Water storage capacity per person

Regional water storage by catchment

Bore/spring pressure

Total runoff from rivers (median annual)

Variability of river flows (maxima and minima)

Runoff of water per catchment/river

Variability of runoff by river (maxima and minima)

Average percentage of time rivers do not flow per year

Incidence of flooding

Water quality: physical, chemical and biological

Temperature

Total dissolved ions (Ca^{2+}, Mg^{2+}, Na^{+}, SO_4^{2-}, Cl^{-}, HCO_3^{-})

Dissolved oxygen

pH

Total phosphorus (TP)

Soluble nitrogen (nitrate plus nitrite)

Chlorophyll *a*

Faecal coliforms

Organic matter content indicated by BOD or TOC

Other toxics in water (atrazine, DDT, endosulfan, hexachlorobenzene, lindane, PAHs, PCBs, blue-green algal toxins)

Total phosphorus in sediment

Dissolved metals — Al^{3+}, As, Cd, Cr, Cu, Fe^{2+}, Hg, Pb, Zn

Sediment concentrations of metals where indicated by water column results

Sediment concentrations of other toxics

Suspended sediment (g/L) or turbidity (NTU)

Total load (tonnes) of metals in effluent

Total load (tonnes) of metals in effluent by industry

Total tonnes of other toxics in effluent

Total load (tonnes) of other toxics in effluent by industry

Concentration of toxicants in tissues of indicator organisms

Biological health of rivers

Health of wetlands

INTRODUCTION

INTRODUCTION

Queensland's commonly depicted image is one of tropical rainforests and sparkling waters. Within limited areas inside the narrow coastal strip east of the Great Dividing Range, where mountains are close to the coastline, rainforests and fresh, clear streams can be found. Most of Queensland is dry, however, extending to arid and desert country in the south-west. Dry areas are present even along the east coast, as in the area between Bowen and Townsville where the mountain ranges are low and set back from the coast.

The State has few perennial streams, making inland water resources scarce and unpredictable. Most streams cease to flow for long periods. During the dry season many streams are reduced to dry channels with remnant billabongs. High evaporation rates west of the Dividing Range reduce surface water availability even further.

Rainfall over most of Queensland is highly seasonal, with more rain in summer than in winter. The effect is more pronounced in the relatively small Wet Tropics area, where more than 90 percent of annual totals falls between November and April. This area also has the highest rainfall in Australia, due mostly to its high relief and coastal location: the Innisfail area receives more than 4000 mm a year. In contrast, Birdsville has the lowest annual average rainfall nationwide, receiving about 200 mm a year.

Queensland's weather is mostly dry, sunny, and warm to hot, with high rates of evaporation. Drought is a predominant feature. Large areas can be declared drought-stricken and remain so for several years.

Although mainly dry, Queensland produces 40–45 percent of Australia's runoff while representing only 20 percent of its land area. This reflects the seasonal and event nature of much of the rainfall and the large falls received by the relatively small Wet Tropics area. Rainfall patterns are also affected by the El Niño Southern Oscillation, resulting in periods of higher- or lower-than-average annual rainfall.

Widespread rainfall, while infrequent, is produced by monsoonal events penetrating from the north, upper level depressions or cold fronts with storms moving from the south-west, and coastal ridging from high pressure systems over southern Australia. These events can cause previously dry streams to flow rapidly or flood surrounding areas. Floods generally subside quickly and normal dry conditions return within weeks. The 'drought or flood' nature of rainfall in Queensland has had a significant influence on development, and is a major factor influencing the physical, chemical and ecological characteristics of inland waters.

Freshwater resources have many values and are required for a wide variety of uses — habitat for aquatic plants and animals, irrigation water for agriculture, process water for mining and industry, drinking water for humans and animals, a facility for recreation activities and a transport medium for waste disposal. Overuse or degradation of freshwater resources by one group of users can affect their availability and suitability for others. As the fastest growing State in Australia and one with an emphasis on job creation, Queensland faces increased demand for water from all user groups. The challenge facing water managers is to ensure that our freshwater resources are managed sustainably to benefit all present and future water users.

Between 1991 and 1995 Queensland recorded the highest rate of population growth in Australia (QDLGP 1997). Population growth and continuing economic development mean the pressures on Queensland's water resources will continue to grow.

This chapter reports on the pressures on Queensland's water resources, the condition of those resources, and responses made to counter the pressures. Periodic reporting on a set of environmental indicators enables trends in water quality to be determined. At present, many of the required monitoring programs are not in place to provide comprehensive data on all the indicators presented. Indicators for which little or no information is available have been included to illustrate the need for additional studies in areas where insufficient data are currently available.

Dudley Nott

During the dry season Lagoon Creek in the Western Gulf catchment is reduced to a mere trickle or a dry channel.

SCOPE

For this report, inland waters include all groundwater and surface waters upstream of the saline reaches of tidal water. This definition means that the physical boundaries of inland waters in coastal areas will change with rainfall patterns, tidal surges and water extraction regimes. To report on discharges to water, the coastal zone includes those local government areas adjacent to the coastline and those with their centroid within 50 km of the coastline. All other discharges inland of the coastal zone are included in this chapter.

DESCRIPTION

Major drainage divisions and catchments

Queensland's inland waters are described in terms of six major drainage divisions and 32 smaller catchments. The divisions are based on the Australian Water Resource Council (AWRC) river basin index (DPI 1993a).

The North-East Coast Division has been subdivided into three smaller subdivisions reflecting the local differences in climate and geography of this major division. For convenience, the Queensland portions of the Lake Eyre and Bulloo divisions have been combined in this report. These are shown in figure 4-1 and listed in table 4-1.

Queensland's drainage pattern is controlled mainly by the Great Dividing Range, a loosely arranged chain of mountains, hills and high country running roughly parallel to the east coast. Drainage from the headwaters in the Great Dividing Range is divided into four major drainage divisions determined by the direction and fate of drainage flows.

Carpentaria

Streams of the Queensland portion of this division drain west and north to the Gulf of Carpentaria. The area has mainly low relief except for headwater catchments along the western side of the Great Dividing Range. Elevated areas also occur in the Selwyn Range to the west near Mount Isa. Most of the division consists of plains, floodplains and tidal flats. Streams traversing these areas are mainly ephemeral and sandy-bedded, with numerous channels that meander across flat, alluvial claypans and tidal coastal areas.

The entire Gulf of Carpentaria Division extending into the Northern Territory produces about 93 000 gigalitres (GL) of runoff a year, the highest runoff in Australia. The Queensland portion accounts for approximately 65 000 GL, the second highest runoff in Queensland.

Rainfall is highly seasonal, produced mainly during the wet season by monsoons and cyclone events. Despite the high rainfall and runoff, the area is mainly hot, dry, open woodland, tussock grassland and claypans, with monsoonal woodlands and forests in northern Cape York. The predominantly dry conditions are due to the event nature of the rainfall, which largely runs off or evaporates quickly, interspersed by long, harsh dry seasons.

Lake Eyre–Bulloo

The vast Lake Eyre Drainage Division occupies parts of the Northern Territory and South Australia as well as Queensland, and is one of six Australian divisions that produce relatively little runoff. The Queensland portion drains the central-western slopes of the Dividing Range and the southern side of the Selwyn Range in the north-west. It produces the bulk of water that flows to Lake Eyre, the main receiving water body. The main direction of drainage is south-west, and surface water resources are scarce.

Widespread rain events occur every few years and can produce considerable flow and flooding in the main drainage lines of the Thomson, Barcoo, Diamantina and Georgina Rivers. In view of the very slight gradients and fine-textured alluvial soils on the floodplains, downstream areas of the rivers tend to form braided channels. In the far south-west, these drainage systems are interspersed by large, windswept sandhill areas.

The zone below where the Thomson and Barcoo Rivers join to form Cooper Creek is known as the Channel Country. For most of the year this is a series of waterholes. However, when flooding occurs, primary channels fill quickly and the muddy water branches outwards as the channels feed into one another. Individual channels are separated by slightly raised clay levees on the otherwise featureless surface. When in flood, the system can be 60 km wide and several hundred kilometres long. These channels provide an important wetland habitat for breeding birds and are vital to the re-emergence of the region's vast grasslands.

The Bulloo is a relatively small catchment in the south-west draining from the western side of the Central Highlands of the Dividing Range. It is confined by the Paroo River catchment to the east and by the Grey Range to the west. Its main distinguishing feature is that, like the Lake Eyre Division, it has no outlet to the sea. Its occasional flows disappear in flat country in the south. It has the second lowest runoff of the twelve Australian divisions.

Murray–Darling

About 17 percent of the area of the Murray–Darling Division is located in Queensland, yet only 4 percent of its water originates in the State. The entire division produces about 25 000 GL of runoff a year.

Rainfall on the eastern side of the Queensland portion is reasonably reliable, especially along the western slopes of the Great Dividing Range. The Condamine and Balonne Rivers drain this area and are major irrigation resources. Rainfall decreases markedly to the west, where semi-arid conditions prevail. However, widespread rainfall occurs occasionally, usually as a result of wet season events. This can produce inundation of the floodplains along the Warrego and Paroo Rivers, exacerbated by the flat terrain.

North-East Coast Division

This division produces more runoff than any other in Queensland — an average of about 83 000 GL a year. This is the second highest runoff in Australia. Drainage is mainly east and north-east to the Coral and Tasman Seas. The area is subdivided into southern, central and northern zones.

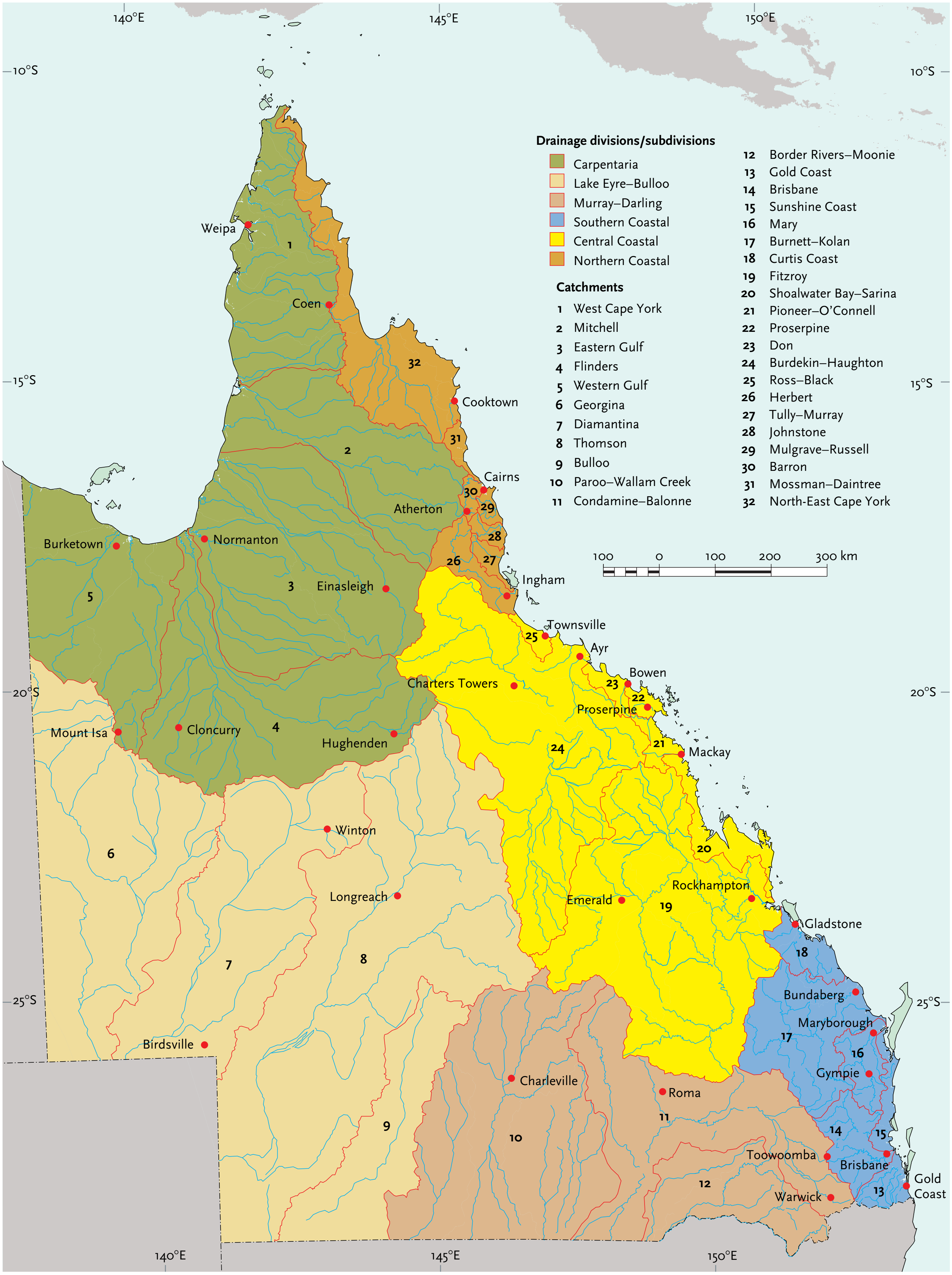


Figure 4-1 Major drainage divisions and catchments of Queensland
(Source: Modified from DPI 1993a)

Southern Coastal

In the southern zone between the New South Wales border and the Bundaberg–Gladstone region, the Dividing Range is relatively close to the coast. This creates fairly reliable rainfall and stream flows, although seasonal with a summer bias and, as in most areas of Queensland, a propensity to undergo drought. The zone has several major dams for urban water supply and irrigation.

Central Coastal

The two large river systems of the central zone, the Burdekin and the Fitzroy, produce higher annual flows than any other Queensland rivers, with the Burdekin yielding about one-third more than the Fitzroy. They flow strongly during major rainfall events such as rain depressions, monsoons or cyclones during the summer wet season. At other times flows can virtually cease. Coastal tributaries of these systems have relatively reliable flows due to orographic rainfall over the coastal ranges that are a dominant feature in this zone. Large dams have been built on both systems for irrigation.

Northern Coastal

In the area north of Ingham, the Great Dividing Range is generally close to the coast. Rainfall is seasonal and dominated by major rainfall events such as monsoonal and cyclone activity during the summer wet period. However, the orographic effect is important, producing coastal rain even during the dry season. Areas between Ingham and Cooktown have the highest annual rainfall in Australia. Streams are mainly short and fast-flowing. The Atherton Tableland area has several dams for irrigation, hydro-electricity and urban supply.

Inland waters

Inland waters are made up of groundwater and surface waters. Groundwater is the portion of rainfall that percolates through the soil to underground aquifers where it is stored. Groundwater is accessible through natural springs and drilled bores. The availability and quality of groundwater are not uniform, but depend on the permeability of the ground and underlying strata, as well as on rainfall. Surface waters include rivers, streams, wetlands, springs, lakes, and reservoirs and other human-made water storages.

In Queensland, groundwater aquifers can generally be divided into three basic types — porous sedimentary rocks such as sandstones, unconsolidated sediments such as alluvial deposits of sands and gravels along the coastal plain, and fractured rocks such as volcanic rocks and karst limestones. The single largest groundwater source in Queensland is the Great Artesian Basin. It comprises porous sedimentary rocks and underlies some 1 124 000 km^2, about 65 percent of Queensland, and acts as the sole source of water for stock and domestic use in many western areas. Several smaller groundwater basins east of the Great Dividing Range provide between 30 percent and 69 percent of the water requirements in this zone (QWRC 1989). Total groundwater use in Queensland is estimated to be 1 400 000 megalitres (ML) a year, about 44 percent of total annual water use (DPI 1993b).

Surface water flows represent the fraction of rainfall that flows off the land into rivers and streams. For Queensland, this fraction is about 11 percent. The mean annual discharge of all Queensland's rivers is estimated to be 159 million ML. However, 76 percent occurs in sparsely populated catchments that drain to the Gulf of Carpentaria and the Coral Sea north of Mackay. Another 17.6 percent discharges into the Pacific Ocean from the coastal zone that extends from south of Mackay to the New South Wales border. Only 6 percent of mean annual river flows discharges to Queensland's inland river systems (WITF 1997).

Some surface water accumulates to form natural wetlands and lakes, mainly in low-lying floodplains and coastal areas, or is captured in purpose-built water storages.

Wetlands are important as habitats for endemic and migratory waterbirds and many species of fish and crustaceans. Queensland's wetlands support the most diverse freshwater fish fauna of any Australian State, providing essential habitat for the entire life cycle of some 130 species (DoE 1997b). Wetlands are also significant for flood control, groundwater recharge, erosion control and water purification. A total of 165 Queensland wetland sites have been identified as nationally 'important' wetlands under criteria defined by the Australian Nature Conservation Agency (ANCA). These all represent 'a good example of a wetland type occurring within a biogeographic region in Australia', meeting the first ANCA criterion.

Of these, 22 are in the 'human-made wetlands' class, which includes artificial storages and canals. One hundred and twenty-five are classified as 'inland wetlands'. ANCA criteria for this class include permanent rivers and streams, and seasonal and irregular rivers and streams. This classification also includes the 80 wetlands defined by the more narrow criteria used in this chapter — swamps, marshes, bogs and floodplains that are permanently or intermittently inundated with fresh or saline waters.

The term 'lakes', as distinct from artificial water storages, refers to areas of open water generally over one metre deep with little or no persistent emergent vegetation (Paijmans et al. 1985). Lakes can be permanent, semi-permanent, seasonal, intermittent or episodic. Queensland has 44 lakes that are classified as important (ANCA 1996). Two of these, Lake Numalla and Lake Wyara, are part of the Currawinya Lakes Ramsar site, having satisfied the criteria that establish them as being of outstanding international significance for their ecological character.

More than 70 percent of rainfall runoff flows into the sea. Only about 2 percent of runoff is captured in water storages. Storages are defined as human-made impoundments and ponds designed as water supplies for irrigation purposes, urban water supply and electricity generation, and for flood mitigation. Queensland has almost 200 storages that each have a storage capacity greater than 1000 ML. Their combined capacity is approximately 10 million megalitres (QWRC 1989). Locations of major water storages in Queensland are shown in figure 4-2.

Environmental values

Environmental value is the worth placed by society on the functions, uses or attributes of a particular habitat or environment. Environmental values are the attributes of waters that promote public benefit, welfare, safety or health and that require protection from the effects of contamination. Once environmental values are determined for a particular body of water, the water quality required to sustain those values can be defined and become an objective for water quality management.

Under the *Environmental Protection (Water) Policy 1997* (EPP Water) the environmental values of waters to be enhanced or protected can have the following qualities:

(a) if the water —
   (i) is a pristine water — biological integrity of a pristine aquatic ecosystem; or
   (ii) is another water — biological integrity of a modified aquatic ecosystem; and
(b) suitability for recreational use; and
(c) suitability for minimal treatment before supply as drinking water; and
(d) suitability for agricultural use; and
(e) suitability for industrial use.

Guidelines are available for a wide variety of biological and physico-chemical parameters depending on the environmental values required for a particular water body. These can be in the form of site-specific documents, the *Australian Water Quality Guidelines for Fresh and Marine Waters* (ANZECC 1992) or documents published by a recognised entity (for example EPP Water Schedule 2).

Table 4-1 Major drainage divisions or subdivisions and catchments of Queensland

Drainage division/subdivision	Catchment	AWRC river basins*	Area (km^2)
Carpentaria	West Cape York	920–927	64 025
	Mitchell	919	71 795
	Eastern Gulf	916–918	121 290
	Flinders	915	108 780
	Western Gulf	910–914	84 925
Total area for division			**450 815**
Lake Eyre–Bulloo	Georgina (includes the Hay)	001, 007	142 710
	Diamantina	002	119 400
	Thomson	003, 004	244 210
	Bulloo	011	55 035
Total area for division			**565 705**
Murray–Darling	Paroo–Wallam Creek	422 (part), 423, 424	133 150
	Condamine–Balonne	422 (part)	87 130
	Border Rivers–Moonie	416, 417	38 795
Total area for division			**259 075**
Southern Coastal	Gold Coast	145, 146	5 490
	Brisbane	143	13 560
	Sunshine Coast	140–142	4 880
	Mary	138	9 595
	Burnett–Kolan	135–137	39 470
	Curtis Coast	132–134	8 655
Total area for subdivision			**81 650**
Central Coastal	Fitzroy	130	142 645
	Shoalwater Bay–Sarina	126–129	11 270
	Pioneer–O'Connell	124, 125	3 925
	Proserpine	122	2 485
	Don	121	3 885
	Burdekin–Haughton	119, 120	133 510
	Ross–Black	117, 118	2 890
Total area for subdivision			**300 610**
Northern Coastal	Herbert	116	10 130
	Tully–Murray	113, 114	2 825
	Johnstone	112	2 330
	Mulgrave–Russell	111	2 020
	Barron	110	2 175
	Mossman–Daintree	108, 109	2 615
	North-East Cape York	101–107	43 300
Total area for subdivision			**65 395**
Total for State			**1 723 250**

*River basin index as defined by Australian Water Resources Council
(Source: DPI 1993a, AWRC 1987)

PRESSURE

HUMAN IMPACTS

Human activities cause disturbances to inland waters which directly or indirectly affect physical, chemical, biological and aesthetic qualities. These effects can detract from the environmental values of waters and their suitability for one or more uses. The major human activities that have an impact on inland water resources are agriculture (including forestry), industry, mining and urbanisation. Some impacts such as soil disturbance and increased sedimentation are common to each of these activities. Impacts that can be attributed to a specific activity are discussed separately under each heading.

Agriculture

Agricultural activities, whether grazing, cropping or more intensive activities, can adversely affect inland waters in two major ways: increasing erosion and sedimentation and introducing agricultural chemicals into the water body. Soil erosion products and the pollutants they might contain can alter the quality of water. Intensive grazing can destroy riparian vegetation that provides a natural filtering and trapping mechanism for sediments and associated contaminants. The removal of riparian vegetation also reduces shading of streams, leading to increased sunlight for macrophyte growth.

The extraction and diversion of water resources affect the quantity, and often the quality, of water available to downstream users. Flow patterns are also affected. Nearly 80 percent of water diverted in Queensland is used for agricultural purposes (DPI 1993b).

Reclamation of wetlands for agriculture results in the loss of important habitats and affects flood and flow regimes in surrounding areas in a variety of unexpected ways. The settling and filtering effects of wetlands are also lost.

The loss of vegetation cover from land due to clearing for agricultural and grazing purposes can have adverse impacts on nearby waterways. Water and wind erosion of exposed soils can add significantly to the sediment load of surface waters, leading to changes in the diversity, distribution and abundance of native plants and animals. Increases in runoff volume and flow rates through vegetation loss can cause hydrological changes that can lead to additional erosion of river and stream banks and beds.

Removal of deep-rooted native vegetation and replacement with shallow-rooted crops and pasture have caused watertables to rise to the surface in some areas of Queensland. Evaporation of this water can increase the concentrations of salts in the topsoil. Runoff from these areas can increase the salt content of nearby surface waters. Salts in irrigation water can also enter streams, due to runoff from irrigated areas either from groundwater or surface water sources. Salts from irrigation water can also increase the salinity of groundwater aquifers (SCARM 1996). The area of salt-affected land in Queensland was estimated to be 14 000 ha in 1996, approximately 0.4 percent of the total salt-affected land in Australia (DNR).

Fertilisers and pesticides used in agriculture, as well as waste from intensive animal industries such as feedlots and piggeries, can find their way into surface waters. When nutrients reach surface water supplies they can increase the biological productivity of the water (see box 'Blue-green algal blooms'). Chemicals that are not bound strongly to soil particles can accumulate in nearby groundwater.

Industry

Industrial waste is any waste arising from manufacturing and service industries. About 400 000 tonnes of liquid industrial waste are produced in Queensland each day, half coming from south-east Queensland. Approximately 120 000 tonnes a day are discharged directly to water or land in south-east Queensland, usually following some form of on-site treatment. Another one-third of the waste is disposed of through sewerage systems, while some 60 tonnes are sent to specialised waste treatment facilities dealing with non-sewerable liquid and hazardous wastes. Relatively small amounts of liquid industrial wastes are collected for reuse and reprocessing (QDEH 1994).

Industrial sites that accumulate surface contamination have the potential to pollute stormwater. Dust, spillages, erosion products, and stockpiles of raw materials, products or waste can be flushed by rainfall or washing activities into stormwater drainage streams. The diversion of stormwater from contaminated areas or the collection of contaminated stormwater for treatment before release reduces this source of pollution significantly (see box 'Stormwater contamination — urban non-point pollution').

Mining

Although the total area affected by mining is small, environmental impacts can be severe within local areas, and can extend over broader areas under certain circumstances. The effects of mine construction, ore extraction and mineral concentration, and the associated transport, infrastructure and processing exert pressures on nearby water resources. Derelict minesites and inadequate rehabilitation can extend some impacts beyond the period a mine is actively producing (see box 'Long-term effects of past mining practices').

The type of mining method used influences the extent of environmental impacts. Open-cut mining involves the removal of surface vegetation and the destruction of soil profiles. Dust and runoff from exposed pits and overburden dumps can increase sedimentation in nearby waterways. Acid drainage can occur if mining dumps are not built and managed properly. Pumping of underground water from mines can produce pollutants that threaten natural waterways. Dredging of stream beds causes turbidity and bank slumping and interferes with benthic habitats.

Tailings (waste materials produced by mineral ore concentration) can contain heavy metal contaminants and residues of chemical reagents such as cyanide used in gold processing. These are generally disposed of in lined tailings dams, which are capped and revegetated when full to prevent leakage into groundwater and surface waters. Statistics on volumes of waste produced by mining operations are not readily available in Australia.

Large volumes of water may be used for mineral extraction and processing. For example, washing of bauxite mined at Weipa uses 4.4 million litres of groundwater an hour; some of this is recycled (Pearcey and McConnell 1994).

Urbanisation

Urban wastes include liquid, solid and hazardous wastes generated by domestic and commercial activities. Wastewater from food preparation, showers and baths, toilets and washing operations in urban areas is generally directed to wastewater treatment plants before disposal to the receiving environment. Domestic sewage contains mainly water contaminated with organic matter, household cleaners and personal products. Other household chemicals such as paints,

Long-term effects of past mining practices

Queensland has many hundreds of minesites, operational and disused. Some of these sites produce water contaminants such as eroded soils, tailings leachate, process chemicals, fuels and oils, and sullage. In some cases the pollutants are inadequately contained or treated, and seep or discharge downstream periodically or continually. The most common pollutant is acid water, which causes a range of water quality and ecosystem problems. These problems are well illustrated at the abandoned Mount Morgan Mine, central Queensland, and in the Dee River, which receives drainage from the site.

Mount Morgan is located in low hinterland ranges 30 km south-west of Rockhampton. It was Queensland's richest goldfield, producing more than 170 tonnes of gold between 1882 and 1987. It also contained copper ore, which was mined and smelted at the site. Mount Morgan was one of several goldmining towns in Queensland that experienced spectacular growth in the late 19th century. At its peak, around the turn of the century, it had a population of 8000. The population dwindled with the depletion of the ore body, and the town is now a small regional service centre.

The massive disused minesite is located immediately adjacent to the Dee River. The minesite drains to the river in a series of gullies and creeks. Many original drainage lines have been filled with mine wastes and mill tailings. The minesite contains a large water-filled open-cut pit measuring 1500 metres by 750 metres, three major waste rock dumps, two mill tailings dams with a total area similar to that of the pit, a smelter site, numerous sumps and outlets, and a series of dams and weirs on the river.

Oxidation of waste sulfides by exposure to air generates sulfates that combine with moisture to produce sulfuric acid. Acidic waters dissolve the metals present in the wastes and provide an effective mechanism for transporting these substances offsite and into the natural waterways downstream.

The major sources of contamination at the minesite are leachate from overburden heaps and tailings deposits, and the large volume of poor-quality water contained in the open-cut pit. The level of water in the pit is rising. The hydrostatic head drives a subsurface flow of contaminated leachate through fractured rock strata around the pit. Most of the contaminated groundwater and leachate is being intercepted by several sumps, from which it is pumped back into the pit. An unknown proportion of this water enters the Dee River adjacent to the minesite.

A study prepared for the Queensland Department of Mines and Energy (QDME) identified three major inputs of contamination to the Dee River under low flow conditions (CSIRO 1995). The first site was a weir pool upstream of a tailings dam and just downstream from a mill sump. Neither the tailings dam nor the mill sump has been positively identified as the source of contamination. The second major input was identified as Mundic Creek, associated with Shepard's tailings dam. The third site was between Mundic Creek junction and Kenbula weir, also associated with Shepard's tailings dam, but not positively identified.

The ecological effects of the contamination are dramatic. Another study for QDME established baseline ecological conditions in 1995 (Duivenvoorden 1995b). All the major components of the river's aquatic biota were adversely affected by the acid mine drainage. Pollution-sensitive invertebrates, and all fish and submerged plants, were absent from sites within 20 km downstream of the mine and the effects were still noticeable for a further 30 km downstream.

The main contaminants leaching and seeping from the mining site are acidic waters with dissolved metals including copper, cadmium, aluminium, manganese, zinc and mercury. Acidic waters damage aquatic organisms by eroding fine tissues and membranes, among other things. These waters are even more dangerous when they contain dissolved metals which are toxic to animals and which accumulate in plants.

A second study commissioned by QDME found that the weir pool upstream of a tailings dam was the major source of contamination during medium flow conditions (CSIRO 1996). Numerous surface and subsurface seeps from the dam were found to be causing the levels of acidity and metals to rise rapidly in the weir, despite the fact that the weir pool had been flushed out during a flood earlier in the year. The levels of aluminium, copper, cadmium and manganese in the Dee River were found to exceed criteria for human drinking water, stock water, irrigation and protection of aquatic life.

The tailings dams are the main sources of contamination from Mount Morgan. The weir pools and alluvial aquifers of the river itself are important secondary sources. With rainfall, contaminants are flushed downstream. The weir pools and river downstream over several kilometres show visible signs of environmental damage — discoloured waters, banks, rocks and beds caused by chemical precipitates, gels and concretions.

Mount Morgan's environmental problems are still being investigated. The objective is to identify causes and locations of various sources of contamination, and evaluate management options. A local Landcare group has commenced an NHT-funded project to improve water quality monitoring with the intention of seeking funding for complete rehabilitation.

Stormwater contamination — urban non-point source pollution

Efforts to control water pollution are typically aimed at reducing point sources of pollution. As point source controls become more effective, non-point sources of pollution become increasingly important to the improvement of receiving water quality. Urban stormwater can contribute significant non-point source pollution to the receiving waters of urban catchments. Urban catchments have been shown to contribute much greater long-term pollutant loads than rural catchments of similar size (Griffin et al. 1980; Randall and Grizzard 1983).

The principal pollutant in stormwater runoff is nearly always suspended solids (Randall and Grizzard 1983). The pollutants most likely to be found in urban runoff include phosphorus, petroleum-based organics and hydrocarbons, heavy metals and oxygen-demanding organics that tend to adsorb onto solid particulates. Faecal coliforms have also been identified as a common urban stormwater pollutant (Vorreiter and Hickey 1994). Sources of faecal coliforms in stormwater include animal faeces, illegal sewer connections to stormwater drains, leaks from old and cracked sewer mains, and sewer overflows due to infiltration of stormwater into sewers during storm events. Air pollution and atmospheric dust fallout are high in urban areas, and can contribute significantly to the pollutant load of runoff (Griffin et al. 1980).

The urban land use characteristic that relates best to runoff load is the degree of imperviousness of a catchment (Griffin et al. 1980). Impervious surfaces are roofed, paved or compacted surfaces that rainwater cannot penetrate. The degree of imperviousness of a surface determines:

- how much rainfall will be absorbed before runoff occurs; and
- the efficiency of physical transport processes associated with the washoff of pollutants (USEPA 1974).

The degree of imperviousness has been used as a measure of the degree of urbanisation of a catchment (Griffin et al. 1980). Urban areas can also contain large areas of cleared, erodable surfaces under development. Erodable surfaces can produce a virtually unlimited supply of suspended solids throughout a rainfall event. Rural catchments have a higher proportion of pervious surfaces that rainwater can penetrate. Extra vegetation in rural catchments filters insoluble pollutants.

Past urban stormwater management practices have been directed at the disposal of stormwater runoff for flood mitigation purposes (Hammerschmid et al. 1989). There is now a growing awareness that urban stormwater is not merely a waste product to be disposed of but should be seen as a resource that can be used to meet the growing water demands of Australia's communities (Cullen 1995).

A study to assess the feasibility of reusing stormwater in the Ultimo–Pyrmont Precinct in inner Sydney concluded that stored stormwater generally would be suitable for uses such as irrigation of turf in landscaped recreation areas, street washing, washing of boats in marinas, and flushing of toilets (Phillips and Maher 1995). These uses would reduce the demand on drinkable water resources. An economic analysis determined that the cost of using recycled water would be considerably greater than the cost of using water purchased from the Sydney Water Board under current tariffs. Costs identified in this study included building a new pumping system, a new rising main to a proposed irrigation tank, a disinfection facility, regular maintenance and replacement of pumps, pipes, valves and electrical control equipment, and routine water quality testing. The authors concluded that a decision to reuse stormwater should not simply take into account the economic analysis but should also consider social and environmental factors.

Another potential use of urban runoff is in the development of urban lakes to provide recreational and aesthetic amenity to urban areas. These lakes can provide valuable nature conservation possibilities such as habitat for birds in urban areas. Such water features can also result in enhanced adjacent land prices (Cullen 1995), offsetting some development costs.

solvents, oils, pesticides and pool chemicals can be present. The level of treatment required is based on the sensitivity of the receiving environment.

Treated wastewater can be used for irrigation and some industrial applications such as cooling. Most treated liquid waste is currently disposed of by being applied to land or discharged directly to waterways.

In highly urbanised areas with a large percentage of impervious surfaces, up to 90 percent of rainfall can flow to drains as stormwater (ANZECC and ARMCANZ 1996). Stormwater is generally not treated, with the exception of screening in some places to remove large objects, but flows with any dissolved or suspended contaminants to surface waters. Surface contaminants can include suspended solids, fertilisers and pesticides from gardens, petroleum and wear products from automobiles, droppings from domestic pets and wild animals, and soap and detergent residues from outdoor washing activities. Domestic and commercial wastes can also reach stormwater drains through illegal connections or by intentional dumping directly into gutters (see box 'Stormwater contamination — urban non-point source pollution').

Pressure indicators

Major human pressures affecting the quality or quantity of inland waters have been grouped into eight categories. Pressure indicators have been identified for each.

Development

The term 'development' encompasses activities that change the original vegetation cover of river catchments, and includes land clearing and reclamation of wetlands for agriculture, industry, mining or urbanisation. Disturbed land is susceptible to wind and water erosion which can create high levels of suspended solids in nearby surface waters. The highest rates of erosion occur immediately after the soil is disturbed. Revegetation, soil compaction and resurfacing reduce the impacts of erosion to varying degrees. Hydrological disturbances have unexpected effects over entire catchments and groundwater areas, and might not be evident until many years after the original development.

Much of Queensland's urban and rural development has occurred on floodplains adjacent to watercourses. These

Figure 4-2 Locations of major water storages in Queensland by drainage division
(Source: DNR)

settlements commonly preceded town planning and development controls now designed to reduce flood impacts.

Development on floodplains can change the nature of flooding. Flooding may become worse through mechanisms such as the loss of flood storage volume (filling of the floodplain), acceleration of flows (straightening channels) and, for more frequent rainfall events, increased runoff from impervious areas. These effects are often incremental, with each development having a small impact beyond the initial disturbance.


Griffith University (AES)

Native forest being cleared for urban development

Several State Government departments have interests in floodplain management issues. This has led to a somewhat fragmented development of legislation. Because responsibility for floodplain management has been delegated mostly to local government, the State's practical involvement has been limited generally to examining disasters associated with major floods or implementing structural solutions to mainstream flooding through mechanisms such as river improvement trusts.

Indicator

Percentage of total catchment area developed for agricultural, industrial, mining or urban sectors

Agriculture is the dominant land use in Queensland, accounting for some 87 percent (151 million ha) of the State. Beef cattle and sheep production accounts for much of this use; other types of agriculture account for approximately 2 percent of Queensland's land area (DPI 1992a). The total area held under mining leases is approximately 0.6 percent; operating mines make up a small fraction of the leased area. Data presented for urban development include only local government areas in south-east Queensland (table 4-2).

Localised studies have provided estimates of development pressures in specific areas. A study of south-east Queensland covering 15 800 km^2 was carried out in 1996. The Brisbane River catchment made up 85 percent of the total study area (DoE 1997a). An estimated 80 percent of the original vegetation has been cleared since European settlement, and more clearing continues in the coastal lowlands than in any other region in the study area. The study area contained more than 62 percent (1.39 million) of Queensland's population in 1991.

A report prepared for the Cardwell Shire Catchment Co-ordinating Committee compared the pre-settlement vegetation cover with remnant vegetation to determine the status of natural habitats within the lowlands of the Tully and Murray River catchments (Tait 1994). These catchment areas have been developed intensively for pastoral and agricultural uses. Large areas of freshwater wetland have been lost or degraded by clearing, draining and exotic grass invasion. Vegetation and soil survey mapping was used to determine pre-settlement vegetation patterns. These were compared with 1991 aerial photographs of the catchments, supported by satellite images and field inspections. Overall, the amount of original vegetation that had been cleared during this period, excluding mangroves, was estimated to be 70 percent. A breakdown of vegetation types in the Tully and Murray River catchments is shown in table 4-3.

The Statewide Landcover and Trees Study (SLATS) was undertaken to map vegetation cover in Queensland (DNR 1997a). The purpose of the study was to develop accurate baseline vegetation data so that tree clearing policies and guidelines would be based on factual information. Data on extent of native vegetation clearance by biogeographic region appear in chapter 7, 'Biodiversity'.

Table 4-2 Percentage of Queensland under development by each sector (adjusted). The figure listed under 'urban' refers to south-east Queensland only. The population of this region is estimated to be 66 percent of the total, while the area covered is approximately 1.3 percent. The urban category includes industrial areas that fall within local government areas.

Year	Agriculture[a]			Mining leases[b]	Urban[c]
	managed by agricultural establishments	under crops	under sown pasture		
1992–93	87	1.5	3.7	0.36	–
1994–95	85	–	–	0.40	6.0
1996–97	87	1.6	–	0.64	–

(Sources: [a]ABS 1994, 1995, 1996, 1997; [b]DME; [c]DLGP 1996)

Table 4-3 Change in vegetation types in the Tully and Murray River catchments since European settlement

Vegetation type	Pre-settlement area (ha)	Post-settlement area (ha)	Percentage change
Gallery rainforest	15 173	5 904	–61.1
Lowland rainforest on hillsides	7 973	3 065	–61.6
Rainforest with eucalypt emergents	9 418	1 430	–84.8
Palm forest	840	166	–80.2
Melaleuca swamp forests	10 360	3 071	–70.4
Mixed open eucalypt forests	14 057	3 281	–76.7
Open woodlands of *Melaleuca viridiflora* and *Lophostemon suaveolens*	803	652	–18.8
Open sedgelands/grasslands	202	319	+58

(Source: Tait 1994)

Indicators

Area of additional land cleared each year by catchment

Changes in developed land use

To gauge the continuing pressure from development, it is desirable to establish an indicator that provides a measure of additional land being cleared and changes to developed land use by sector. An example is the conversion of farmland to residential property. Many of Australia's urban areas are located on or near productive agricultural land. Continued urban expansion into these areas may reduce rates of production and the efficiency of Australian agriculture (SCARM 1996).

Indicators

Changes in area of riparian vegetation as a percentage of total riparian zone by catchment

Few data are available on the extent of riparian vegetation cover along stream and river banks in Queensland. Localised studies of stream habitat for selected catchments are reported where available. Maps locating some of the following catchment areas appear in chapter 5, 'Coastal zone'.

The Johnstone River catchment (1680 km^2) in the Wet Tropics south of Cairns is dominated by the North and South Johnstone Rivers, which rise in the Atherton Tableland. These rivers join to flow into the Coral Sea near Innisfail. The catchment contains the geophysical regions of the Tableland, the Mountain Range (coastal escarpment), and the Coastal Uplands (major part of the coastal plain). The condition of the riparian zones was assessed using a riparian zone index (Russell and Hales 1993). On the Tableland, 80 percent of the sites were assessed to be in poor or very poor condition. Only 10 percent were rated as good, very good or excellent. All sites in the Mountain Range were rated as very good or excellent, with most of the area under protection by World Heritage listing. In the Coastal Uplands, 54 percent of sites were rated as poor or very poor, and only 11 percent were assessed as in good or excellent condition.

The Mulgrave–Russell Rivers catchment, also in the Wet Tropics area south of Cairns, contains two geophysical regions not under tidal influence — the Tableland (77 km^2) and the Upper Floodplain (440 km^2). Three-quarters of the catchment is in the World Heritage Wet Tropics estate or forested areas outside the estate. Sugar production is the main land use in the floodplain. Streams on the coastal floodplain and tablelands have had their treed riparian buffer zones reduced by more than 70 percent, making grasses the major component in many areas. A riparian disturbance index, similar to the one used in the Johnstone River catchment study, was used as a rapid assessment tool to determine the impacts on riparian vegetation due to human activities. On the Russell floodplain, 55 percent of sites were classified as characterised by high disturbance or extreme disturbance, while 36 percent of sites on the Mulgrave floodplain fell within these categories (Russell et al. 1996a).

The Moresby River catchment (147 km^2) begins in the Basilisk Range and ends near Mourilyan. The non-tidal zone makes up about 60 percent of the catchment and consists predominantly of agricultural floodplain areas. Stream assessments were performed at 20 non-tidal sites with a total stream length of 5.05 km. Riparian vegetation was found to be heavily affected by agricultural activities: disturbance levels in non-tidal sites were rated as extreme (50 percent), high (5 percent), moderate (15 percent) and low (30 percent). All riparian vegetation was rated as having some degree of disturbance. Impacts due to agriculture were also reflected in the composition of riparian vegetation — 55 percent grass versus 45 percent trees and shrubs in non-tidal areas. The majority of sites within treed corridors showed significant gaps in the continuity of riparian growth, again attributed to adjacent agricultural activities (Russell et al. 1996b).

The Condamine River catchment (29 150 km^2), on the western slopes of the Great Dividing Range in southern Queensland, encompasses Toowoomba, Warwick, Millmerran, Pittsworth, Oakey, Dalby and Chinchilla. This is a major source of irrigation water for the Darling Downs area. An assessment of the catchment (Condamine Catchment Committee 1995) found that riparian vegetation was generally in poor condition, exotic weed species occupying from 7 percent to 90 percent (mean 37 percent) of the catchment. Sites where the riparian zone was in better condition were mainly in protected areas such as national parks and state forests. Some 94 percent of the banks in the non-protected areas were found to be undergoing some erosion due to clearing and the presence of stock. Bank stability was rated as good, 72 percent being rated as quite stable or stable and only 11 percent being rated as unstable or very unstable.

The mean width of the riparian zone varied from 4.3 m to 33.5 m. Condition was related to width. Most stream sections had aquatic vegetation in poor or very poor condition, the condition of the terrestrial vegetation and land adjacent to the stream being rated as very poor to good. Areas with low condition ratings were associated with rain-fed cropping and sown pastures, while areas in moderate to good condition were often subject to cleared native pasture and other types of native pasture grazing. Grazing management appeared to influence the extent of riparian vegetation disturbance.

A study of the Upper Condamine River and major tributaries, upstream of the junction with Myall Creek, south-west of Dalby, found widespread degradation of the riparian zone (DPI 1995b). The catchment area of this system was 13 292 km^2. The length of major streams surveyed totalled 3919 km. The major land use recorded adjacent to the streams was grazing, made up of sown pastures (37 percent) and grazing on cleared native pasture (53 percent). Cultivation of row crops occurred adjacent to 44 percent of sites and irrigated cropping occurred at 17 percent of sites. Grazing damage was cited at 83 percent of sites.

A study of the Bremer River and major tributaries found that the riparian vegetation throughout the catchment was generally in poor to very poor condition (DNR 1997b). These ratings were attributed to the loss of riparian vegetation through clearing and invasion of riparian zones by weed species. The Warrill Creek–Lake Moogerah subcatchment received the highest ratings for riparian vegetation condition, and the Western Creek–Franklin Vale Creek subcatchment the poorest ratings. Generally, those areas with riparian vegetation in good condition had wider riparian zones and fewer weed species, and included a variety of vegetation structural levels and associated groundcovers.

A study of the Dawson River and its major tributaries found widespread degradation of the riparian zone due to clearing of natural vegetation, invasion by exotic species and high disturbance levels in the reach environs (DPI 1995a). The total catchment surveyed was 50 800 km^2, the length of major streams totalling 13 000 km. Grazing was cited as the major land disturbance in 90 percent of the reach environs. Conditions of riparian vegetation in the subcatchments surveyed were rated as very poor (59 percent), poor (24 percent), moderate (9 percent), good (6 percent) and very good (3 percent).

A report assessing the Herbert River and its tributaries included marine and inland water subcatchments. Only the inland subcatchments are considered here. Approximately 40 percent of the lower Herbert River catchment has been cleared for sugarcane. Rainforest occurs in higher areas where rainfall exceeds 1200 mm a year (DNR 1996a). Grazing, horticulture, urban residential, urban parks and reserves, national parks and conservation reserves are other land uses listed within the catchment.

Thirty-two percent of the Lower Herbert River subcatchment was rated as being in very good condition, while riparian vegetation was rated as being 50 percent quite good and 50 percent poor. The streams in the Coastal Streams subcatchment were rated as in generally moderate to poor condition, with very poor riparian vegetation. The South Upland Streams were rated as good to very good, with good riparian vegetation. In the Upper Herbert River, about half the stream lengths were rated as good, with only 14 percent in poor condition, and riparian vegetation was found to be in moderate condition. The stream length of the Dry Catchment Streams subcatchment was rated generally as in moderate condition, with riparian vegetation varying from very good (21 percent) to very poor (34 percent). The riparian vegetation of the Wet Catchment Streams was rated as very poor for the greater majority of the stream length, while the stream lengths were found to be in generally moderate condition.

A survey of the Mary River and its tributaries covered a catchment area of 9697 km^2 and 2947 km of major stream length (DNR 1997c). The Mary River originates in the Conondale Range and flows north and north-east to enter the coast near Maryborough. Dominant land uses in the catchment are cattle grazing, forestry, cropping, mining and residential development. Several large tributaries with large storages and weirs provide irrigation and urban water supplies to the catchment.

Land degradation is widespread in the Mary River catchment, soil erosion and landslip being the most common problems. Fifty percent of the annual erosive rainfall occurs from December to February. Most erosion occurs on grazing lands, which cover 50 percent of the catchment. High grazing pressures, especially during periods of drought, expose grazing land to erosion. Erosion may also occur on cropping areas that cover 3 percent of the catchment. Substantial deposits of sand and gravel are mined from instream deposits, leading to bank erosion, especially where riparian vegetation has been cleared. The ratings of riparian width in the Mary catchment were low overall, 67 percent rating as very poor, 23 percent as poor, 8 percent as moderate and only 2 percent as good. The mean width of riparian vegetation was 17 m, with a range of 0.5 m to more than 50 m.

Lockyer Creek and its tributaries lie in a catchment of approximately 2971 km^2, with a major stream length totalling 1089 km (DNR 1997d). The area supports one of Queensland's most important centres of diversified agriculture, a number of water storages and weirs providing water for irrigation and the local population of approximately 22 000. An assessment of the catchment found that most stream lengths showed high to moderate disturbance, and riparian vegetation was in generally poor condition. Riparian zones had been cleared for agricultural purposes mostly to the edge of the stream banks, and invasion by exotic species was common. Stream banks were relatively stable throughout, with moderate to low susceptibility to erosion. Stream channel habitat types were of low diversity, with aquatic habitat rating low to moderate due to a lack of stream features to provide habitat. Table 4-4 summarises the ratings received for riparian vegetation from State of the Rivers surveys.

Table 4-4 Summary ratings of riparian vegetation from selected catchments

	Area of catchment drained (km²)	Length of major streams (km)	Percentage stream length rated very poor	Percentage stream length rated poor	Percentage stream length rated moderate	Percentage stream length rated good	Percentage stream length rated very good
Dawson River	50 800	13 000	59	24	9	6	3
Herbert River	8 574	2 622	58	18	11	6	7
Lockyer Creek	2 971	1 089	41	34	9	8	8
Mary River	9 697	2 947	4	36	31	18	11
Upper Condamine	13 292	3 919	79	9	8	2	2

(Sources: DPI 1995a, 1995b; DNR 1996b, 1997c, 1997d)

Table 4-5 Change in the area of wetlands in the Johnstone, Moresby and Mulgrave–Russell River catchments between 1951–52 and 1992

Catchment	1951–52 (ha)	1992 (ha)	Net change (ha)	Percentage change
Johnstone:				
Melaleuca forests	1 277	282	−995	−78
Mixed melaleuca	462	258	−204	−44
Palm/pandanus	439	160	−279	−64
Freshwater swamps/reeds	499	225	−274	−55
Moresby:				
Non-tidal	3 363	1 175	−2 188	−65
Mulgrave–Russell:				
Melaleuca forests	3 860	1 808	−2 052	−53
Mixed melaleuca	666	319	−347	−52
Palm forest	1 766	738	−1 028	−58
Sedge swamps	1 077	562	−515	−48
Rainforest	1 759	308	−1 451	−82
Total	**15 168**	**5 835**	**−9 333**	**−62**

(Sources: Russell and Hales 1993; Russell et al. 1996a, 1996b)

Indicator

Area of wetlands lost to development

Because of Queensland's climate and geography, freshwater wetlands are unusually transitory compared with those found in other parts of the world. Wetland ecosystems appear to be resilient to wide natural variability but are vulnerable to human intervention. Loss of wetland habitats can occur directly through intentional reclamation efforts and inadvertently through the use or management of surrounding land (DoE 1996).

Major threats to wetland systems include flood mitigation and flow improvement works, reclamation for agricultural, industrial, commercial and residential developments, mining, grazing, sedimentation, water pollution, feral animals and the introduction of non-native plants such as ponded pastures (DPI 1993b).

The extent of wetland loss in Queensland is unknown due to deficiencies in knowledge of wetland resources. A comparison of inventories of wetlands in the Johnstone, Moresby and Mulgrave–Russell River catchments shows the extent of wetlands lost in this region between 1951–52 and 1992 (see table 4-5).

Indicator

Percentage of protected area by catchment

Riparian vegetation and wetlands have a greater likelihood of survival when threats are reduced through protection of catchments. The percentage of protected area by catchment gives an indication of the likely long-term viability of those features.

The protected areas in table 4-6 consist of the following four types: conservation park, national park, national park (scientific) and resources reserve, as defined under the *Nature Conservation Act 1992*.

Table 4-6 Percentage of protected area by catchment

Catchment	Total protected area (km^2)	Percentage of protected area in each catchment
West Cape York	7 356	11.51
Mitchell	1 075	1.50
Eastern Gulf	5 605	4.59
Flinders	262	0.24
Western Gulf	3 756	4.44
Georgina	10 263	6.98
Diamantina	7 942	6.67
Thomson	3 061	1.25
Bulloo	1 303	2.36
Paroo–Wallam Creek	2 704	2.02
Condamine–Balonne	751	0.85
Border Rivers–Moonie	389	1.04
Gold Coast	432	7.93
Brisbane	189	1.39
Sunshine Coast	697	14.35
Mary	89	0.95
Burnett–Kolan	373	0.94
Curtis Coast	302	3.44
Fitzroy	5 139	3.60
Shoalwater Bay–Sarina	209	1.90
Pioneer–O'Connell	251	6.36
Proserpine	329	12.87
Don	107	3.00
Burdekin–Haughton	1 843	1.37
Ross–Black	168	7.01
Herbert	1 114	11.32
Tully–Murray	380	13.39
Johnstone	305	13.13
Mulgrave–Russell	620	31.09
Barron	47	2.18
Mossman–Daintree	650	26.52
North-East Cape York	8 440	19.65

Diversion

The physical redirection of water that alters its natural flow regime is referred to as 'diversion'. Dams, barrages and weirs are used to divert flows for water supply, irrigation and power generation.

Water storage requirements are influenced by the type of agriculture, industry and urban development in a catchment. Australia's high rainfall variability has necessitated construction of dams and weirs to store water during periods when rainfall is insufficient to meet requirements, giving Australia the highest per capita water storage capacity in the world, and significantly affecting natural flow regimes.

Natural variations in flow have been managed by stream regulation, generally to provide stability of water supply for irrigation and the public. This affects plants and animals adapted to the highly variable flows (McMahon and Finlayson 1992). For example, dams and weirs create barriers for migratory native fish and can affect their distribution and abundance upstream and downstream. Storages also trap sediments, nutrients and other contaminants, contributing to the incidence of algal and nuisance macrophyte blooms.

The Commonwealth Government, the Agricultural and Resource Management Council of Australia and New Zealand (ARMCANZ) and the Australian and New Zealand Environment and Conservation Council (ANZECC) have developed a set of National Principles for the Provision of Water for

Table 4-7 Average annual runoff compared with major storage capacity by catchment and division/subdivision. Figure 4-2 (a map)shows the locations of major Queensland dams and barrages.

Drainage division/ subdivision	Catchment	Average annual runoff ('000 ML)	Major storage capacity >2500 ML ('000 ML)	Major storage capacity as a percentage of average annual runoff	Population ('000)	Total storage capacity per person (ML)
Carpentaria	West Cape York	28 750	–	–	6	–
	Mitchell	12 000	–	–	5	–
	Eastern Gulf	12 100	41	0.33	3	13.67
	Flinders	3 050	16	0.52	8	2.00
	Western Gulf	9 100	301	3.3	26	11.58
Division totals		**65 000**	**358**	**0.55**	**48**	**7.46**
Lake Eyre–Bulloo	Georgina	1 600	–	–	1	–
	Diamantina	950	–	–	2	–
	Thomson	2 350	–	–	12	–
	Bulloo	1 100	–	–	2	–
Division totals		**6 000**	**–**	**–**	**17**	**–**
Murray–Darling	Paroo–Wallam Creek	1 400	–	–	10	–
	Condamine–Balonne	1 500	261	17.4	162	1.61
	Border Rivers–Moonie	2 850	336	11.8	22	15.27
Division totals		**5 750**	**597**	**10.4**	**194**	**3.08**
Southern Coastal	Gold Coast	1 700	235	13.8	381	0.62
	Brisbane	1 350	1 846	137	1 104	1.67
	Sunshine Coast	2 300	252	11.0	125	2.02
	Mary	2 300	133	5.8	58	2.29
	Burnett–Kolan	2 900	1 327	45.8	100	13.27
	Curtis Coast	1 500	315	21.0	40	7.88
Subdivision totals		**12 050**	**4 108**	**34.1**	**1 808**	**2.27**
Central Coastal	Fitzroy	7 100	1 752	24.7	147	11.92
	Shoalwater Bay–Sarina	3 700	63	1.7	55	1.15
	Pioneer–O'Connell	2 650	10	0.38	19	0.53
	Proserpine	1 400	500	35.7	10	50.00
	Don	700	–	–	10	–
	Burdekin–Haughton	10 850	2 040	18.8	39	52.31
	Ross–Black	1 100	420	38.2	112	3.75
Subdivision totals		**27 500**	**4 785**	**17.4**	**392**	**12.21**
Northern Coastal	Herbert	5 000	–	–	18	–
	Tully–Murray	5 300	212	4.0	22	9.64
	Johnstone	4 700	–	–	8	–
	Mulgrave–Russell	4 200	45	1.1	73	0.62
	Barron	1 150	407	35.4	27	15.07
	Mossman–Daintree	4 250	95	2.2	7	13.57
	North-East Cape York	19 100	–	–	3	–
Subdivision totals		**43 700**	**759**	**1.7**	**158**	**4.80**
Queensland totals*		**160 000**	**10 607**	**6.6**	**2 617**	**4.05**

*Excluding offshore islands
(Source: Adapted from DPI 1993a)

Table 4-8 Estimated water use as a percentage of total water available in 1991–92

Sector	ML withdrawn	ML withdrawn per person[a]	Percentage of total withdrawn	Withdrawal as percentage of average annual runoff[b]
Agriculture:				
irrigation	2 100 000	0.722	65	1.313
stock and rural domestic	448 000	0.154	14	0.280
Urban	560 000	0.193	17	0.350
Industry (including mining)	92 000	0.032	3	0.058
Power generation[c]	43 000	0.015	1	0.027
Totals	**3 243 000**	**1.116**	**100**	**2.027**

[a]Based on an estimated Queensland population of 2 906 800 at 30 June 1990
[b]Based on an average annual runoff of 160 000 000 ML
[c]Figures exclude water that is available for reuse.
(Source: DPI 1993b)

Ecosystems. The stated goal for providing water for the environment is to sustain, and where necessary restore, ecological processes and biodiversity of water-dependent ecosystems (Commonwealth of Australia 1996).

The principles state that providing water for ecosystems should be on the basis of the best available scientific information on the water regimes that are necessary to sustain the ecological values of water-dependent ecosystems. Currently, information is lacking on how much water is required, how any releases should be timed and how to manage the quality of water released from storages.

To determine the ecologically sustainable level of water diversion, it is essential that considerably more research be carried out to improve our understanding of environmental water requirements. The Commonwealth's National River Health Program will provide funding to assist in the provision of long-term scientifically determined environmental flow requirements and an understanding of consistent methods for determining adequate environmental flows.

Indicators

Total percentage of flow diverted by catchment and division

Total storage volume per person by catchment, by division and statewide

An estimated 2 percent of Queensland's average annual rainfall runoff is collected in existing storages. The capacity of major storages is almost 7 percent of average annual rainfall. The amount of total annual flow diverted each year varies according to rainfall and water consumption. Figures for catchment and division major storage capacities as a percentage of average annual runoff are given in table 4-7.

Extraction

Extraction is the withdrawal of water for agriculture, mining, industry or urban sectors.

Under the *Water Resources Act 1989*, Queensland's waters are allocated through a system of licences issued by the Department of Natural Resources (DNR). These licences apply to users of regulated and unregulated watercourses, in declared groundwater areas and in irrigation areas.

Applications for licences to obtain water (apart from in irrigation areas) have historically been considered in relation to availability of supply, generally on a 'first come, first served' basis. Allocation continues until the available resource shows signs of stress, then restrictions are implemented. In regulated watercourses, in irrigation areas and in groundwater areas, water entitlements are allocated in accordance with the system yield. Entitlements can vary from year to year by announcement, depending on the amount of water available at the start of the water year.

This system is being replaced gradually by two processes developed by DNR. These are water management planning (WMP) and water allocation and management planning (WAMP) processes. These are described in more detail in the 'Response' section of this chapter.

Indicators

Water withdrawal by agricultural, industrial, mining and urban sectors

Water withdrawal for irrigation by crop type

Water withdrawal by industry type

Total water withdrawal as a percentage of average annual runoff

Nearly 80 percent of water diverted in Queensland is used for agricultural purposes. The urban sector, including industries that use urban sources of water, uses approximately 17 percent of diverted water. Estimated percentages of withdrawals

DNR

Irrigation boom: part of a large-scale irrigation system of water by sector are shown in table 4-8. Table 4-9 shows area of irrigated agriculture by crop type. Information on water withdrawal by industry type is not at present available on a statewide basis.

The mean annual discharge of Queensland rivers is approximately 159 million ML (DPI 1993b). Only about 2 percent of Queensland's median annual runoff is currently being diverted by approximately 200 artificial storages, each with a capacity of more than 1000 ML. Based on historical records, more than 30 percent of that total is available each year for all uses (QWRC 1989).

A further estimated 700 000 ML is pumped from unregulated streams each year by private operators.

Indicators

Total water withdrawal per person

Percentage of water withdrawn from groundwater and surface waters

Quantity of water withdrawn by major groundwater system

Recharge of major groundwater systems

Queensland's total water use in 1991–92 was 3 243 000 ML. Based on a population of 2 906 800 at 30 June 1990, the withdrawal per capita was 1.1 ML a year, or more than 3000 L a day.

Table 4-10 shows sources of irrigation water used in Queensland. Groundwater provides about 44 percent of all water used in Queensland (DPI 1993b). Irrigation accounted for 54.4 percent of groundwater use, while stock and rural domestic (35.4 percent), urban supply (3.8 percent) and industrial/mining (6.4 percent) sectors make up the balance of groundwater use (DPI 1994).

The most extensive groundwater system in Queensland is the Great Artesian Basin (GAB), which provides the bulk of water to many inland areas of Queensland (figure 4-5). Excessive water withdrawals and uncontrolled bores from the GAB are believed to have reduced flows to its springs significantly, and have reduced water levels by up to 120 metres in some locations since the bores were first drilled. About three-quarters of the 240 spring groups recorded are now no longer flowing. The remaining active springs have substantially reduced flows (Wilson 1995).

Groundwater recharge is the downward flow of water through soil and underlying rock to a saturated zone known as an aquifer. Recharge occurs through natural processes such as rainfall and infiltration from watercourses, and through artificial means such as downward leakage from irrigation schemes and diversion of water from surface storages to weirs and channels.

In large groundwater systems such as the GAB, water extracted today could have entered the aquifer many thousands of years ago. The information on recharge rates in table 4-11 is based on estimates derived from mean annual rainfall and local geology and topography (DNR 1996a). Much of this recharge is in dispersed aquifers with little overall yield, and low individual bore yield.

Table 4-9 Area of crops, pastures and horticultural plantings irrigated in Queensland, 1996–97

	Area irrigated (ha)
Sugarcane	172 267
Pastures	47 748
Cereals	30 753
Vegetables	23 398
Fruit	22 535
Grapevines	822
Other crops	106 252
Total	**403 775**

(Source: ABS 1999)

Table 4-10 Area of crops, pastures and horticultural plantings irrigated by Queensland statistical division, 1996–97

Statistical division	Area irrigated (ha)
Moreton and Brisbane	37 190
Wide Bay–Burnett	75 319
Darling Downs	73 904
South-West	23 246
Fitzroy	34 733
Central West	255
Mackay	58 268
Northern	78 259
Far North	22 381
North West	220
Queensland	**403 775**

(Source: ABS 1999)

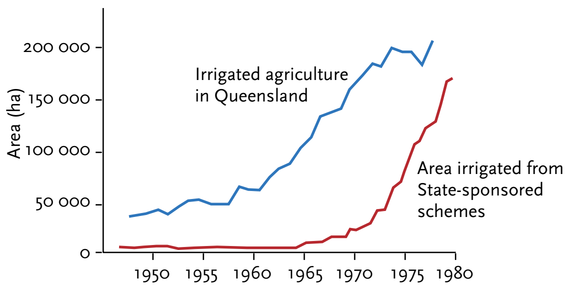


Figure 4-3 Irrigated agriculture in Queensland
(Source: Powell 1991)

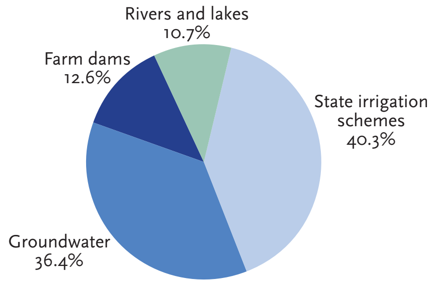


Figure 4-4 Sources of irrigation water used in Queensland
(Source: DPI 1994)

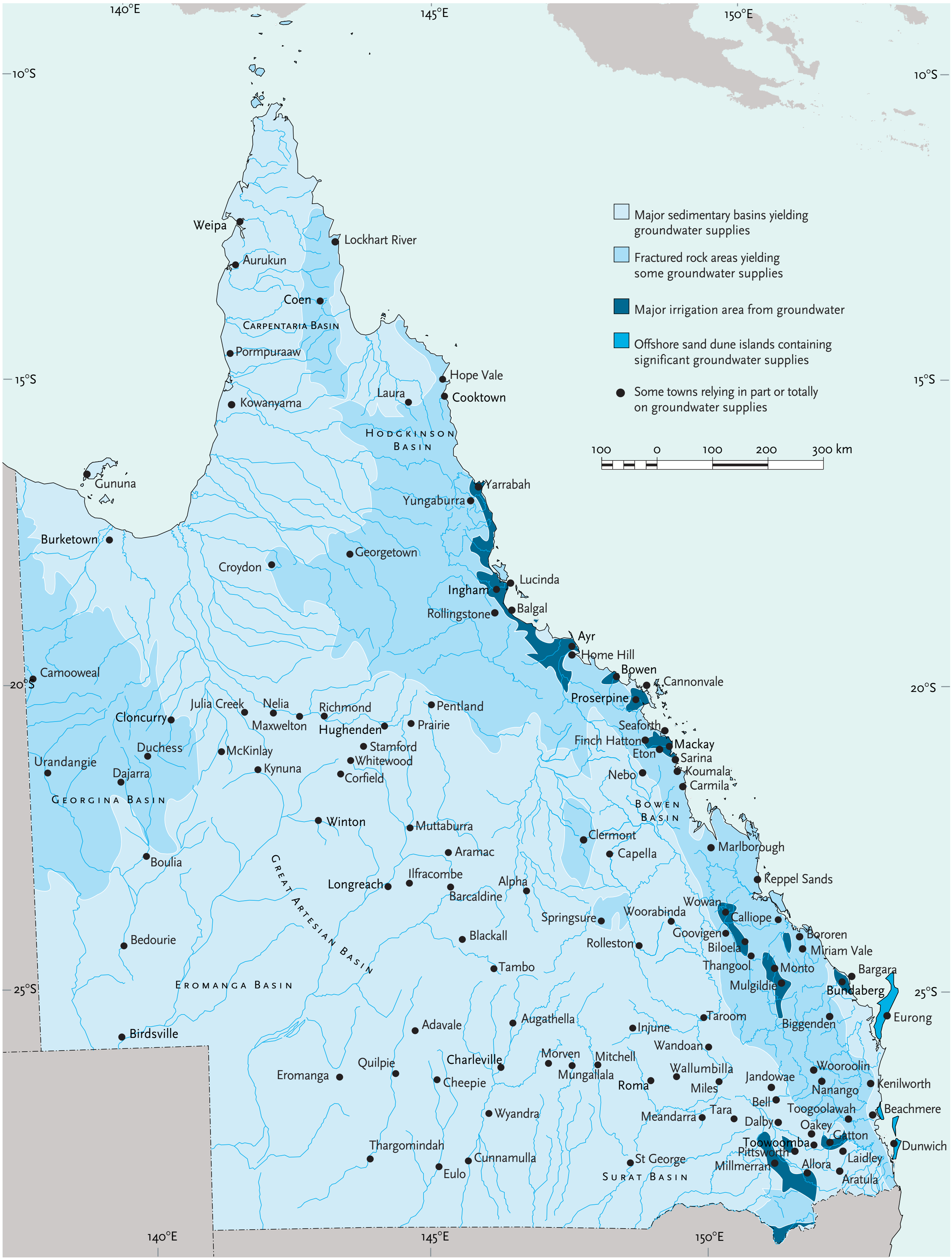


Figure 4-5 Queensland groundwater sources
(Source: DNR)

Table 4-11 Estimated average annual recharge in major groundwater systems in Queensland

Catchment	Average (ML/year)
Western Gulf	2 233 600
Fitzroy	1 460 000
Burdekin–Haughton	1 212 900
West Cape York	895 070
Sunshine Coast	554 450
North-East Cape York	549 600
Burnett–Kolan	465 500
Condamine–Balonne	458 600
Eastern Gulf	452 500
Flinders	414 600
Shoalwater Bay–Sarina	240 500
Border Rivers–Moonie	235 820
Gold Coast	213 800
Herbert	206 000
Brisbane	177 700
Georgina	177 600
Thomson	114 000
Diamantina	110 600
Mitchell	110 200
Curtis Coast	92 640
Ross–Black	73 400
Tully–Murray	65 400
Pioneer–O'Connell	55 000
Don	39 000
Warrego–Paroo	36 600
Johnstone	36 100
Mulgrave–Russell	33 500
Mary	28 750
Bulloo	23 500
Mossman–Daintree	16 200
Proserpine	15 600
Barron	13 100
Total recharge	**10 811 830**

(Source: DNR)

Indicator

Changes to groundwater table

Groundwater levels can vary widely, depending on natural and human causes. Both rising and falling groundwater levels can have undesirable environmental effects. Falling levels indicate that the resource is being depleted more rapidly than the aquifer is recharging. Rising groundwater levels can dissolve underground salt deposits. Induced salinity can occur when changes in the level of the watertable bring salts to the soil surface. Evaporation can increase salt concentration of these soils further.

Salt-affected land is prone to erosion and is unable to support productive vegetation (DPI 1993b). An estimated 14 000 ha of land in Queensland is salt-affected. The Condamine–Balonne, Brisbane, Mary, Burnett–Kolan, Curtis Coast, Fitzroy and Burdekin catchments contain land of moderate to very high salinity.

Rising groundwater levels can also introduce contaminated or poor-quality groundwater into adjoining streams and wetlands. Data on groundwater levels are shown in figures 4-6 and 4-7.

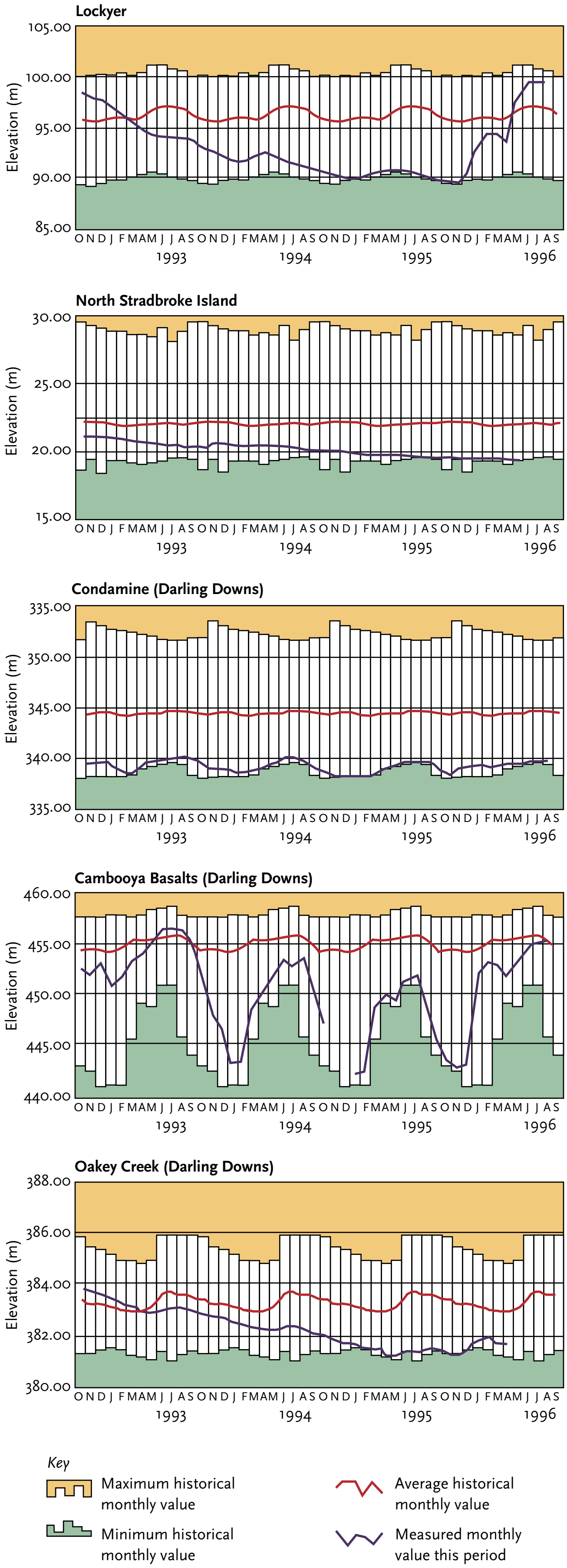
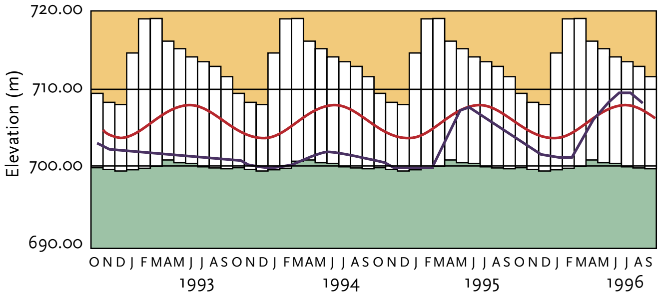
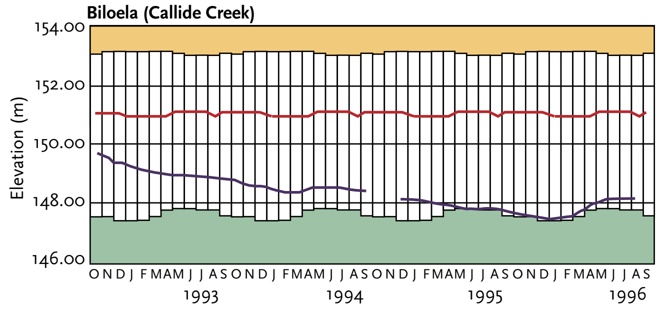


Figure 4-6 Monthly groundwater storage variation in major shallow groundwater areas, 1992–96, in selected parts of Queensland. Maximum, minimum and average historical monthly values are shown for comparison. Gaps on some trend lines indicate that data were not collected.
(Source: DNR)

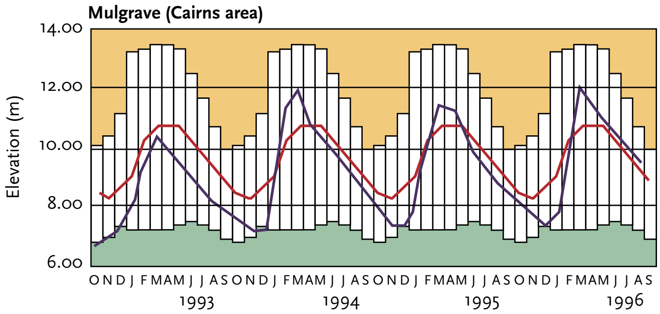
Atherton



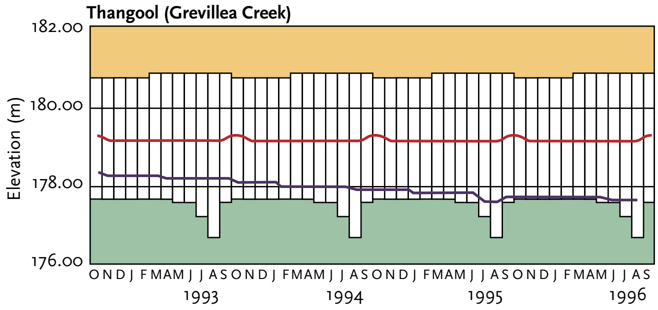
Biloela (Callide Creek)



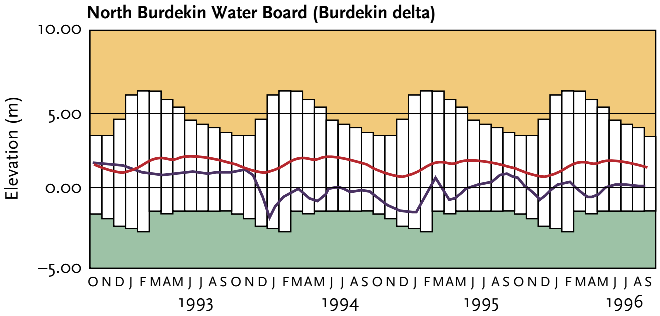
Mulgrave (Cairns area)



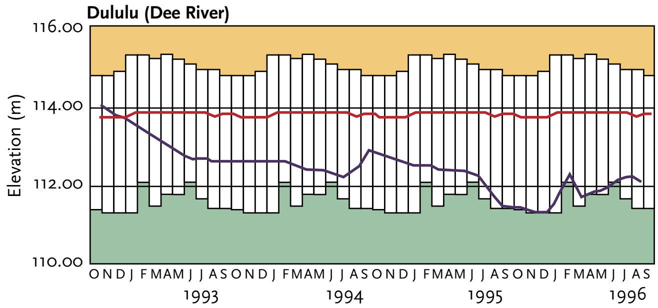
Thangool (Grevillea Creek)



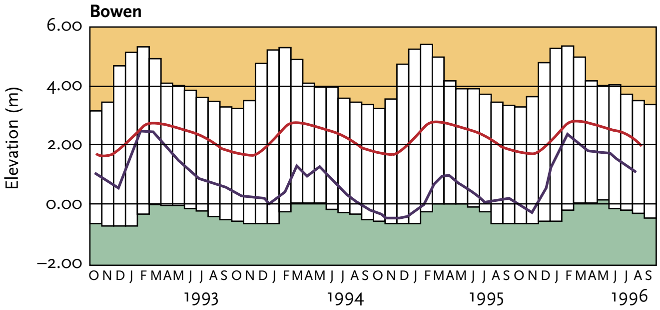
North Burdekin Water Board (Burdekin delta)



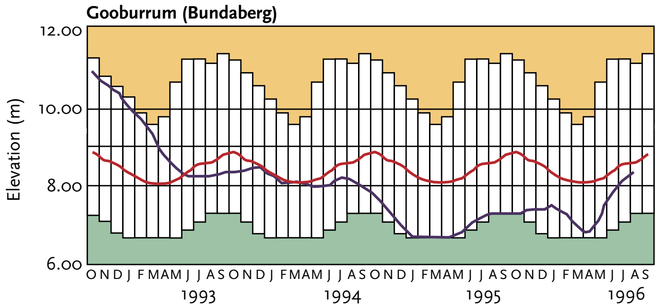
Dululu (Dee River)



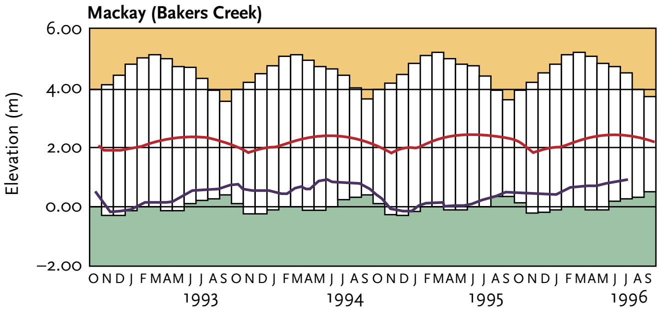
Bowen



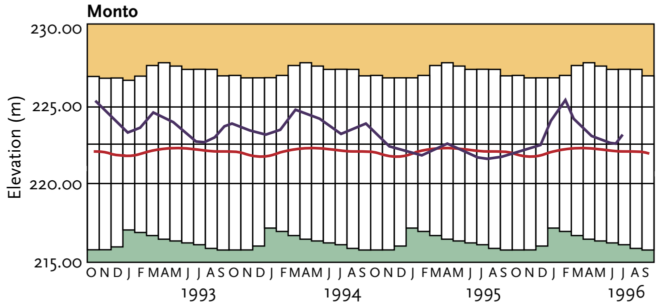
Gooburrum (Bundaberg)



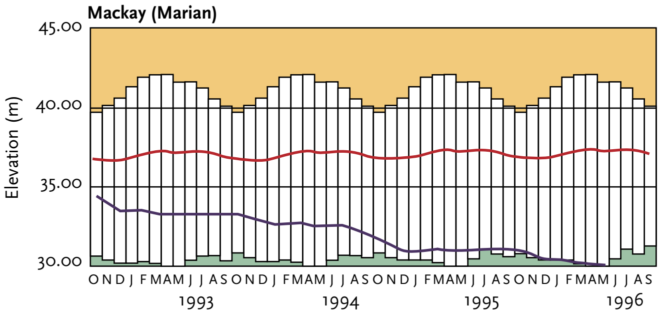
Mackay (Bakers Creek)



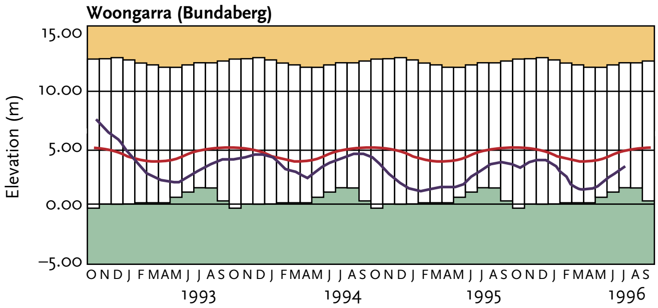
Monto



Mackay (Marian)



Woongarra (Bundaberg)



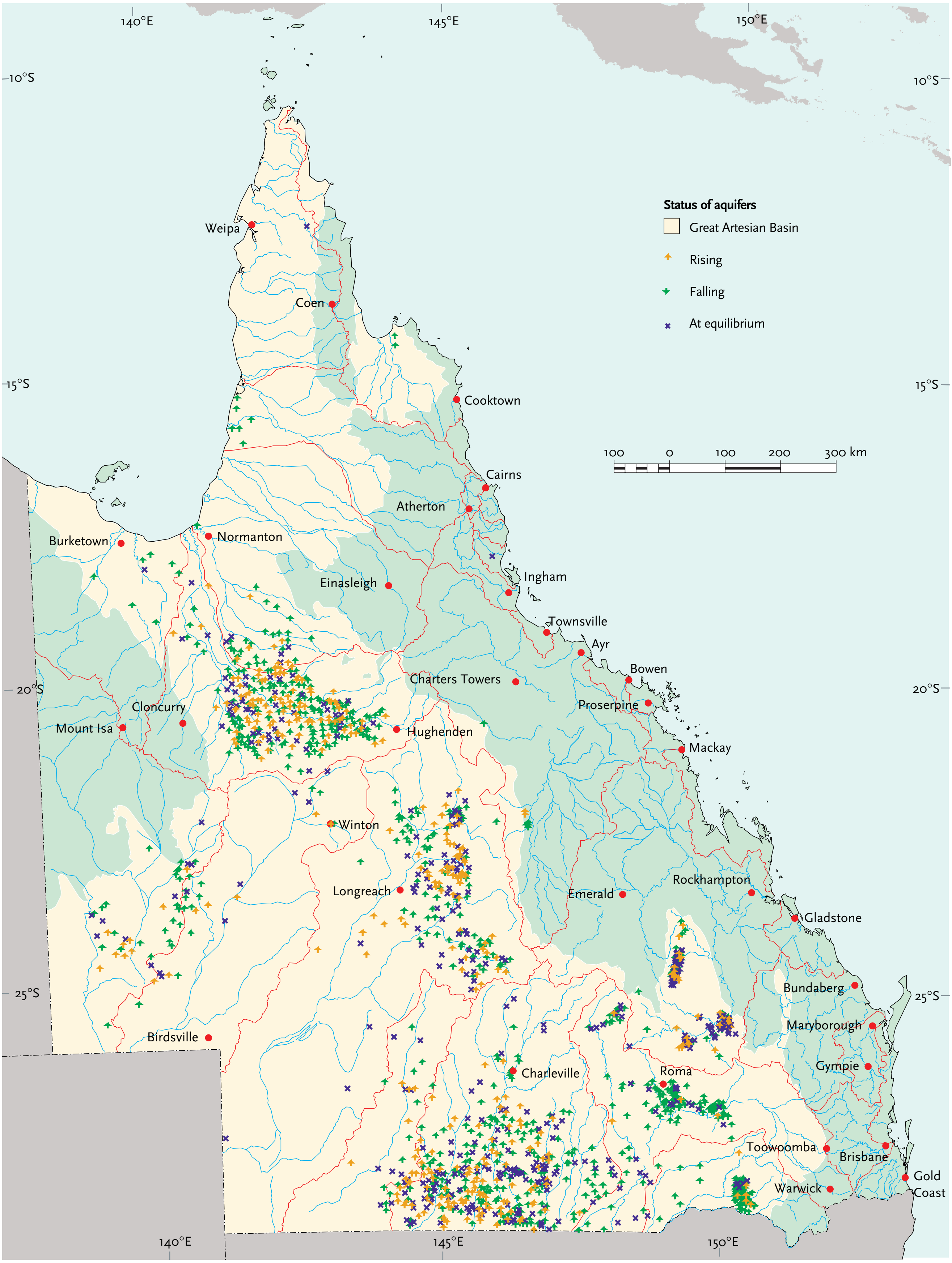


Figure 4-7 Location and status (rising, falling, at equilibrium) of selected aquifers in the Great Artesian Basin in Queensland
(Source: DNR)

Table 4-12 Number of incidents of hazardous materials reported spilled or dumped in Queensland by year

Year	Number
1993–94	115
1994–95	127
1995–96	94
1996–97	88

(Source: DES)

Incidents

The term 'incidents' refers to reported dumping and accidental releases of hazardous materials. Accidental and intentional releases of hazardous materials can occur despite precautions and regulations designed to prevent them. While the unpredictable nature of these incidents makes response procedures difficult to design, contingency plans can be adopted by State and local agencies to minimise their immediate and long-term impacts on the environment. Most incidents have the potential to affect local water supplies through runoff or leaching.

Indicators

Reported incidents where hazardous materials were spilled or dumped per year

Numbers of hazardous material incidents reported to the Department of Emergency Services each year between 1993 and 1997 are shown in table 4-12.

Introduced, translocated and nuisance species

Indicators

Proportion of catchments affected by introduced or nuisance species by species

Incidence of introduced and nuisance species

Introductions of plant and animal species into Australia have occurred frequently since the arrival of European settlers (see tables 4-13 and 4-15). Acclimatisation societies actively imported plants and animals between 1862 and 1896. The number of exotic fish species reported from Queensland waters is at least 27 (Arthington and McKenzie 1997; QFMA 1996a; Webb, A., pers. comm.; Zeller 1998). At least 11 of these have established self-sustaining feral populations (table 4-13).

Large-scale mapping of introduced and nuisance species is being undertaken by the Department of Natural Resources. Information on five terrestrial species has been compiled statewide. Their distributions are given in chapter 7, 'Biodiversity'.

Introduced animals

The mosquitofish (*Gambusia holbrooki*) is one of the many fish species brought in as an aquarium fish. From the 1920s onwards it was released for controlling mosquitoes. As well as affecting native fish species through competition and predation, the mosquitofish has been shown to have significant effects on invertebrate species other than mosquitoes (Lloyd 1990).

Aquatic invertebrates have been inadvertently introduced into Australia through aquaculture and aquarium releases. Their impact on native species and the environment is not well understood (Arthington and Blühdorn 1995). Snail species from the family Lymnaeidae are known to be intermediate vectors for the mammalian liver fluke which can affect sheep and cattle. Large populations of the snail *Potamopyrgus antipodarum* have caused problems in southern Australia by building up large populations in water pipes and distribution systems (Ponder 1988).

Introduced and translocated Crustacea have caused water quality deterioration, habitat alteration and displacement of indigenous species (Welcomme 1988). The burrowing behaviour of the Louisiana red crayfish has caused extensive damage to earthen irrigation structures and aquaculture ponds in many areas where it has been introduced. Yabby burrows in the banks of billabongs have been blamed for bank destabilisation and the collapse of riparian trees in the Northern Territory (Arthington and McKenzie 1997).

Translocated animals

Translocation of freshwater fish species has been common practice in Queensland since the early days of European settlement. Originally, deliberate translocation was used to expand natural distributions of native fish to artificial impoundments for recreation. More recently, translocation has also occurred through escape from aquaculture facilities. Detrimental effects of translocating fish are similar to those from introduced species: increased predation and competition, the spread of disease and reduction in genetic diversity (QFMA 1996a). Native fish are also more accessible than imported fish, allowing individuals to bypass the necessity to obtain permits or follow quarantine procedures.

Table 4-13 Exotic fish species with established self-sustaining feral populations in Queensland, reasons for their introduction and dates of initial/major introduction into Australia

Species	Common name	Reason	Date
Carassius auratus	Goldfish	Ornamental	1876
Cyprinus carpio	European carp	Ornamental/aquarium	1850–80, 1960–64
Gambusia holbrooki	Eastern gambusia, mosquitofish	Aquarium/biological control	1926
Misgurnus anguillicaudatus	Oriental weatherloach	Aquarium/ornamental	1984
Oreochromis mossambicus	Mozambique mouth brooder, tilapia	Aquarium/ornamental	1978(?)
Poecilia latipinna	Sailfin molly	Aquarium/ornamental	1969
Poecilia reticulata	Guppy	Aquarium/ornamental	1965
Salmo trutta	Brown trout	Acclimatisation	1864
Tilapia mariae	Black mangrove, Niger cichlid	Aquarium/ornamental	1978
Xiphophorus helleri	Swordtail	Aquarium/ornamental	1965
Xiphophorus maculatus	Platy	Aquarium/ornamental	Unknown

(Source: Arthington and McKenzie 1997)

Table 4-14 Translocated fish in Queensland inland waters, reasons for their translocation and approximate dates when they became self-sustaining

Species	Common name	Reason	Date
Acanthopagrus berda	Pikey bream	Unknown	By 1996
Amniataba percoides	Banded grunter	Unknown	Mid-1980s
Arias sp.	Fork-tailed catfish	Unknown	By 1990
Arias midgeleyi	Midgeley's catfish	Unknown	By 1990
Bidyanus bidyanus	Silver perch	Accidental/unknown	Recent
Glossamia aprion	Mouth almighty	Unknown	Mid-1980s
Hephaestus fuliginosus	Sooty grunter	Recreational/unknown	1980s
Hypseleotris gallii	Firetailed gudgeon	Unknown	By 1990
Kuhlia rupestris	Jungle perch	Unknown	Unknown
Lates calcarifer	Barramundi	Accidental/unknown	By 1990
Leiopotherapon unicolor	Spangled perch	Unknown	1980s
Maccullochella macquariensis	Trout cod	Unknown	Unknown
Maccullochella peeli	Murray cod	Unknown	By 1990
Macquaria ambigua	Golden perch	Accidental/unknown	1980s
Macquaria australasica	Macquarie perch	Unknown	Unknown
Macquaria novemaculeata	Australian bass	Unknown	Unknown
Melanotaenia splendida	Rainbowfish	Unknown	By 1990
Nematolosa erebi	Bony bream	Recreational/unknown	Mid 1980s
Neoceratodus forsteri	Queensland lungfish	Preservation	1865
Oxyeleotris lineolatus	Sleepy cod	Recreational	1980s
Porochilus rendahli	Rendahl's catfish	Unknown	By 1990
Scleropages jardinii	Gulf saratoga	Unknown	By 1990
Scleropages leichhardti	Saratoga	Unknown	By 1990
Strongylura krefftii	Freshwater longtom	Unknown	Unknown
Tandanus tandanus	Freshwater catfish	Unknown	Recent
Toxotes chatareus	Archerfish	Unknown	Mid-1980s

(Source: Webb, A. pers. comm.)

Very little information is available on the frequency, location and timing of such translocations. At least 26 native fish species have been translocated in Queensland, primarily for recreation (table 4-14). There have also been apparently deliberate, though unauthorised, releases for unknown reasons.

Introduced plants

Aquatic plants have been introduced into Australia intentionally as ornamental and aquarium plants, and inadvertently through ship ballast water (table 4-15). Warm waters, an abundance of sunshine and a lack of natural predators have permitted many introduced aquatic plants to multiply unchecked in Queensland.

Alligator weed can grow in water or soil. It can form dense mats up to 3 metres thick over open water and can be easily spread from small fragments of stem. It is a major threat to irrigated crops, wetlands and river systems in Queensland and is a declared weed.

Rubber vine can be found along all watercourses north of Bundaberg, extending into the Gulf Country. It thrives in dry tropical areas, both as a common component of the fringing vegetation of streams and on floodplains that have a high watertable. It climbs over and smothers tall trees and can extend into run-down pastures. Its thickets along watercourses can be so dense as to be impenetrable, restricting access to water by livestock (see chapters 3, 'Land', and 7, 'Biodiversity'). Rubber vine is highly toxic to cattle, goats, sheep and horses, yet because it is unpalatable it rarely causes stock losses unless other feed is scarce.

Salvinia grows rapidly in nutrient-rich conditions, having been known to double its weight in 2.2 days. It can form large, thick mats that completely cover water storage areas. It is often found where runoff from agricultural lands, managed forests and urban areas increases the nutrient load of the aquatic system. Dense growth can restrict navigation, fishing and recreation and has been known to interfere with pumping for irrigation and drinking. Light penetration, oxygen levels and the pH of infested waters can be reduced, while the weed mass can act as a harbour for disease vectors. Salvinia may become established in rice fields during irrigation and compete directly with the crop.

Water hyacinth has become a serious weed in tropical, subtropical and warm temperate regions worldwide. It is

Water hyacinth choking a lagoon

Griffith University (AES)

Salvinia

common in the coastal rivers of Queensland and has been found in rivers west of the Great Dividing Range. It grows rapidly in still or slow-flowing freshwater bodies such as dams, streams, drains and irrigation channels, making the water impassable to boats and swimmers. Propagation can be so rapid that an infestation can double its mass in a week. High rates of transpiration through leaves can cause up to four times the normal loss of water from storages during summer, while dense growth removes oxygen from the water and reduces the surface area available for waterbirds. The plants can also foul hydro-electric generators, choke irrigation systems and pumps, and reduce water flow.

Water lettuce has the potential to be a very serious pest in Queensland. It spreads rapidly over the entire surface of lakes, rivers and canals, reducing light penetration, oxygen levels and pH, while its leaves provide shelter and a breeding habitat for mosquitoes. When the growth of water lettuce is dense, waterfowl and recreational access can be restricted. Pumping rates for irrigation equipment may be affected, increasing the time and energy required to supply water to irrigated crops.

Nuisance species

Nuisance species are naturally occurring organisms that become a nuisance when they overpopulate their environment due to favourable conditions.

Indicators

Reported number of algal occurrences for report period by catchment

Blue-green algae are a naturally occurring group of aquatic micro-organisms that can grow to nuisance levels when adequate concentrations of the nutrients nitrogen and phosphorus, abundant sunlight, moderate turbidity and calm water conditions occur in freshwater supplies.

Algal blooms result in a decline in water quality, while the decomposition of large numbers of dead cells depletes oxygen from water and can lead to fish kills. Some species of blue-green algae produce toxins that pose potential health problems in people and animals. Stock deaths associated with blue-green algae have been widely reported in Australia and throughout the world.

Blue-green algal blooms have been recorded in Australia since the 1830s, but were not considered a serious problem in Queensland until 1991–92 when simultaneous blooms occurred in several water storages. As a result, storages were closed for many months, restricting access for recreation and, in a few cases, domestic water supply. This coincided with a major drought across eastern Australia and a 1000 km bloom in the Darling River, which receives flows from several of Queensland's inland streams (see box 'Blue-green algal blooms').

Recently, a regular program of monitoring selected storages has been implemented. The numbers of occurrences of significant levels of blue-green algae reported are shown in table 4-16 for each catchment by year. Reports within two weeks of one another in the same water body have been counted as one event.

Table 4-15 Introduced plants considered to pose a significant threat to wetlands in Queensland, with reasons for their introduction and approximate dates when they became self-sustaining

Species	Common name	Reason	Dates
Alternanthera philoxeroides	Alligator weed	Ballast water	1940s
Brachiaria mutica	Para grass	Biological control	1880
Cabomba caroliniana or *C. australis*	Cabomba, fanwort	Aquarium	Unknown
Cryptostegia grandiflora	Rubber vine	Ornamental	1860s
Echinochloa polystachya	Amity grass	Ponded pasture	1980s
Egeria densa	Dense waterweed	Aquarium	Unknown
Eichhornia azurea	Anchored water hyacinth	Unknown	Unknown
Eichhornia crassipes	Water hyacinth	Ornamental	1890s
Gymnocoronis spilanthoides	Senegal tea plant, temple plant	Aquarium	Mid-1970s
Hymenachne amplexicaulis	Olive grass	Ponded pasture	1980s
Lagarosiphon major/Elodea crispa	Oxygen weed	Aquarium	By 1977
Limnocharius flava	Yellow burr-head	Unknown	Unknown
Ludwigia peruviana/Jussiaea peruviana	Peruvian primrose	Ornamental	Unknown
Mimosa pigra	Giant sensitive plant	Unknown	Late 1880s
Parkinsonia aculeata	Parkinsonia, Jerusalem thorn	Shade	c. 1900
Pistia stratiotes	Water lettuce	Aquarium	1887
Pontederia rotundifolia	Tropical pickerel weed	Unknown	Unknown
Sagittaria pygmaea	Dwarf arrowhead	Unknown	Unknown
Salvinia spp.	Salvinia	Aquarium/ornamental	1950s
Trapa spp.	Water chestnuts	Unknown	Unknown

(Sources: Parsons and Cuthbertson 1992; DNR)

Blue-green algal blooms are a worldwide phenomenon with a long history. They have been recorded in Australia since the 1830s. A description of the lethal effects of blue-green algal toxins from the Murray River appeared in an 1878 edition of the journal *Nature* (Carmichael 1994). The potential scale of blue-green algal blooms came to world attention in November 1991 when a 1000 km bloom along the Darling River, New South Wales, became the largest recorded bloom in the world.


DNR

Algal bloom

Blue-green algal blooms are caused by a unique group of phytoplankton known as cyanobacteria. Cyanobacteria are microscopic, photosynthetic aquatic organisms naturally present in all surface waters in low numbers. Like plants, they contain the green pigment chlorophyll, as well as other pigments which give them their characteristic blue-green colour. For this reason they have often been classified in the past as blue-green algae, the term by which they have become commonly known. Strictly speaking, however, they are not algae but primitive bacteria. They are believed to have played a major part in the early production of atmospheric oxygen some 3.5 billion years ago (Carmichael 1994).

The term 'algal bloom' originally referred to the sudden appearance of surface scum and discoloured water, but has been expanded to include any concentrations of phytoplankton sufficient to impair water quality (QWQTF 1992). Blue-green algal blooms create problems in affected waters. They can form unsightly, smelly scums on the surface and along the shore of water bodies. As the cells decay, they deplete the dissolved oxygen to levels that in extreme cases can cause fish kills. Their decay can also produce sulfurous compounds such as hydrogen sulfide, which impairs drinking and recreational water supplies. Some groups of blue-green algae produce metabolites that give the water pungent, earthy tastes and odours. A small number of strains produce toxins that can affect humans and livestock that drink contaminated water. The consumption of low doses of these toxins in drinking water is suspected of contributing to a high rate of human liver cancer in certain parts of China (Carmichael 1994).

Blue-green algae possess several characteristics that give them a competitive advantage over other types of phytoplankton (QWQTF 1992):

- Some species of blue-green algae are able to utilise atmospheric nitrogen dissolved in the water column. True algae require more complex forms of nitrogen that often have biological origins. This gives blue-green algae an advantage in situations where nitrogen concentration is low in relation to that of phosphorus.
- Blue-green algae are able to store phosphorus in excess of what is immediately required, sufficient to support a four- to eight-fold increase in cell mass without additional phosphorus inputs.
- Blue-green algae contain gas vacuoles that allow them to regulate their position in thermally stratified water bodies to optimise their temperature, light and nutrient environment.
- Some species produce thick-walled spores packed with food reserves, which are resistant to changes in temperature and can survive in sediments for several months or even years. These spores can act as a means of seeding other water bodies during flooding and, once these species develop, they are likely to re-establish in subsequent years.
- The production of toxins by some species of blue-green algae may reduce predation by phytoplankton feeders.

Strategies to reduce the incidence of recurrent algal blooms have focused on reducing the phosphorus input to affected surface waters. Phosphorus input to water bodies may come from point sources or non-point sources. Point sources are traceable to a particular concentrated effluent source such as sewage treatment works, intensive animal industries and irrigation drains. Phosphorus from these sources can be removed by treating polluted water before release, although this is expensive.

Non-point sources of phosphorus are those that are generated by runoff over a wide surface area such as diffuse agricultural, forest and urban drainage. Although the concentration of phosphorus might be relatively low in non-point runoff compared with a point source, the magnitude of runoff can make it the largest contributor of phosphorus in some catchments (Cullen 1983). Most phosphorus in non-point runoff is attached to suspended solids. To eliminate this source of phosphorus the runoff of suspended solids to surface waters must be stopped.

In water supplies with a history of phosphorus inputs the bottom sediments contain considerable amounts of insoluble phosphorus that can become available to algae when conditions are favourable. Even without phosphorus from new sources entering these waters, stored phosphorus might be sufficient to meet requirements of blue-green algae for several years (Hammock 1994).

In addition to adequate nutrient supplies, other factors influence the development of blue-green algal blooms. The most influential factors include temperature, turbidity, light penetration, streamflow, turbulence, flooding, evaporation and the depth, size and stratification of a water storage (QWQTF 1992). Water temperatures above 20°C give blue-green algae a competitive advantage over diatoms and green algae, although different blue-green genera have different temperature tolerances.

Since blue-green algae are photosynthetic they require light for survival. They can use low light intensities by absorbing light over a wide range of the visible spectrum. Suspended particles of clay, silt, organic matter and plankton in water can result in turbidity that reduces the light available for photosynthesis. Since blue-greens can compensate by rising to the water surface, they have an advantage over true algae in turbid water or low light conditions.

Moderately flowing or turbulent water generally reduces the incidence of algal blooms. The extra water movement might reduce the ability of the blue-green algae to optimise their position in the water column. Flowing water might also reduce blooms by continuously transporting algae downstream. If the export of cells is faster than the production rate, cell counts might not be able to reach bloom proportions. Storm events and surface runoff can increase the flow and turbidity of surface waters, but can also add nutrients. Flooding is an important factor in linking water supplies, and may help to spread blue-green algal cells and their spores.

Table 4-16 Number of reported algal occurrences in Queensland by catchment

Catchment	1992	1993	1994	1995
Thomson	0	0	0	1
Condamine–Balonne	20	14	5	4
Border Rivers–Moonie	3	0	0	0
Gold Coast	4	7	5	15
Brisbane	10	10	5	0
Sunshine Coast	0	0	0	2
Mary	0	6	6	0
Burnett–Kolan	6	13	5	2
Fitzroy	0	4	0	0
Shoalwater Bay–Sarina	0	2	0	0
Unknown	0	0	0	1
Totals	**43**	**56**	**26**	**25**

(Source: DNR)

Pollution by sector

Indicators discussed in this section deal with recurrent releases of pollutants into inland waters. These occur by intentional liquid waste disposal practices or as incidental runoff contaminated by the normal operations of certain activities.

Point sources of these pollutants are licensed and regulated through the *Environmental Protection Act 1994* if they originate from declared environmentally relevant activities. Non-point sources tend to be more difficult to identify and control, although they can be significant sources of water pollution (see box 'Stormwater contamination — urban non-point pollution'). The contaminants most commonly associated with each sector are identified as pressures ascribed to that sector.

Agriculture

Indicators

Tonnes of nitrogen and phosphorus fertilisers used by catchment or region

Tonnes of nitrogen and phosphorus fertilisers used by crop type

Tonnes of pesticides used by catchment or region

Tonnes of pesticides used by crop type

The importance of agriculture to Queensland's economy has brought about a heavy reliance on fertilisers and pesticides (see table 4-17). The Darling Downs area used the greatest concentration of artificial fertilisers in 1995–96, when 607 000 ha was fertilised, equivalent to 40 percent of the total fertilised land area (ABS 1998). Fruit cropping accounts for the highest fertiliser application rates, and vegetables and sugarcane are also relatively high (see table 4-18). Estimates of phosphorus and nitrogenous fertilisers used in catchments adjacent to the Great Barrier Reef are shown in figures 4-8 and 4-9.

Records on the total or regional amounts of pesticides used in Australia are not routinely available. An Australian Government report in 1990 on agricultural and veterinary chemicals indicated that of Australia-wide pesticide sales 67 percent of the total were herbicides, 22 percent were insecticides and 7 percent were fungicides (Australian Government 1990).

Estimates of pesticide use in the Condamine–Balonne catchment, based on an audit by Rayment and Simpson (1993),

Table 4-17 Estimated total area fertilised and amounts of fertiliser used annually

	1991–92	1993–94	1995–96
Area of crops artificially fertilised (ha)	1 026 000	1 032 000	1 523 814
Quantity of fertiliser used (tonnes)	381 000	407 000	409 481

(Sources: ABS 1994, 1996, 1998)

Table 4-18 Average fertiliser application rates (tonnes/ha) for selected crops grown in Queensland

	1991–92	1992–93	1993–94
Fruit	1.04	1.02	na
Vegetables	0.8	0.85	na
Sugarcane	0.68	0.66	na
All other crops	0.37	0.38	0.39

na=not available
(Sources: ABS 1994, 1995, 1996)

Table 4-19 Estimated use of pesticides per year in the Condamine–Balonne catchment area based on the DPI Infopest database. Listed values were calculated from recommended spray concentrations of active ingredient assuming an application rate of 1000 L/ha. Actual use may vary.

Pesticide type	Use (kg/year)
Herbicides	865 822
Insecticides	281 454
Fungicides	2 580
Veterinary drugs/treatment	1 400
Total pesticides	**1 151 256**

(Source: Adapted from Rayment and Simpson 1993)

Drift of pesticides from aerial spraying can be a source of contamination of adjacent water supplies.

are reported in table 4-19. These estimates were calculated from data supplied through the Infopest database and from land uses within the catchment. Infopest is maintained by DPI and contains information on all pesticides registered for use in Queensland. It also reports the registered uses for each pesticide and the usual application rates.

An investigation into the use of pesticides in the sugarcane industry found that 30 of the 40 pesticides registered were in common use (see table 4-20) (DPI 1996a). Pesticide use for purposes other than sugarcane production was not included.

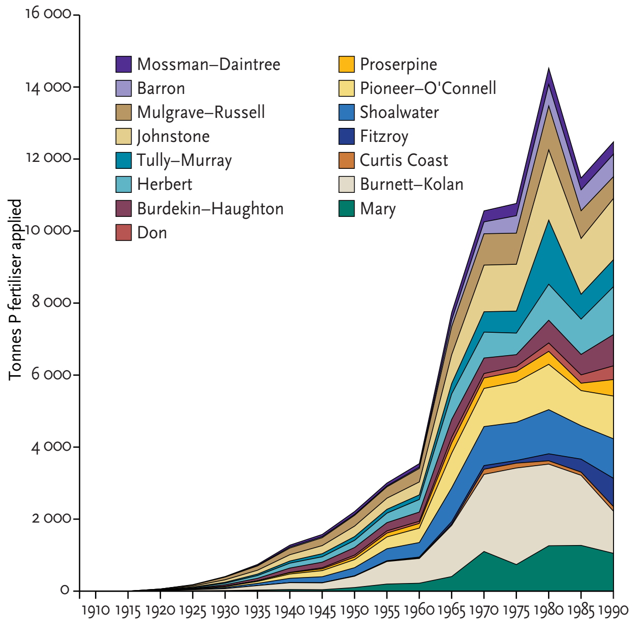


Figure 4-8 Estimated use of phosphorus fertilisers in river catchments adjacent to the Great Barrier Reef Marine Park, 1910–90
(Source: Based on data supplied in Pulsford 1993)

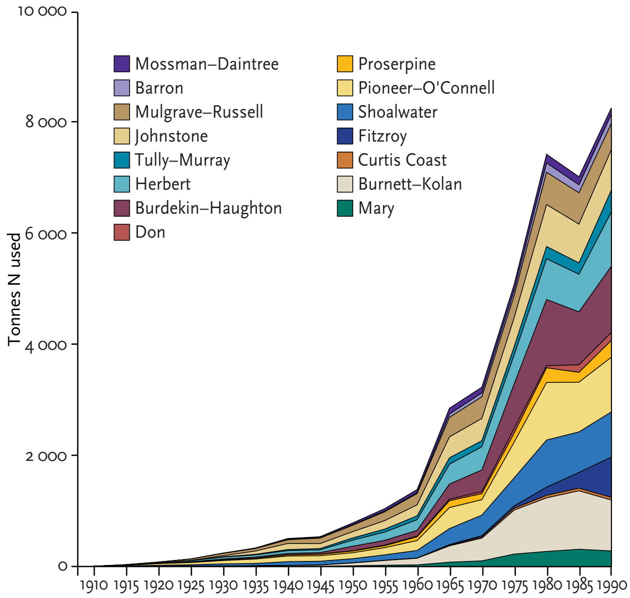


Figure 4-9 Estimated use of nitrogenous fertilisers in river catchments adjacent to the Great Barrier Reef Marine Park, 1910–90
(Source: Based on data supplied in Pulsford 1993)

Table 4-20 Estimated average pesticide application rates used in sugarcane production within the major cane-growing catchments (kg of active ingredient per year)

Pesticide	Totals
Aldicarb	1 582
Ametryn	75 982
Asulam	18 665
Atrazine	331 585
Chlorpyrifos	75 028
2,4-D	141 557
Diuron	197 446
Ethoprophos	4 751
Glyphosate	85 624
Hexazinone	5 595
Ioxynil	3 355
MEMC	2 291
MSMA	10 588
Paraquat	42 805
Pendimethalin	5 893
Prochloraz	562
Trifluralin	21 221

(Source: Based on data supplied in DPI 1996a)

Industry

Indicators

Units/tonnes of product by industry type

Total volume of waste produced by industry type

Data on manufactured goods produced in Queensland are not routinely available. An Australian Bureau of Statistics survey of manufacturing businesses in Queensland in 1992–93 found that 6187 establishments added value estimated at $8122 million in that year.

Many manufacturers undertake environmentally relevant activities which are required to be licensed or approved under the Environmental Protection Act. Some establishments are authorised to release treated liquid wastes directly to fresh or marine waters. In March 1996, 22 industrial wastewater treatment plants were authorised to release a combined maximum volume of 24 804 m^3 a day into inland waters.

Liquid industrial waste treated off-site can be discharged to sewer if it is suitable for treatment by a sewage treatment plant. The volume released to sewer is combined with domestic and commercial liquid waste, and incorporated into totals reported under 'Urbanisation'.

Non-sewerable liquid wastes are those that are toxic, corrosive, flammable or too thick or greasy to be dealt with by conventional sewage treatment. Those wastes that are also unsuitable for landfill require specialised treatment and disposal so that they will not cause environmental harm. Queensland has limited facilities for these wastes.

In south-east Queensland these wastes were accepted by Brisbane City Council's Willawong Liquid Waste Treatment Plant (see table 4-21) and Gurulmundi Secure Landfill. Willawong stopped receiving waste in November 1997 and officially closed in June 1998. Types of waste previously sent to that facility are now being treated by the private sector at licensed facilities in Queensland and elsewhere. Gurulmundi stopped receiving waste in September 1997.

Smaller waste disposal facilities operate at Townsville, the Gold Coast, Mackay and elsewhere for some categories of waste. Interstate facilities exist to accept some types of waste not provided for in Queensland. Some waste produced in Queensland is stored, awaiting the development of economically viable treatment and disposal options.

Mining

Statistics on waste produced by mining operations are not routinely available in Australia. Some ores are extracted from parent materials at the rate of a fraction of a percent of the

Table 4-21 Wastes received by the Willawong Liquid Waste Treatment Plant, 1992–93 and 1993–94. Typical industry sources are listed. The Willawong facility was closed on 30 June 1998 and wastes are now treated at licensed facilities in Queensland and elsewhere.

Waste type	Contents	Typical sources	1992–93	1993–94
Biodegradable	Grease trap wastes, sludges	Food outlets, grease trap treatment plants, chicken processors, glue and dye producers, tallow recyclers	7.7 ML	19.6 ML
Oily water	Waste water with high levels of BOD, salinity and potential contaminants such as lead	Garages, ship bilges	4.2 ML	5.0 ML
Phenolic and emulsified/concentrated oil	Waste waters contaminated with degreasers, decarbonisers and concentrated or emulsified oil that may be contaminated with lead or cadmium	Light fabrication industries, oil recyclers, machine shop and service station waste, liquid waste haulers, engineering workshops	2.3 ML	2.6 ML
Acid/alkali/metal wastes	Dilute and concentrated washings	Electroplaters, galvanisers, aluminium extruders, metal finishers, timber processors and paint manufacturers	8.4 ML	8.9 ML
Cyanide		Electroplaters	24 kL	45 kL
Pesticide, paint and solvent	Aqueous wastes contaminated with pesticides and aqueous solvents	Pesticide formulators, paint industry, laboratories and households	0.6 ML	0.4 ML
Solid	Petroleum waste refinery catalyst, foundry dust, contaminated soil	Petroleum industry, industrial sludges	3000 tonnes	2700 tonnes

(Source: Brisbane City Council 1995)

total material mined. The processes of mineral concentration and processing can produce large volumes of material that must be stored until used to back-fill areas during rehabilitation. Tailings and waste rock with trace amounts of extractable ore are seen as a potential resource for future processing. These materials are often retained on site and not subjected to normal rehabilitation processes so that access for reprocessing can be achieved readily in future. However, such stockpiles are subject to rainfall leaching and thus constitute a potential source of contamination if not properly managed.

Indicators

Tonnes of ore produced annually by mining type

Tonnes of overburden produced annually by mining type

Tonnes of tailings produced annually by mining type

Area of open-cut mining by catchment

Open-cut mining can cause water pollution problems if runoff and pit pumpings are not properly managed. Disturbed land is usually susceptible to wind and water erosion which can create high levels of suspended solids in nearby surface waters. In Australia, current mining practice requires water and waste materials to be retained within the mining lease and managed to minimise downstream pollution.

Table 4-22 shows the amounts of ore that were mined in Queensland from 1990–91 to 1995–96. Data on the amounts of overburden and tailings produced, as well as total area of open-cut mining, are not generally available.

Indicator

Number of licensed dredging operations

Dredging material from the bed of any waters is an environmentally relevant activity under the Environmental Protection Act. The Environmental Protection Agency licenses dredging operations mainly for extracting sand and gravel for the building industry and for products such as mineral sands and tin (table 4-23).

Instream and floodplain extraction of commercial sand and gravel resources occurs in the Upper Brisbane, Mid Brisbane, Lockyer and Pine Rivers subcatchments. Current extraction rates for the larger freshwater, instream and floodplain operations can be up to 40 000 m^3 a month.

Urbanisation

Sewage

Indicators

Volume of sewage effluent discharged to inland waters

Volume of sewage effluent discharged to inland waters per person

Percentage of total sewage effluent discharged to inland waters

Percentage of population served by sewage treatment plants

Percentage of treatment plants with primary, secondary or tertiary levels of treatment

Megalitres of sewage per person by urban area

Megalitres of sewage effluent released to inland waters with primary, secondary or tertiary levels of treatment

The Environmental Protection Agency issues licences for sewage treatment and wastewater facilities that discharge treated wastewater to water or land. At March 1996, 21 sewage treatment plants (STPs) were authorised to release effluent into Queensland's inland waters. See chapter 5 for coastal zone discharges. The total maximum volume of effluent authorised to be released was 47 489 m^3 a day, about 3.8 percent of the total authorised sewage effluent volume in Queensland, excluding overflows.

Table 4-22 Ore minerals produced in Queensland, in thousands of tonnes unless otherwise indicated

Ore type	1991–92	1992–93	1993–94	1994–95	1995–96
Bauxite	9 083	8 770	8 616	9 335	9 179
Black coal	84 085	85 301	85 739	94 496	93 763
Clays	1 382	1 529	1 605	1 498	1 192
Copper concentrate	702	827	838	749	1 007
Diatomite	1	1	0.8	0.9	0.8
Dimension stone	40	31	25	33	30
Dolomite	34	29	25	29	35
Gold bullion, gold concentrate (kg)	41 035	47 230	44 011	41 770	38 108
Lead concentrate	411	393	413	299	359
Limestone	2 369	2 432	2 485	2 596	2 519
Magnesite	180	246	284	218	288
Mineral sands	256	269	255	314	308
Nickel ore	826	259	200	222	3
Pearlite	3	3	4	4	6
Peat	2	2	1	2	2
Phosphate rock	–	–	18	–	–
Salt	237	262	238	318	224
Silica	2 020	2 421	2 494	2 864	3 055
Tin concentrate (tonnes)	71	83	79	52	82
Zinc concentrate	445	508	525	382	446
Zinc-lead concentrate	157	114	95	57	48

(Sources: ABS 1995, 1996, 1997, 1998)

The percentage of Queensland's population whose sewage receives treatment at STPs has been estimated to be between 82.5 and 87.5 percent. The portion of the non-coastal population served by plants discharging to inland waters is between 4.3 and 5.4 percent. Wastewater is more likely to be disposed of in inland areas by evaporation ponds or overland flow than by discharge to waters.

A 1992 survey of Queensland's STPs by the Department of Natural Resources found that 3.5 percent of final effluent was treated to a tertiary level, 95 percent to a secondary level and 1.5 percent to a primary level (DNR).

At March 1996, all STPs with environmental authorities permitting the release of effluent to inland waters provided secondary level treatment.

Table 4-23 Licensed dredging operations in inland waters by DEH region in 1997

Region	Number of licences	As at
Southeastern	4	17/03/97
Central Coast	8	30/09/97
Northern	5	23/10/97
Far Northern	2	30/06/96

Stormwater

Indicators

Megalitres of stormwater runoff by urban area

Tonnes of suspended solids in stormwater runoff by urban area

Percentage of impervious surface area by urban area

Flooding is a common physical occurrence which has benefits and costs for a community. The result depends on the interaction between the use and management of land and the physical characteristics of flooding — volume of floodwater, sediment load, height, rate of rise, period and velocity — as these characteristics apply to each location.

Impervious surfaces are areas of the ground that have been roofed, paved or otherwise compacted so water is unable to penetrate (see box 'Stormwater contamination — urban non-point pollution'). Urban and industrial catchments generally contain more impervious surfaces than agricultural and forested catchments. The degree of imperviousness has been used as an indicator of the level of urbanisation of a catchment (Griffin et al. 1980).

High levels of imperviousness result in increased total stormwater volume, higher peak discharge during storms and greater pollutant runoff loads. In addition, the time required for peak runoff to occur can be greatly reduced, exacerbating the potential for flash floods (SEAC 1996). High volumes and rates of urban stormwater runoff can also have an adverse effect on surrounding river habitats, causing increased bank and bed erosion and resultant downstream sedimentation (Pratt 1995). Queensland taxpayers spend an estimated $31 million a year on repairing damage from urban soil erosion and on sediment control. Reduced water penetration in urban areas also reduces the amount of recharge to underlying groundwater aquifers.

Figures for percentage imperviousness are not generally available for most local government areas in Queensland. Brisbane City Council initiated a study of three small catchments in the Brisbane area to evaluate the applicability of models developed in southern States of Australia and overseas to conditions in Brisbane (Bycroft et al. 1995). The Sandy Creek catchment in Indooroopilly is an established residential catchment in the western suburbs of Brisbane, covering 227 ha. Overall, the catchment was estimated to have 95 ha (42 percent) of impervious surfaces and 132 ha

Table 4-24 Estimated impervious areas in Oxley Creek subcatchments

Subcatchment number	Total area (ha)	Single largest land use (%)	Impervious area (ha)	Percentage impervious
1	2 212	Grasslands/parks and schools (29)	1 206	55
2	1 028	Dense urban (37)	620	60
3	2 438	Industrial/commercial (28)	1 502	62
4	4 111	Bushland (53)	976	24
5	6 709	Bushland (46)	1 413	21
6	4 174	Partially cleared bushland (36)	368	9
7	5 075	Bushland (74)	220	4
Totals	**25 747**		**6 306**	**24**

(Source: Kinhill Cameron McNamara 1996)

(58 percent) of pervious surfaces. Using the results of pollutant load relationships determined by 11 storm events, it was estimated that 95 tonnes of suspended sediment, 1.7 tonnes of total nitrogen and 0.2 tonnes of total phosphorus wash off the Sandy Creek catchment each year. Other catchments still under investigation are a mainly residential catchment and a forested site with no impervious surfaces.

As part of a report on the state of Oxley Creek catchment in Brisbane (Kinhill Cameron McNamara 1996), estimates were made of the percentage imperviousness of seven subcatchments adjacent to Oxley Creek (see table 4-24). Land use, soil profiles and vegetation cover were also reported for each subcatchment. Average water nutrient concentrations and turbidity measurements were included for selected sample sites in some subcatchments.

Further investigations of rainfall and runoff could provide valuable local data about the efficiency of rainfall penetration based on land use, soil type and vegetation patterns in each subcatchment.

Waste

Indicators

Tonnes of solid waste produced by urban area

Tonnes of regulated waste by broad category by urban area

The total solid waste produced in Brisbane in 1991 was estimated at 2 572 461 tonnes (RPAG 1993). A breakdown by category is presented in table 4-25. The population in this area was approximately 1 800 000 in 1991.

Regulated and hazardous waste management in Queensland has suffered in the past due to the lack of an integrated approach to dealing with waste, the lack of adequate facilities for industrial waste disposal and the wide disparity in the standard of municipal landfills.

Current controls over the storage, disposal and transport of industrial waste in regional areas are minimal. Surface and groundwater supplies can be threatened by releases of stormwater contaminated with waste, groundwater leachate from waste storage sites, accidental spillages and illegal dumping.

A regulated and hazardous waste survey for Queensland was commissioned by the Department of Environment and Heritage in 1997 (see chapter 8, 'Human settlements'). Its purpose was to quantify waste generated, transported, stored, treated and disposed of in the State.

Complementing the survey, the EPA is developing a waste tracking system to track the movement of regulated and hazardous waste within Queensland and interstate. All scheduled regulated and hazardous waste produced, transported or received in Queensland will require a waste tracking manifest to enable regulatory agencies to track it from production to disposal.

The waste tracking system is designed to be implemented as part of the Environmental Protection (Waste Management) Policy. This will establish legislative requirements for all aspects of regulated and hazardous waste management in Queensland and limit the types and amounts of these materials generated by industrial and commercial operations.

Table 4-25 Estimated tonnes of solid waste generated in Brisbane in 1991 by sector

Composition	Municipal	Domestic	Commercial	Industrial	Construction/demolition
Glass	51 822	25 308	30 958	8 125	–
Plastic	38 003	18 743	31 105	11 737	–
Oil	–	–	3 277	–	–
Paper	92 293	98 662	165 160	77 333	–
Non-ferrous metals	4 935	2 569	2 445	48	–
Ferrous metals	25 171	59 844	26 312	3 374	10 021
Organic	246 772	522 326	120 214	93 132	50 106
Other	34 548	223 867	109 552	43 834	340 722
Totals	**493 544**	**951 413**	**489 073**	**237 582**	**400 849**
Percentage of total	**19**	**37**	**19**	**9**	**16**

(Source: Adapted from data in RPAG 1993)

Recreation

Indicators

Number of boats using freshwater recreational areas
Number of visitors to freshwater recreational areas
Estimated freshwater fish catch by recreational fishers
Number of fish stocking programs

Recreational activities in freshwater areas can have significant impacts on downstream water quality. Swimming and wading can increase levels of suspended solids, turbidity, nitrogen, phosphorus and faecal coliforms in an affected water body (ACTFR 1996). Bank erosion can occur where riparian vegetation has been cleared to provide entrance points for swimming, fishing or boating. Disturbance of stream beds can destroy the habitat of resident wildlife.

The use of some consumer goods such as cleaners and the dumping of waste in or near water can not only affect water quality but also have a direct impact on wildlife.

The introduction of non-native fish and the stocking of native or non-native fish beyond natural production levels can cause long-term, irreversible damage to native wildlife (see 'Introduced, translocated and nuisance species').

The building of access and support facilities for tourism alters the nature of the environment being visited. Surveys of the impacts of recreational use on freshwater areas are rare in Queensland. A report on the effects of ecotourism in Wet Tropics streams made the following recommendations:

> *'There is an urgent need for almost all kinds of information about visitors to Wet Tropics streams and rivers and the nature of their use. Numbers of users and their patterns of use in space and time are urgently required…The nature of the activities undertaken and their differing impacts will also need to be documented. This information is vital for the effective application of management approaches.'* (ACTFR 1996).

This statement should be extended to apply to all freshwater areas that are visited for recreational purposes across Queensland.

The number of boats used in freshwater recreational areas is not known. However, 129 126 households in Queensland own at least one boat that is used for recreational fishing. An estimated 192 100 people fished in Queensland during the 12 months to September/October 1996, accounting for 1 728 900 days or part-days of fishing in the State's freshwater recreational areas. During this period, 49 400 people fished only in freshwater areas. An additional 52 600 people fished in salt and fresh water (QFMA 1996b).

Recreational use of inland waters can have significant impacts on water quality.

Limited data are available on visitors to freshwater storages. Estimates of the numbers of visitors to selected DNR water storages are shown in figure 4-10.

In 1986–87 the Queensland Government's Recreational Fishing Enhancement Program was created to develop recreational freshwater fisheries by stocking fingerlings of popular angling species (QFMA 1996b). Since then, approximately 15 million fingerlings have been released throughout the State, about half by the Queensland Government and half by some 70 fish stocking groups. Under the *Fisheries Regulation 1995*, any group wishing to stock State waters requires a fish stocking permit.

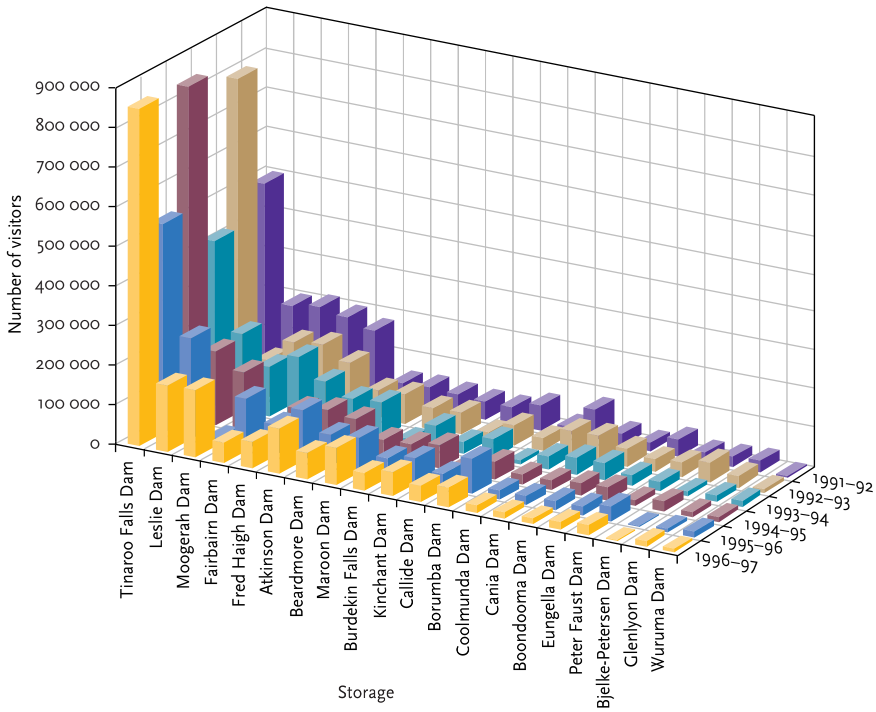


Figure 4-10 Estimated number of visitors to selected DNR water storages by year
(Sources: DPI 1995c, 1996b, 1997)

Table 4-26 Expenditure by river improvement trusts

Year	Capital works	Restoration of works	Maintenance of works	Interest and redemption	Administration	Other	Total
1994–95	$2,140,574	$335,663	$113,914	$1,003,301	$224,224	$148,839	$3,966,515
1995–96	$1,664,340	$292,277	$131,197	$950,039	$214,005	$42,271	$3,294,129
1996–97	$2,483,780	$96,171	$111,828	$1,087,185	$237,242	$75,309	$4,091,515

(Sources: DPI 1996c; DNR 1997d, 1997e)

River modification

Indicators

Number of river modification projects

Tonnes of sediment removed from river, wetland or floodplain

Area/length of river, wetland or floodplain affected by river modification

Length of river modified as a percentage of total length managed by each river improvement trust

River improvement trusts are statutory authorities under the *River Improvement Trust Act 1940*. Their objectives are to protect and improve the bed and banks of rivers; repair and prevent damage to the bed and banks of rivers; and prevent or mitigate flooding of land by floodwaters from rivers. Their primary role is to plan, design, finance, undertake and maintain stream improvement works for the benefit of the community within their river improvement areas. Sometimes these objectives conflict with ecological objectives.

Riparian vegetation binds bank soils and filters sediments and nutrients displaced from adjoining land during rainfall runoff. Channel management activities such as bank clearing, bank concreting and channel straightening can degrade water quality by removing the binding, filtering and trapping mechanisms of vegetation (McColl and John 1981).

Channelisation can also increase the speed and energy of the water movement in a river, leading to increased bank erosion (EEA 1995). Increased solar radiation due to loss of overhead vegetation can lead to increased light levels and higher water temperature, conditions that favour the growth of algae. Channelisation reduces the physical variability of banks and sediments, reducing the number and diversity of biological habitats.

Desnagging — removal of logs and wood debris from river beds — also reduces habitat and increases stream erosion and sedimentation.

Table 4-26 shows expenditure on river modification projects as defined by river improvement trusts. The expenditures are a compilation of individual reports submitted by the trusts to the Department of Natural Resources for the year ending 30 June. Details of projects undertaken are reported annually to the Department of Natural Resources.

The required data for river modification indicators are not currently being collected by most river improvement trusts.

Griffith University (AES)

Channelising can degrade water quality and habitat values but improve flood runoff in urban areas.

State

Indicators used to describe the state of inland waters fall into two broad categories — those associated with the quantity and those associated with the quality of water.

Water quantity indicators

The quantity of Queensland's water resource can be described using a variety of indicators. At less than statewide scales, these reflect variability in the amount of water that falls on catchments (affected by climate and weather patterns), the amount that runs into rivers (affected by catchment area and incident rainfall), and the amount that is held for longer periods in storages or groundwater reserves (affected by the extent of surface reservoirs or aquifers and the proportion of runoff captured or recharging the aquifer). This variability in water quantity makes water resource planning an increasingly crucial factor in development decisions. Future indicators will need to include both human and environmental water requirements.

Indicators

Total water storage capacity

Water storage capacity per person

Regional water storage by catchment

Bore/spring pressure

Total runoff from rivers (median annual)

Variability of river flows (maxima and minima)

Runoff of water per catchment/river

Variability of runoff by river (maxima and minima)

Average percentage of time rivers do not flow per year (historical data to be included to establish normal variation)

Incidence of flooding

Queensland has almost 200 water storages with capacities greater than 1000 megalitres. Data on water storage by catchment, drainage division and statewide are given in tables 4-7 and 4-27.

The Great Artesian Basin (GAB) is the most extensive groundwater resource in Queensland. Some early bores drilled into the GAB produced discharges of more than 10 ML a day each. Initial high flows and pressures decreased rapidly as numerous bores were drilled (see figure 4-11). In 1914 the total flow from bores in the GAB peaked at 750 000 ML/year. However, this rapidly declined due to uncontrolled bores and earth drain systems. In some areas a pressure drop of over 80 metres of head has occurred in the 100 years since development began (DNR).

The rate of decline of artesian pressure is slowing as the basin approaches a steady state between recharge — the ability of the aquifer to transmit water — and decreasing flow from

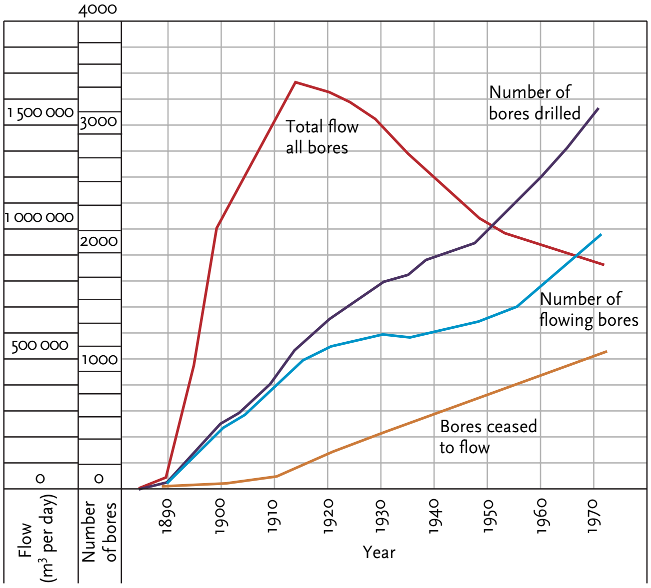


Figure 4-11 Number of bores drilled, flowing bores and non-flowing bores, and total flow to all artesian bores in Queensland
(Source: AWRC 1975)

existing bores. In some areas where efforts have been made to rehabilitate or cap uncontrolled bores, artesian pressure and discharge have increased. Of 1437 bores measured in the GAB, 347 (24 percent) are rising, 376 (26 percent) are at equilibrium and 714 (50 percent) are still falling (DNR 1996a).

The mean annual discharge of all Queensland's rivers has been estimated at approximately 160 million ML (QWRC 1989). Up-to-date information on variability of river flow in Queensland is not available statewide due to a lack of gauging sites in rural areas, particularly in the Western and Far Northern regions.

DNR

Water flowing from a bore

Table 4-27 Water storage data by major storages by catchment and region

Drainage division/ subdivision	Catchment	Percentage of average flow diverted	Population ('000)	Total storage volume (ML) per person
Carpentaria	West Cape York	–	6	–
	Mitchell	–	5	–
	Eastern Gulf	0.34	3	13.67
	Flinders	0.52	8	2.00
	Western Gulf	3.31	26	11.58
Division totals		**0.55**	**48**	**7.46**
Lake Eyre–Bulloo	Georgina	–	1	–
	Diamantina	–	2	–
	Thomson	–	12	–
	Bulloo	–	2	–
Division totals		**–**	**17**	**–**
Murray–Darling	Paroo–Wallam Creek	–	10	–
	Condamine–Balonne	17.40	162	1.61
	Border Rivers–Moonie	11.79	22	15.27
Division totals		**10.38**	**194**	**3.08**
Southern Coastal	Gold Coast	13.82	381	0.62
	Brisbane	136.74	1 104	1.67
	Sunshine Coast	10.96	125	2.02
	Mary	5.78	58	2.29
	Burnett–Kolan	45.76	100	13.27
	Curtis Coast	21.00	40	7.88
Subdivision totals		**34.09**	**1 808**	**2.27**
Central Coastal	Fitzroy	24.68	147	11.92
	Shoalwater Bay–Sarina	1.70	55	1.15
	Pioneer–O'Connell	0.38	19	0.53
	Proserpine	35.71	10	50.00
	Don	–	10	–
	Burdekin–Haughton	18.80	39	52.31
	Ross–Black	38.18	112	3.75
Subdivision totals		**17.40**	**392**	**12.21**
Northern Coastal	Herbert	–	18	–
	Tully–Murray	4.00	22	9.64
	Johnstone	–	8	–
	Mulgrave–Russell	1.07	73	0.62
	Barron	35.39	27	15.07
	Mossman–Daintree	2.24	7	13.57
	North-East Cape York	–	3	–
Subdivision totals		**1.74**	**158**	**4.80**
Queensland totals		**–**	**2 617**	**4.05**

Locations of representative gauging stations are shown in figure 4-12. Data from these stations are shown in figure 4-13.

The average annual flood damage in Queensland was estimated in 1992 at $91 million in tangible cost only. This represents about 30 percent of the estimated total average annual flood losses for Australia. The number of urban properties subject to stormwater and mainstream inundation was estimated to be 55 000. More recent data suggest that the number is about twice the 1992 estimate.

Griffith University (AES)

Floods occur regularly in many Queensland areas.

The traditional view of the use of the water resources of the nation has been to provide water for urban and industrial supply, irrigation and stock water (AWRC 1988). In developing surface water resources, a significant number of weirs, dams, pumping stations, treatment plants and reticulation systems have been constructed to deliver water to the user. The provision of these consumptive supplies has, however, tended to ignore the fact that there are very significant uses of water within the stream itself. These instream water uses are the ecological, recreational, scientific, cultural and commercial uses made of the State's water resources in their natural setting, whether flowing or standing, ephemeral or permanent. As with consumptive offstream uses, these uses have significant value to the community, although they are often intangible or difficult to quantify. To sustain these various uses, the appropriate flow regime and water quality must be provided.

Instream use of water resources encompasses use by wetlands, river systems and estuaries. It must be recognised that often there will be conflict between different types of instream use. It is important that these uses should essentially be able to be sustained over time without degradation of the resource, loss of riverine values or loss of essential ecological processes.

Traditionally, land and water developments have tended to be considered in isolation, resulting in incremental loss of instream values (AWRC 1988). However, there is now a requirement that resource development must occur under the guidelines of ecologically sustainable development, in which a broad perspective is taken which allows integration of all factors, including environmental and social issues.

Clearly, the planning for water resource development needs to be closely linked with consideration of the effects of the water's use, including rural land use and land management practices in areas supplied with the water. An emerging issue is the need to protect biological diversity and to maintain basic ecological processes of instream, wetland and riparian environments, while still providing for future water needs. Ecologically sustainable water resource development can thus be achieved by integrating environmental concerns, as well as economic and financial factors, into planning and decision-making processes concerning water resource use. It is important that the value of the total water resource is considered, encompassing both instream and consumptive uses and present and future options for water use.

Consequently, for the ecologically sustainable use of the water resources, there must be an understanding of the value of the different uses the resource has. Most people can appreciate the value of water for irrigation, industry, domestic supply or stock consumption, but seeing and understanding the value of retaining the water in the stream is not as easy. Generally, people do not believe they benefit directly, and in some cases this belief may be justified.

The value can be appreciated by examining the ecological basis of environmental flows. Stream-dependent ecosystems are the ecosystems of streams, wetlands, estuaries and the riparian zone adjacent to the water bodies. These ecosystems provide services such as purification of water, stabilisation of stream banks, flood storage, production of fish and other wildlife and recreational and scenic amenity. Ecosystems are detrimentally affected, and therefore so too are the services provided, by changing flow characteristics through consumptive use and/or by damming.

Construction of a barrier in a stream allows build-up of nutrients, plants and algae and prevents migratory fish such as mullet and barramundi from moving upstream to complete their life cycle. Fluctuating water levels in regulated flow sections of streams during the important spring breeding season can destroy eggs and prevent successful breeding of many species. The removal of excessive volumes of water from the stream for irrigation, stock, industry or domestic use can have similar impacts.

Recognition of the interrelatedness of all of the systems within the catchment is expanding through the community. This work is being assisted through the work of Landcare groups and Integrated Catchment Management Committees.

To reach the goal of ecologically sustainable development there must be understanding of how the water resource is an important element of the whole catchment. A change of attitude towards water resource use must be grasped. This is to change from extraction of every drop of water from a stream for offstream use, which reduces the stream to a drain, to a situation where only water that is in excess of that required to maintain the natural system can be extracted. Managing the resource in this way will ensure that both uses can be sustained indefinitely.

(Source: DPI 1992b; reproduced with permission)

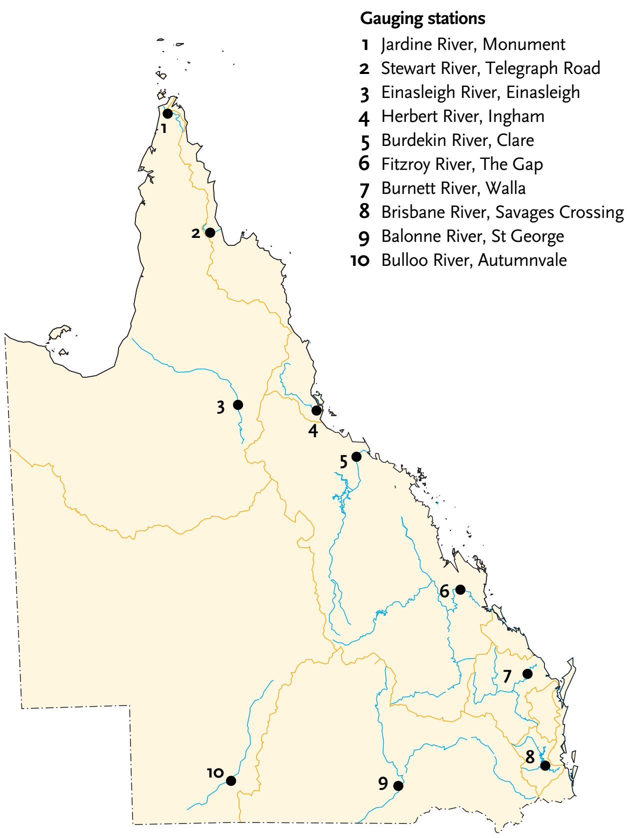


Figure 4-12 Locations of the ten representative gauging stations in figure 4-13
(Source: DNR)

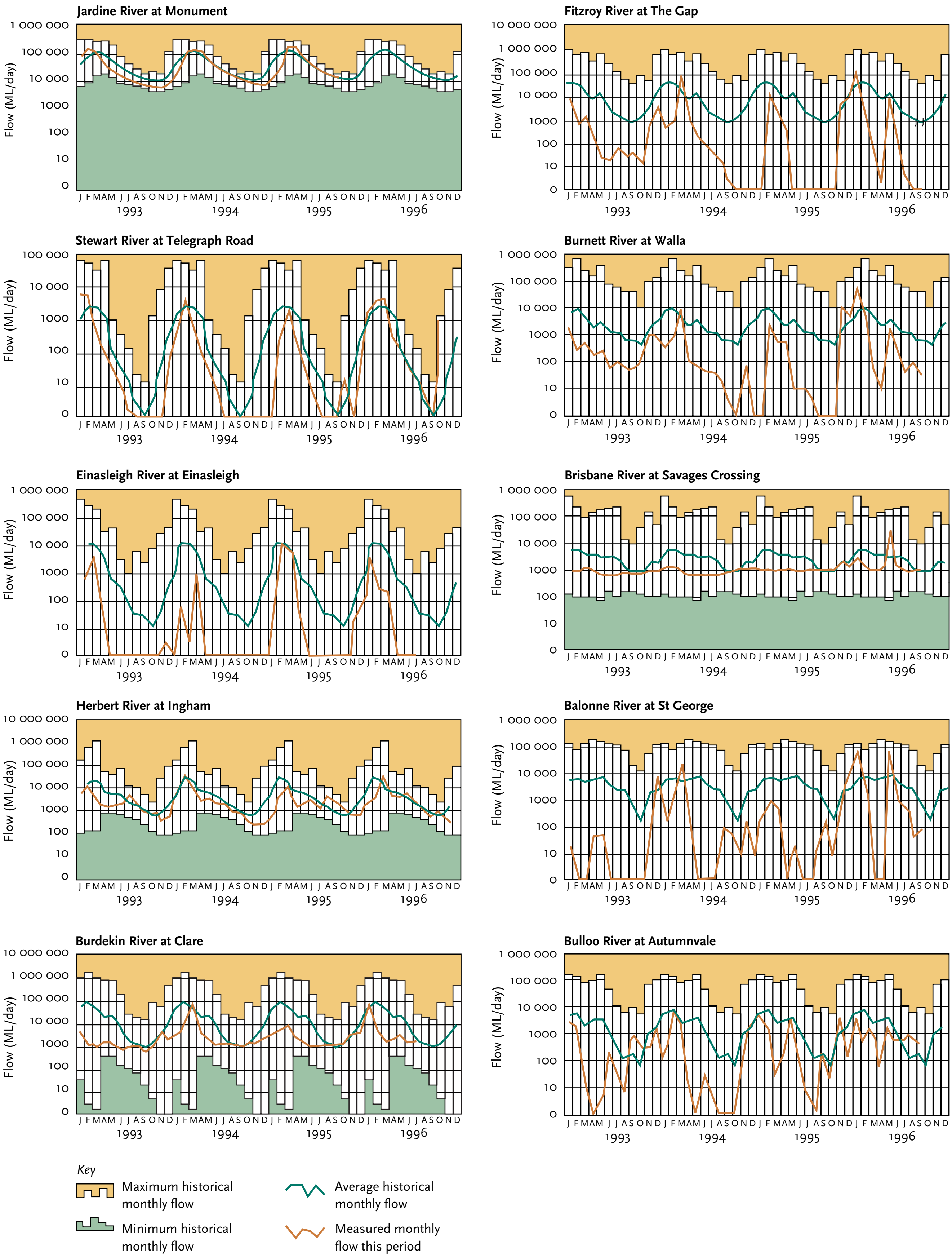


Figure 4-13 Variability of monthly river flow for ten representative gauging stations across Queensland, 1993–96. Maximum, minimum and average historical monthly flows are shown for comparison.
(Source: DNR)

WATER QUALITY INDICATORS

Water quality can be discussed meaningfully only when it is related to a use (Ayibotele and Falkenmark 1992). The National Water Quality Management Strategy recognises that water quality need not be the same for all uses. Water quality criteria describe the water quality that must be maintained to sustain specific uses or to protect specific values (ANZECC and AWRC 1992). The *Australian Water Quality Guidelines for Fresh and Marine Waters* (ANZECC 1992) define environmental values as particular values or uses of the environment that are conducive to public benefit, welfare, safety or health and that require protection from the effects of pollution, waste discharges and deposits. The five environmental values defined for water quality are: drinking water; ecosystem protection; recreation and aesthetics; agricultural water; and industrial water (ANZECC 1992).

Many of the quality indicators listed are not monitored routinely in Queensland rivers and streams. Adequate indicative reporting would rely on collecting and monitoring a standard list of selected indicators. Sampling should be strictly standardised and carried out at 50–100 predetermined monitoring stations. A statistical approach to monitoring design is required to ensure information reliability.

Indicators

Temperature

Total dissolved ions (Ca^{2+}, Mg^{2+}, Na^{+}, SO_4^{2-}, Cl^{-}, HCO_3^{-})

Dissolved oxygen

pH

Total phosphorus (TP)

Soluble nitrogen (nitrate plus nitrite)

Chlorophyll a

Faecal coliforms

Organic matter content indicated by BOD or TOC

Other toxics in water (atrazine, DDT, endosulfan, hexachlorobenzene, lindane, PAHs, PCBs, blue-green algal toxins)

Total phosphorus in sediment

Dissolved metals: Al^{3+}, As, Cd, Cr, Cu, Fe^{2+}, Hg, Pb, Zn

Sediment concentrations of metals where indicated by water column results

Sediment concentrations of other toxics

Suspended sediment (g/L) or turbidity (NTU)

Total load (tonnes) of metals in effluent

Total load (tonnes) of metals in effluent by industry

Total tonnes of other toxics in effluent

Total load (tonnes) of other toxics in effluent by industry

Concentration of toxicants in tissues of indicator organisms

Surface waters

Data on concentrations of contaminants in most industry effluents are not widely available. Exceptions are where effluent disposal is licensed or where the effluent is used for a purpose such as land application.

The use of sewage biosolids and intensive animal industry wastes in fertiliser is an example of a situation in which an analysis of nutrients, salinity and heavy metal concentrations is necessary to determine safe application rates. Use of these effluents for irrigation can provide a source of nutrients for the agricultural crop and an acceptable form of effluent disposal.

Table 4-28 Composition of a range of biologically sourced effluents after pre-treatment in lagoons. Such effluents from intensive rural industries are characterised by high levels of nitrogen (N), phosphorus (P), potassium (K), soluble salts (measured by electrical conductivity — EC) and reactive organics.

Source	N (kg/ML)	P (kg/ML)	K (kg/ML)	EC (dS/m)
Feedlots	700	75	850	8
Piggeries	640	80	520	8.7
Abattoirs	120	20	30	2.1
Sewage treatment plants	10–50	5–15	10–40	0.6–1.7
Potable water	<1	<2	<1	0–4
Tanneries	940	9	70	11.2
Dairy farms	210	25	300	2.9
Dairy factories	200	100	160	0.2–5.0
Starch	850	160	1250	2.5
Pulp and paper	<10	<10	30	1.9
Distillery	1700	130	–	–
Fellmongers	220	1	50	2
Wool scour	390	13	1470	–

(Source: Gardner and Barry 1996)

Table 4-29 Nutrient and contaminant concentrations in biosolids from two sewage treatment plants in the Brisbane area. Concentrations of contaminants in biosolids can vary widely depending on activities occurring in the catchment. Industrial effluents generally produce biosolids with higher concentrations of heavy metals.

Nutrient/contaminant	Industrial	Domestic
Total solids (%)	25	25
Total nitrogen (%)	3.3–4.3	4.8–5.0
Ammonia — N (%)	0.35–0.58	0.07–0.02
Nitrate — N (%)	0.02–0.03	0.01–0.02
Total phosphorus (%)	1.5–2.0	1.2–1.3
Cadmium (mg/kg)	15–25	4–15
Arsenic (mg/kg)	7–15	4–6
Copper (mg/kg)	700–900	280–520
Mercury (mg/kg)	3–5	1–2
Nickel (mg/kg)	60–120	10–140
Zinc (mg/kg)	1000–1400	320–480
Dieldrin (mg/kg)	0.6–1.0	0.03–0.05

(Source: After Gardner and Barry 1996)

Water quality parameters and flow data

Figures 4-14 to 4-30 are maps of 17 catchment areas and drainage divisions in Queensland. They contain water quality data for 13 parameters — turbidity, pH, total dissolved ions, total suspended solids, nitrate + nitrite, total phosphorus, aluminium, total cadmium, total chromium, soluble copper, total lead, soluble zinc and chlorophyll *a*. Each parameter is divided into three ranges based on NWQMS and NHMRC/AWRC guidelines (ANZECC and ARMCANZ 1992; NHMRC/AWRC 1987).

These ranges appear on each figure as pie charts of proportional area for each range: green for low, yellow for medium and red for the high range (see box at right). See table 4-30 for explanations of ranges for each parameter.

The number of samples measured for each parameter is denoted by 'n'. The locations of sampling sites appear on the catchment or drainage division maps as coloured circles corresponding to the amount of water that flows past the sample point per year based on continuous recordings taken automatically (see 'Flow' below). Water quality and flow data came from DNR. Additional data from monitoring undertaken by EPA in freshwater streams are provided in the *Testing the Waters* report (DEH/DNR 1999).

Water quality samples	Flow (ML/year)
High	0–1000
Medium	1000–10 000
Low	10 000–100 000
No data	100 000–1 000 000
	1 000 000–3 000 000
	>3 000 000

Table 4–30 Ranges of low, medium and high for water quality parameters

Parameter	Unit	Low	Medium	High
Turbidity (Turb)	NTU	<1	1 to 5; pretreatment advised before disinfection	>5; above potable guidelines
pH	pH units	<6.5; acidic and corrosive	6.5 to 8.5; for most environmental values	>8.5; undesirably alkaline
Total dissolved ions (TDI)	mg/L	<500; suitable for most environmental values	500 to 1500; marginal for most environmental values	>1500; unsuitable for drinking, variable for crops
Total suspended solids (TSS)	mg/L	<80	80 to 400; marginal freshwater fisheries	>400; unlikely to support good fisheries
Soluble nitrogen (nitrate + nitrite) (SN)	mg/L	<0.1; algal blooms rare	0.1 to 0.75; supports algal blooms	>0.75; blooms likely if other factors favourable
Total phosphorus (TP)	mg/L	<0.01; algal blooms rare	0.01 to 0.1; supports algal blooms	>0.1; blooms likely if other factors favourable
Aluminium (Al)	mg/L	<0.1	0.1 to 0.2; unsuitable for ecosystem guidelines	>0.2; above potable guidelines
Total cadmium (TCd)	µg/L	<0.2	0.2 to 2.0; marginal ecosystem guidelines	>2.0; above potable and ecosystem guidelines
Total chromium (TCr)	µg/L	<10	10 to 50; above ecosystem guidelines	>50; above potable guidelines
Soluble copper (SCu)	mg/L	<0.005	0.005 to 1; above ecosystem guidelines	>1; above potable guidelines
Total lead (TPb)	µg/L	<5	5 to 10; above ecosystem guidelines	>10; above potable guidelines
Soluble zinc (SZn)	mg/L	0.005	0.005 to 3; above ecosystem guidelines	>3; above potable guidelines
Chlorophyll *a* (Chl *a*)	µg/L	<3	3 to 10; above potable guidelines	>10; possibly a developing algal bloom

WATER QUALITY IN THE CARPENTARIA DRAINAGE DIVISION

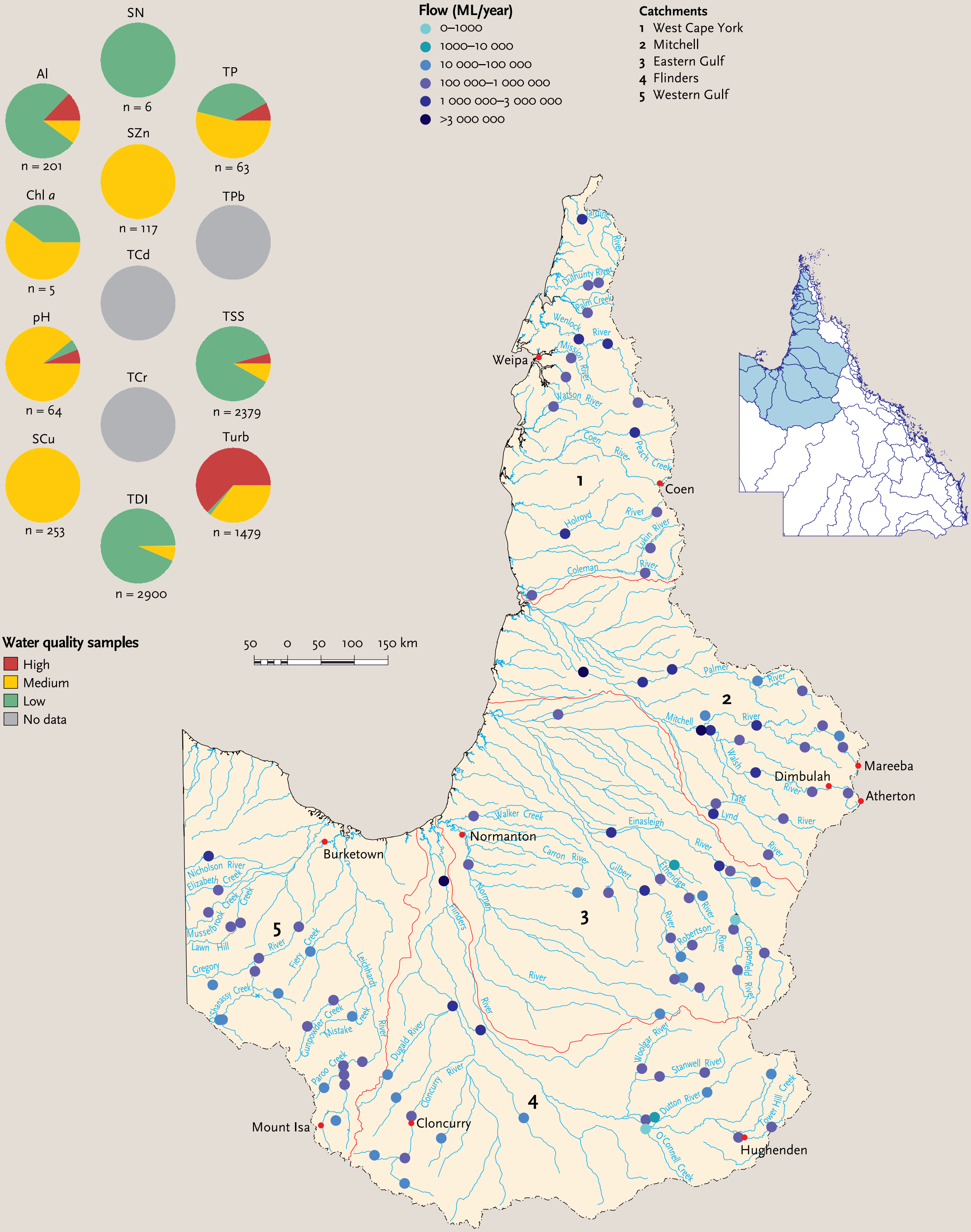


Figure 4-14 The Carpentaria Drainage Division includes the West Cape York, Mitchell, Eastern Gulf, Flinders and Western Gulf catchments. The major industries in this division are grazing (all catchments) and mining (Weipa and Mount Isa areas). Widespread erosion occurs in all catchments, especially in the Mareeba–Dimbulah area of the Mitchell catchment, the upland forest of the Flinders catchment and the forest frontage and upland areas of the Western Gulf catchment. The wetlands of the Jardine River (West Cape York) and the rivers of the Eastern Gulf catchment are areas of high conservation value.

WATER QUALITY IN THE LAKE EYRE DRAINAGE DIVISION

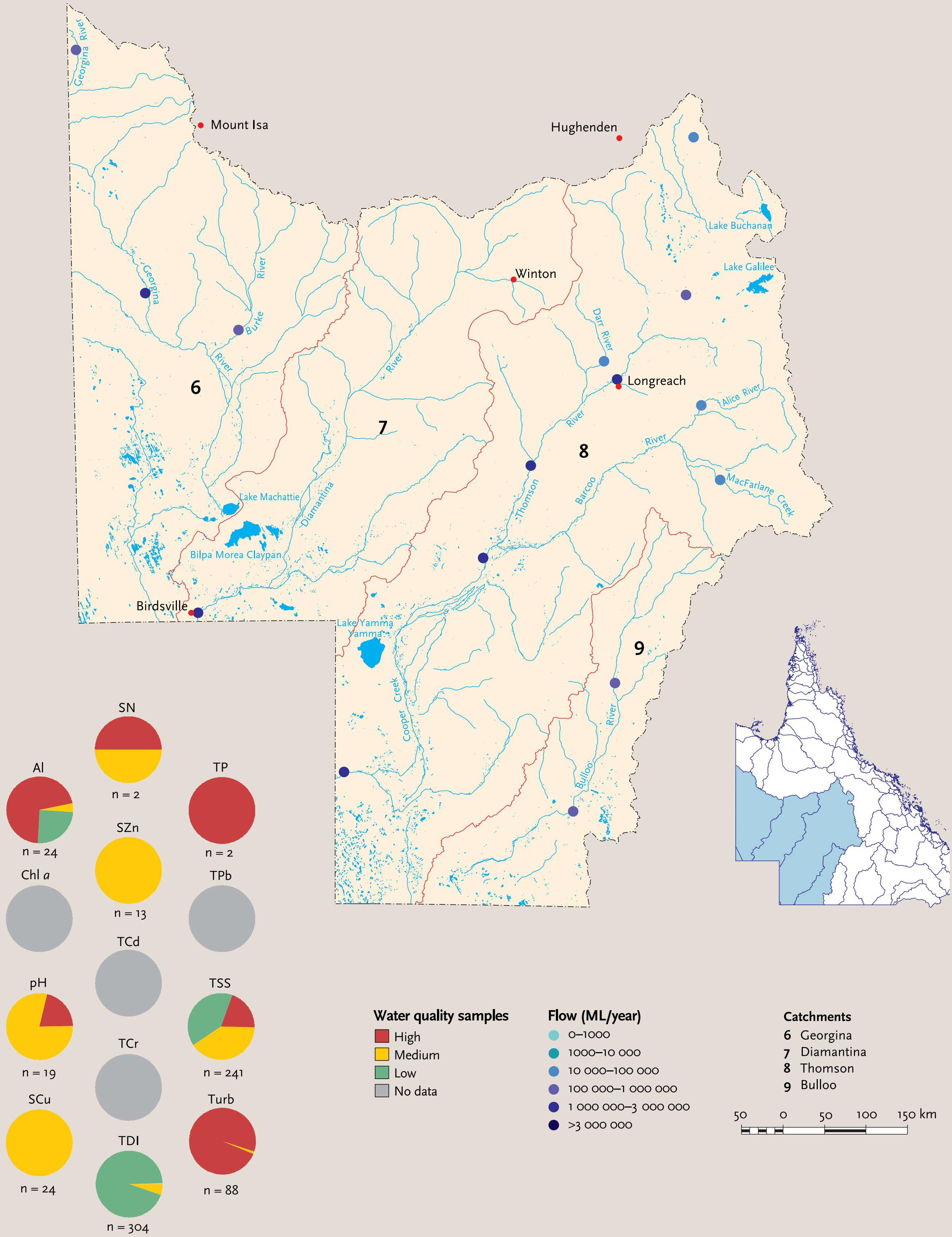


Figure 4-15 The Lake Eyre Drainage Division includes the Georgina, Diamantina, Thomson and Bulloo catchments. Grazing is the dominant land use in each catchment of this division. Land degradation and erosion are widespread, due to the natural instability of the soil structure and overgrazing. The lack of groundcover in some areas has led to very high levels of rainfall runoff, leading to severe erosion in stream channels.

WATER QUALITY IN THE MURRAY–DARLING DRAINAGE DIVISION

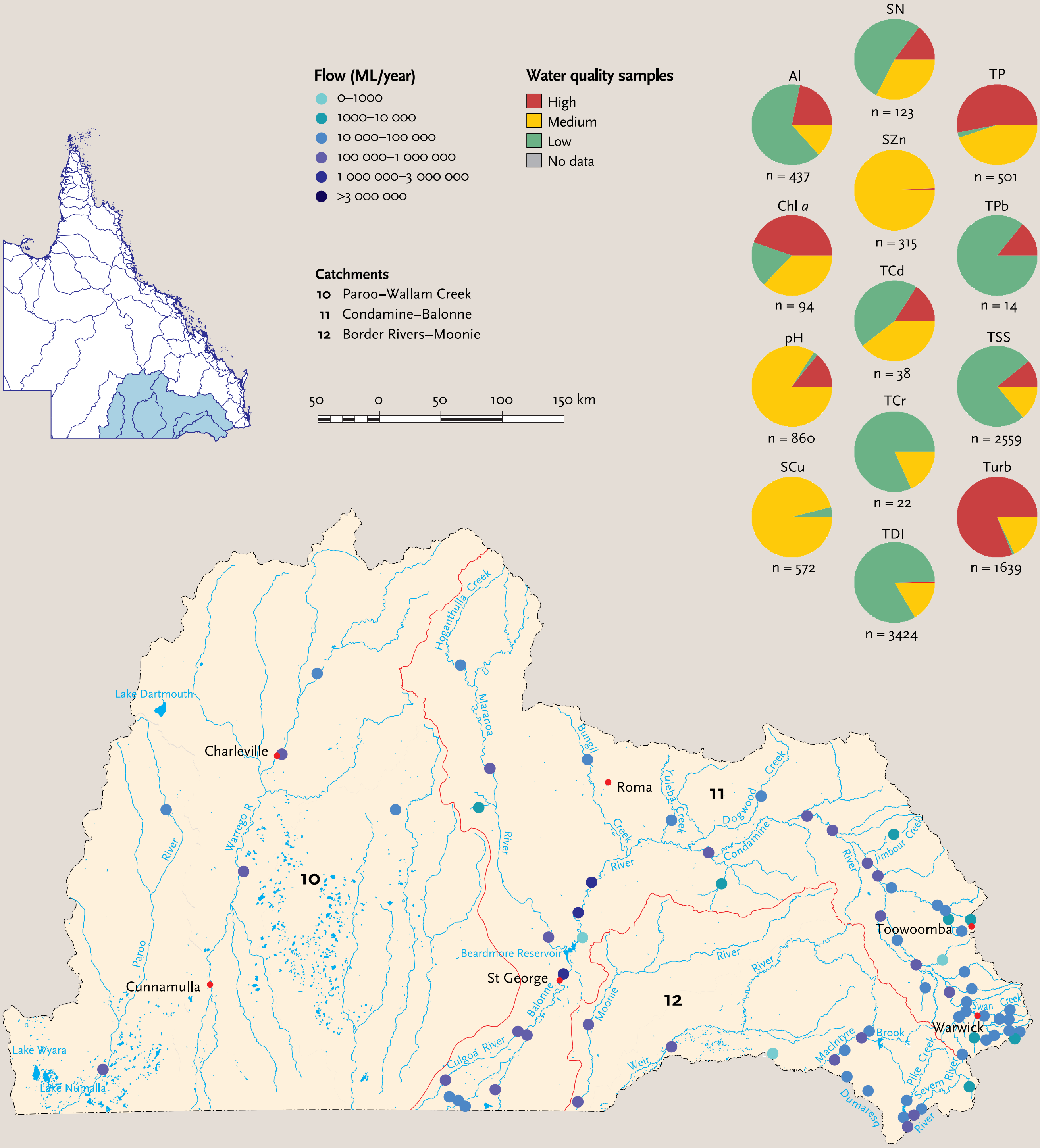


Figure 4-16 The Murray–Darling Drainage Division includes the Paroo–Wallam Creek, Condamine–Balonne and Border Rivers–Moonie catchments. Grazing land covers 99.9 percent, 75.4 percent and 77.1 percent (Queensland portion) of these catchments respectively. The Condamine–Balonne also contains the Darling Downs farming area, the largest area of cropping in the State. Land degradation and erosion occur over vast areas of this division. Loss of riparian vegetation, runoff of agricultural chemicals and poor water quality in remnant waterholes are also consequences of land use in this division. In the Condamine–Balonne catchment, many water storages have been constructed to supply water to the area. Most rivers have multiple weirs affecting the movement of migratory fish species.

WATER QUALITY IN THE GOLD COAST CATCHMENT AREA

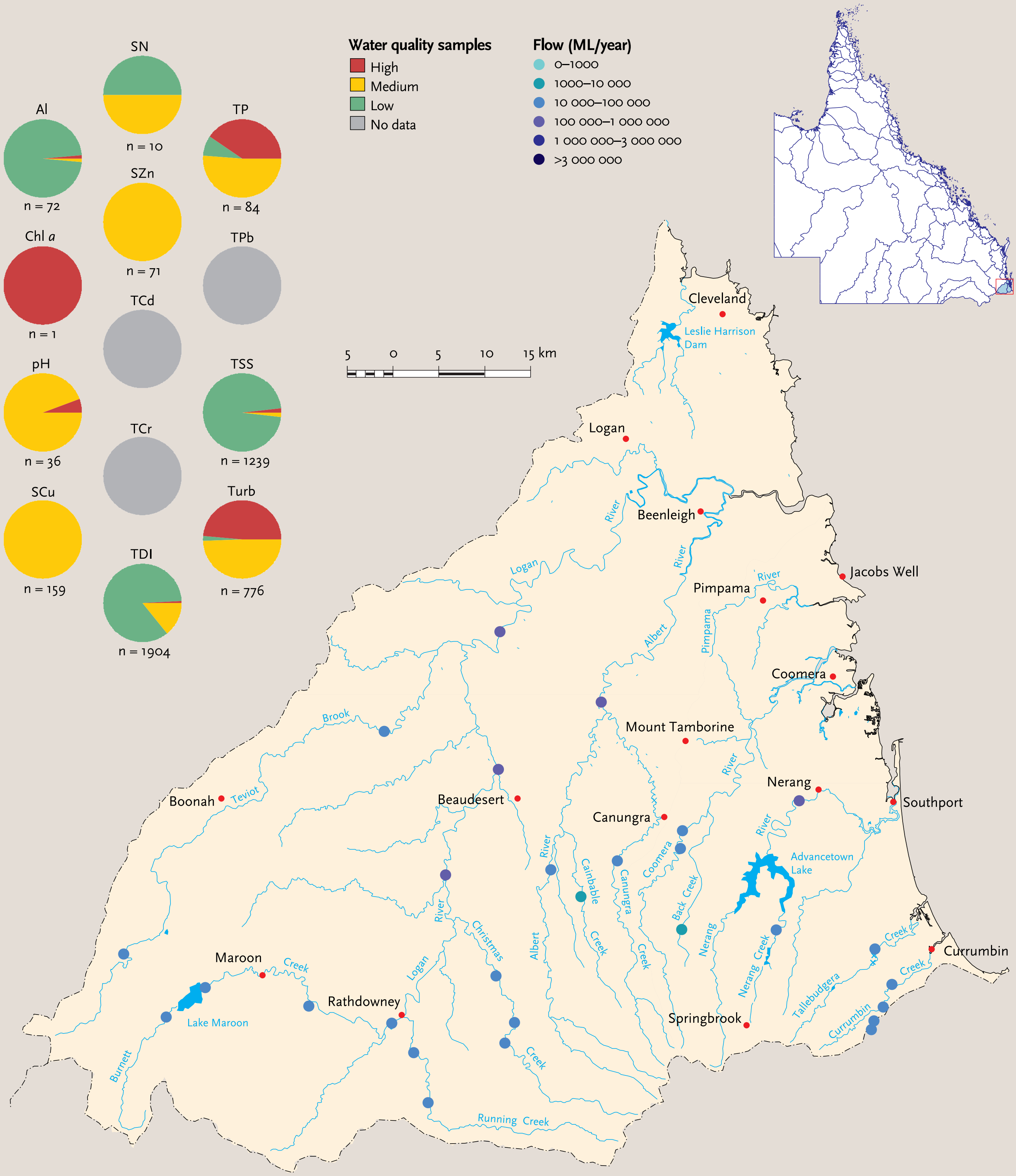


Figure 4-17 Grazing is the dominant land use in the upper inland sections of the Gold Coast catchment. Sugarcane is also grown along the Pimpama River. Extensive soil erosion has resulted, due to high stocking rates and inappropriate burning regimes. Significant areas of agricultural land have been redeveloped into urban use in the coastal area, which has the highest population concentrations in Queensland.

WATER QUALITY IN THE BRISBANE CATCHMENT AREA

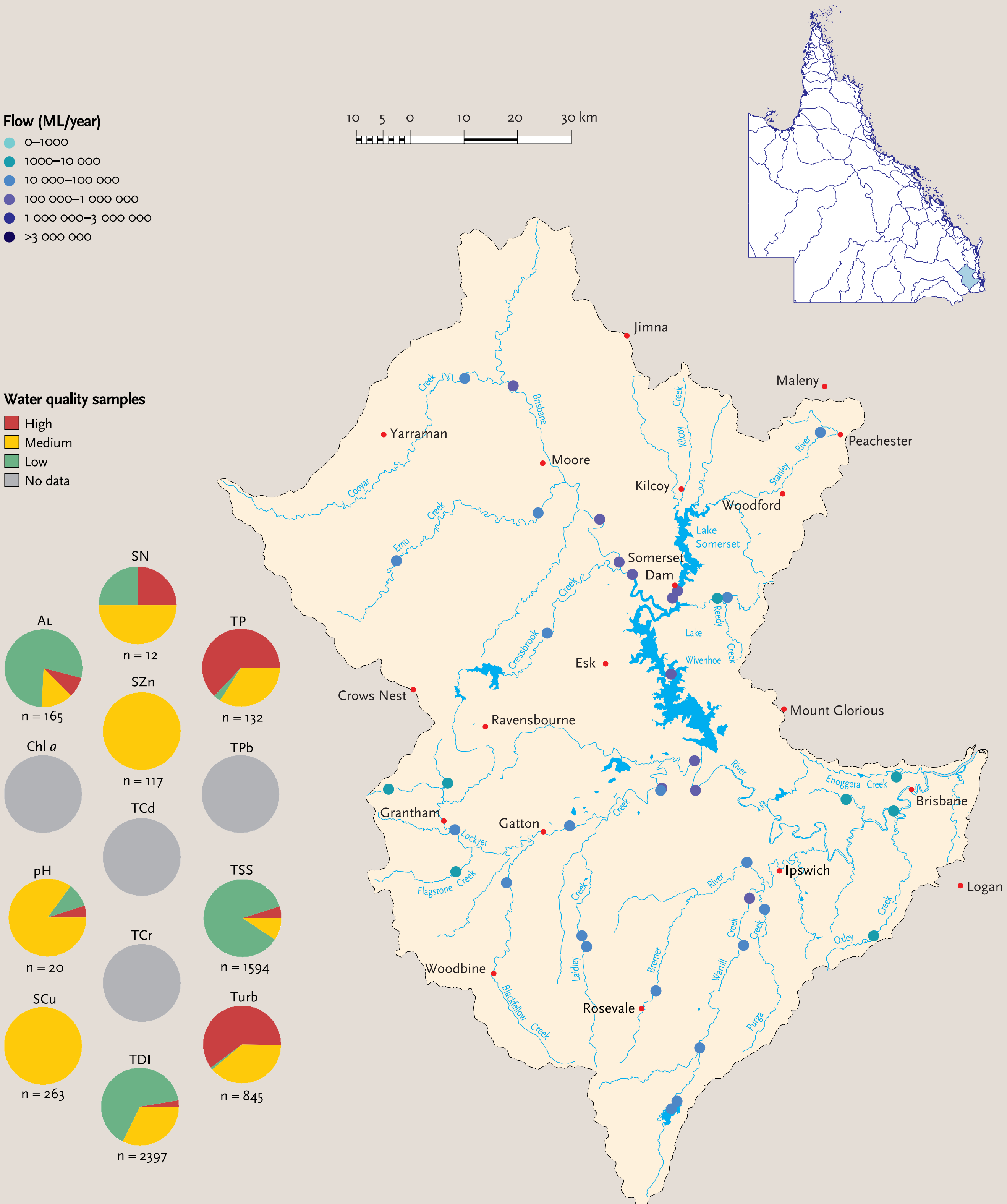


Figure 4-18 Just under half of the Brisbane catchment area is used for grazing. State forests, timber reserves and forest plantations account for another 35 percent of the land area. Intensive agricultural activities have caused concerns about chemical discharge in the catchment. Some soils in the Lockyer Creek area have been under cultivation for more than 100 years. Irrigation from groundwater sources has resulted in salinity problems. Some tributaries have conservation value as habitat for the eastern freshwater cod.

WATER QUALITY IN THE SUNSHINE COAST CATCHMENT AREA

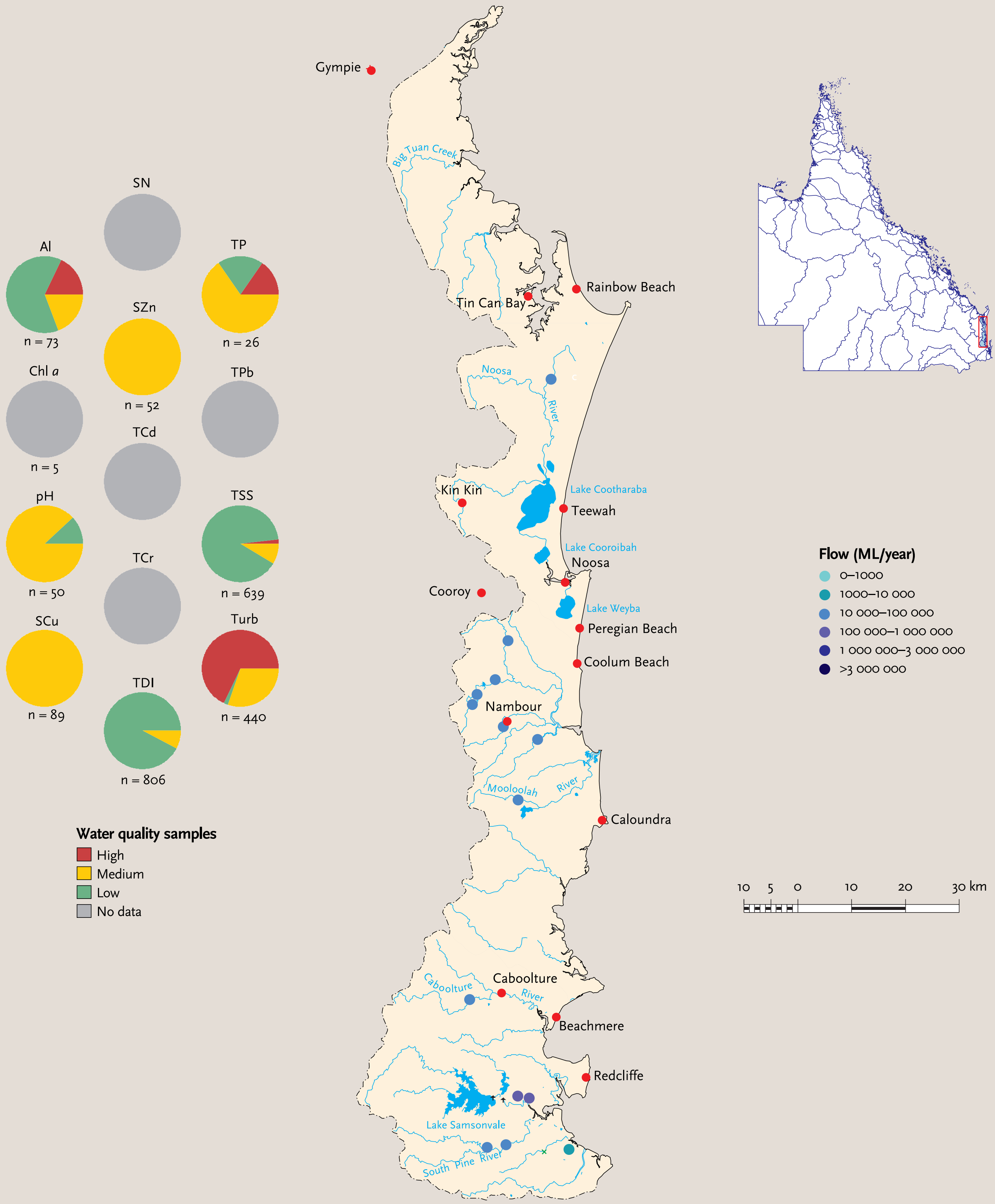


Figure 4-19 Overgrazed lands and cultivation of steep slopes have caused significant soil erosion problems and declines in productivity in the Sunshine Coast catchment. High levels of nutrients are used to alleviate the productivity declines. Water storages built to provide urban water supplies and extraction of sand and gravel from stream beds have affected fish habitats. Pressure from urban expansion has resulted in the loss of wetland areas. Native forests within reserves make up 27 percent of this catchment.

WATER QUALITY IN THE MARY CATCHMENT AREA

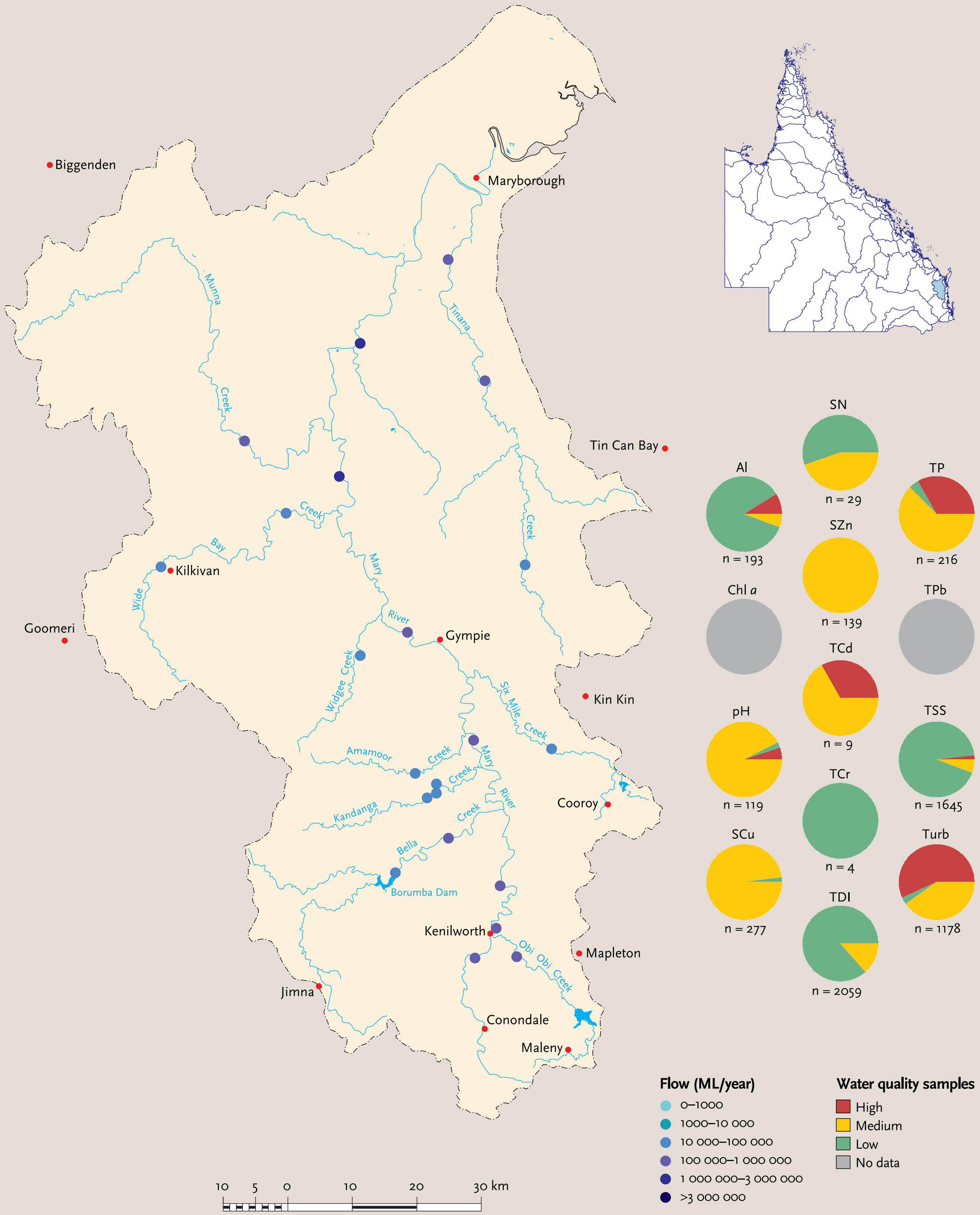


Figure 4-20 Grazing activities occur on just over 60 percent of the Mary catchment area. State forests, timber reserves and forest plantations account for another 35 percent of the land area. Soil erosion is a problem in the middle reaches of the Mary River, particularly in the pineapple and sugarcane areas of the lower catchment. Flooding, associated erosion and streambank failures are major issues due to loss of groundcover and riparian vegetation. Salinity is a problem in the middle to lower reaches of the Mary River, caused mainly by the clearing of forested areas. The Mary River upper reaches are in relatively natural state.

WATER QUALITY IN THE BURNETT–KOLAN CATCHMENT AREA

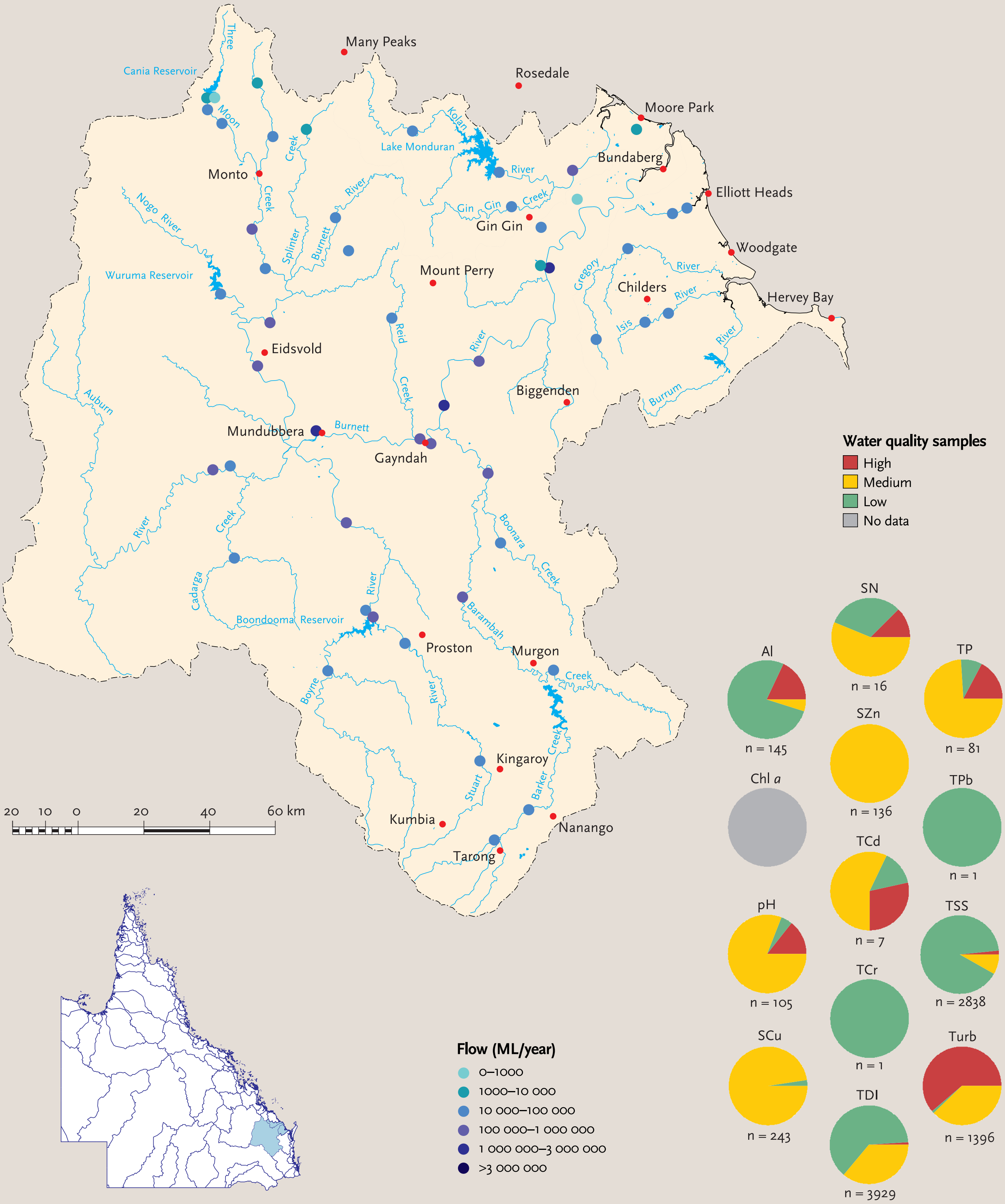


Figure 4-21 Grazing occurs on 67 percent of the Burnett–Kolan catchment; native forest reserves (16 percent) and cropping (3.4 percent) are also significant land uses. Salinity is a problem associated with high watertables on cultivated lands in the South and Central Burnett and coastal Burnett–Kolan. Rising watertables and associated salinity have occurred in surface water irrigation areas. Water storage structures and irrigation infrastructure have resulted in siltation of the Burnett River below the barrage and restriction of fish movement.

WATER QUALITY IN THE CURTIS COAST CATCHMENT AREA

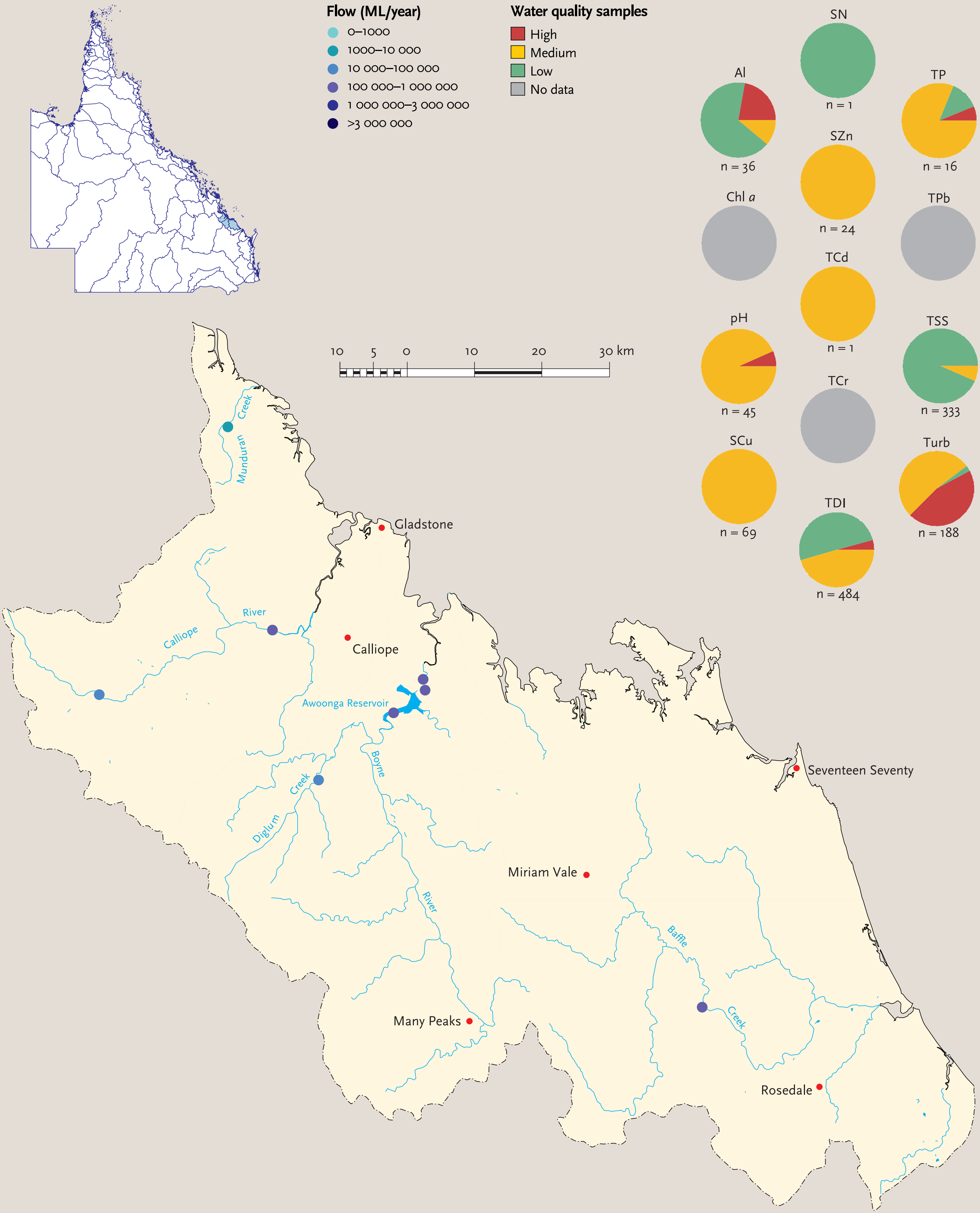


Figure 4-22 The dominant land use is cattle grazing, occurring on 69 percent of the Curtis Coast catchment. This land has been subjected to clearing on steep slopes and marginal woodland country, leading to erosion and salinity problems within the catchment. Heavy industrial development around Gladstone has affected significant fishery resources in the immediate area through pollution. The major water source is the Awoonga Dam, which supplies urban and industrial water for Gladstone and some water for Callide B power station.

WATER QUALITY IN THE FITZROY CATCHMENT AREA

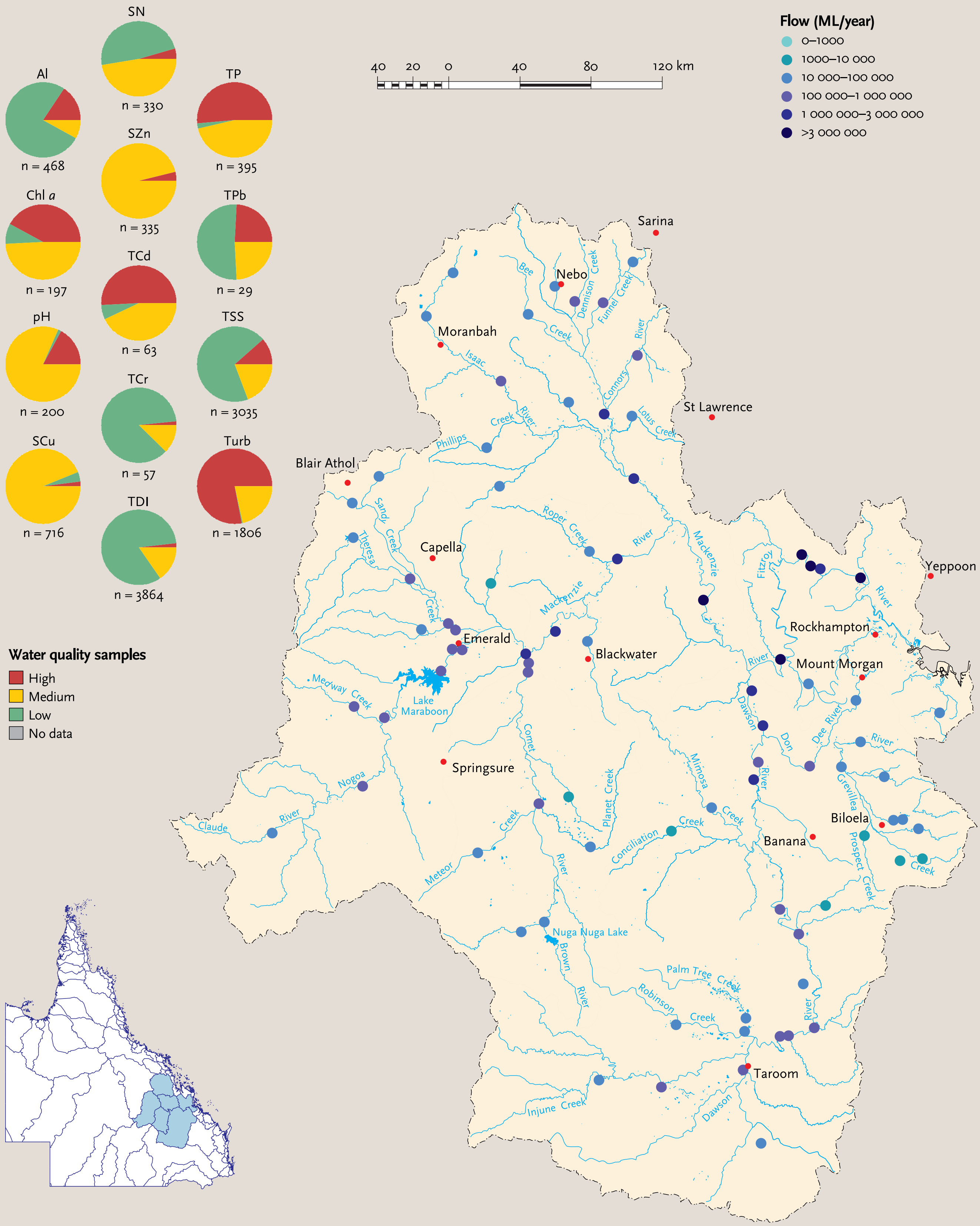


Figure 4-23 Grazing is the dominant land use in the Fitzroy catchment, occurring on 84 percent of the land area. Large reserves of coal exist in this catchment, and the mining industry is well developed. Numerous water storages have been built to supply water for irrigation and for urban, stock and industrial use. All the major rivers except the Isaac have multiple weirs. This catchment is extensively used by commercial and recreational fishers. Catches of barramundi are reported to have declined downstream of the Fitzroy Barrage since its construction.

WATER QUALITY IN THE SHOALWATER BAY–SARINA CATCHMENT AREA

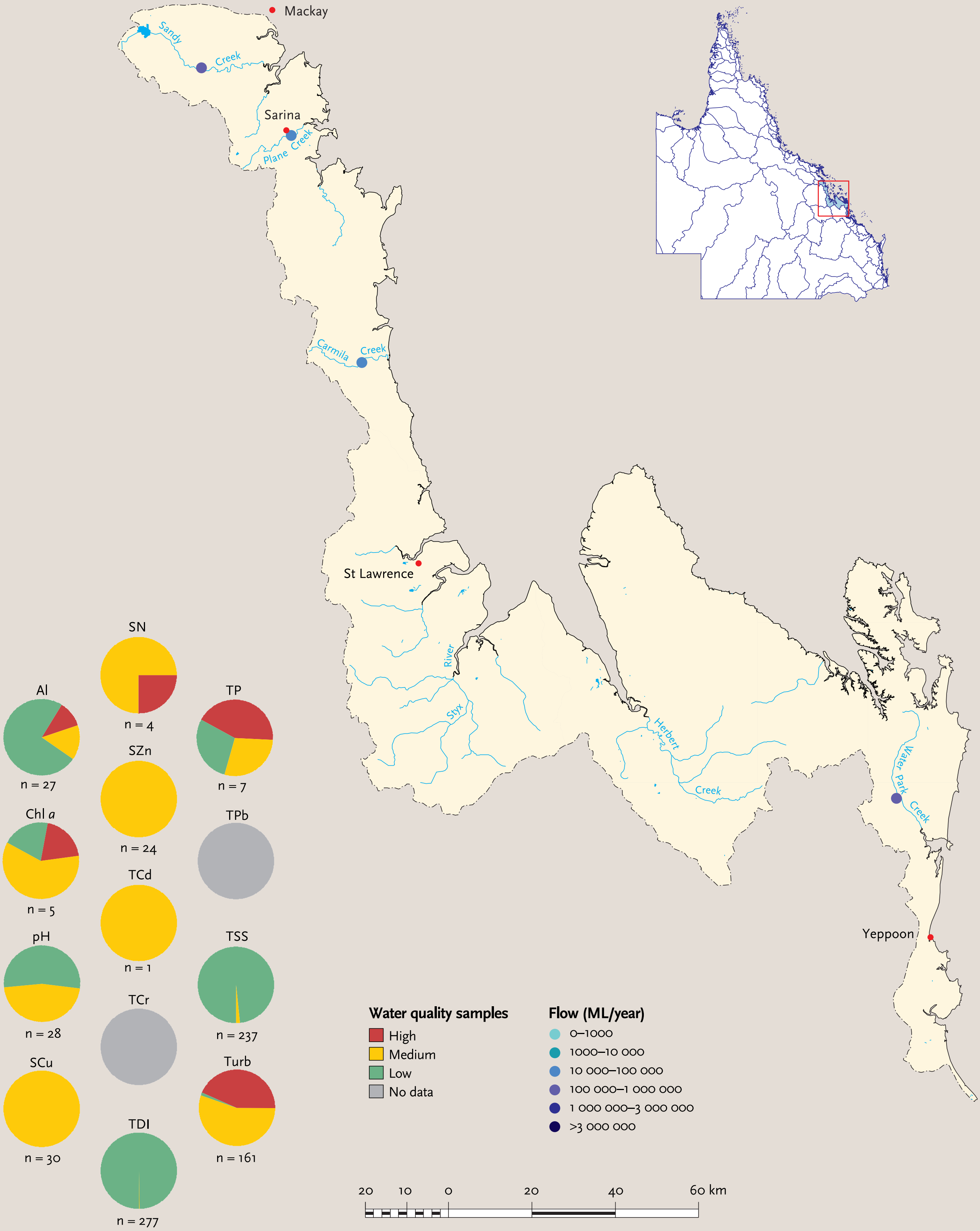


Figure 4-24 Grazing occurs on 44 percent of the Shoalwater Bay–Sarina catchment, while native state forest and timber reserves account for 21 percent of the land area. Cropping land occupies 4 percent, approximately one-third of which is irrigated. Grazing lands from south of the catchment to Sarina show signs of erosion caused by overgrazing and inappropriate land clearing practices. The Plane Creek section of the catchment has significant areas of sugarcane cultivation.

WATER QUALITY IN THE PIONEER–O'CONNELL CATCHMENT AREA

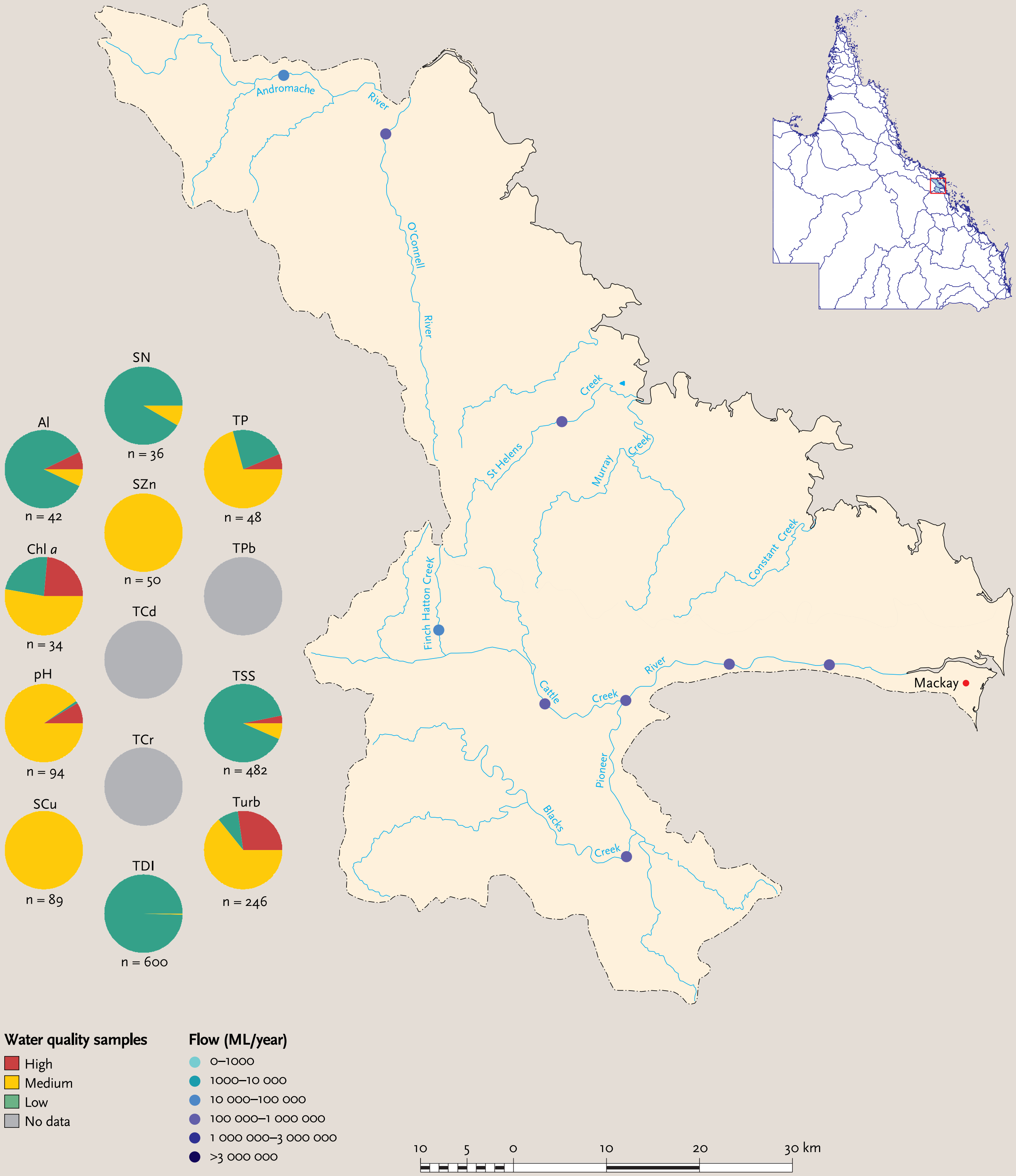


Figure 4-25 Grazing is the dominant land use, covering more than 49 percent of the Pioneer–O'Connell catchment. Cultivation, state forests and timber reserves each occupy approximately 13 percent and national parks nearly 6 percent of the catchment. The O'Connell River flats are severely eroded because land was cleared and left exposed during development for improved pastures. The Pioneer subcatchment is used extensively for sugarcane production. Serious erosion has occurred on the upland areas. Significant river modifications on the Pioneer River protect the city of Mackay from flooding. Several weirs have been built on the river for irrigation, urban and industrial use.

WATER QUALITY IN THE PROSERPINE CATCHMENT AREA

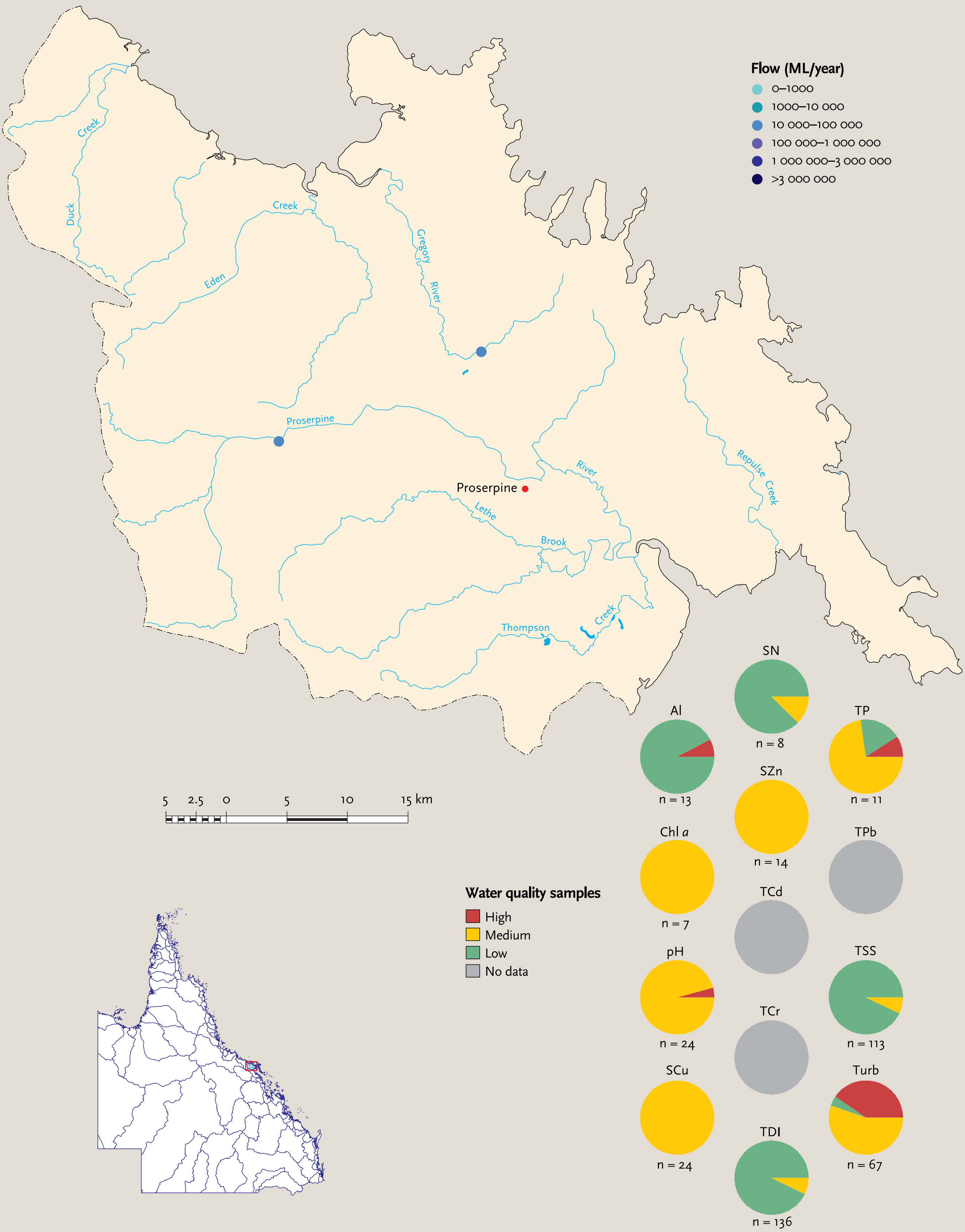


Figure 4-26 Grazing occurs on 67 percent of the Proserpine catchment, with cropping land covering more than 6 percent. Significant areas of forest have been cleared to establish improved pastures. Sugarcane is grown primarily on the river valley soils and the coastal plain. The Peter Faust Dam, upstream of Proserpine, offers flood protection, and provides water for irrigation and urban uses. Rising watertables and salinity are problems in some areas. The expansion of agriculture has resulted in the draining of the Gorganga Swamps.

WATER QUALITY IN THE DON CATCHMENT AREA

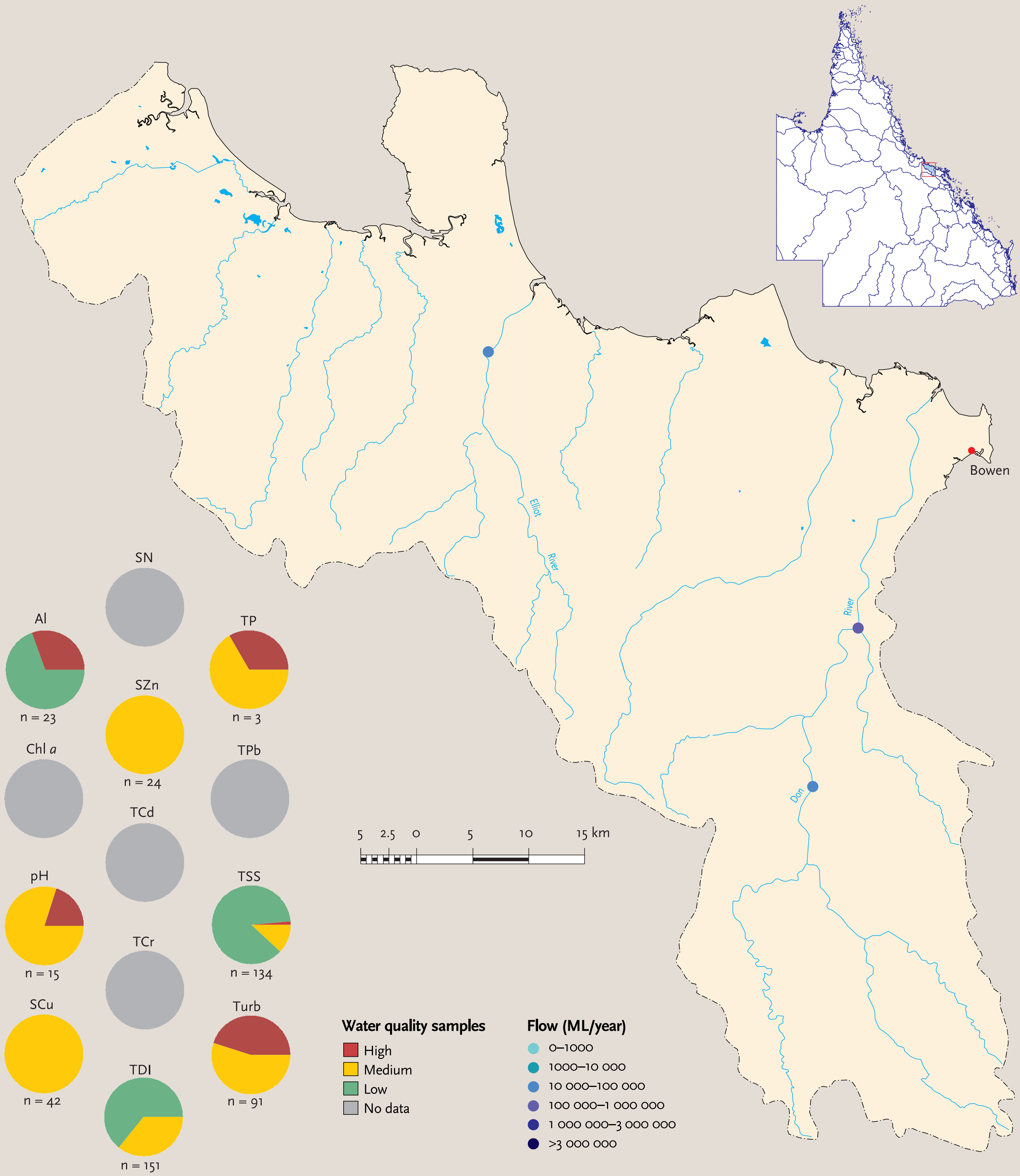


Figure 4-27 Grazing occurs on nearly 99 percent of the Don catchment, while horticultural cropping accounts for just 1 percent. Cropping occurs primarily on the river delta and flats, where soil erosion from flooding is significant. Intensive agriculture with extensive use of chemicals in these areas is an issue. Erosion is widespread in cleared grazing lands. Major stream modifications have been built to minimise flooding to urban and agricultural areas. Water supplies are restricted during dry periods. Urban water is supplied through a pipeline from the Peter Faust Dam in the Proserpine catchment.

WATER QUALITY IN THE BURDEKIN—HAUGHTON CATCHMENT AREA

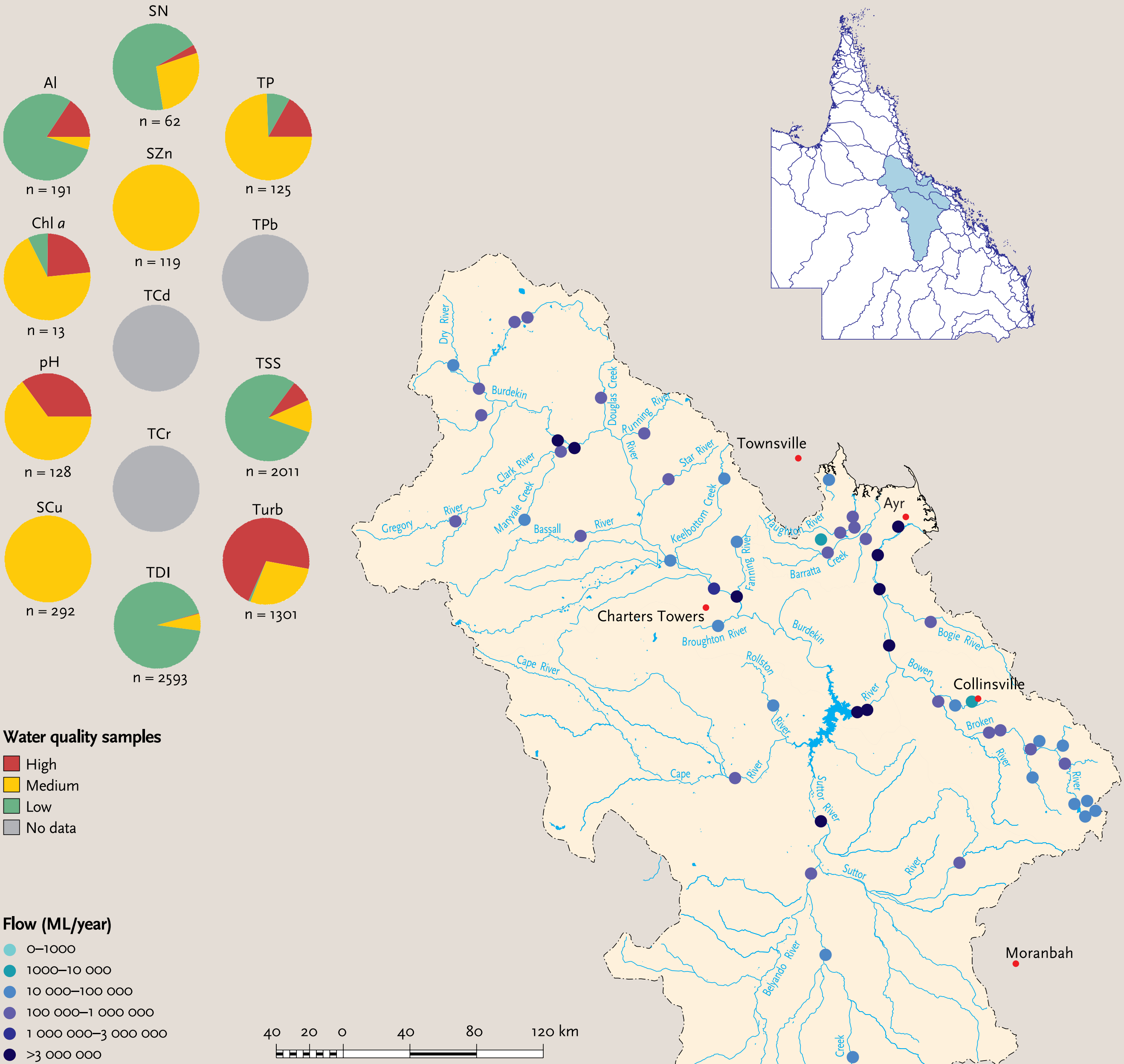


Figure 4-28 Grazing is the predominant land use in the Burdekin–Haughton catchment, accounting for more than 88 percent of the area. Diverse landscapes are represented in this large catchment: wet tropical rainforest inland of Mackay; drier upper subcatchments of the Belyando and Burdekin Rivers; and the very wet coastal plains of the lower Burdekin and Haughton Rivers. Grazing has contributed to the degradation of instream habitat and channel stability in the Burdekin River, and to widespread soil erosion. The catchment has high recreational, commercial fishing and conservation value. Development of the Burdekin River Irrigation Project poses a threat to wetlands, water quality and instream water requirements. Significant flooding of rural and urban areas occurs regularly in this catchment due to seasonal rain. Flooding is a major cause of soil erosion in the delta. Mining activities are well developed throughout the catchment: coal at Collinsville and gold near Charters Towers and Burdekin Falls Dam.

WATER QUALITY IN THE ROSS–BLACK CATCHMENT AREA

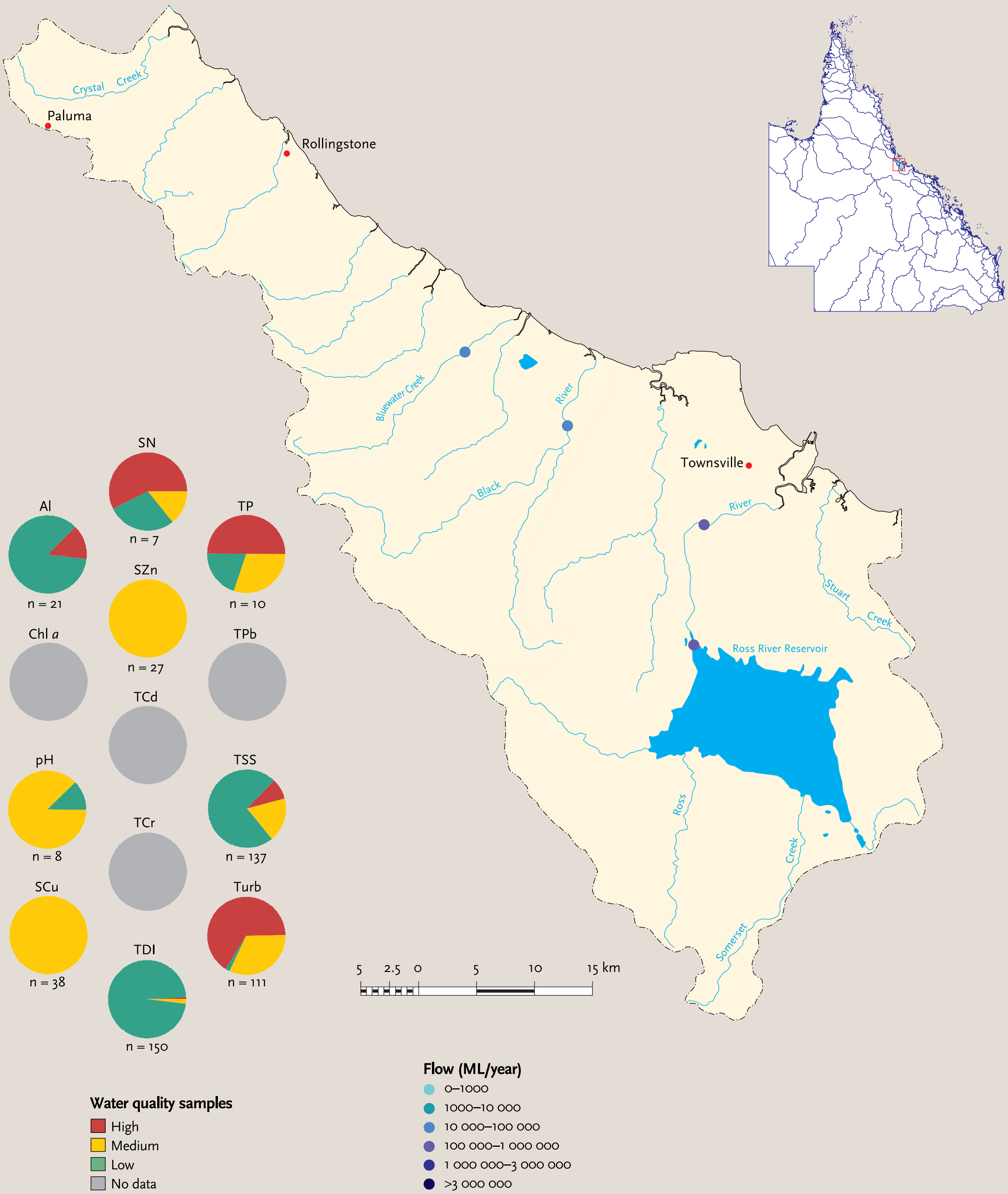


Figure 4-29 Grazing land occupies 29 percent of the Ross–Black catchment, with native state forest and national parks covering 8 percent and 11 percent respectively. The Ross River Dam is the major source of Townsville's water supply. The Black River is used for sand and gravel extraction for the Townsville market, creating instream environmental impacts. The river banks are severely eroded as well. Drainage of swamplands and the installation of floodgates on drains and creeks have been detrimental to fish nurseries. There are persistent water hyacinth and salvinia problems in the catchment.

WATER QUALITY IN THE NORTHERN COASTAL SUBDIVISION

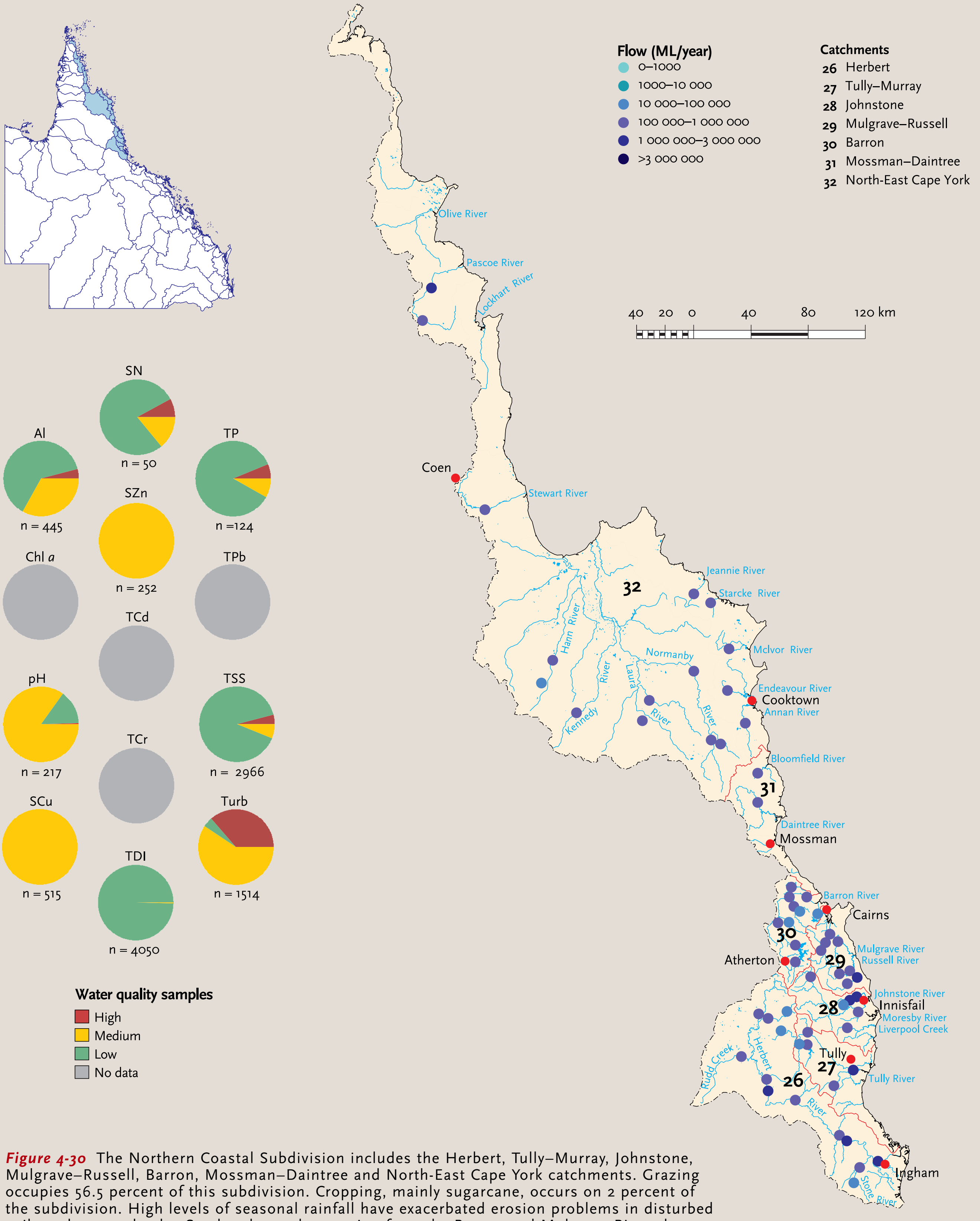


Figure 4-30 The Northern Coastal Subdivision includes the Herbert, Tully–Murray, Johnstone, Mulgrave–Russell, Barron, Mossman–Daintree and North-East Cape York catchments. Grazing occupies 56.5 percent of this subdivision. Cropping, mainly sugarcane, occurs on 2 percent of the subdivision. High levels of seasonal rainfall have exacerbated erosion problems in disturbed soils and stream banks. Sand and gravel extraction from the Barron and Mulgrave Rivers has led to stream-channel instability and loss of riverine habitat. River modifications to reduce flooding and stabilise banks have affected instream habitats in some rivers. Large areas of wetlands have been lost through drainage for agricultural development in the Herbert, Tully–Murray, Johnstone, Mulgrave–Russell and Barron catchments. Tin mining in the Herbert and North-East Cape York catchments has reduced water quality and led to degradation of streams. The Wet Tropics World Heritage area extends through the Herbert, Johnstone, Barron, Mossman–Daintree and North-East Cape York catchments, containing areas of relatively undisturbed land and pristine streams.

Groundwater

A 1985 review of groundwater contamination in Australia found no evidence of major widespread groundwater pollution in Queensland. There were, however, four significant potential contamination concerns at that time. They included the possibility of contamination from:

- nutrients and pesticides resulting from agricultural practices in the Darling Downs, the Lockyer Valley and the Burdekin and Bundaberg regions;
- total dissolved solids from agricultural practices in the Lockyer Valley, around Rockhampton, and in the Fitzroy, Theodore, Isaac and Burdekin Rivers;
- acid waters and cyanide from the practice of heap leaching in some goldmines; and
- organic solvents and petroleum hydrocarbons from hazardous industrial waste at the Willawong and Kingston hazardous waste sites (AWRC 1987).

Significant changes to legislation, agricultural practices, and site remediation programs of hazardous waste sites have been implemented since this report (see 'Response' section, this chapter, and 'Contaminated land' section in chapter 3).

The 1985 review also noted that while the thick sediments overlying most of the Great Artesian Basin protect it from many sources of pollution, the potential for contamination in the recharge areas at the Basin edges was growing.

The greatest threat to groundwaters in coastal areas is saltwater intrusion. Restrictions to control water withdrawal have been imposed in problem areas (see box 'Groundwater intrusion by seawater' in this chapter, and 'Soil salinity' section, chapter 3, page 3.36).

Localised groundwater contamination has resulted where leaching has occurred from mine tailings dams. Improved standards for dam construction and more strict monitoring have reduced events of this nature.

Indicator
Biological health of rivers

The Monitoring River Health Initiative (MRHI) began in 1994 as a national program, the goal of which was to develop models for monitoring and assessing river health using benthic macro-invertebrates as biological indicators (DNR 1996b). (See table 4-31.) Benthic macro-invertebrates are small animals without backbones that live in the sediments of water bodies. Examples include insects, larvae, shrimps, crayfish, snails and mussels.

The advantages of macro-invertebrates compared with other types of biological indicators are that they are widespread,

Table 4-31 Preliminary results from the MRHI macro-invertebrate sampling sites in Queensland. Numbers represent a count of sample sites in each region, ratings being based on the expected numbers of organisms as compared with reference sites. Ratings were defined as: good — large numbers of taxa, sensitive taxa present; fair — medium numbers of taxa, some sensitive taxa present; poor — low numbers of taxa, tolerant taxa predominant.

Region	Quality				
	Good	Fair	Poor	Not sampled	Total
Carpentaria	3	14	2	2	21
Murray–Darling	3	16	3	2	24
Southern Coastal	13	27	5	5	50
Central Coastal	7	51	5	18	81
Lake Eyre–Bulloo	0	8	0	0	8
Northern Coastal	31	12	0	1	44
Total	**57**	**128**	**15**	**28**	**228**

(Source: DNR)

Groundwater intrusion by seawater

In the 1880s Bundaberg established itself as a major centre for growing and milling sugarcane and refining sugar. High sugar prices, favourable government policies and readily available water caused a rapid expansion of the sugar industry in the region so that Bundaberg became the largest southern source of sugarcane in Queensland. Today, the cultivation and manufacturing of sugar remain the mainstay of the region's economy.

In 1992 Bundaberg was the largest of Queensland's major irrigation areas, 55 638 ha being supplied with water from a combination of surface water and groundwater. Surface water is provided to the Bundaberg area from the Burnett, Kolan and Elliott Rivers. Four major storages in the area have a combined capacity of 159 000 ML per year.

The Bundaberg Groundwater Area (BGA) occupies a coastal strip approximately 20 km wide, extending north from Theodolite Creek to the Kolan River. The aquifers consist of a series of poorly interconnected sand and gravel channels that slope gently towards the coast. These aquifers are split by an intervening clay layer into two vertical components. The Elliott Formation lies between 5 m and 35 m below sea level and is intersected by the estuaries of the Kolan, Burnett and Elliott Rivers. The underlying Fairymead Formation extends to 100 m below sea level in some places.

The BGA's total annual groundwater allocation is 65 000 ML, based on 1970 use levels. Based on sustainable water levels, the estimated yield is 54 500 ML. Actual water use ranges from 30 400 ML to 65 000 ML, but has exceeded the allocation in drought years — for example, 74 400 ML in 1994–95. When this happens, the salt front (where freshwater, acting like a piston, prevents underground seawater intrusion) moves inland. Water withdrawn downstream of the salt front will be contaminated.

Since 1994–95 excess use of groundwater has been banned in the BGA. Restrictions have been implemented to limit use, particularly in coastal areas where saltwater intrusion is more likely. Saltwater intrusion monitoring occurs at 80 sites to determine the movement of the salt front, changes in extent, responses to changes in groundwater level, long-term trends and responses to management.

Saltwater now underlies 580 ha at Elliott Heads and 6700 ha of the Burnett Heads peninsula. Water quality in the Elliott Formation appears stable. Water quality in the Fairymead Formation deteriorated to a low in 1994, but seems to have improved slightly since restrictions were imposed.

occupy a central role in the ecology of rivers, form key links in the aquatic food chain, are not very mobile, are in close contact with sediment and water, and are sensitive to adverse environmental conditions. Biological monitoring using these organisms complements data obtained through physico-chemical water quality monitoring and can be used to detect past, intermittent and synergistic effects of disturbances and water pollution.

The MRHI models use reference sites, representing areas where relatively little impact has occurred, to predict the number of categories of organisms expected at more than 200 sites from a wide range of climatic, geological and biogeographical regions in Queensland. Sampling was undertaken in October and November 1994 towards the end of the dry season. Most sites were affected by drought at this time. Additional sampling was performed in autumn 1996 after floods to assess the impact of and recovery from drought and flood conditions.

The majority of the sites in the Carpentaria region were rated as fair. A few upland sites in the Mitchell River and its tributaries were found to be in good condition. These sites were relatively undisturbed and in areas that receive high rainfall. Two sites were found to be in poor condition. The first was upstream of the Collins Weir on the Walsh River. This site was a sandy channel with very little habitat diversity. The second site was the Flinders River at Richmond, which was found to have a very high conductivity. Subsequent visits to the site indicated that the high conductivity was temporary. Because of the unrepresentative nature of the site, an alternative site upstream was sampled. Conductivity there was found to be lower and the condition was assessed as fair.

The upper reaches of the Condamine River in the Murray–Darling region were found to be in good condition. The rest of the Condamine River and the Border Rivers catchments were generally rated as in fair condition with a few stretches rated as poor.

All sites sampled in the Lake Eyre–Bulloo region were in fair condition. The region experiences extreme environmental conditions and it is not surprising that most of the organisms found there were tolerant species. The 'fair' rating was a result of mainly natural conditions and not due to any identifiable human-induced impacts.

Most sites in the Southern Coastal region were in fair condition. Those in good condition were located in wetter areas of the catchment in tracts of rainforest. Sites in poor condition were found in arid areas of the upper catchments or areas affected by agriculture and urban development in the lower catchments.

Because of prevailing drought conditions, some sites in the Central Coastal region had dried up or were fouled by cattle droppings and were not sampled. Most sampled sites were in fair condition. Sites rated as good were high in the catchment or in small rainforest streams. Sites in poor condition mainly had poor-quality water due to the drought and were fouled by cattle droppings. A site downstream of the sewage treatment plant in Proserpine rated as poor. This site had elevated phosphorus levels and an abundance of aquatic plants, indicating a eutrophic condition.

Generally, the condition in the Northern Coastal region was rated as good, particularly in high-rainfall areas between Cairns and Ingham. Two sites rated fair were in lowland sandy channels. In the drier areas of the Herbert River conditions were generally fair, with the smaller tributaries in good condition. In the drier northern region west of Cooktown, conditions were generally fair, one site on the Haan River being good. A site on the Normanby River (at Battlecamp) that was identified as a sampling site in August had dried up by October and therefore was not sampled.

The First National Assessment of River Health (FNARH) commenced in 1997 with sampling of 300 new sites throughout Queensland. It aimed to sample about 600 new sites by the end of 1999. Results of this study will be used to assess the condition and trend of Australia's rivers and provide the first comprehensive assessment of river health in the State.

Indicator
Health of wetlands

The state of wetlands is difficult to determine because large areas of Queensland have not been surveyed systematically for wetland sites. All categories of wetlands combined are estimated to cover about 4.3 percent of Queensland's mainland, nearly 74 000 km^2. Seasonally or intermittently inundated inland wetlands account for 72 percent of the total. See chapter 7, 'Biodiversity', for further discussion of the state of Queensland's wetlands.

RESPONSE

As well as being governed by the natural variability of climate and weather, the quantity and quality of Queensland's inland waters are affected by agricultural, industrial, mining and urban activities. The success or failure of efforts to protect Queensland's water resources will ultimately depend on the everyday practices of individual landholders, industrial and commercial operators, and domestic water users, all of whom live and operate in water catchments.

The role of government in water management is to facilitate society's efforts to achieve the most beneficial uses of this scarce resource while ensuring that these uses occur in an ecologically sustainable way. To address these issues the national and State environmental legislation and policy frameworks have evolved significantly over the past decade. The general trend has been for integration of legislative tools and strategies to facilitate progress towards the goals of ecologically sustainable development, increasing environmental responsibility and integrating processes for development and infrastructure planning and assessment.

Societal responses demonstrate a growing appreciation of ecological processes, recognition of the need to adopt sustainable water management practices, and a stewardship role for local communities and private landholders. This role, as stewards of the water environment, is also recognised in national and State policies, strategies and legislation, and reinforced by a 'user pays' principle in environmental legislation and water licensing requirements.

In light of the above, efforts to manage aquatic systems are often coordinated and funded by national and State governments, but implemented at the local level.

The responses in this section have been divided into two categories: those that deal with issues associated mainly with quantity, and those that deal with issues associated mainly with quality. Within each category information and responses are presented from the international, national, State, regional and local levels where relevant.

QUANTITY

International agreements/conventions

Convention on Wetlands of International Importance

Australia is a contracting party to the Convention on Wetlands of International Importance 1971 (the Ramsar Convention). This agreement provides the framework for intergovernmental cooperation in the protection and sustainable use of wetlands. Queensland has one inland Ramsar site: the Currawinya Lakes, consisting of Lake Numalla and Lake Wyara (see location on figure 4-16). Four coastal Queensland sites have also been listed under the Ramsar Convention (see chapter 5, 'Coastal zone').

National and State policy statements and strategies

The need to provide water for ecosystems has been formalised in national policy statements and amendments to water management planning processes under the *Water Resources Act 1989*.

Council of Australian Governments strategies for reform of the water industry

In February 1994, the Council of Australian Governments (COAG) endorsed a set of strategies for the reform of Australia's water industry. These involve water pricing reform, clarifying property rights, allocating water for the environment, adopting trading arrangements for water, institutional reform and public consultation and participation (COAG 1994).

In relation to groundwater management, the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) task force on the COAG water reform policy made twelve recommendations regarding the allocation and use of groundwater in Australia (Commonwealth of Australia 1997). These reforms include consideration of:

- water pricing to recover costs;
- developing water allocation or entitlement systems to provide for water trading and include provisions for the environment; and
- integrating natural resource management, integrated catchment management approaches and consultative mechanisms.

National Principles for the Provision of Water for Ecosystems 1996

In 1996, ARMCANZ and the Australian and New Zealand Environment and Conservation Council (ANZECC) released a set of national principles to provide policy direction to deal with the issue of water for the environment in the context of general water allocation decisions (ARMCANZ and ANZECC 1996). The goal for providing water for the environment is to sustain and, where necessary, restore ecological processes and biodiversity of water-dependent ecosystems.

Wetland Policy

In 1997 the Commonwealth Government launched its Wetland Policy to provide a set of objectives, principles and strategies for the wise use of wetlands in Australia. This policy is designed to implement the National Strategy for Ecologically Sustainable Development and to meet Australia's obligations under the Ramsar Convention. Commonwealth funding will be provided, in part, to ensure a sound scientific and technological basis for the conservation, repair and ecologically sustainable development of wetlands. These initiatives should help provide information to evaluate trends in wetlands use for subsequent reporting. The choice of appropriate indicators to determine wetland health will depend, to

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Ory Lagoon, north Queensland — a healthy wetland community

a large extent, on the information made available through the Commonwealth Wetland Policy.

The National Wetlands Program will receive funding under the Natural Heritage Trust to support local efforts to rehabilitate degraded wetlands. The Queensland objective is to retain, conserve and manage wetlands in accordance with the principles of ecologically sustainable development. Priority wetlands are the Ramsar sites and others listed in *A Directory of Important Wetlands in Australia* (ANCA 1996).

Strategy for the conservation and management of Queensland's wetlands

The Queensland Government has produced a strategy for conserving and managing Queensland's wetlands. This provides a framework to guide State agencies responsible for wetlands management and sets out initiatives to encourage and assist landholders to sustainably manage wetlands under their control (DoE 1997b). The Queensland Government's objectives for wetlands are to:

- avoid further loss or degradation of natural wetlands, unless overriding public interest can be shown;
- base the management and use of natural wetlands on the principles of ecologically sustainable management and integrated catchment management; and
- develop community awareness of and respect for the values and benefits of wetlands.

These objectives provide a framework for a range of wetlands initiatives. Implementing these objectives will depend on many research programs, to make it possible for planning and management decisions about wetlands to be based on the best available knowledge. The strategy recognises that wetlands rehabilitation is an important component of efforts to maintain and restore ecological processes and functions in a catchment. Public education on the role of wetlands will be aimed at achieving voluntary support for conserving remaining wetlands.

Water Infrastructure Task Force

A Water Infrastructure Task Force was established within the Queensland Department of Natural Resources in early 1996 to identify and prioritise proposals to accelerate the development of surface water infrastructure projects throughout the State (WITF 1997). A Water Infrastructure Planning and Development Implementation Plan (WIPDIP) has been developed to collect data and establish baseline monitoring systems to provide a basis for evaluation of new infrastructure proposals. The implementation of any proposed structure will involve environmental and social impact studies and an environmental management plan to minimise adverse impacts on the environment.

Water management and planning

The Queensland Department of Natural Resources has introduced two new planning processes in relation to water allocation. These are the water management planning (WMP) process and the water allocation and management planning (WAMP) process (DNR 1997e). These planning processes have a whole-of-basin focus that can be applied to a groundwater or river basin.

The Water Resources Act was amended in 1996 to provide for a statutory basis for the WMP process. The intention was to provide the policy and principles for dealing with licence applications in basins that are not fully developed but are considered to be sensitive and have high environmental value. These basins are expected to face increasing pressure for future development of water resources on a significant scale. The outcome of a WMP process is to define the extent to which water resources within a basin may be allocated in the future.

A WAMP is a more detailed and rigorous process based on social and economic data as well as environmental and hydrological analyses of entire catchments. The aim of the process is to determine total water resources within a catchment, the extent of existing entitlements, environmental flow requirements and whether further allocations are possible. A completed WAMP will also provide the natural resource basis for establishing permanently transferable water entitlements.

The WAMP process is generally applied to basins where there is some existing development plus significant potential demand for further water resource development. WAMPs are at various stages of development in the Condamine–Balonne, Fitzroy, Border Rivers (with NSW), Logan and Barron River Basins.

In August 1998 a draft WAMP for the Fitzroy Basin was released for public consultation. It was developed to be consistent with the COAG water reforms, the National Competition Policy (NCP) Agreements, the Intergovernmental Agreement on the Environment, the National Principles on the Provision of Water for Ecosystems, and the statutory requirements of the *Environmental Protection (Water) Policy 1997*. Once the WAMP is approved, it is expected to become a statutory plan under the appropriate State Government water resource management legislation.

Water conservation

WaterWise is an initiative of the Department of Natural Resources and local governments designed to reduce the demand for water through public awareness and education campaigns focusing on water quality and quantity issues. It targets consumers of water in four components — at home, in the workplace, on the farm and in the catchment. Regular studies are planned to monitor community attitudes through public surveys, and to compare any changes against a 1992 benchmark study. Attitudes will also be assessed in a quantitative approach by measuring water consumption, and through water quality monitoring.

The goal of the WaterWise campaign in the home and workplace components is a 20 percent reduction in water consumption. Criteria for measuring the success of the farm and catchment components have yet to be developed. Successes since water conservation campaigns were implemented include:

- Toowoomba City Council saved $130,000 in water production costs in 1992–93.
- Hinchinbrook Shire Council saved $60,000 in pumping costs in 1992–93.
- Maroochy Shire Council reported a 25 percent reduction in water consumption.
- Hervey Bay City Council reduced consumption from 600 L/person/day in 1988 to 400 L/person/day in 1997.
- Mount Isa City Council reduced consumption by 20 percent and saved $200,000 annually in water treatment and pumping costs.

Water pricing

The Department of Natural Resources water pricing policy for State-owned schemes requires that irrigation users in existing schemes cover, as a minimum, operating, maintenance and refurbishment costs where practical. Urban and industrial users are required to meet all or nearly all of the capital, operating and refurbishment costs of providing bulk water supplies. Currently, the performance of irrigation schemes varies from falling short of meeting operating and maintenance costs to making a small contribution to capital. While attempts are made to reduce costs of service delivery as a first priority, it is likely that price increases will be required in many schemes to ensure that funding is available for the continued operation of irrigation schemes.

New water supply schemes will proceed only once they are shown to be economically viable and ecologically sustainable. The policy for future water supply schemes, including expansion of existing schemes, is that the operating, maintenance and refurbishments costs, as well as a contribution to all or a major proportion of capital, will be covered through annual pricing arrangements and sale of water allocations from the outset.

The Queensland Government does not charge for water drawn from unregulated sources.

Cleaner production

The Queensland Cleaner Production Taskforce Association and the Environmental Protection Agency are promoting cleaner production by industry in a strategy to improve environmental performance. Voluntary reductions in water use by industry are being promoted. Seminars across Queensland in 1997 demonstrated the economic and environmental benefits of cleaner production through industry case studies. Examples include:

- Potable water demand was reduced at Barbera Family Farms, Bundaberg, by soil moisture monitoring. Fertiliser runoff and percolation were also reduced, helping to minimise impact on surface water and groundwaters. These measures contributed to an increased profit of $197,900 in their first season.
- A runoff collection system at Birkdale Nursery, near Brisbane, led to reduced potable water consumption and a reduced risk of contaminated runoff. Estimated savings in town water costs were $90,000 a year.
- An increase in the use of treated, recycled wastewater at Excel's six concrete batching plants is estimated to save $72,000 a year for each plant.

The potential exists for greater participation in water conservation programs by domestic, industrial and agricultural users. Increased efficiency of water distribution and use should be promoted by all levels of government. Practices such as refurbishment of leaking channels and pipes in water distribution systems, minimum tillage and trash retention to reduce evaporation rates on irrigated crops, and trickle irrigation can reduce water consumption significantly. Installation of private rainwater tanks would reduce the demand for potable water for non-potable uses.

Water reuse

Reuse of wastewater in Queensland has been limited to parks, gardens, irrigated agriculture and some industrial uses. Access to significant supplies of wastewater typically is limited to areas downstream of major urban centres. The cost of providing a separate distribution network for non-potable water supplies can make reused water more expensive than potable water.

Floodplain management

Several Queensland State Government departments have an interest in floodplain management issues. This has led to a somewhat fragmented development of legislation. Because responsibility for floodplain management has been delegated mostly to local government, the State's practical involvement has been limited generally to examining disasters associated with major floods or implementing structural solutions for mainstream flooding through mechanisms such as river improvement trusts.

Historically, flood risk management, particularly in the urban environment, has been seen as a local government responsibility. Uncoordinated State policies and legislation about flooding and floodplain management have led to a variety of local policies and controls to deal with the issue.

In 1996 the Queensland Flood Co-ordination Committee (QFCC) was established to improve the coordination of flood risk management across the State. Flood risk management requires the coordination of integrated catchment management processes, emergency service planning, land use planning and land and water management efforts.

The QFCC found that management of flood risk in Queensland needed improvement, principally through more effective controls on development in floodplains. Problems identified by the committee were:

- a need for leadership by the State through policy, guidelines and incentives for flood risk management;
- coordination of all activities impinging on flood risk management and between the responsible government agencies; and
- a move from disaster response to a more integrated approach linking flood risk assessment, the management of development on floodplains and flood disaster management.

Borehole capping

In 1989 the Great Artesian Basin Rehabilitation Program was initiated by the Commonwealth and State governments to repair or plug and replace bores flowing uncontrollably. At the start of the program the number of bores flowing uncontrollably was estimated to be more than 1380 basin-wide. Between June 1991 and June 1996 more than 175 bores (almost 13 percent) were rehabilitated, amounting to a total annual water saving of 32 000 ML (DNR).


DNR

Capped bore head

The Bore Drain Replacement Project (BDRP) began in south-west Queensland in 1993 to provide financial and technical assistance to bore owners to replace bore drains with piped systems. For the first three years of the project the Queensland and Commonwealth Governments shared 80 percent of the cost of the systems. From 1994 to 1997, twelve piping systems were installed under BDRP at a cost of $2.2 million. The area served by the installed pipelines was 219 000 ha for an annual water saving of 4000 ML.

A 20 percent subsidy is available through the Department of Natural Resources to Bore Water Area Boards when replacing bore drains with pipelines. The landholder portion of bore repair and the replacement of bore drains with piped systems qualify for Landcare loans under the Primary Industries Productivity Enhancement Scheme (PIPES) through the Queensland Industry Development Corporation.

Groundwater recharge

Queensland's highly variable rainfall patterns can limit natural recharge of aquifers and this, in turn, restricts groundwater yield. Artificial recharge of aquifers occurs by diverting water from surface storages and artificial channels to recharge areas. Six recharge schemes operating in Queensland are described briefly below (DNR).

About 200 000 ML/year is diverted from the Burdekin River system to the Burdekin Delta aquifer system, mainly from natural flows using a system of natural and artificial channels and trenches coupled with weirs and barrages.

About 10 000 ML of water from Callide Dam and 3000 ML from Kroombit Dam are diverted for recharge in adjoining Callide Valley catchments.

A system of weirs holds natural flows and releases from surface storages to increase recharge to the Lockyer Valley's aquifers.

A system of weirs and natural and artificial channels is used to divert natural stream flow and releases from Cania Dam, near Monto, to the aquifer.

A recharge weir has been built on Cressbrook Creek to hold natural flows and increase recharge.

A system of old creek channels and lagoons is used to recharge Mackay's water supply aquifer.

Local government initiatives

Water meters

Water meters provide local governments with the means of charging domestic water users for their water consumption. Meters also encourage the conservation of drinking water resources. Of the 121 local government areas in Queensland with water supplies, 97 have installed water meters for domestic dwellings.

Commonwealth and State legislation

Water Resources Act 1989

Water licences and rights are allocated under the *Water Resources Act 1989*, administered by the Department of Natural Resources (table 4-32). In areas with regulated watercourses, allocation is announced yearly, based on existing and anticipated supplies. Water rights are attached to a property descrip-

Table 4-32 Licences issued under the Water Resources Act, 1991–92 to 1994–95

		1991–92	1992–93	1993–94	1994–95
Waterworks licences (surface and groundwater)	Applications for renewal	–	–	10 829	15 762
	New applications	3 621	3 496	3 285	3 098
	Issued	2 883	2 725	8 945	17 971
	Withdrawn	116	145	–	83
	Refused	101	53	0	47
Drillers' licences	Artesian	44	52	51	52
	Subartesian	178	240	172	242
Stock and domestic permits	Issued	656	513	514	–
	Cancelled	54	5	44	–
Water permits — government departments	Issued	5	1	21	–
	Cancelled	1	14	0	–
Prosecutions*	Offences investigated	14	10	25	7
	Convicted	2	8	10	12
	Dismissed	1	0	0	1

*Might be carried over from previous year
(Source: DNR)

tion. In areas with unregulated watercourses annual licences are issued, based on the number of hectares to be irrigated.

Relevant protocols/reports

Stream Stabilisation for Rehabilitation in North-East Queensland is a report funded by the Land and Water Resources Research and Development Corporation, the National Landcare Program and the Queensland Department of Natural Resources (Kapitzke et al. 1998). The report is the outcome of several research and development projects involving staff from James Cook University and Commonwealth, State and local government agencies. It provides comprehensive guidelines for ecologically sensitive and sustainable stream management practitioners. The report is based on extensive case histories of problems associated with river modification and development of riparian zones and stream beds, with a focus on coastal streams in north-east Queensland.

QUALITY

National and State policy statements/strategies

National Water Quality Management Strategy

In 1992 the Australian and New Zealand Environment and Conservation Council (ANZECC) and the Australian Water Resources Council (AWRC) released a draft reference document containing policy principles for water quality management in Australia. The policy objective was defined as: 'to achieve sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development' (ANZECC and AWRC 1992). This objective would be implemented at the State level using water quality planning and policy instruments.

Draft water quality guidelines have been published that contain criteria regarded as necessary to sustain specific uses or protect specific environmental values. Guidelines are available for:

- fresh and marine waters;
- drinking water; and
- groundwater protection.

Additional draft documents are available that provide guidelines in water quality management for:

- monitoring and reporting;
- rural land uses and water quality;
- urban stormwater management;
- sewerage systems — effluent management, acceptance of trade wastes (industrial), sludge management (biosolids), use of reclaimed water, overflows; and
- effluent management — dairy sheds, dairy processing plants, piggeries, aqueous wool scouring and carbonising, tanning and related industries, wineries and distilleries.

Natural Heritage Trust

In 1996 the Commonwealth Government established a Natural Heritage Trust (NHT) to fund projects in five major environmental areas — vegetation, rivers, biodiversity, land, and coasts and marine. The NHT has also provided funding for the National Land and Water Audit to make the first comprehensive appraisal of the environmental, social and economic costs of land and water degradation in Australia.

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Water sample being taken

The Commonwealth's objectives for the NHT are to:
- provide a framework for strategic capital investment, to stimulate additional investment in the natural environment;
- achieve complementary environmental protection (including biodiversity conservation), sustainable agriculture and natural resources management outcomes consistent with agreed national strategies; and
- provide a framework for cooperative partnerships between communities, industry and all levels of government.

Several subprograms have a direct impact on inland water resources. These are the National Rivercare Initiative, the National Landcare Program, Murray–Darling 2001, the Fisheries Action Program and the National Wetlands Program (discussed previously). Other NHT-funded programs will have significant effects on freshwater resources as well, but are discussed in other chapters of this report.

National Rivercare Initiative

The National Rivercare Initiative will provide funding until 2001–02 to assist sustainable management, rehabilitation and conservation of rivers outside the Murray–Darling basin. Programs funded under this initiative include:
- the National River Health Program, which monitors and assesses the health of Australia's rivers through the use of biological indicators and conducts research into the environmental flow requirements of rivers and streams;
- Waterwatch Australia, which will continue its water quality monitoring program. It aims to raise community awareness about the relationship between water quality and catchment health. Schools, community groups and local governments participate to regularly monitor local waterways for common parameters such as plants and animals. Waterwatch activities also include public awareness campaigns, tree planting, dealing with specific water quality problems and clean-up days; and
- the Fisheries Action Program, which will encourage local participation in the sustainable management of fisheries and fish habitats.

The Fisheries Action Program is designed to help achieve the repair of Australia's aquatic environment and assist in the conservation and sustainable use of fish resources in freshwater, estuarine and marine environments. The objectives for Queensland are to:
- foster fisheries habitat restoration and protection;
- raise community awareness of and participation in fisheries resource issues;
- ensure responsible and sustainable resource use; and
- encourage an integrated approach between resource users, the community, and resource management and research agencies.

One of the priorities of this program is the restoration of aquatic habitat, including riparian systems.

National Landcare Program

The National Landcare Program (NLP) is a national movement that includes all levels of government, the community and individual landholders to increase the long-term productivity and ecological sustainability of Australia's land, water and vegetation resources (Commonwealth of Australia 1997). The NLP provides funding to enable governments to work with the community in areas such as sustainable land management, developing new land and water management technologies, rangeland management and community landcare. The aim is to support Landcare activities by providing information or infrastructure or coordinating activity within or between Landcare groups or regions. In 1994–96, 102 projects operating in Queensland included a water erosion component, 10 projects addressed irrigation-induced soil salinity and 50 projects focused on dryland salinity.

The NLP will receive funding until 2001–02 to support activities that contribute to the sustainable management of land, water and vegetation resources. The NLP encourages strategic activities which result in improved on-ground outcomes and enhance community capacity building. The objectives, to be achieved through working with all levels of government, industry and the community, are to:
- increase community awareness and understanding of river issues and promote links to facilitate community involvement in developing responses;
- promote integration of riverine action plans with land and vegetation management issues;
- assist in developing responses which address critical barriers or impediments to improved river health, particularly within catchment or regional contexts, through targeted management responses;
- assist and stimulate investment in activities which address national, State and regional strategies and priorities for improved river outcomes; and
- assist in providing high quality data and decision support systems which will support investment and decisions in relation to environmental water provisions.

Murray–Darling 2001

The goal of this program is to contribute to the rehabilitation of the Murray–Darling Basin with a view to achieving a sustainable future for the basin, its natural systems and its communities. The core objectives of the program are:
- improving water quality by reducing salt and nutrient levels in the river system;
- developing integrated catchment plans for all Murray–Darling catchments and commencing major on-ground works to address land and water degradation;
- restoring riparian land systems, wetlands and floodplains by establishing environmental flows capable of sustaining natural processes and protecting water quality and the aquatic environment;
- improving the health of key river systems in the basin by integrated catchment management and flow management strategies; and
- encouraging ecologically and economically sustainable land use by reducing salinity and waterlogging in irrigated lands and encouraging the highest value use of scarce water resources.

Queensland will receive 8.5 percent of the funding provided by the NHT for this initiative. Queensland is required to match funds provided to accelerate on-ground and irrigation water management activities.

Integrated Catchment Management

In October 1991, the Queensland Government launched an Integrated Catchment Management (ICM) Strategy. Its goal was to achieve balanced and sustainable use of land, water and related biological resources through community participation and coordination of decision making. In 1997 the ICM Coordinating Committee and the Landcare Council combined to form the Landcare and Catchment Management Council (LCMC). The LCMC provides strategic advice to the Minister for Natural Resources on Landcare and catchment management in Queensland and provides a link between community organisations and government. It is also responsible for providing advice and strategic direction for the operation, management, administration, monitoring and evaluation of the NHT in Queensland.

Blue-Green Algae Task Force

In 1992 a Blue-Green Algae Task Force was established to minimise algal problems in the summer of 1991–92 and to recommend actions and policies to minimise the occurrence and extent of blooms in the future (QWQTF 1992). Its prime concern has been managing blooms that now occur frequently in Queensland's water bodies. Guidelines on actions necessary in bloom situations have been developed, primarily to protect public health, particularly in regard to drinking water and the use of water bodies for recreation. Research is being carried out on long-term strategies to reduce and eliminate the recurrence of blue-green algal blooms.

Minesite rehabilitation

Previously mined land can be rehabilitated to reduce the impacts of stormwater runoff on nearby water supplies. Rehabilitation involves replacement of stockpiled overburden and revegetation of the disturbed land. In 1992 the Department of Mines and Energy implemented a policy on environmental management for mining in Queensland to mitigate adverse environmental impacts of mining operations (table 4-33). The policy includes:

- a set of technical guidelines for mining in Australia;
- a requirement for mining leaseholders to complete an environmental management overview strategy (EMOS);
- a plan of operations to deal with the environmental issues identified by the EMOS;
- an evaluation of each mine's performance by audit; and
- a compliance assessment to determine whether the requirements of the Mineral Resources Act are being met.

Data about the long-term impacts of the policy are not available.

Table 4-33 Area of previously mined land that has been rehabilitated

Year	Total cumulative rehabilitated land (ha)	Area of land rehabilitated (ha)
1990	12 163	n.a.
1991	12 676	514
1992	14 605	1 929
1993	15 697	1 092
1994	17 330	1 633
1995	19 662	2 332
1996	23 000	3 338

(Source: DME)

Response to contamination

Emergencies arising from chemical spills are dealt with by the Queensland Fire and Rescue Authority and the Queensland Police Service. These services receive advice and support from the Response Advice for Chemical Emergencies (RACE) section of the Chemical Hazards and Emergency Management (CHEM) Unit of the Department of Emergency Services.

Known cases of pre-existing contamination are dealt with under the contaminated land provisions of the *Environmental Protection Act 1994* (which repealed the *Contaminated Land Act 1991*). The Environmental Protection Act requires a register of sites to be maintained and describes the process and responsibilities for site investigation and site remediation.

Two cases that exemplify the process of contaminated site remediation are the former Kingston hazardous waste disposal site and the Willawong Hazardous Waste Facility.

The State Government conducted an extensive remediation program at the former Kingston disposal site (south of Brisbane) to address potential groundwater impacts. The approximately $10 million program involved relocation of affected residents, capping of waste disposal areas with impermeable materials to prevent surface water infiltration, and a continuing groundwater monitoring program. The program has shown that the remedial works have been effective in protecting the environment beyond the site from contamination.

The Willawong Hazardous Waste Facility (southern Brisbane) was closed on 30 June 1998. Brisbane City Council is currently implementing an extensive surface and groundwater monitoring and progressive site remediation program (worth approximately $40 million over six years) expected to be completed in 2005. Strategies involve capping problem areas with impervious materials to reduce surface water infiltration, strategically placed leachate collection systems and artificial wetlands to address stormwater quality. Initial remedial works, including wetland construction and leachate collection, have been successful in improving groundwater and surface water quality.

Legislation

Environmental Protection (Water) Policy 1997

The Queensland *Environmental Protection (Water) Policy 1997* commenced in 1998 to achieve the object of the Environmental Protection Act ('ecologically sustainable development') in relation to Queensland waters. This is done by providing a framework for identifying environmental values for Queensland waters, establishing water quality guidelines and objectives to enhance or protect the environmental values, promoting efficient use of resources and best practice environmental management, and involving the community through consultation and education. This policy is administered by the Environmental Protection Agency and applies to all Queensland waters.

Land Act 1994

The Department of Natural Resources administers the *Land Act 1994*, which deals with the clearing of vegetation on State-owned lands and properties held under leasehold or licence. The Act provides for clearing controls in critical areas including riparian zones. The changing attitudes and values of the community, as well as local land management practices, are taken into consideration when administering the Land Act.

Fisheries Act 1994

The *Fisheries Act 1994* was enacted to manage fish and invertebrates in marine and fresh waters. The Department of Primary Industries and interest groups have developed a policy for translocating fish in Queensland freshwater systems, including rivers, impoundments, farm dams and aquaculture facilities. The Act sets out key principles under which the

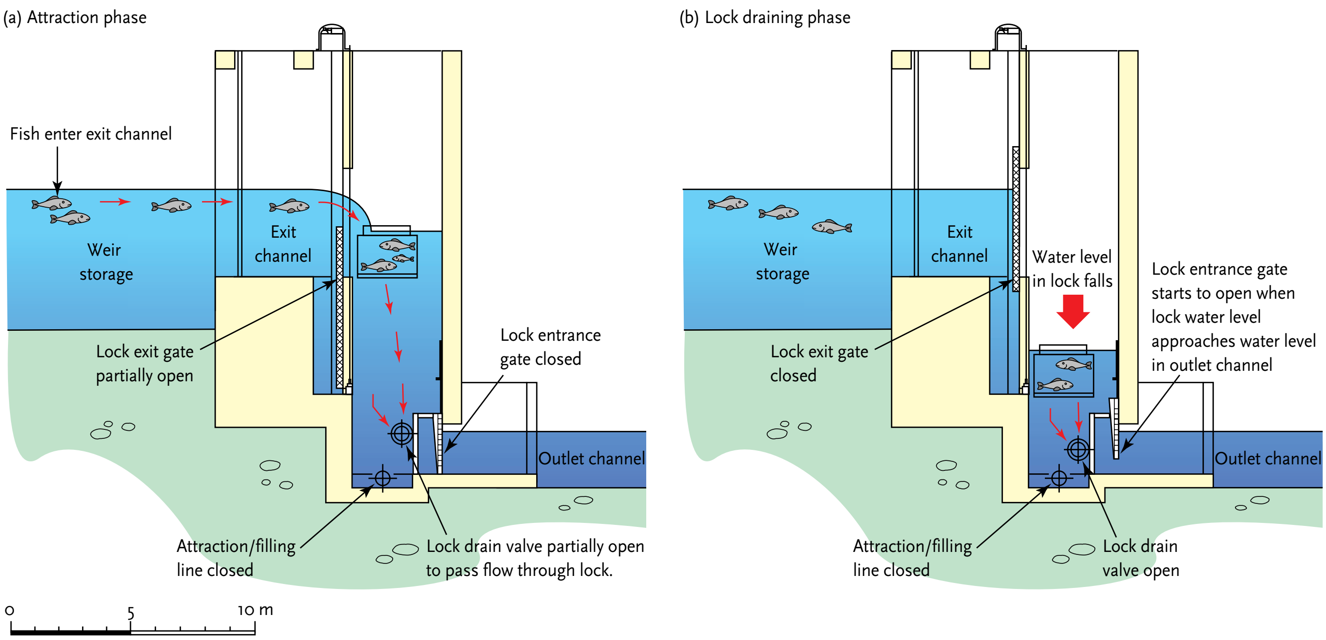


Figure 4-31 Walla Weir fish lock: stages of operation for downstream passage
(Source: DNR)

Department will operate, and decision-making procedures following specific protocols (Arthington and McKenzie 1997).

The Fisheries Act established the Queensland Fisheries Management Authority to provide for the development of specific fisheries and habitat management plans based on the principles of ecologically sustainable development.

The effect of artificial barriers on the movement of migratory fish species has brought about the introduction of fishways to allow free movement of fish in streams. Most early fishways were built along the lines of Northern Hemisphere fishways, which were designed to allow the passage of salmon and trout. The steep gradients and high velocities of these types of designs were ineffective for native fish.

Since 1990 the Queensland Government has implemented a program to modify ineffective fishways where possible, and to install fishways on new impoundments where required. Research has shown that well-designed fishways can be very effective. In February 1997, 25 fishways were operating in Queensland. Recently constructed fishways have been of vertical slot, rock ramp and lock designs (see figure 4–31). These designs will be monitored to gauge their effectiveness. Under the Fisheries Act, the Department of Primary Industries can approve or reject applications to build barriers or require a fishway to be built on newly constructed or existing barriers that are being modified (QFMA 1996a).

Fisheries Regulation 1995

Under the *Fisheries Regulation 1995*, areas closed to fishing were introduced as a way to protect fish that congregate in particular areas due to an inability to pass artificial barriers. The Regulation defines closure lengths upstream and downstream of specific impoundments.

Queensland has an interim contingency plan for dealing with outbreaks of diseases and parasites transmitted via aquaculture stock to wild fish. Freshwater aquaculture cannot be undertaken without a permit, which can contain any condition deemed appropriate by authorities. These conditions are included to prevent the escape of fish, juveniles, eggs and larvae into natural waters.

Regional and local government initiatives

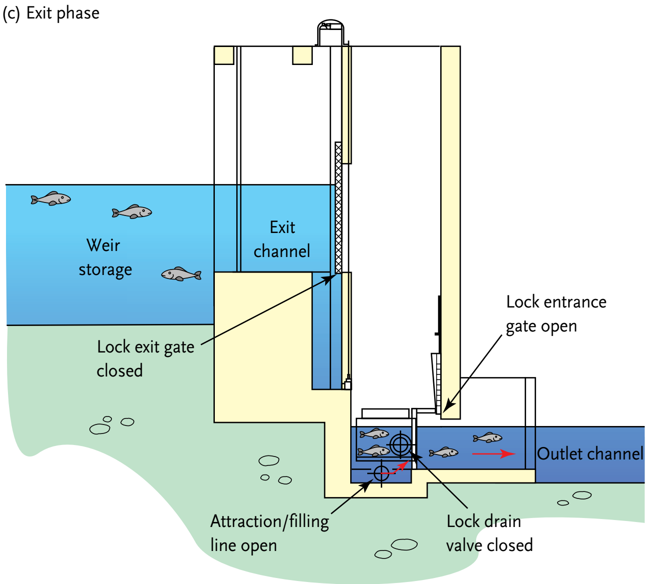
Catchment Co-ordinating Committees

Twenty-six local Catchment Co-ordinating Committees, covering 89 percent of Queensland, have been established. Their role is to provide a forum for community input and discussion, to identify and prioritise the complex land and water resource issues in their catchment and to develop catchment management strategies (Dawson 1993). Eleven implementation grants have been paid to successful applicants to carry out works of strategic value in eight catchments. Catchment committees and other community-based groups have received project funding to assist in the preparation of catchment management strategies and in undertaking various investigative and educational projects in their catchments (DNR).

Brisbane River Management Group

The Brisbane River Management Group (BRMG) and the Brisbane River and Moreton Bay Wastewater Management Study have jointly developed a Waterways Management Plan to coordinate the management of the Brisbane River and Moreton Bay Catchment (DEH 1998). The Plan provides a framework for desirable management outcomes to ensure that the river remains healthy and capable of supporting the livelihoods and lifestyles of the people of south-east Queensland. Existing local integrated catchment management groups have contributed local input via detailed management plans at the sub-catchment level. Eight issue-specific implementation programs have been proposed, including catchment land use, recreation, water quality, extractive industries, and water entitlements and flow. Implementing final plans will be achieved through various State and local government departments acting as lead agencies to provide effective legislative and administrative support, strong

(c) Exit phase



coordination and monitoring arrangements, and an appropriate level of public education and involvement.

Community group responses

Waterwatch

Waterwatch Queensland began in 1993 as a community water quality monitoring program. Schools, land users, community groups, local authorities and government were the groups targeted for participation. A State steering committee was set up to establish direction and gain support for Waterwatch programs. Catchments officially engaged in Waterwatch projects at June 1995 were Pioneer, Port Curtis, Mary, Maroochy, Lockyer, Upper Brisbane Valley, Condamine and Lake Eyre Basin.

Riverbank Restoration Grants Scheme

The Riverbank Restoration Grants Scheme began in September 1995 with $140,000 from Commonwealth Drought Landcare and $50,000 from Cooloola Shire Council. As part of this program, several catchment groups have initiated projects to improve their riparian zones. The Mary River Catchment Co-ordinating Committee oversees a riverbank replanting scheme involving 50 landholders involved in dairy farming and grazing. Landholders applied for funds for tree planting, fence construction, restricted stock watering points, hardened cattle pads (to reduce bank erosion at stock access points), pipework and pumps for reticulation, cattle troughs, placing riffles to slow stream flow, stream bed restoration and the control of woody weeds. Some reported benefits from its first year of operation were the planting of more than 6000 trees, with an estimated three million new seedlings emerging in trial plots in the riparian zone. Stock access has been limited by 50 km of fencing along the Mary River and its tributaries, with 68 new offstream watering points. Limited access has also reduced the amount of faecal contamination and associated nutrients from cattle droppings in the riparian zone.

Revegetation programs

Community and government-based groups are active in revegetation efforts in the Wet Tropics area. Some examples are listed below:

- Trees for the Evelyn and Atherton Tablelands (TREAT) has a goal to stabilise steep slopes and control erosion on stream banks.
- The Wet Tropics Tree Planting Scheme (WTTPS) aims to improve water quality by establishing vegetative buffers along rivers and streams.
- The Revegetation Plan for the Johnstone River catchment coordinates community- and government-sponsored groups involved in long-term revegetation.

Saltwatch

Saltwatch is a community-based environmental action program in operation since 1991. It promotes awareness of and education about soil salinity. Water samples from rivers, creeks, bores, channels, drains, tanks, dams and taps in participating local areas are collected during May of each year. Samples are tested for salt content and data are collated and distributed by the Department of Natural Resources.

Relevant protocols/reports

The Brisbane River and Moreton Bay Wastewater Management Study was produced by six local councils in south-east Queensland (Brisbane, Pine Rivers, Caboolture, Ipswich, Redland and Redcliffe), with support from the Department of Environment and Heritage and the Department of Natural Resources, and funding from the Natural Heritage Trust. It has led to the development of wastewater management strategies (BRMG and BR&MBWMS 1998) for the catchments that drain into the rivers and streams, ultimately reaching Moreton Bay. Its goal is to achieve ecologically sustainable use of the water resources in the region, while still maintaining economic and social development. This is to be done by staged improvements to the quality of effluent released by point sources into the region's waterways.

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CHAPTER 5

QUEENSLAND'S COASTAL ZONE

Coastal zone

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Contents

Key issues and findings

Queensland's extensive coastal zone is biologically diverse, is rich in natural resources and contains landforms and ecosystems of international significance. The zone is also home to some 2.62 million people, about 85 percent of the State's population. Population growth is unevenly distributed along the coast, with a number of areas, particularly in the south-east, experiencing very rapid growth.

Resource development, together with a relatively large and growing population, puts the environmental resources of the coastal zone under considerable pressure from human activity.

Resources are not limitless. In some cases, human activity has adversely affected the abundance and quality of a resource. The extinction and rarity of once abundant animals and plants and the decline in certain forest and wetland types are obvious examples. While development has changed forever the landscape of the coastal zone, the condition of most major environmental resources is generally good. Yet some resources remain threatened and continue to decline.

Increasing community awareness of environmental issues and action by both government and industry are changing the way in which coastal resources are managed and used. Many significant programs and actions aimed at redressing deficiencies in environmental regulation or management have been introduced in recent years.

- Information relating to the status of the natural resources of the coastal zone is very limited. In many instances, data are insufficient for conclusions to be drawn about the condition of particular resources or the trend in condition.
- The coastal zone supports an immense diversity of plants and animals, with 2195 species of vascular plants recorded from the 552 continental islands in the Great Barrier Reef Marine Park. Seventy-nine of these are listed as rare and threatened. One thousand and nine species have been recorded on the Mackay coast, and 834 on the Curtis Coast. Queensland also has 37 species of mangroves and 15 species of seagrass.
- The number of invertebrate species occurring in Queensland waters and their status are unknown. Of the larger invertebrates, 374 species of sponges, 350 echinoderms, 400 species of coral, 113 species of barnacles and 550 species of crabs have been identified.
- Six species of turtle are found in Queensland. The nesting population of loggerhead turtles has declined by 50–80 percent since the early 1970s. One species of dugong, 10 species of dolphins and 18 species of whales have been recorded in Queensland waters. The population of dugong in southern Queensland waters, particularly in Hervey Bay, has declined significantly in recent years. The population of humpback whales has increased from fewer than 100 in 1962 to 2500 in 1996.
- Forty-six species of wader birds are known in Queensland; many of these are migratory. A total summer population of approximately 399 000 has been estimated. An estimated 1.159 million breeding pairs of seabirds nest on the islands off the Queensland coast.
- Major land uses in 22 east coast catchments (total area 375 250 km^2) in 1995–96 were: grazing — 320 966 km^2 (85.6 percent); timber — 26 439 km^2 (7.1 percent); crops — 11 763 km^2 (3 percent); pristine — 9337 km^2 (2.5 percent); and urban — 6754 km^2 (1.8 percent). Land use within the coastal zone is changing. In general, a trend of increasing development is apparent: land use is changing from natural to agricultural/ mining to urban/built infrastructure.
- Land clearing has affected most of Queensland's coastal zone to some degree. Clearing for grazing has been extensive. Clearing for urban development has been extensive along the south-east coast. By 1987, some 71.5 percent (173 568 hectares) of coastal lowlands (within 10 km of the coast) in south-east Queensland had been cleared. In the period from 1987 to 1994 a further 6754 hectares were cleared. Clearing constitutes a major pressure on the biological resources of the coastal zone and is continuing.
- Changing catchment land use and vegetation clearing have significantly increased the amount of fine-grained suspended sediment exported downstream to estuarine and nearshore waters. While there is still uncertainty about the size of the increase, the available information indicates that exports have increased by between two and five times over natural levels.
- Extensive areas of both shallow and deeper water seagrasses are known along the Queensland coast. In some areas shallow water beds are under pressure from sedimentation resulting from river runoff. In 1992, an estimated 100 000 ha of seagrass was destroyed in Hervey Bay following a series of major flood events.
- At June 1996, 185 sewage treatment plants, 12 water supply treatment plants and 136 industry treatment plants were licensed to discharge wastewater to estuarine and marine waters. In total, sewage treatment plants discharge an estimated 25 280 kg/day of nitrogen and 7220 kg/day of phosphorus.
- Flow regulation of rivers now occurs throughout Queensland. Overall, of 57 mainland drainage basins which flow to the coast, 25 (44 percent) are now subject to some degree of flow regulation. The flow record of Queensland rivers is not sufficiently long to enable the detection of long-term trends in flow. However, the influence of periodic events, such as the El Niño Southern Oscillation, on flow are clearly evident.
- One hundred and twenty-two exotic species, including 18 species of algae and 104 species of fish, molluscs, arthropods and polychaetes, are known or likely to have been introduced into Australian waters, largely through shipping activity (ballast water discharge and hull fouling). At least 20 species are known from Queensland waters, although it is acknowledged that the actual number is

likely to be much higher. Such introductions have the potential to be highly destructive to marine communities.

- The introduction and spread of exotic terrestrial plant species represent a significant threat to native plant communities. Some 215 exotic species are known from the 552 continental islands of the Great Barrier Reef Marine Park, while 268 have been recorded from the Mackay coast. Some 185 exotic species are established as weeds on the sandy shores of Queensland's east coast. Between 1987 and 1997 an additional 68 exotic species became established on the Sunshine Coast. The trend is one of rapid spread and increasing pressure on plant communities. The primary factors responsible for introductions and spread are urban sprawl, the development of once remote areas, and increased human visitation to offshore islands and remote locations.
- Queensland's wetlands are of outstanding diversity, 38 of the 40 types of wetlands found in Australia being represented. Some 165 important wetlands, of which 83 are coastal, have been identified in Queensland. These 83 wetlands cover some 4 923 844 ha, plus the area of the Great Barrier Reef Marine Park (34 076 800 ha). The major plant community types include an estimated more than 189 500 ha of mangroves, more than 447 100 ha of saltpan, and 2 077 000 ha of seagrass.
- Only on the more remote coasts have freshwater wetlands been spared some degree of modification or loss. Clearing has been particularly severe in south-east Queensland, where an estimated 50 percent (8778 ha) of the melaleuca wetlands present in 1974 were cleared by 1989. Clearing has continued in the 1990s. In the Brisbane area, melaleuca wetlands have been reduced from an estimated 13 000 ha in 1820 to about 390 ha in 1987. Between 1951–52 and 1992 some 9306 ha of freshwater wetland communities were destroyed in three north Queensland coastal catchments, largely for agricultural development.
- Saline wetlands remain in a largely undeveloped condition along most of the Queensland coast. Clearing and modification have occurred, although only on a localised scale. An estimated 1240 ha of mangrove habitat was destroyed in Moreton Bay between 1974 and 1989. Approximately 646 ha were lost from the Curtis Coast and 400 ha from Trinity Inlet. However, in some areas mangroves have expanded.
- The Great Barrier Reef lagoon is particularly susceptible to the effects of nutrient enrichment due to its relatively enclosed and shallow nature. Nutrient inputs to the lagoon have increased substantially over past decades as a result of extensive land clearing and catchment development. However, while localised increases in nutrient concentrations are evident in nearshore waters following significant river runoff, concentrations at other times and in offshore waters are very low. The data are insufficient to identify any trend in concentrations.
- The value of Queensland's fisheries catch is over $200 million, based on a catch of about 26 500 tonnes. The direct and indirect impacts of fishing activities constitute one of the most immediate and identifiable pressures on the native plants and animals of coastal waters. However, the significance to marine communities of impacts such as seabed disturbance and the taking of bycatch is largely unknown.
- Clear trends in the status of Queensland's major commercial fisheries are difficult to identify. However, some appear to show signs of over-exploitation. The barramundi, coral trout and mud crab fisheries are listed as 'probably declining' while the king prawn, saucer scallop and Spanish mackerel fisheries are listed as 'declining'. In some cases, stocks may be declining only locally.
- Tourism is one of Queensland's major industries and one of the fastest growing sectors of the Queensland economy. Areas around Cairns, Townsville, the Whitsunday islands and the southern Queensland coast are particularly subject to the pressures of tourism. The activities of tourists and the infrastructure required to service their transport, accommodation, waste disposal and entertainment needs all combine to place considerable pressure on the coastal zone.
- A range of coastal zone habitats and resources are protected through the provisions of international treaties. Five major wetland areas of significance to wading birds are listed under the Ramsar Convention (Currawinya Lakes, Shoalwater and Corio Bays Area, Moreton Bay, Great Sandy Strait and Bowling Green Bay). Three coastal sites are inscribed on the World Heritage List (the Great Barrier Reef, the Wet Tropics of Queensland and Fraser Island). These sites have been accepted internationally as having outstanding universal values and have been afforded the highest level of international environmental recognition and protection.
- Coastal wetlands and other marine habitats are protected to varying degrees under the Queensland conservation reserve system. Protected areas include 79 fish habitat areas (603 000 ha), 6 marine parks (5 204 660 ha), and the Great Barrier Reef Marine Park (34 076 800 ha). Several different types of reserves can coexist over the same area.
- Queensland has 260 island national parks. The largest include Hinchinbrook Island (39 900 ha), Whitsunday Island (17 000 ha) and Moreton Island (16 800 ha). Many national parks are also located on the mainland. Major coastal parks include the Jardine River National Park (237 000 ha); Lakefield National Park (537 000 ha); Mungkan Kandju National Park (457 000 ha); Cape Melville National Park (137 000 ha); and Great Sandy National Park (219 555 ha).

Pressure

Coastal development

Number of people living in the coastal zone

Average annual population growth rate by local government area

Area of land changed from its natural state

Annual number of dwelling commencements in coastal local government areas

Indicative naturalness/Wilderness Index

Rate of clearing of wetland communities — mangroves, saltmarsh and freshwater wetlands

Number of marine plant permits issued under the Fisheries Act and area involved

Aquaculture production

Number of aquaculture licences

Area under aquaculture ponds

Number of dams and weirs (>25 ML capacity) in the principal coastal drainage divisions

Number of drainage basins subject to flow regulation in the principal coastal drainage divisions

Catchment sediment runoff

Rate of extraction of silica and mineral sands

Annual cargo throughput for Queensland ports

Annual number of vessel visits to Queensland ports

Annual tonnage of petroleum products moved by sea (imports and exports)

Annual number of pollution incidents in Queensland's territorial waters and offshore reported to the Australian Maritime Safety Authority

Contaminants

Number of sewage treatment plants licensed to discharge

Volume of domestic wastewater

Quantity of nitrogen and phosphorus discharged

Number of industrial treatment facilities licensed to discharge

Volume of industrial wastewater

Catchment nutrient runoff

Catchment suspended sediment runoff

Exotic and displaced species

Ship arrivals from foreign ports and ballast water discharged to Queensland waters

Number of exotic and displaced marine species established in Queensland waters

Number of exotic and displaced terrestrial plant species established in the coastal zone

Fishing, hunting and collecting

Total catch of major commercial fish, crustacean and mollusc species

Fishing effort

Annual total bycatch by fishery

Area of seabed trawled and intensity of trawling

Recreational fish catch

Recreational fishing effort

Number of authorities to collect aquarium fish

Number of permits to collect shells

Turtle and dugong mortality through indigenous hunting

Turtle, dugong and dolphin mortality through commercial fishing activity and shark nets

Tourism and recreation

Number of visitors to Queensland

Commercial accommodation available

Air passenger movements at selected airports

Number of visitors to the Great Barrier Reef Marine Park

Number of Marine Park Tourism Program permits

Number of recreational (motor and sail) and commercial vessels registered in Queensland

State

Beaches and dune systems

Area of coastal heath vegetation remaining

Number and geographic distribution of introduced plant species

Soft-bottom systems

Area of soft-bottom habitats not subject to trawling

Coastal wetlands

Area of coastal wetlands

Area of mangrove forests

Area of seagrass beds

Area of melaleuca wetlands

Area of saltpan

Mid-water column systems

Catch by unit effort (catch rate)

Stock status

Freshwater inflows

Annual discharge of major east coast rivers

Runoff-to-rainfall ratio of major east coast rivers

Coastal and estuarine waters

Concentration of nitrogen

Concentration of phosphorus

Land

Area of land allocated to different uses

Minerals and sand

Defined silica sand resources (tonnes)

Defined mineral sand resources (tonnes)

Climate

Sea level

El Niño Southern Oscillation

Intensity and number of tropical cyclones

Storm surge height

Summer minimum temperature

Seafood quality

Concentration of heavy metals in selected seafood

INTRODUCTION

Of Queensland's many diverse environments, those of the coastal zone most typify the Queensland lifestyle. Golden beaches, abundant native plants and animals, extensive coastal wetlands and the world's largest sand island and coral reef all contribute to the quality of life and prosperity of Queenslanders.

About 85 percent of the State's population live in the coastal zone. Its resources are a natural inheritance of immense economic, cultural and intrinsic value. Used wisely, these living and non-living resources can continue to contribute to the prosperity of all Australians. However, like so many natural resources, they are subject to increasing pressure from human activity.

SCOPE

What constitutes the 'coastal zone' is subject to different interpretations. Some definitions extend the zone to the landward limit of coastal catchments. Others specify distances from the shoreline, landward and seaward. Some use political or administrative boundaries. All are somewhat arbitrary and artificial and do not necessarily reflect physical or biological relationships between various coastal landscapes or marine biophysical regions.

The *Coastal Protection and Management Act 1995* defines the coastal zone as 'coastal waters and all areas to the landward side of coastal waters in which there are physical features, ecological or natural processes or human activities that affect, or potentially affect, the coast or coastal resources'. This definition acknowledges that zone limits cannot be set and that a range of human activities and natural processes influence land and sea along the 'coast'.

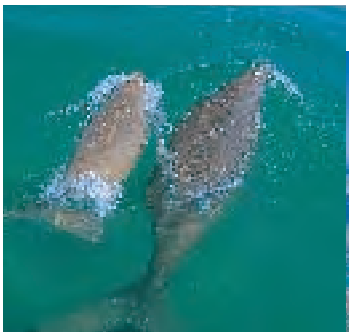
In this chapter, the coastal zone is considered to comprise those areas of land that clearly affect estuarine and marine processes and are adjacent to saline waters, and those waters that are within the zone of influence of terrestrial processes or that are of particular interest to Queensland. Therefore it covers coastal cities and towns, coastal lowlands and wetlands, the Great Barrier Reef region and all coastal waters where Queensland has a fisheries or other interest (see box 'Jurisdiction over coastal waters').

PURPOSE

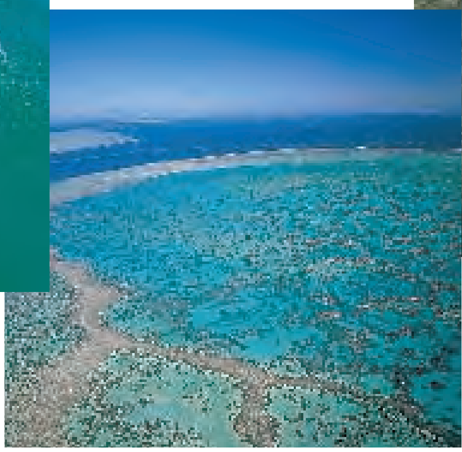
This chapter documents the current state (condition) of Queensland's coastal resources and identifies pressures and changes resulting from human activity. Such information contributes to an understanding of the relationships between human activity and coastal systems and provides a basis for improved management of our coastal resource heritage.

The Coastal Protection and Management Act requires the report on the state of the coastal zone to include an assessment of the condition of major coastal resources, to identify significant trends in coastal values, and to review significant programs for coastal protection and restoration.

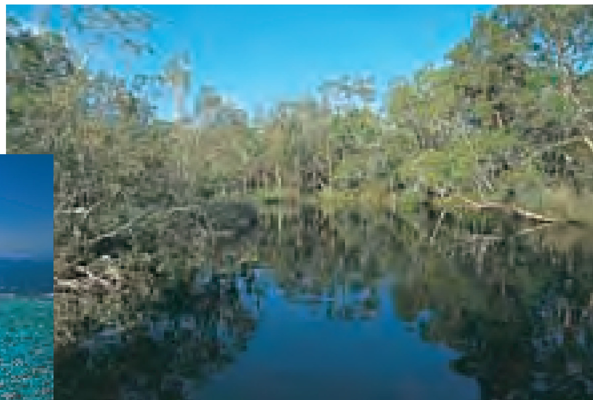
The terms 'coastal resources' and 'coastal values' are explained in table 5-1. The resources form the basis for discussion in terms of their condition, the environmental values they provide and any observed trend in such values. The chapter concludes by discussing the programs and activities directed at protecting or enhancing the coastal zone ('response').



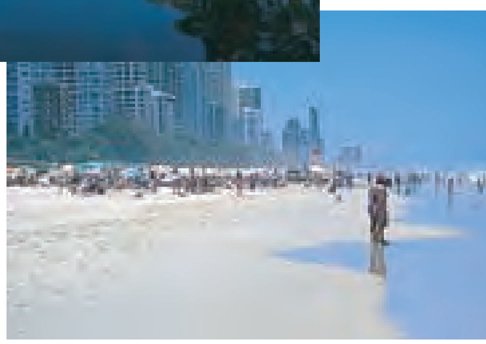
Dugong and calf in Moreton Bay



Hook Reef



Cooloola



Jurisdiction over coastal waters

The question of who controls what and where in the maritime environment is highly complex. Jurisdiction over coastal waters is governed by international, Commonwealth and Queensland law.

In 1975, the High Court determined that the Commonwealth has sovereignty and sovereign rights over the territorial sea and continental shelf adjacent to Australia. However, in 1983 the Commonwealth, through the *Coastal Waters (State Title) Act 1980* and by the 1979 Offshore Constitutional Settlement, granted to the State and Northern Territory Governments title to the seabed and concurrent legislative power within three nautical miles of the territorial sea baselines.

These instruments define Queensland's sovereignty rights, which are limited to its emergent land (mainland and islands) and to its coastal waters. The coastal waters (Queensland's territorial sea) extend three nautical miles seaward of the low water mark (specifically lowest astronomical tide), seaward of connecting lines across estuaries and mouths of bays as set out in Article 7 of the Convention on the Territorial Sea, and seaward of proclaimed 'baselines'. The State of Queensland therefore has legal and administrative responsibilities for managing marine resources in Queensland coastal waters. (See figure 5-1.)

The Commonwealth Government retains concurrent legislative authority in these coastal waters but has primary responsibility for the oceans and seabed from three nautical miles to more than 200 nautical miles.

The 1982 United Nations Convention on the Law of the Sea took effect in 1994 and established a new and comprehensive international legal regime for the sea. Australia claimed sovereignty over 11.1 million square kilometres of marine waters in its declared 200 nautical mile Economic Exclusion Zone (EEZ). When the area of the claimable continental shelf is determined, the Commonwealth's management responsibilities will extend over about 15 million square kilometres. The Law of the Sea provides Australia with sovereign rights over its EEZ and continental shelf resources.

Description

Queensland's mainland coastline extends about 6000 km — from the Gulf of Carpentaria in the west (138ºE) and Cape York in the north (10º41'S) to Point Danger in the south-east (28º10'S, 153º33'E) (figure 5-2). When Queensland's 1165 offshore islands and cays (not reefs) are included, the coastline is about 9500 km long.

The total mainland east coast catchment draining to the coast is 447 655 km^2, and that of the Gulf of Carpentaria is 450 815 km^2. Individual catchments range in size from several square kilometres to 142 645 km^2 (Fitzroy River catchment).

Today's coastline has developed almost entirely over the past 6000 years during a period of relatively constant sea level. However, some beach and dune deposits have formed over hundreds of thousands of years. The coast's form and features continue to evolve in response to a combination of processes and forces, including marine and atmospheric energy inputs and marine and land-sourced sediment supply. The zone's dynamic nature means that changes in coastal form and distribution and occurrence of physical and biological resources are inevitable over time.

The major physical factors influencing coastal environments include winds, ocean currents, tidal flows, waves and freshwater inputs. The main ocean currents affecting waters outside the Great Barrier Reef are the South Equatorial Current, which dominates the circulation of the Coral Sea, the East Australian Current and the Hiri Current.

The South Equatorial Current brings warm, nutrient-poor tropical surface waters to the outer Great Barrier Reef, dividing as it approaches the continental shelf to flow north and south along the edge of the shelf. These currents strongly modulate the flows in the Great Barrier Reef matrix on seasonal and inter-annual time scales. The import of this nutrient-poor water is also a significant factor responsible for the relatively low productivity of east Australian waters.

In the Great Barrier Reef lagoon, tidal streams converge towards central Queensland where, funnelled into the larger inlets of Broadsound and Shoalwater Bay, they result in a tidal range of 10 m. The influence of tidal currents is clearly evident in the north, where oscillating tidal waters race through the maze of reefs and islands.

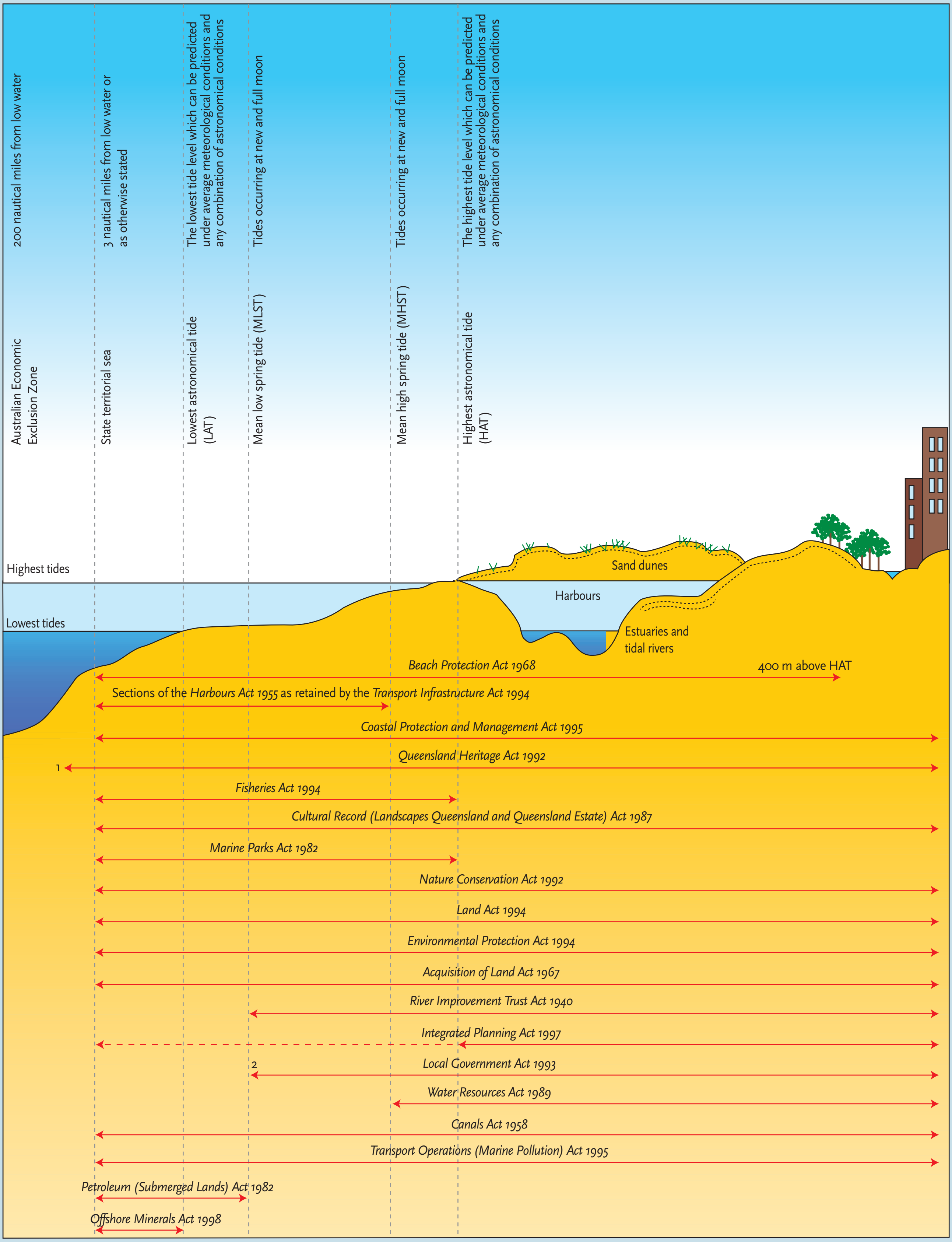
In more inshore waters south of the Tropic of Capricorn, south-easterly waves generated by prevailing winds are the major feature influencing coastal processes. Sediment on the high-energy beaches of southern Queensland is typically moved north by such waves. Further north, as the Great Barrier Reef approaches the coast, wave energy is reduced. This creates a depositional regime where fine sediments can accumulate close to the coastline.

In addition to the relatively continuous influence of waves and tidal currents, episodic events, particularly tropical cyclones, can have pronounced effects. High winds and storm surges can redistribute shoreline deposits, while large waves can induce deep mixing and re-suspension of bottom sediments. In addition, flood runoff associated with heavy rains carries fresh water and sediments offshore. Such events can cause significant transient and permanent changes to coastal systems.

Landforms and habitats

The coastal zone is composed of mosaics of landforms, marine habitats, communities and ecosystems that can be identified on spatial scales ranging from metres to hundreds of kilometres. The 14 major marine biophysical regions of the Queensland coastal zone are shown in chapter 7, 'Biodiversity'. These regions are defined on the basis of major geological, bathymetric, climatic and biological characteristics.

The major physically distinct shore types and environments of the coast include rocky shores (296 km), sand (2664 km), mud (74 km) and mud/mangrove (1406 km) (Fairweather and Quinn 1995). The remaining shoreline is coral reef or estuary mouths.



1. Includes water adjacent to Queensland to which the *Historic Shipwrecks Act 1976* (Cwlth) does not apply.

2. Redland Shire and Brisbane City local government areas extend to low water mark; normally local government areas stop at high water mark.

Figure 5-1 Key legislation and jurisdiction over the coastal zone. Management and administration of tidal lands and marine waters rest with three levels of government. Many Commonwealth and Queensland Acts influence the way coastal resources are managed and the way the coastal zone is developed.
(Based on diagram in State of the Environment Tasmania, Volume 1 — Conditions and Trends *[SDAC 1996])*

Sand-dominated systems occur along much of the coastline. Significant coastal dune systems occur in the north, notably around Newcastle Bay, Shelburne Bay, Orford Bay, Cape Bedford and Cape Flattery. In the south, coastal dune systems occur as massive sand islands, including North Stradbroke, Moreton, Bribie and Fraser Islands, and the high dune systems of Peregian–Noosa, Cooloola and Byfield.

Estuaries and associated wetlands are a prominent feature of the coastal zone. Estuarine mangrove wetlands are distributed along the entire coast, with the most diverse and extensive systems occurring in the tropical north. These wetland habitats are of critical significance to innumerable marine species, including wading birds and many of Queensland's most important commercial fish and crustacean species.

Saenger (1995) identifies 307 estuaries and enclosed marine waters on the Queensland coast. Located at the interface of land and sea, estuaries are of importance in relation to the physical, chemical and biological processes of nearshore waters.

The Great Barrier Reef is the most significant feature of Queensland's coastal zone. Consisting of 3400 separate coral reefs, shoals and other formations, it extends more than 2300 km from Bramble Cay in the north to Lady Elliot Island in the south. On the basis of its outstanding natural, cultural and historical features and its integrity as a self-perpetuating ecological system, 34 870 000 ha of the Great Barrier Reef was inscribed on the World Heritage List in 1981. This area includes about 2900 reefs, 300 cays and 600 continental islands.

ENVIRONMENTAL RESOURCES

The coastal zone can be considered as a single, complex environment or resource which has many uses and values. However, at a finer level it can be considered as a number of different but related resources, each with distinct values. It is appropriate, therefore, to report separately on the state of each resource.

Reporting focuses on the resources listed below. They comprise five major recognisable habitats; physical resources, identified because of their importance in sustaining coastal ecosystems and physically shaping the coastal zone; and biodiversity.

Habitats

- Beaches and dune systems
- Coral reef systems
- Soft-bottom systems
- Coastal wetlands:
  mangroves
  seagrass
  saltmarsh
  sandflats and mudflats
  freshwater wetlands
- Mid-water column (pelagic) systems

Physical resources

- Freshwater inflows
- Coastal and estuarine waters
- Land
- Minerals and sand
- Climate

Coastal biodiversity

ENVIRONMENTAL VALUES

Environmental values are the significant qualities or physical characteristics of a particular resource that are conducive to ecological health, public amenity or safety. While the values are expressed rather broadly, each grouping encompasses multiple and diverse specific values. In this report, environmental values are discussed only at the broader level.

The environmental values of Queensland's coastal resources are listed in table 5-1.

Table 5-1 Major environmental values of Queensland's coastal resources. Values specific to other sectors are to be found in the relevant chapter.

Coastal resource	Values
Beaches and dune systems	Scenic amenity Recreational amenity Groundwater recharge (regional) Dissipative barrier to erosive forces Habitat Biodiversity Sediment sink and source Habitat for native plants and animals
Coral reef systems	Scenic amenity Recreational amenity Commercial fishing Commercial collecting Biological productivity Dissipative barrier to erosive forces Habitat for native plants and animals Biodiversity
Soft-bottom systems	Commercial fishing Habitat for native plants and animals Nutrient sink and source Biodiversity
Coastal wetlands	Biological productivity Habitat for native plants and animals Nursery habitat Biodiversity Shore and sediment stabilisation Dissipative barrier to erosive forces Nutrient sink and source
Mid-water column systems	Biological productivity Commercial fishing Biodiversity Habitat for native plants and animals
Freshwater inflows	Nutrient and organic matter source Sediment source
Coastal and estuarine waters	Scenic amenity Recreational amenity Medium which supports marine life Nursery habitat Commercial fishing Biodiversity
Land	Substrate to support terrestrial and littoral ecosystems Substrate to support human structures and activities
Minerals and sand	Commercial mining Beach stabilisation and replenishment
Climate	Weather regime compatible with the survival and maintenance of existing species and ecosystems
Coastal biodiversity	Recreational amenity Commercial fishing Biological productivity

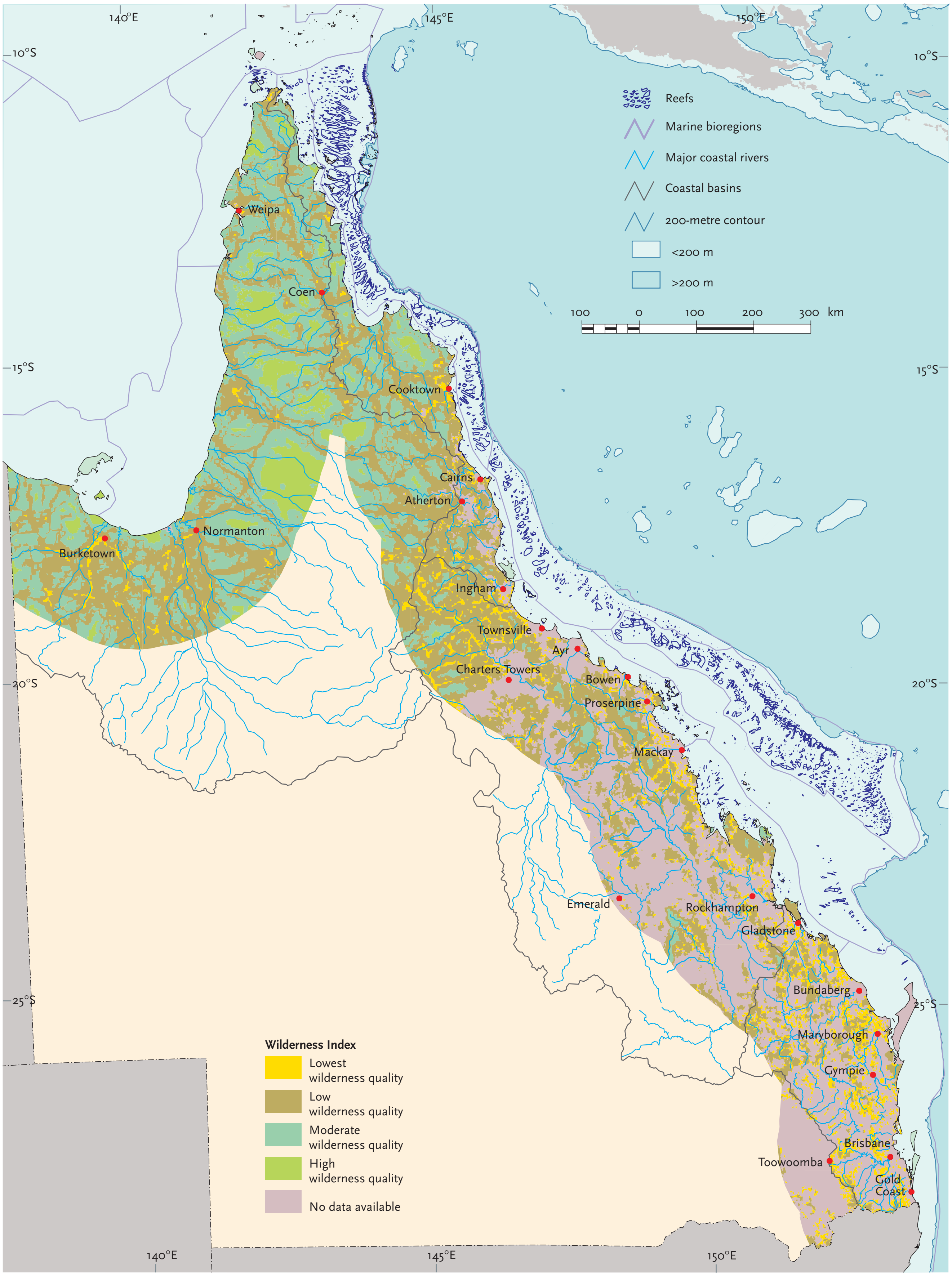


Figure 5-2 The extent of coastal development in Queensland and the degree to which the natural environment has been influenced by human activity are shown by the Wilderness Index developed by the Australian Heritage Commission.
(Source: Australian Heritage Commission)

The coastal zone is used by many people for many purposes. Fish stocks are harvested, coastal land is developed, mineral sands are mined, and beaches and seas are used for recreation. The multiple demands that people place on these resources can be considered as pressures. That is, they move, alter, change or otherwise affect them in some way. This does not mean that all human activity causes damage or irreversible resource depletion. However, should this use (pressure) increase beyond a critical level, the capacity of the coastal zone to continue to provide certain environmental services or values could be compromised. Intensive fishing can deplete fish stocks, continued urban development can reduce wildlife habitat, and wastewater inflow can degrade water quality.

Ecological processes and the ways human activity can influence them are complex, and simple cause-and-effect relationships linking a resource with a pressure can therefore be difficult to identify. For example, the state of seagrass meadows might be affected by the combined pressures of nutrient enrichment, sedimentation, industrial effluent inflows, storms, disease and boating activity. No one pressure is responsible for any observed change in seagrass condition.

The link is more obvious, however, in cases such as fishing pressure and fish stocks.

In recognition of the fact that any one pressure might affect a number of resources and many pressures might affect the one resource, the major pressures on Queensland's coastal resources are discussed under broad groupings of activities or substances (contaminants) which affect them. These activities thus represent the major sources of pressure on coastal resources. Major pressures associated with human activity are:

- coastal development;
- contaminants;
- exotic and displaced species;
- fishing, hunting and collecting; and
- tourism and recreation.

Identifying an activity as a pressure means that the activity involves the use of or affects the resource in some way. This report does not judge whether a given level or intensity of use is 'good' or 'bad', or is the most appropriate. However, it does comment on whether the intensity of use is compatible with sustaining the resource's environmental values.

Table 5-2 Population of the Queensland coastal zone (defined as the population of local government areas adjacent to the coastline and those with their centroid within 50 km of the coastline). Populations are calculated by local government area boundaries according to Australian Standard Geographical Classification 2.5.

Year	Population	Percentage of Queensland total
1986	2 051 573	78.2
1991	2 347 968	79.3
1996	2 844 913	85.2

(Sources: QDHLGP 1995; ABS 1996; QDLGP 1997)

Table 5-3 Population and average annual population growth rate of some of Queensland's most rapidly growing coastal areas, 1991–96

Statistical district	1991	1996	Average annual growth rate (%)
Sunshine Coast	119 625	156 136	5.5
Gold Coast–Tweed	279 443	354 232	4.9
Cairns	86 294	106 563	4.3
Mackay	54 454	61 020	2.3
Gladstone	33 447	37 381	2.2
Bundaberg	49 305	54 032	1.8
Townsville	114 063	122 587	1.5
Rockhampton	63 598	64 496	0.3

(Source: ABS)

COASTAL DEVELOPMENT

Population growth

Indicators

Number of people living in the coastal zone

Average annual population growth rate by local government area

The number of people living in the coastal zone is one of the most important factors influencing the severity of human pressure on coastal resources. If population increases, the pressure on coastal resources can also be expected to increase. Population in the coastal zone and its rate of growth are thus good general indicators of pressure on coastal resources. They indicate the overall trend in pressure and where pressure is increasing most rapidly.

Between 1986 and 1996, the number of people living in the coastal zone increased significantly and the proportion of the total population living there increased from 78.2 percent to 85.2 percent (table 5-2).

Population growth is not evenly distributed along the coast. Several areas, particularly in the south-east, are experiencing very rapid growth (table 5-3). (See also chapter 8, 'Human settlements'.)

Land use change and building activity

Indicators

Area of land changed from its natural state

Annual number of dwelling commencements in coastal local government areas

Indicative naturalness/Wilderness Index

Change in land use — particularly the initial change from 'natural' to 'developed' — is one of the most significant pressures on coastal habitats and biodiversity. Such change, whether due to a new tourist resort, a rural subdivision or agricultural expansion, inevitably involves destroying or markedly modifying the natural biophysical setting. This change is probably the most significant in terms of pressure on the coastal zone's biological resources. Subsequent changes, such as converting agricultural land to housing, might be considered of lesser significance. Change from the natural to the developed state is expressed in this chapter as the area of native vegetation cleared.

Detailed data relating to land use change are available for only selected areas. However, an indicative estimate of the degree and extent of development activity is provided by the Australian Heritage Commission's Wilderness Index. This is based on the primary indicators of apparent naturalness, biophysical naturalness, remoteness from access, and remoteness from settlement. It indicates the extent of development and the degree to which the natural environment has been influenced by human activity. Figure 5-2 shows the Wilderness Index for a band 200 km wide along the Queensland coast.

Clearing of natural vegetation has affected most of Queensland's coastal zone to some degree. Clearing for grazing has been extensive: grazing now accounts for more than 85 percent of the area in the Fitzroy, Don and Burdekin catchments. Clearing for urban development has been extensive along the south-east coast. Catterall et al. (1996) reported that, by 1987, 71.5 percent (173 568 ha) of coastal lowlands (within 10 km of the coast) in south-east Queensland had been cleared. Between 1987 and 1994 a further 6754 ha were cleared. Clearing is a major pressure on the coastal zone's biological resources.

Drainage and dredging have also changed the nature of large areas of the coastal zone. Whether for agriculture or for urban development, land drainage has affected wetlands, floodplains and mangroves. When drainage is on acid sulfate soils, the periodic release of sulfuric acid from the soil after rainfall or flooding adversely affects local aquatic ecosystems (see box 'Acid sulfate soils'). Acid sulfate soils are common along the entire Queensland coastline.

Table 5-4 Rate of bushland clearing in local government areas in south-east Queensland, 1974–87 and 1987–94, expressed as a percentage of the total local government area cleared each year

Local government Jurisdiction	Total area (ha)	1974–1987	1987–1994
Brisbane: total	113 879	0.40	0.22
— mainland, small islands	96 649	0.46	0.26
— large sand islands	17 230	0.07	0.00
Caboolture	120 618	0.42	0.20
Caloundra	109 094	0.39	0.22
Gold Coast: total	134 290	0.035	0.23
— mainland, small islands	132 263	0.035	0.23
— large sand islands	2 027	0.27	0.07
Logan	24 629	0.38	0.50
Maroochy	115 130	0.34	0.24
Noosa	86 284	0.33	0.19
Pine Rivers	76 360	0.36	0.18
Redcliffe	3 608	0.53	0.05
Redland: total	50 341	0.25	0.24
— mainland, small islands	24 037	0.40	0.29
— large sand islands	26 304	0.11	0.20

(Sources: Catterall and Kingston 1993; Catterall et al. 1996)

The rate of land use change on the south-east Queensland coast is presented in table 5-4. These data show a high rate of conversion of land from its natural state to a developed state. Although the rate of change appears to have slowed in the early 1990s, this was largely because most suitable land had been developed and only marginal lands (steeper slopes, waterlogged areas) remained natural. Most land with development potential that was not protected in the reserve estate has been cleared. Remaining native vegetation tends to be restricted to the steeper slopes of the hinterland, although such areas continue to be cleared.

In the Mackay region, a 28 500 ha strip of coastal land extending 5 km inland and 70 km north–south between Shoal Point and Salonika Bay illustrates land use change on coastal lands subject to agricultural development. By 1993, 66.9 percent of the original native vegetation had been

Raby Bay

Acid sulfate soils are found extensively in low-lying areas with elevations generally below 5 m Australian Height Datum (AHD) along the Queensland coast. Although these wetland soils are harmless in their natural waterlogged state, they can generate large quantities of sulfuric acid where they are disturbed by excavation or drainage. Discharge of acid into waterways can cause catastrophic environmental damage.

Acid sulfate soils contain naturally high levels of the mineral iron pyrites (iron sulfide). In its natural state, iron pyrites is stable and does not present environmental problems. However, when exposed to air, it reacts with oxygen to form iron sulfate. Water reintroduced by rainfall or flooding quickly forms sulfuric acid, which can have a devastating affect when washed into local waterways.

Acid sulfate soil disturbance in Queensland has been linked to major fish kills and outbreaks of red spot disease in fish, and to the increased incidence of disease-carrying, acid-tolerant mosquitoes.

Acid sulfate soils along the Queensland cover an estimated 2.3 million hectares. Only in the last decade or two have they been recognised as one of the most important environmental issues on the coastal lowlands.

Recent major coastal developments that have required consideration of acid sulfate soils include those at Earl Hill (Cairns), Port Hinchinbrook (Cardwell), Oyster Cove (Coomera), Twin Waters (Sunshine Coast), Newport Waters (Redcliffe), Pelican Waters (Caloundra), Pacific Harbour (Bribie Island), Couran (South Stradbroke Island) and the Pimpama River area (Gold Coast).

Acid sulfate soils are also a major issue for coastal zone agriculture involving drainage of low-lying land. Past expansion of the sugar industry and drainage schemes on coastal lowlands have led to unintended offsite impacts that have lasted for decades — for example, in the cane-growing areas at Rocky Point (south-east Queensland), Bundaberg, Cairns and Innisfail. In some cases, acidification of soils through lowering of the watertable and spreading of acidifying drain spoil on fields has led to poor sugarcane growth. The CSR expansion of sugarcane into the East Trinity area near Cairns collapsed because of acid sulfate soil problems.

Response

Since 1995, considerable attention has been given to the acid sulfate soils issue, particularly in raising awareness, obtaining technical information and giving management options. Communication and coordination between the diverse interested parties — the private sector, industry groups, State and local government and community groups — are improving.

In 1995, a Queensland Acid Sulfate Soils Investigation Team (QASSIT) was established at the Department of Natural Resources (DNR) to map and research acid sulfate soils, to implement improved laboratory methods and drainage management, and to provide technical guidelines and advice, an information service and a training program.

QASSIT's technical work was complemented in 1996 by the establishment of the Queensland Acid Sulfate Soils Management Advisory Committee (QASSMAC). The committee, coordinated by DNR, represents the urban development, sugar, fishing and sand-extraction industries, Landcare and conservation groups, local Governments and affected State Government agencies.

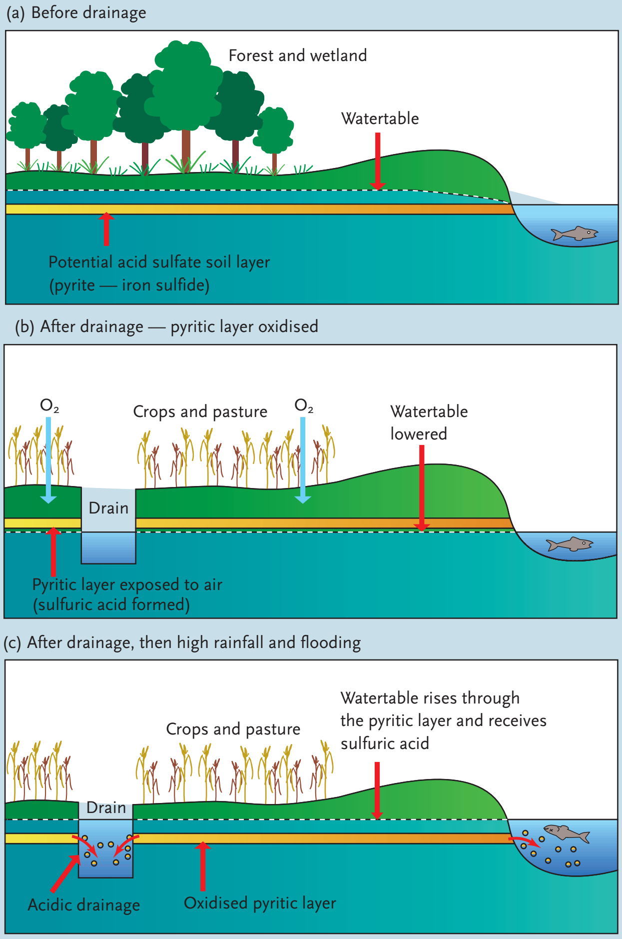


Figure 5-3 Potential acid sulfate soils do not harm the environment when covered by water (a), but when drained and exposed to air — (b) and (c) — they react with rainwater to release sulfuric acid into the drainage system, affecting aquatic life.

cleared (Batianoff et al. 1996). Virtually all of the original dryland plant communities had been cleared (6.8 percent remaining), leaving only mangrove and saltmarsh areas undisturbed.

In the southern Tully–Murray catchment extending north and south of Cardwell, about 29 percent of the original tropical lowland plant communities (6892 ha) has been cleared. Their total area was reduced from 23 916 ha in 1942 to 17 024 ha in 1992 (Skull 1996). The vegetation types most affected are tall eucalypt open woodlands (78 percent cleared), low open woodlands (56 percent cleared) and melaleuca woodlands (41 percent cleared).

Building activity also indicates the pressure of human activity on coastal land resources. While some building activity might simply reflect a change in the type of building, many new buildings are built on previously undeveloped land. These 'commencements' contribute to the spread of urban centres along the coast. Building activity in several rapidly growing local government areas, expressed as dwelling commencements, is presented in table 5-5.

Table 5-5 Number of dwelling commencements in rapidly growing coastal local government areas (LGAs), 1991–92 to 1994–95

Coastal LGA	Dwelling commencements 1991–92	1992–93	1993–94	1994–95
Brisbane	5 225	7 747	8 515	8 891
Albert*	3 531	3 375	4 778	–
Caboolture	2 327	2 916	2 704	1 881
Maroochy	2 306	2 659	2 800	2 446
Redland	2 010	1 781	1 856	1 663
Logan	1 997	2 089	2 494	1 811
Gold Coast*	1 926	1 954	3 538	7 181
Pine Rivers	1 700	1 224	1 447	1 292
Caloundra	1 069	1 392	1 254	1 451
Mulgrave	1 019	1 370	1 790	–
Hervey Bay	987	1 306	1 219	952
Thuringowa	905	1 034	1 023	732
Moreton	846	1 005	1 077	–
Noosa	700	904	1 161	1 236
Townsville	620	891	884	821
Cairns	429	688	978	2 518
Total	**27 597**	**32 335**	**37 518**	**32 875**

* Shire boundary changes resulted from the Albert Shire/Gold Coast City amalgamation; new boundaries also affected the existence or area of several other local governments.
(Source: QDHLGP 1995)

Changes to wetlands

Indicators

Rate of clearing of wetland communities — mangroves, saltmarsh and freshwater wetlands

Number of marine plant permits issued under the Fisheries Act and area involved

The loss of wetland communities, including mangroves, saltmarsh and freshwater wetlands, is a particularly important impact of coastal land use change. Only on the more remote coasts have wetlands been spared some degree of modification or loss. In the intensively developed and developing areas, large areas of wetlands have been destroyed or severely modified. This trend of wetland loss continues. The greatest losses are attributable to agriculture, urban and industrial development, and tourism and maritime transport facilities and services.

The statewide rate of wetland clearing is not known, although some regional data are available.

Between 1974 and 1989 an estimated 8778 ha of melaleuca woodland was cleared in the coastal zone of south-east Queensland. In the Brisbane area, melaleuca woodlands have been reduced from an estimated 13 000 ha in 1820 to about 390 ha in 1987. An estimated 1240 ha of mangrove habitat in Moreton Bay was destroyed between 1974 and 1989 (Catterall and Kingston 1993).

Studies of the Mulgrave–Russell, Moresby and Johnstone Rivers in north Queensland show that 9306 ha of freshwater wetland communities were destroyed between 1951–52 and 1992. The area of mangrove wetlands increased by 678 ha, largely in the Moresby River catchment due to saltwater intrusion into previously non-tidal areas. A net loss of 8655 ha (47 percent) of the original wetland area over 40 years is apparent in these river catchments (table 5-23).

Removal of or damage to marine plants, which include mangroves and other species growing on tidal lands, is prohibited under the *Fisheries Act 1994* unless otherwise authorised. An indicator of some interpretive value is the number of marine plant permits issued (and area of wetland involved). In 1993, 119 permits covering almost 900 ha were issued. In 1995, 80 permits covering 135 ha were issued.

Data suggest that coastal wetland communities are under pressure in some localised areas. Areas which have experienced a high rate of wetland loss include the south-east coast between Noosa and Coolangatta, the Curtis Coast near Gladstone, the Mackay coast and the Cairns coast. However, many wetland areas, particularly in north Queensland and the Gulf of Carpentaria, are not under threat.

Aquaculture

Indicators

Aquaculture production

Number of aquaculture licences

Area under aquaculture ponds

Aquaculture has a long history in Queensland, dating from 1860 with the culture of oysters in Moreton Bay. In the last two decades the industry has grown and is now growing rapidly. The major aquaculture activities in Queensland include the growout of oysters, marine prawns, freshwater crayfish and fish (largely barramundi), and pearl culture.

Aquaculture has the potential to become a significant pressure on coastal resources as a result of habitat loss associated with pond construction and wastewater discharges. However, such discharges are subject to environmental controls. In 1996, 51 aquaculture establishments held licences to discharge wastewater, and some were discharging up to 100 000 m^3 a day.

Around Moreton Bay, 10 marine prawn farms currently operate 67 production ponds covering 61 hectares. Commercial oystering is also undertaken in the Bay, with 118 areas covering a total licensed area of nearly 500 ha.

Hydrologic developments

Indicators

Number of dams and weirs (>25 ML capacity) in the principal coastal drainage divisions

Number of drainage basins subject to flow regulation in the principal coastal drainage divisions

Water flowing downstream transports significant quantities of fine particles (suspended sediment), nutrients and organic matter to estuarine and coastal waters. During floods, the quantities carried increase greatly. This periodic influx of sediment and nutrients plays a critical role in the physical, chemical and biological processes of nearshore waters. Altered flow regimes resulting from dams and barrages potentially have significant implications for coastal ecosystems due to changes in the timing and magnitude of such inputs. In addition, barrages can prevent fish migrating and so disrupt natural breeding cycles.

In view of Queensland's variable and generally low rainfall, harvesting water has been a priority throughout its recent history. The Brisbane River catchment alone has 52 dams and weirs, of which the Wivenhoe Dam (1150 GL capacity) and Somerset Dam (369 GL) are the largest. Together, they regulate flow from 52 percent of the catchment.

Flow regulation now occurs throughout Queensland, even in more remote regions. Of 57 mainland drainage basins flowing to the coast, 25 (44 percent) are now subject to some degree of flow regulation (tables 5-6 and 5-7).

Although the full ecological implications of flow regulation are not known, flow regulation affects important physical and ecological processes. Activity that changes the natural hydrologic regime is considered a pressure on coastal ecosystems. The Queensland Fisheries Management Authority specifically identified barrage construction in the estuaries of the Gulf of Carpentaria as a cause of environmental degradation potentially threatening fisheries resources (QFMA 1996a). Flow regulation of Queensland's rivers has increased progressively since colonisation and continues to increase.

Table 5-6 Number and storage capacity of dams in Queensland's four principal coastal drainage divisions in 1993

Drainage division	Number of dams and weirs*	Total storage capacity (ML)	Number of dams >10 000 ML	Capacity of dams >10 000 ML (ML)
Carpentaria	12	297 800	5	281 500
Northern Coastal	22	3 484 860	10	3 447 000
Central Coastal	17	2 009 267	9	1 965 900
Southern Coastal	56	3 795 595	25	3 650 400
Total	**107**	**9 587 522**	**49**	**9 344 800 (97.5%)**

*Excludes dams and weirs of less than 25 ML capacity.
(Source: DPI)

Table 5-7 Percentage of drainage basins subject to flow regulation by dams or weirs in the four principal drainage divisions

Drainage division	Number of basins in drainage division	Number of basins affected	Percentage of basins affected
Carpentaria	17	4	23
Northern Coastal	23	8	35
Central Coastal	7	3	43
Southern Coastal	10	10	100
Total	**57**	**25**	**44**

Drainage basins include coastal mainland basins only, not islands. Basin numbers: Carpentaria 910–928; Northern Coastal 101–125; Central Coastal 126–133; Southern Coastal 134–146 (see chapter 4, 'Inland waters').
(Source: DPI)

Sediment supply changes

Indicator

Catchment sediment runoff

Sediment from rivers is transported along the coast by waves and currents. Changes to sediment supply patterns might significantly influence rates of coastal erosion and deposition, with consequent impacts on coastal resources. Human activities changing natural sediment supply regimes can be regarded as a pressure on coastal resources. These include catchment activities that affect riverine sediment supply and transport rates, and dredging and dumping activities.

On a regional scale, riverine sediment supply to nearshore environments is controlled primarily by climatic and drainage basin characteristics. Climatic factors are largely beyond the influence of human activity and therefore variability due to rainfall is not of concern. However, drainage basin characteristics are subject to human interference. Changes in land use, vegetation type and cover, and flow regime can influence catchment sediment yield. Consequently, the influence of human activity is reflected in changes in sediment yield per unit runoff. This can increase significantly as a result of certain land use activities.

Few data are available from which accurate estimates of historical catchment sediment yield can be made, although studies now in progress are attempting to estimate yield. Using data from six north Queensland catchments, Neil and Yu (1996) suggest a two- to four-fold increase in sediment yield per unit runoff due to human activity. An estimated 26 percent of total yield today is attributable to natural processes, while 66 percent can be attributed to grazing practices and 8 percent to cropping.

From studies on the South Johnstone River, north Queensland, sediment deposition is thought to have increased significantly from pre-1940s rates. This increase correlates well with a significant increase in the catchment area cleared and cultivated for sugarcane, most of the increase being related to the extension of farming to erosion-prone areas (Connor 1986; Connor and Hill 1989). The current sedimentation rate in this system is estimated to be more than 300 000 tonnes/year, indicating a further increase above the 100 000 tonnes/year for the 1942–83 period (Arakel et al. 1989).

Intensive monitoring of the Johnstone River system (North and South Johnstone Rivers) during a 1994 flood event associated with cyclone Sadie indicated that almost 200 000 tonnes of suspended sediment were transported downstream in four days (Hunter 1997). This equates with a sediment yield of 0.25 tonnes for each megalitre of runoff. Sediment yield from the Herbert River catchment during the same flood event was estimated at approximately 100 000 tonnes (0.19 t/ML) (Mitchell and Bramley 1997).

Neil (1996) indicates that the net effect of land use changes due to human activity in the Tully River catchment, north Queensland, has been an increase in potential sediment yield by a factor of about 2.2. Calculations of sediment yield from east coast rivers by Moss et al. (1992) suggest that yield is now three to five times higher than it was before colonisation. The increase is considered attributable to the higher sediment yield per unit runoff of cleared land.

In view of continuing coastal development, and in particular vegetation clearing, the natural sediment supply regime can be expected to be affected further in some regions and be particularly evident in more remote regions now being developed.

Mineral recovery

Indicator

Rate of extraction of silica and mineral sands

By its very nature, the recovery of mineral sand resources involves removing the resource itself. The primary pressure on mineral resources is extraction, with the rate of extraction being the indicator.

Silica sands

Queensland has considerable silica sand resources which have been mined for many years. In 1996–97, 2.6 million tonnes of silica sand were mined, a substantial increase on the 670 000 tonnes produced in 1980. Most mining activity occurs at Cape Flattery, north Queensland. Most production is exported.

Mineral sands

Rutile, ilmenite and zircon are the major components of heavy mineral sands. They are used as paint pigments and in foundry applications. Virtually all of Queensland's mineral sands are produced at mining operations on North Stradbroke Island. Production in 1996–97 was:

- rutile 50 827 t,
- zircon 37 130 t, and
- ilmenite 70 335 tonnes (DME 1998).

North Stradbroke Island's mineral resources will be substantially depleted within 20 years.

Shipping and boating

Indicators

Annual cargo throughput for Queensland ports

Annual number of vessel visits to Queensland ports

Annual tonnage of petroleum products moved by sea (imports and exports)

Annual number of pollution incidents in Queensland's territorial waters and offshore reported to the Australian Maritime Safety Authority

Commercial shipping activity is a potential pressure on marine environments. Potential impacts include those associated with port development, dredging of shipping channels, oil spills and introduced organisms.

More than 5000 ships visit Queensland ports each year, moving more than 130 million tonnes of cargo including 11 million tonnes of petroleum products. The port facilities for this traffic — docks, roads, rail, deepwater channels and swing basins — inevitably have an impact on natural resources. While impacts of port development and shipping differ, the intensity of shipping activity is a valuable general indicator of such pressure. As shipping activity increases, pressure on coastal habitats can be expected to increase. Cargo throughput for Queensland ports and vessel movements and their gross tonnage as indicators of shipping pressure are presented in tables 5-8 and 5-9.

Table 5-8 Cargo throughput for Queensland's ports. Throughput has risen significantly in recent years from 53.2 million tonnes in 1978–79.

Year	Cargo throughput (million tonnes)
1989–90	108.02
1990–91	111.9
1991–92	114.4
1992–93	119.9
1993–94	122.0
1994–95	132.6

(Source: QT)

Table 5-9 Piloted vessel movements and gross tonnage

Year	Piloted vessel movements (arrivals and departures)	Tonnage of piloted vessels (million gross tonnes)
1990–91	7 201	83.7
1995–96	8 691	108.8
1996–97	10 244	118.8

(Source: QT)

While Queensland has been spared the catastrophic consequences of a major oil spill, the potential for such a disaster exists. The grounding of the freighter *Peacock* on Piper Reef in June 1996 was a reminder of such potential. The ship was refloated without loss of oil, and damage was confined to destruction of 423 m^2 of coral. As shipping traffic increases, the potential for a spill of oil or some other hazardous substance will also increase. Data on petroleum products shipping movements and pollution incidents reported in Queensland's coastal waters are given in tables 5-10 and 5-11.

Commercial shipping also presents a significant threat by introducing non-native organisms through ballast water discharge and hull fouling (see 'Exotic and displaced species', page 5.20).

Shipping activity and shipping traffic are increasing. Continued growth at the current rate will increase pressure on coastal resources, particularly wetland communities near major ports and transport corridors.

Boating activity refers to all other seaborne transport activity including private recreational boating, tourist charter vessels and commercial fishing activity. Boating pressures are discussed under 'Fishing, hunting and collecting' (page 5.22) and 'Tourism and recreation' (page 5.28).

Table 5-10 Petroleum products movement by sea (imports and exports) in Queensland waters. Petroleum products include crude oil, LPG, petroleum, general oil and fuel.

Year	Petroleum products movement (million tonnes)
1989–90	10.309
1990–91	10.062
1991–92	9.750
1992–93	9.738
1993–94	10.887

(Source: ABS)

Table 5-11 Pollution incidents reported in Queensland. Incidents are usually visible slicks, often attributable to oil pollution from shipping (boating) activity. Reports relate to slicks ranging in size from tens of square metres to 210 km^2. Of the 75 incidents reported in 1995–96, 30 required a response. Of the 81 reported in 1996–97, 37 required a response.

Year	Number of pollution incidents reported
1990–91	62
1991–92	79
1992–93	78
1993–94	75
1994–95	60
1995–96	75
1996–97	81

(Source: QT)

CONTAMINANTS

Contaminants entering estuarine and marine waters are of many types and come from many sources. Some are highly toxic while others are relatively benign. In view of the potential to affect marine life adversely, their input is regarded as a pressure. The quantity of contaminants entering marine waters is an appropriate indicator of this pressure.

Contaminants can enter coastal waters from discrete, identifiable sources such as industrial and sewage discharges (point sources), and from diffuse sources such as catchment runoff and groundwater infiltration. Available data are only indicative. No data about concentrations of specific toxicants such as heavy metals in domestic and industrial effluent discharges are available.

Point-source inputs

Indicators

Number of sewage treatment plants licensed to discharge

Volume of domestic wastewater

Quantity of nitrogen and phosphorus discharged

Number of industrial treatment facilities licensed to discharge

Volume of industrial wastewater

Griffith University (AES)

As boating activity increases, pressure on coastal habitats can be expected to increase.

Oil spill at Kings Beach, Caloundra, in south-east Queensland

Industrial and domestic wastewater discharges have considerable potential to degrade the environment near an effluent outfall. The extent of any impact is influenced by factors such as volume and toxicity and the dilution and flushing characteristics of the receiving water body. Point-source discharges occur wherever human settlements occur. However, given the distribution of Queensland's population, most domestic and industrial wastewater is discharged to waters between Noosa and the New South Wales border. Significant discharges also occur at Gladstone, Rockhampton, Mackay, Townsville and Cairns. The remaining coast is virtually unaffected by wastewater discharges.

Domestic wastewater

In 1995–96, 185 sewage treatment plants and 12 water supply treatment plants were licensed to discharge a total of approximately one million cubic metres of wastewater a day. Luggage Point Sewage Treatment Plant, Brisbane, is licensed to discharge 220 000 m^3/day of treated effluent to the mouth of the Brisbane River.

Of the 197 discharges, 14 discharge directly to open marine waters and can be considered 'ocean outfalls'. The largest are Western Suburbs, Townsville (30 000 m^3/day to Cleveland Bay); Coombabah (65 000 m^3/day), Elanora and Merrimac (46 000 m^3/day, combined), all on the Gold Coast; and Kawana Waters (34 000 m^3/day) on the Sunshine Coast.

Eleven sewage treatment plants discharge to Moreton Bay or to waters close to and flowing into the Bay. The combined annual discharge is approximately 117 GL of secondary treated effluent, containing an estimated 1551 tonnes of nitrogen and 447 tonnes of phosphorus.

Domestic wastewater contains many substances potentially harmful to aquatic life, although most occur in very small quantities. The most important substances in terms of potential impacts are organic matter, nutrients (nitrogen and phosphorus) and pathogenic organisms. An estimated 25 280 kg of nitrogen and 7220 kg of phosphorus are discharged to Queensland's estuarine and coastal waters daily. As a result of increasing concern over the potential impact of these nutrients, some large treatment plants have been or are being upgraded to remove nitrogen. These include Merrimac, Coombabah, Luggage Point, Albany Creek, Wacol, Thorneside, Capalaba and Loganholme.

The large and growing population in south-east Queensland has resulted in an ever-increasing effluent load being discharged. While all effluent is treated to a secondary standard, some estuaries and bays are subject to high nutrient inputs. These include the estuaries of the Maroochy, Caboolture, Brisbane, Logan and Albert Rivers, Cabbage Tree Creek and parts of Moreton Bay including Hays Inlet, Bramble Bay and Waterloo Bay.

The presence of pathogenic organisms in waters used for recreation or drinking threatens human health. All discharges to waters where human contact could be expected are disinfected, usually through chlorination. However, pathogenic organisms can enter waters as a result of mechanical breakdowns and effluent overflows. Chlorination is not fully effective against certain pathogens including some viruses and parasites. Consequently, the presence of sewage effluent in waters used for recreation is a potential though low-level threat to human health.

Stormwater drain at Toorbul, Pumicestone Passage. Stormwater runoff discharges nutrients into the marine environment.

Industrial wastewater

Industrial wastewater is any wastewater other than from a sewage treatment plant, and includes effluent from sources such as power stations, food processing plants, metal fabricators, abattoirs and aquaculture farms.

Industrial activity generates considerable quantities of wastewater. In many cases, the major pollutants are heat (industrial plants), organic matter (food processing) and suspended solids (washing plants). Although they are not without adverse impacts, they are neither highly toxic nor persistent in the environment. Consequently, the presence of industrial wastewater does not necessarily indicate the presence of toxic compounds.

However, a range of industries do discharge wastewater containing an array of chemical compounds used in modern industrial processes. These can include heavy metals such as mercury, cadmium and chromium, polychlorinated biphenyls (PCBs), organochlorine insecticides and polyaromatic hydrocarbons (PAHs). Even at very low levels, these substances can persist in the environment, move considerable distances from their source and accumulate in living organisms.

In 1995–96, 136 industry treatment plants were licensed to discharge 7.5 million cubic metres of wastewater a day. Data for quantities of substances in the effluent are not available. Many smaller industries discharge wastewater to the local sewerage system rather than to rivers and creeks. Residues of industrial chemicals are found in sewage effluent, even after treatment.

Diffuse-source inputs

Indicators

Catchment nutrient runoff

Catchment suspended sediment runoff

A variety of substances originating in mainland catchments can be transported downstream to estuarine and coastal waters. These include pesticides, herbicides, heavy metals, organic matter, nutrients and sediment. Agricultural activity is the major source of pesticides and herbicides, while mining activity can be a major source of heavy metals. However, most of these substances occur in very low concentrations and are of little significance to marine life, particularly further offshore where dilution reduces concentrations still further, although they can be significant in some estuarine areas.

Substances of greater environmental significance and transported in larger quantities include nutrients (particularly nitrogen and phosphorus), suspended sediment and organic matter, all of which occur naturally.

Quantities of pesticides and herbicides used annually for sugarcane production in the coastal zone have been estimated, but only limited monitoring of residues in river systems has occurred. Available results suggest widespread but low-level contamination of east coast river systems.

Algal bloom, Scarborough, south-east Queensland

Diffuse-source nutrients and suspended sediment inputs, while natural, are of interest because of their potential to adversely affect marine ecosystems, particularly if inputs are increased as a result of human activity. Elevated concentrations of suspended sediment and nutrients are potentially detrimental to marine life. High concentrations of sediment can adversely affect plants and animals due to physical smothering or reduced light penetration. Diffuse-source inputs of suspended sediments to the marine environment are considered to have increased substantially as a result of catchment development (see 'Sediment supply changes', under 'Coastal development').

Elevated concentrations of nutrients can stimulate the growth of marine algae to such an extent that they form 'blooms'. These can extend over thousands of square kilometres and persist for weeks. Algal blooms have been reported from many locations along the Queensland coast, including Moreton Bay and a number of estuaries. However, blooms were also recorded by the first colonists. Scientists debate whether increased nutrient inputs have affected bloom incidence. Most agree that nutrient inputs have increased substantially over the last century, but the significance of this increase remains unclear.

River flows constitute a major source of nutrients to coastal waters. Queensland's rainfall pattern means that river runoff is typically episodic and highly variable. As a consequence, nutrient input associated with runoff is also episodic and variable. Mitchell and Bramley (1997) estimate that more than 600 tonnes of nitrogen and 65 tonnes of phosphorus were transported by the Herbert River in six and a half days during a flood event. Because of this variability, any human influence on the magnitude of nutrient inputs is hard to detect by simply comparing absolute input between years. Land use practices such as vegetation clearing and agriculture can increase sediment and nutrient yield per unit area significantly. Therefore yield might change in response to catchment land use changes.

Recent water quality monitoring studies of the Johnstone, Burdekin, Fitzroy and Herbert Rivers have provided estimates of catchment nutrient yield. However, a common fault with many studies is that sampling during periods of highest flow is inadequate, inevitably leading to gross underestimates of nutrient yield. Mean annual inputs to the Great Barrier Reef region have been estimated at 15 440 tonnes of nitrogen and 1530 tonnes of phosphorus. However, another method of calculation results in average annual values of 38 000 tonnes of nitrogen and 11 000 tonnes of phosphorus (Furnas et al. 1997). Clearly, inadequacies in sampling lead to highly variable and inaccurate estimates of nutrient inputs.

The limited detailed monitoring data available indicate that about 11 000–15 000 tonnes of phosphorus are currently transported annually from east coast catchments, depending on flow.

Few estimates of historical yield are available. However, nutrient yield appears to have increased significantly over the past century, possibly by between two and five times.

The Great Barrier Reef lagoon is particularly susceptible to nutrient enrichment due to its relatively enclosed and shallow nature. While the ecological significance of existing nutrient inputs is not known, some scientists are concerned that adverse impacts are beginning to show. Diffuse-source nutrient inputs have increased and current development patterns suggest that this pressure is continuing to increase.

EXOTIC AND DISPLACED SPECIES

In this chapter 'exotic' means species which are not native to Australia. 'Displaced' refers to species which are not native to an area but originate elsewhere in Australia.

Coastal and marine environments are under pressure from introduced species. Exotic species are being introduced and those which are established are spreading. The CSIRO Division of Marine Research (CSIRO 1996) lists 122 exotic species, including 18 species of algae and 104 species of fish, molluscs, arthropods and polychaetes known or likely to have been introduced into Australian waters. Introductions have been both intentional (for aquaculture) and accidental (through hull fouling or ballast water).

Several hundred exotic terrestrial plant species have been introduced to coastal environments. Many are now well established and some, like groundsel and lantana, threaten coastal plant communities.

Marine species

Indicators

Ship arrivals from foreign ports and ballast water discharged to Queensland waters

Number of exotic and displaced marine species established in Queensland waters

A study of the ballast water in 23 bulk carriers coming from Japan to three Australian ports found 67 taxa (species or species groups), seven of which are endemic to Japan (Thresher 1996). The discharge of untreated ballast water to Queensland waters poses a potential pressure on marine ecosystems. Most ballast water discharged to Queensland waters comes from bulk carriers to Hay Point, Abbot Point and Weipa.

Lantana is found throughout the coastal zone.

Exotic organisms can also be introduced in association with mussels or oysters used in mariculture and by hull fouling. Many marine organisms, including burrowing worms, bivalve and gastropod molluscs, crustaceans and algae, attach to ship hulls and detach at another location. Marine organisms known to have been introduced to Queensland waters are listed in table 5-12.

Increased shipping traffic, particularly to areas of north Queensland at present not subject to high-volume international traffic, can be expected to increase the risk of successful exotic introductions.

Terrestrial plant species

Indicator

Number of exotic and displaced terrestrial plant species established in the coastal zone

Terrestrial plant species can be introduced intentionally for ornamental, agricultural or horticultural purposes, or accidentally. Of 45 exotic problem weed species known in the Mackay region, 84 percent were introduced intentionally (Batianoff et al. 1996). Of the 35 most troublesome exotic weeds invading Queensland's sandy shore habitats, 30 were introduced intentionally (Batianoff 1997).

Causes of problem weed infestations have been identified as:
- disturbance to the natural vegetation, and
- human introductions.

With the direct assistance of humans, the Singapore daisy (*Wedelia trilobata*) became established along 2500 km of the Queensland coast in 15 years. The species is now a problem along much of the Queensland coast, and is spreading.

Table 5-12 Known or likely exotic marine species in Queensland waters in 1996. At December 1996, the CSIRO Division of Fisheries had not undertaken detailed surveys of Queensland ports and surrounding waters looking for introduced organisms. Consequently, the number of species present might be considerably higher than the 20 listed.

Common name or category	Species	Probable origin	Likely introduction vector
Isopod	*Syndotea laevidorsalis*	North-west Pacific	n.a.
Isopod	*Paracerceis sculpta*	North-east Pacific	Hull fouling
Isopod	*Paradella dianae*	North-east Pacific	Hull fouling
Isopod	*Sphaeroma walkeri*	North Indian Ocean	Hull fouling
Ascidian	*Ciona intestinalis*	North Atlantic	Hull fouling/mariculture
Ascidian	*Styela plicata*	Philippines	Hull fouling/mariculture
Ascidian	*Mogula manhattensis*	n.a.	n.a.
Ascidian	*Botryllus schlosseri*	North-east Atlantic	Hull fouling/mariculture
Ascidian	*Botryllus aurantius*	n.a.	n.a.
Ascidian	*Botrylloides leachi*	Northern Europe	Hull fouling/mariculture
Fish	*Oreochromis mossambicus*	South-east Asia	Intentional
Fish	*Triso dermopterus*	West Pacific	Ballast water
Ectoprocta	*Conopeum tenuissimum*	North-east Atlantic	Hull fouling/mariculture
Ectoprocta	*Schizoporella unicornis*	Japan	Hull fouling/mariculture
Lace coral	*Watersipora arcuata*	East Pacific, Mexico	Hull fouling/mariculture
Sea slug*	*Aeolidiella indica*	n.a.	n.a.
Sea slug	*Okenia plana*	n.a.	n.a.
New Zealand screw shell	*Maoricolpus roseus*	South-west Pacific	n.a.
Algae	*Caulerpa taxifolia*	n.a.	n.a.
Algae	*Caulerpa racemosa*	n.a.	n.a.

*Reported by Gibbs (1993) as found on the Curtis Coast, southern Queensland. Not listed by CSIRO as known from Queensland

(Sources: CSIRO 1996; Furlani 1996; Jones 1991)

Batianoff (1997) found a strong and direct relationship between human habitation and weed invasions. Urban sprawl and the location of developments such as tourist resorts and mines in previously isolated areas appear to be important factors facilitating the spread of exotic weeds.

Coastal islands are also susceptible to weed invasion. Once a species is established on the mainland, its spread to islands and from one island to another is facilitated by human activities. Chaloupka and Domm (1986) consider that, as more people visit islands, more exotic species will be introduced. This hypothesis is consistent with the present distribution of exotics, which shows fewer species on the more remote islands. The pressure on native plant communities can be expected to increase as more of the Reef becomes accessible to humans. Distribution is also facilitated by natural means such as birds.

Moreton Bay is one of the most intensely trawled areas in Queensland.

Batianoff and Dillewaard (1996) report that between 5.5 percent and 13 percent of flora on the continental islands of the Great Barrier Reef Marine Park are exotic.

The more widespread invasive exotic species occurring on continental islands are: *Acacia nilotica* subsp. *indica*, *Agave* spp., *Annona squamosa*, *Bidens pilosa*, *Brachiaria mutica*, *Bryophyllum* spp., *Catharanthus roseus*, *Cenchrus echinatus*, *Cryptostegia grandiflora*, *Euphorbia cyathophora*, *Lantana camara*, *Leucaena leucocephala*, *Macroptilium atropurpureum*, *Melinus* spp., *Mimosa pudica*, *Opuntia stricta*, *Panicum maximum* var. *maximum*, *Passiflora* spp., *Psidium guajava* and *Stachytarpheta jamaicensis* (Batianoff and Dillewaard 1996).

Possibly the most widespread invasive exotic is *Lantana camara*, recorded on most continental islands except Lizard Island. In addition, local infestations of particular species occur — for example, *Yucca aloifolia* on Newry Island and *Tradescantia spathacea* on Shaw and Thomas Islands.

Exotic species are continuing to spread throughout the coastal zone. More exotic species are being introduced. The trend is one of increasing pressure on native plant communities. The primary causes are urban sprawl, development of once remote areas and increased human visitation to offshore islands.

FISHING, HUNTING AND COLLECTING

The direct and indirect impacts of fishing, hunting and collecting activities are an immediate pressure on the plants and animals of coastal waters, because they involve direct harvesting of living resources. Fishing is one of the most significant human pressures on certain fish stocks. Indirect impacts of fishing, such as bycatch and disturbance to the seabed, might be a significant pressure on other species and communities. Hunting is largely restricted to indigenous hunting of dugong and turtles in far north Queensland and Torres Strait. While not widespread, it is a pressure on target species. Collecting tends to target shells, corals and certain fish for the aquarium trade and is a significant pressure on some species.

Fishing

The intensity of human pressure on fish stocks is reflected in the size of the commercial and recreational catch. Relatively accurate data are now available on the commercial catch, but not on the recreational catch. Estimates of the recreational catch have been made, but the severity of pressure on most fish stocks imposed by recreational fishing is not known.

Very few data are available by which to estimate the pressure on non-target species. In some circumstances and fisheries, the discarded bycatch might include many species and be a major part of the catch. The size of the bycatch, and therefore the impact of fishing pressure on non-target species, could be significant. Habitat disturbance due to fishing activity, especially trawling the seabed, might affect some species.

Commercial fishing

Indicators

Total catch of major commercial fish, crustacean and mollusc species

Fishing effort

In 1996, the value of Queensland's 26 508 tonne fisheries catch was over $200 million. Management of all fish and invertebrates in waters adjacent to Queensland and within the 200 nautical mile limit came under Queensland jurisdiction and law on 10 February 1995. Exceptions include the northern prawn fishery, the tuna and billfish fishery and certain fish stocks in the Torres Strait Protected Zone, which remain under Commonwealth Government jurisdiction.

Fisheries resources occur along the entire coastline. Those on the southern and central coast have been exploited for many years while those of the more remote northern Great Barrier Reef Region and the Gulf of Carpentaria have been developed over the last three decades. As a result of more boats and more fishing, a more structured fisheries management regime

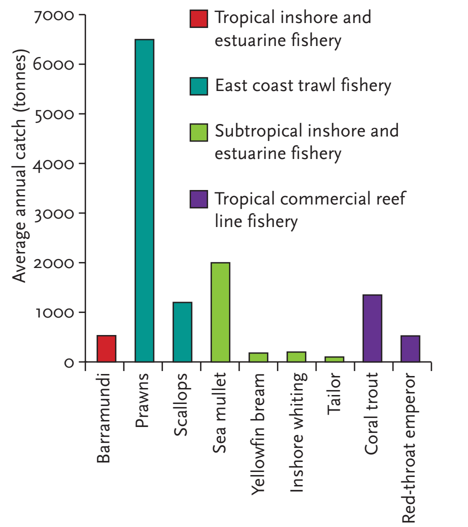


Figure 5-5 Average annual catch of major commercially valuable species

was introduced after 1979 incorporating limits on the number of vessels using a fishery. Compulsory logbooks for recording catch details and fishing effort were introduced in 1988. These data are now central to fisheries planning and management strategies. The *Fisheries Act 1994* provides for the management, use, development and protection of fisheries resources under Queensland jurisdiction.

Fish catch and fishing effort (expressed in terms of days fished, boat numbers and gear used) are indicators of the intensity of pressure on fish stocks (see figures 5-5 and 5-6). However, many variables other than fishing can place pressure on fish stocks. These include natural pressures (climate, disease) and other human pressures (pollution and habitat destruction). Nevertheless, fish catch and fishing effort are the most appropriate measures of direct human pressures.

Queensland's commercial fishing fleet consists of approximately 1900 licensed primary fishing vessels — 900 trawlers, 650 net fishing vessels, 180 crab fishing vessels and 200 line fishing vessels. Many vessels hold multiple fishing endorsements entitling them to operate in several fisheries. In 1996 the commercial catch comprised 4480 tonnes of bugs and crabs, 12 000 tonnes of fish, 9180 tonnes of prawns and 870 tonnes of scallops and squid. Total annual catch data for Queensland's major commercial species are presented in table 5-13.

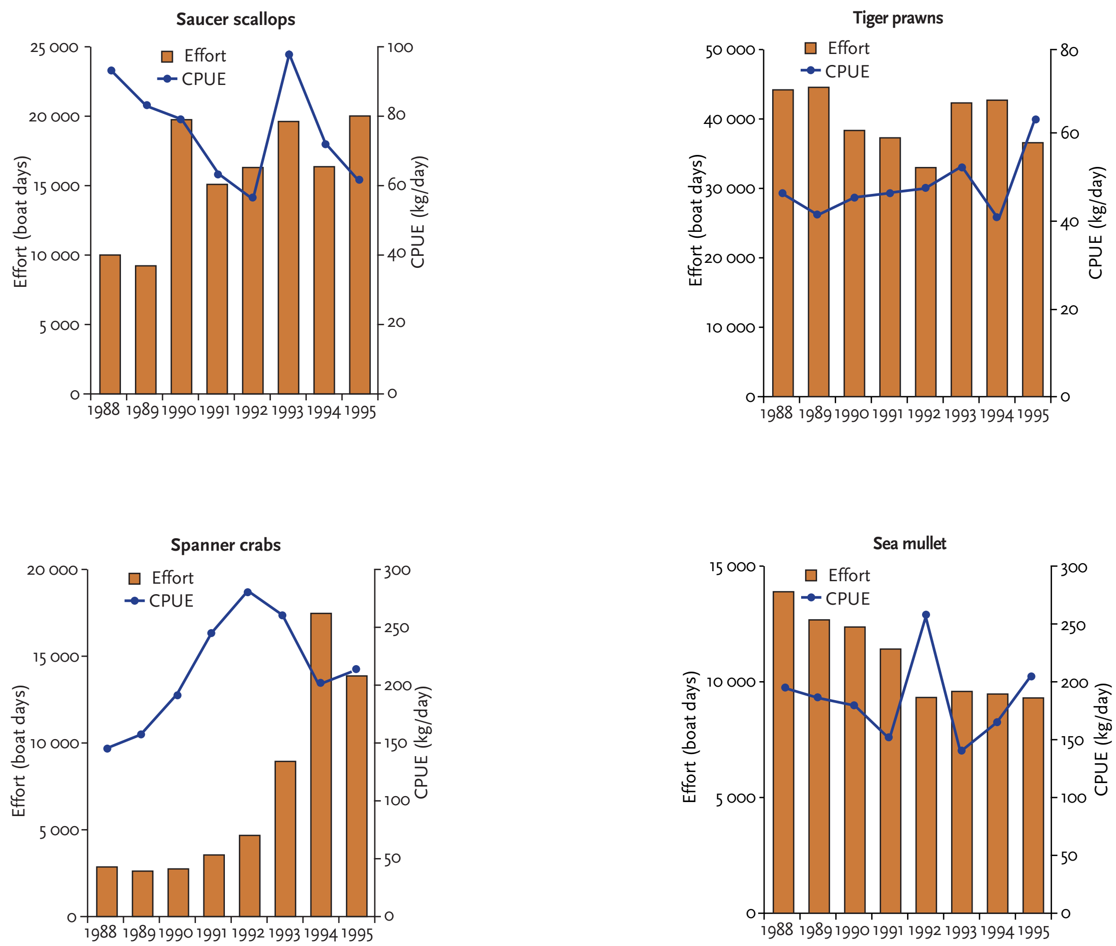


Figure 5-6 Commercial catch trends for saucer scallops, tiger prawns, spanner crabs and sea mullet. Annual catch rate, or CPUE, is a useful indicator of the status of the fish stock. While interpretation is difficult due to a variety of complex factors, a declining trend in the value of catch rate may indicate that the fish stock is declining. (CPUE = catch per unit of effort)

Table 5-13 Reported total annual catches (tonnes) for Queensland's major finfish, crustacean and mollusc fisheries. (Catches are Queensland totals and may therefore differ from catches reported on an individual fishery basis.) Catch data are based on logbook returns by commercial fishers.

Species	1988	1989	1990	1991	1992	1993	1994	1995	1996
Crustaceans									
Bugs	445.01	442.35	416.44	439.78	556.11	651.27	554.23	726.98	662.05
Mud crabs	279.07	374.65	414.14	387.50	408.88	429.81	388.44	425.85	479.44
Sand crabs	455.57	442.77	421.70	484.20	297.11	142.62	158.81	173.28	192.13
Spanner crabs	411.81	450.69	543.64	872.76	1 340.36	2 373.81	3 597.50	3 086.40	2 920.89
Other	10.16	15.09	25.05	12.59	60.91	217.53	229.47	299.49	225.15
Total	**1 601.62**	**1 725.55**	**1 820.97**	**2 196.83**	**2 663.37**	**3 815.55**	**4 928.46**	**4 712.00**	**4 479.66**
Banana prawns	594.18	836.85	419.51	1 083.49	597.51	467.48	542.75	369.75	701.91
Tiger prawns	2 447.42	1 906.17	1 782.67	1 792.52	1 614.32	2 274.58	1 718.62	2 513.91	2 668.54
Endeavour prawns	1 700.28	1 592.84	1 412.21	1 100.60	1 025.34	1 314.91	1 396.85	1 553.89	1 531.08
King prawns	2 168.42	2 268.40	2 357.31	2 779.03	2 515.97	2 331.93	1 996.97	3 025.23	3 349.46
Bay prawns	289.68	450.98	478.71	403.43	441.14	285.45	240.81	428.97	623.14
Other	700.17	674.50	569.66	591.75	453.55	339.60	222.04	360.30	302.65
Total	**7 900.16**	**7 729.72**	**7 020.06**	**7 750.82**	**6 647.82**	**7 013.96**	**6 118.04**	**8 252.05**	**9 176.77**
Finfish									
Coral trout	860.65	1 027.57	1 322.55	1 492.57	1 545.42	1 320.14	1 255.52	1 504.11	1 742.89
Red-throat emperor	382.74	436.29	488.39	523.71	564.19	552.25	528.17	480.18	576.01
Spanish mackerel	596.37	734.51	691.48	597.40	669.13	718.50	712.18	625.56	708.84
Snapper	34.70	98.39	97.14	105.29	125.97	110.29	73.00	107.47	112.03
Barramundi	186.94	758.77	562.38	755.12	503.80	566.09	498.73	570.25	665.37
Bream	235.14	232.65	225.78	177.22	196.93	146.22	118.21	215.27	156.67
Mullet	2 892.53	2 502.31	2 286.55	1 744.00	2 641.42	1 389.85	1 524.33	2 279.69	1 933.49
Tailor	202.40	241.80	172.10	126.98	169.30	110.83	178.72	127.35	166.04
Whiting	421.84	774.90	2 157.35	913.08	1 226.90	1 295.88	2 721.79	2 615.05	2 286.10
Grey mackerel	261.59	270.03	343.30	208.70	207.00	123.97	203.67	221.14	370.00
Shark	394.31	432.39	459.05	351.44	420.92	510.67	539.23	734.11	674.82
Blue salmon	105.20	146.05	141.69	156.77	157.50	154.03	162.41	148.53	152.31
King salmon	91.37	332.28	387.57	436.73	361.05	325.58	225.92	231.99	269.51
Other	1 163.28	1 496.36	1 564.79	1 558.36	1 612.09	1 775.08	1 538.13	1 829.17	2 212.68
Total	**7 829.08**	**9 484.35**	**10 900.19**	**9 147.43**	**10 401.67**	**9 099.42**	**10 280.08**	**11 689.94**	**12 026.76**
Molluscs									
Saucer scallops	943.42	796.34	1 631.08	982.40	953.86	1 954.43	1 168.00	1 647.55	717.29
Squid	137.02	209.01	195.60	231.28	206.34	134.69	135.93	133.48	153.31
Total	**1 080.44**	**1 005.35**	**1 826.68**	**1 213.68**	**1 160.20**	**2 089.12**	**1 303.93**	**1 781.03**	**870.60**

(Source: DPI)

Tropical inshore and estuarine fishery

The tropical inshore and estuarine fishery targets tropical finfish species in inshore and estuarine habitats along the east coast from about Baffle Creek near Bundaberg to Cape York and the Gulf of Carpentaria. The main target species are barramundi, king salmon, blue salmon and mackerel. The annual catch is about 2600 tonnes. About 545 boats (95 in the Gulf of Carpentaria and 450 on the east coast) participate regularly in the fishery. This fishery is also becoming increasingly popular with recreational fishers.

The total commercial catch remained relatively stable between 1988 and 1995. However, the composition appears to have changed, and the catch of some species has declined in recent years. The fishing effort (boat days) directed at the fishery has also declined considerably over the last five years.

East coast trawl fishery

The east coast trawl fishery is a multi-species fishery which targets 19 commercially important species of prawns, saucer scallops and various finfish; other species are taken incidentally. Other commercially important species, including slipper lobster (bugs), are also caught. Several types of trawl apparatus are used and the fishery covers a range of inshore (including estuaries), offshore and lagoon environments. While the range extends along most of the east coast, more than half the catch is taken from less than 30 percent of the coastline. The most intensively trawled areas are Moreton Bay, the Townsville and Bowen regions and Princess Charlotte Bay (figure 5-7).

About 840 vessels are licensed to use otter trawl equipment; a further 210 are licensed to use beam trawl equipment, although only 100 of these are regarded as being primarily involved in the fishery. Five vessels are licensed to trawl for stout whiting. The otter trawl fishery currently works about 70 000 fishing days between Cape York and the New South Wales border.

In 1994–95 the fishery produced 9172 tonnes of seafood. This comprised 5450 tonnes of prawns, 1210 tonnes of scallops, 1950 tonnes of stout whiting and 562 tonnes of bugs (QFMA 1996b).

Fishing effort directed at banana prawns has decreased by half since 1988; a corresponding decline in catch has occurred, although catch and effort have been highly variable. The species is heavily exploited. Endeavour prawns are also heavily exploited, although catch and effort have remained relatively stable over the last seven years. Catches of king prawns and tiger prawns have been relatively stable.

Fishing effort in the scallop fishery increased sharply in the early 1990s, and by 1995 was double that in 1988. However, while catch increased initially, it declined sharply in 1994 and 1995. Catch rates at the beginning of the 1996 season were at historically low levels. The fishery is believed to be heavily exploited (DPI 1997). The harvest level for scallop is very much market-driven; the very high prices received during the mid-1990s made scallop harvesting profitable despite what were regarded as low catch rates.

The effort on the stout whiting fishery increased by about 300 percent between 1991 and 1995. The catch increased by about 400 percent over the same period and has now stabilised, with the harvest level being export market-driven and very price-dependent.

Bugs are generally taken as incidental catch, particularly to the scallop fishery. Fishing effort directed at bugs has increased since the early 1990s, however, and stock depletion has occurred in some areas such as Moreton Bay.

The measure of fishing effort, the boat day, does not necessarily reflect fishing efficiency improvements resulting from technological innovations such as use of the global positioning system (GPS).

Subtropical inshore and estuarine fishery

The subtropical inshore and estuarine fishery extends from Rockhampton to the New South Wales border and targets eight main species of commercial and recreational importance. Of an annual catch around 2500 tonnes, sea mullet comprises about 2000 tonnes, yellowfin bream 165 tonnes, inshore whiting 150 tonnes and tailor 100 tonnes. Five hundred boats reported catch of these species; of them, about 200 operate full-time in this fishery.

Total inshore fishery catch declined from 3642 tonnes in 1988 to 2418 tonnes in 1995, and fishing effort declined in proportion to the decline in catch. The most significant fall has been in the mullet catch, although the decline is nearly proportional to the reduced fishing effort. While there was a decline in catch and fishing effort, catch rates remained relatively constant, indicating that fish stocks seem to be in a stable condition.

Tropical commercial reef line fishery

The tropical commercial reef line fishery is a multi-species fishery in which more than 50 species of coral reef finfish are caught routinely. Target species occur predominantly in Great Barrier Reef waters. The main species groups landed are coral trout (52–56 percent of the catch), red-throat emperor (19–23 percent) and red emperor (1–2 percent). Currently 251 operators are licensed; a further 1563 licence holders have the right to have a fishing line on their boat, but most of them do not catch reef species in any quantity.

Catch rates for the major species have shown some variation between years, although the annual total catch for 1989–94 remained relatively steady, at around 2500 tonnes. Fishing effort has also remained relatively constant.

Crab fishery

Mud crabs are taken in estuaries along the entire Queensland coast. Spanner crabs are taken in coastal waters south of Yeppoon. Blue swimmer crabs (sand crabs) are taken mainly in Moreton Bay, Great Sandy Strait and Hervey Bay. Of the total 1996 catch of about 3500 tonnes, nearly 3000 tonnes comprised spanner crabs.

Effort directed at spanner crabs increased from 2737 boat days in 1988 to 13 869 in 1995. The catch increased from 391 to 2927 tonnes. Management plans have recently been introduced for this fishery to limit the total catch to 2600 tonnes each year as part of a specific plan for the spanner crab fishery.

Blue swimmer crabs are usually taken as incidental catch to the prawn and scallop fishery. The trawl fishery targeting blue swimmer crabs increased from 7639 boat days in 1988 to 15 841 boat days in 1995.

Other finfish

Other commercially significant finfish species caught along the Queensland coast include the narrow-barred Spanish mackerel and smaller mackerel species, snapper and sharks.

Snapper is taken on the southern Queensland coast using hook and line. The commercial catch is about 100 tonnes a year, and the recreational catch is estimated to be several times larger. Fishing effort and catch in recent years have remained relatively constant. The commercial shark catch consists mainly of whaler sharks. The east coast shark catch in 1989–95 varied from 219 to 366 tonnes/year, while fishing effort varied from 4581 to 6757 boat days a year. In the Gulf of Carpentaria, the catch increased from 39 tonnes in 1988 to 290 tonnes in 1995, while effort over the same period almost doubled from 1117 to 2162 boat days.

The catch of spotted mackerel and the fishing effort have increased significantly in recent years. The catch increased from 8 tonnes in 1988 to 90 tonnes in 1995, while effort increased from 149 to 559 boat days. Nearly all of the commercial catch is harvested in the Townsville–Bowen and Hervey Bay regions. Conversely, the grey mackerel catch declined from 343 tonnes in 1990 to 221 tonnes in 1995. The decline has been most pronounced in Hervey Bay and Moreton Bay. The two species have considerable natural inter-year variation, which is reflected in the effort and catch figures. Market prices also have a strong effect in these fisheries, especially in southern Queensland.

Bycatch

Indicator

Annual total bycatch by fishery

The term 'bycatch' is used to describe those species caught which are of no commercial value and which are generally discarded overboard.

Compared with other forms of commercial fishing, trawling operations (particularly prawn trawling) result in the capture of a greater range of species than those targeted and generate the highest rate of bycatch. In some trawl fisheries, the ratio of bycatch to target species can be as high as 8:1 or 10:1 (QFMA 1996b). The bycatch in the Gulf of Carpentaria tiger prawn fishery between 1981 and 1985 was estimated at 4100 tonnes a year (Harris and Poiner 1995). The Moreton Bay prawn fishery bycatch has been estimated at about 3000 tonnes a year (Wassenberg and Hill 1990).

While several isolated studies have determined the relative size of the bycatch, the composition and quantity of bycatch caught by the Queensland fishing industry is unknown. Given the proportion of bycatch in some fisheries, the total annual industry bycatch could be very significant. The mortality of non-target species of fish and invertebrates has the potential to adversely affect the populations of some species. However, the significance of bycatch mortality for individual species or at the ecosystem level is unknown.

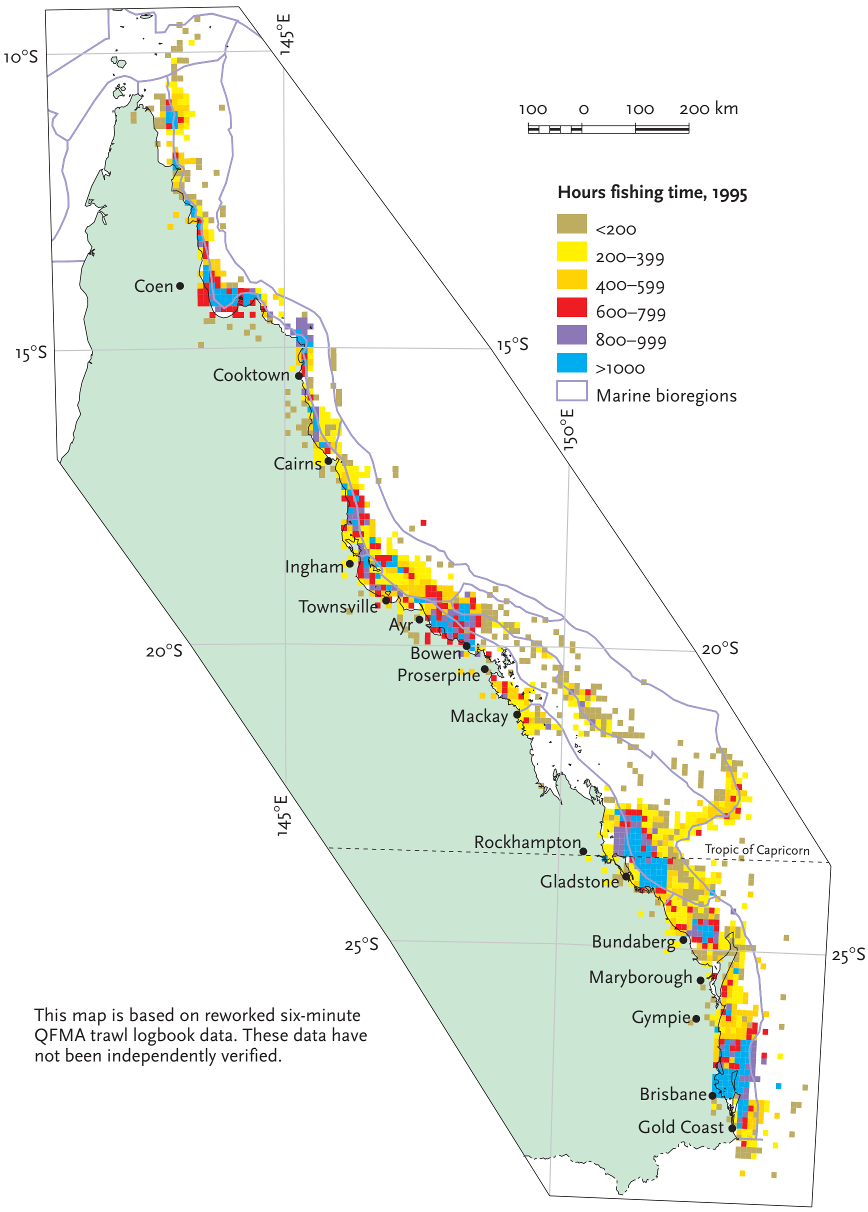
Habitat disturbance

Indicator

Area of seabed trawled and intensity of trawling

Physical disturbance by trawling has the potential to affect seabed habitats significantly. Disturbance can remove or destroy sessile (immobile) benthic organisms such as sponges and gorgonians and alter the composition and diversity of benthic communities. Preliminary analyses of the effects of trawling at different frequencies in the Great Barrier Reef Marine Park Far Northern Section indicated that each trawl removed roughly 5–20 percent of the available living, immobile organisms growing on the seabed (Pitcher et al. 1996). Some 70–90 percent of the initial living biomass was removed after 12–13 trawls. The study showed that the cumulative effect on the benthos of frequent trawls over the same grounds might be substantial. Conversely, in areas trawled sparsely or infrequently, effects might not be detectable.

The pressure on benthic communities from trawling is related in part to the frequency with which the area is subject to trawl disturbance. This can vary widely depending on location. Consequently, while trawling might be permissible over large areas of seabed, the area subject to frequent trawl disturbance might be relatively small. Trawl frequency, expressed as the number of times the same area is trawled in a year, is an indicator of trawl pressure. As trawling occurs along most of the east coast, with effort most concentrated in Moreton Bay, the Curtis Channel off Gladstone, the Bowen region and Princess Charlotte Bay in north Queensland, benthic communities in these areas are most subject to adverse impacts from trawling (see figure 5-7).



This map is based on reworked six-minute QFMA trawl logbook data. These data have not been independently verified.

Recreational fishing

Indicators

Recreational fish catch

Recreational fishing effort

Fishing continues to be one of the most popular recreational activities undertaken by Queenslanders. At least one member (over 15 years old) of about 25 percent of Queensland households went fishing, crabbing or prawning in the year October 1995 to September 1996. About 60 percent of these fished less than once a month, while 17 percent fished at least fortnightly. The marine environment was fished by 92 percent of fishers (QFMA 1996c).

Despite this popularity, the contribution of recreational fishing to total fish catch and the overall impact of recreational fishing on stocks are largely unquantified. Limited data are available relating to catch rates, target species and fishing destination. However, these data are often insufficient to enable any evaluation of trends in catch rate or fish weights over time.

The most intensively fished areas are Fraser Island/Great Sandy Strait, Moreton Bay including Pumicestone Passage, and coastal waters around Townsville and Cairns. The Moreton Bay recreational fishery is used by an estimated

Griffith University (AES)

Fishing continues to be one of the most popular recreational activities undertaken in Queensland.

300 000 fishers each year (QFMA 1997). The popularity of such areas and, therefore, the intensity of fishing pressure have grown significantly in recent years.

Swallowtail dart and tailor are the most important ocean beach catches. Yellowfin bream and inshore whiting are heavily fished in estuarine and bay areas south of Hervey Bay. The recreational snapper fishing catch in Moreton Bay and on offshore reefs is believed to be several times the commercial catch.

Mackerel is a popular recreational species in southern Queensland waters. A 1994 survey indicated that 19 000 registered recreational boats were used to target mackerel. The effort was estimated at 120 000 boat days, with a catch of 370 000 fish. Recreational effort directed at all popular species in southern Queensland can be expected to continue to increase as the population grows.

Gulf rivers and estuaries are increasingly popular with recreational fishers. Improved access has resulted in a significant increase in tourist numbers in recent years. An estimated 100 000 recreational fishers now fish the Gulf of Carpenteria each year (QFMA 1996c). Principal target species are barramundi and king salmon.

Tropical coral reef fish are of particular importance to recreational fishers. Between 1980 and 1990, increases in the numbers of pleasure craft used for fishing in the Great Barrier Reef region ranged from 47 percent (Townsville) to 89 percent (Mackay).

In the absence of accurate data on recreational fish catch and fishing effort, trends cannot be determined or conclusions drawn about the impact of the recreational catch on fish stocks. The limited information available suggests that recreational fishing pressure has increased as a result of population growth, improved access to coastal areas and increased boat ownership.

Collecting

Indicators

Number of authorities to collect aquarium fish

Number of permits to collect shells

Collecting activities involve removing living organisms or dead specimens from coastal waters. These include commercial and recreational shell collecting, commercial coral collecting, marine aquarium fish collecting, and bêche-de-mer collecting.

Collecting activities in the Great Barrier Reef Marine Park are subject to authorisation by permit. In 1995–96, 127 permits were issued. However, the number of specimens taken is usually not known and the impact of collecting on target species is also largely unknown.

Shell collecting returns between 1982 and 1988, from 19.4 percent of permit holders, totalled 12 509 live shells of 327 species (Barnett 1989). This suggests that about 60 000 shells were taken. Collectors tend to target rare species such as many *Cypraea* (cowrie) species and all species of Volutidae (volutes), thus making them even rarer. Evidence of population decline and depletion of certain mollusc species is largely anecdotal. The few reliable reports of depletion focus on Langford, Heron, North West, Tryon and Lady Musgrave Reefs, and coastal sites off Dingo Beach, Four Mile Beach and Kurrimine Beach (Barnett 1989).

The aquarium fish trade targets a number of small, colourful fish including surgeon fish, clown fish, butterfly fish and wrasse. In 1996, 67 authorities to take aquarium fish commercially in Queensland waters were current. Fifteen were for Moreton Bay (QFMA 1997).

The trend in collecting pressure and its impact on species and communities are unknown. The tendency of collectors to target some rare (and therefore valuable) species suggests that collecting can be a great pressure on some species.

Combined fishing, hunting and collecting

Indicators

Turtle and dugong mortality through indigenous hunting

Turtle, dugong and dolphin mortality through commercial fishing activity and shark nets

Some marine species are subject to pressure from the combined impact of fishing, hunting and collecting. Data on the severity of these pressures are generally available only for the larger species such as turtles, dugong and dolphins, and species of particular value or interest.

Marine turtles

Marine turtle populations are adversely affected by hunting, incidental catch in fisheries, shark nets, habitat loss, marine pollution and boat strikes. While commercial hunting is not permitted in Australian waters, hunting in other parts of the world has a direct impact on some Australian turtle populations due to their migratory behaviour. A significant cause of hawksbill turtle mortality is the tortoiseshell trade. Although Australia does not participate, Japan imported 743 296 kg of tortoiseshell between 1970 and 1990, equal to tens of thousands of hawksbill turtles (Miller 1994).

Between 1985 and 1987 the indigenous harvest of green turtles in Torres Strait by Torres Strait Islanders and the Kiwai people of Papua New Guinea was estimated at 5200–6300 a year (Kwan 1989). Egg collecting by indigenous people in the Torres Strait is also a cause of population loss.

On the basis of Queensland studies in 1991 and 1992, it is estimated that 5295 ±1231 turtles are caught annually by the east coast trawl fishery (Robins 1995). At an assumed mortality rate of 6.8 percent, turtle deaths associated with the trawl fishery are estimated at 276–444 a year. The species caught include loggerhead (50.4 percent), green (30.1 percent) and flatback turtles (10.9 percent).

The estimated annual incidental turtle catch by the northern prawn fishery (Gulf of Carpentaria) is 5730, with an estimated mortality of 6–10 percent (Poiner and Harris 1994; Poiner et al. 1990).

About 4300 turtles (about 114 each year) were caught in shark control nets in Queensland waters from 1962 to 1998, and about 80 percent were released alive. In the last five years fewer than eight turtles died in the nets, and about 70 animals were released each year.

Dugong and dolphins

An unknown number of dugong are killed as a result of entanglement in fishing nets. Concern over the impact of gill netting recently led the Commonwealth Government and the Queensland Government to ban their use in some areas.

Accidental deaths of dugong from the shark control nets along the Queensland coast have averaged fewer than four each year for the last five years. This is a result of modifications to the netting practices to allay concerns about the capture of species incidental to the program. From 1962 to 1998 there were an estimated 619 dugong deaths in total. The majority of these deaths occurred before 1978.

Hunting by indigenous peoples has been and continues to be a cause of dugong mortality, although total numbers taken are unknown. Hunting is most intense in Torres Strait. Between mid-1991 and mid-1993, an average of 1226 ±204 dugong were taken each year in the Torres Strait Protected Zone (Harris et al. 1994). In 1994 the catch was estimated at 860 animals. These figures do not include catch data from Papua New Guinea, and total mortality due to indigenous hunting could therefore be considerably higher.

The number of Great Barrier Reef Marine Park Authority (GBRMPA) permits issued for 'traditional hunting' has varied over the years. The number of dugong taken is not reported.

The gill net fishery for barramundi and threadfin salmon in tropical waters is known to be a cause of dolphin mortality (McPhee and Hale 1995), although numbers are unknown. Some mortality occurs in shark control nets: 730 dolphins were caught in nets from 1962 to 1998 (about 20 each year). In the last five years about twelve dolphins died in shark control nets each year.

Whales

Between 1912 and 1963, when whaling ceased in the western Pacific Ocean, 19 687 whale captures were reported. At the east Australian shore stations of Tangalooma and Byron Bay, 7423 humpback whales were processed between 1952 and 1962. The exploitation was so severe that only 34 to 137 humpback whales remained in the east Australian stock in 1962 (Paterson et al. 1994). The level of exploitation was far in excess of the resource's capacity to renew itself.

Only when the industry had effectively ceased to exist did the International Whaling Commission extend complete protection to Southern Hemisphere stocks of humpback whales. Whales in Australian waters today are fully protected and sustain a more benign industry — whale-watching.

TOURISM AND RECREATION

Indicators

Number of visitors to Queensland

Commercial accommodation available

Air passenger movements at selected airports

Number of visitors to the Great Barrier Reef Marine Park

Number of Marine Park Tourism Program permits

Number of recreational (motor and sail) and commercial vessels registered in Queensland

Tourism is one of Queensland's major industries and one of the most rapidly growing sectors of the Queensland economy. Visitors staying in commercial accommodation in 1996–97 spent an estimated $5.4 billion in Queensland. While the environmental impact of tourism and tourists is variable and case-specific, the sheer size of the industry inevitably places pressure on the environment. The potential impact of the industry is particularly relevant to the coastal zone, as most tourism activity in Queensland is focused on the coast. Areas around Cairns, Townsville, the Whitsunday Islands and the south Queensland coast are particularly subject to the pressures of tourism.

The environmental impacts of tourism activity are difficult to define because they range in scale and severity. Impacts can be transitory and highly localised, irreversible and highly destructive, or insidious and chronic. Impacts range from disturbed seabird nesting to wetlands destruction and increased wastewater discharged to coastal waters. The activities of tourists and the facilities required to service their transport, accommodation and entertainment needs combine to place considerable pressure on the coastal zone.

The absence of a clear cause-and-effect relationship between tourism and environmental impacts is a problem for the industry and resource managers. Taken individually, the additional environmental impact resulting from a particular activity or development might seem negligible. However, the incremental pressure resulting from the progressive expansion of the industry inevitably makes the impacts more significant. How to manage this incremental increase in pressure is a significant resource management issue.

Indicators of the pressure of tourism on coastal resources are defined largely in terms of visitor numbers and accommodation capacity. These indicators do not quantify the real impact of tourism, but provide indicative measures of tourist numbers and infrastructure growth relative to the past. Evidence of rapid growth in visitor numbers and infrastructure is taken to imply increasing pressure on the surrounding environment.

Estimated total visitor numbers to coastal regions are given in table 5-14. Most regions have experienced some growth in numbers in recent years, although growth has been most pronounced in the far north, Sunshine Coast, Gold Coast and Brisbane tourism regions. The environmental implications of

Table 5-14 Queensland tourism coastal region destinations, visitors and visitor nights. In some instances, tourist destinations extend further inland than the coastal zone. However, most tourism activity in these regions is focused on the coastal zone.

Destination*	Visitors ('000)			Visitor nights ('000)		
	1995–96	1996–97	Growth (%)	1995–96	1996–97	Growth (%)
Gold Coast	2 122	2 321	9	10 656	11 286	6
Brisbane	1 511	1 592	5	4 746	4 586	–3
Sunshine Coast	1 412	1 302	–8	6 147	6 173	0
Wide Bay–Burnett	776	829	7	2 503	2 634	5
Fitzroy	603	769	28	1 782	1 997	12
Mackay	382	387	1	1 006	1 034	3
Whitsundays	323	342	6	1 541	1 563	1
Northern	544	593	9	1 767	1742	–1
Far North	1 278	1 408	10	6 491	6 693	3

*Regions do not conform strictly to ABS statistical regions used in this report.
(Source: QTTC 1998)

Table 5-15 Visitor numbers to selected recreation areas. Overnight campers spend much more time in an area than day-tour visitors but their impact is not necessarily greater.

Recreation area	1991–92	1992–93	1993–94	1994–95	1995–96	1996–97
Fraser Island						
Campers	77 795	81 849	80 492	80 019	85 096	87 746
Tour passengers	114 716	123 673	139 876	146 398	142 488	148 726
Green Island						
Campers	No camping allowed					
Tour passengers	255 149	293 372	318 959	305 500	280 000	270 000

Table 5-16 Annual camper nights spent in some popular coastal zone national parks. These figures are minimum estimates because ranger presence, and therefore permit issue, vary between parks.

National park	1990	1991	1992	1993	1994	1995
Eungella	10 992	10 484	11 932	12 050	11 670	10 576
Orpheus Island	273	365	711	912	786	1 168
Cape Tribulation	4 200	3 686	3 156	2 607	5 371	5 065
Lakefield	13 180	16 304	15 446	16 247	15 800	15 041
Whitsunday Islands	9 859	10 760	11 612	11 131	8 308	5 723
Conway	15 737	5 769	6 394	6 272	6 628	2 717*
Cooloola	44 994	37 141	59 551	69 718	65 098	68 038

*Nine months' data

Table 5-17 Number of islands in the Great Barrier Reef region important as seabird nesting sites and which come or are coming within the one-day tourist vessel range. Islands are classified for seabirds as 'significant' (58 islands) and 'minor' (20 islands).

Year	Number of significant islands within 1-day vessel range	Number of minor islands within 1-day vessel range	Combined percentage of important islands within 1-day vessel range
1985	5	5	13
1990	14	9	30
1994–2000	31	15	59

(Source: Stokes et al. 1996)

such growth arise from the need to expand services such as waste treatment and disposal, accommodation, transport, and power and water infrastructure.

In 1996, Queensland had 1128 hotels/motels, 630 caravan parks, 710 letting entities, and 141 visitor hostels. These offered 43 007 hotel/motel rooms, 54 994 caravan park sites, 18 966 units/flats/holiday houses for short-term accommodation, and 8824 hostel bed spaces.

In the year to September 1997, the stock of hotel/motel rooms grew by 2014 rooms (5 percent), the number of units grew by 1175 units (6 percent) and the number of hostel beds grew by 1098 (12 percent). This growth slightly affected occupancy rates in the same period — 60 percent for hotels/motels (down 1 percent on 1996), 46 percent for caravan parks (unchanged), 59 percent for holiday flats and units (down 1 percent) and 52 percent for visitor hostels (unchanged). Although these data relate to the whole of Queensland, about 90 percent of tourist accommodation is located in the nine coastal regions.

Tourism pressure on particular areas is indicated by total visitor numbers to an area (table 5-15).

Tourism pressure on particular areas is also indicated by camper nights spent (table 5-16).

The Great Barrier Reef is a major tourist destination subject to tourism pressure. From an estimated 150 000 visitor days in the early 1980s, tourism had increased to about 1.7 million visitor days by 1995–96. Continued growth of up to 10 percent a year is anticipated (GBRMPA estimate). The number of commercial tourism vessels has increased from about 275 in 1985 to more than 1300 in 1997. Tourism pressure is not distributed evenly, as more than 80 percent of tourism focused on the Cairns and Whitsunday areas. About 65 percent of tourist use involves only 15 reefs.

Most commercial activities in the Great Barrier Reef Marine Park require authorisation by GBRMPA permit. In 1994–95, 864 Marine Park Tourism Program permits, for carrying more than 10 million passengers (visitor days), were current (Dinesen and Oliver 1997). Permits included 751 separate tourism operators, 1348 tourism vessels, 36 aircraft operations, 23 facilities such as pontoon complexes, and numerous miscellaneous facilities.

Currently, only about 1.7 million of the 10 million allowed visitor days are used. As this 'spare' capacity is filled progressively, tourism pressure will increase significantly, presenting a major challenge for conservation managers.

One factor increasing tourism pressure on the Great Barrier Reef is the trend to larger and faster commercial charter vessels. In the 1970s and early 1980s the larger vessels carried up to 50 passengers at a speed of 10 knots, allowing a one-day tour range of 20 nautical miles. Taken from the major embarkation points, this translates to an operational range encompassing about 4 percent of the Great Barrier Reef region.

The size and range of vessels have increased to the point where, in early 1996, 19 charter vessels were each carrying 140–400 passengers at speeds of 25 knots. As a consequence, the one-day operational range is now over 24 percent of the region. Vessel capacities of 450 and speeds of 35 knots are possible. This trend means that an ever-increasing number of once-remote reefs are becoming subject to the pressures of tourism. The effect of this transition is demonstrated in terms of the number of important island seabird nesting colonies coming within the range of the one-day tour. The data in table 5-17 indicate that many more islands are coming within the range of the one-day tourist visit — from 13 percent of important nesting colonies in 1985 to over 59 percent today.

As more people have access to coastal waters, the associated pressure resulting from human activity can be expected to increase. The extent of recreational access to nearshore and offshore waters can be inferred indirectly from the number of recreational and commercial vessels registered (tables 5-18 and 5-19). Data indicate a significant increase in the number of sail and motor boats registered in Queensland in recent years, suggesting that access to coastal waters is increasing.

Tourism is a rapidly growing industry which can place significant pressures on coastal resources. As growth continues, the industry will inevitably change the nature of the coastal zone and its inherent environmental values. The presence of many people in areas that previously were seldom visited clearly changes the quality and nature of the recreational experience enjoyed. This is not to say that the environment has been significantly degraded as a result of tourism, but that the environmental values an area can provide have been changed.

The trend in all indicators is one of increasing pressure over time. Continued growth in the industry is expected, inevitably at the cost of some of the coastal zone's environmental values.

Increasing numbers of recreational boats provide wider access to coastal waters.

Table 5-18 Number of recreational vessels (motor and sail) registered in Queensland

Category	1990	1991	1992	1993	1994	1995	1996
Speed/motor	n.a	n.a	105 044	109 053	115 956	118 737	117 996
Sail	n.a	n.a	2 783	2 983	3 034	3 066	3 145
Total	**102 853**	**104 745**	**107 827**	**112 036**	**118 990**	**121 803**	**121 141**

Note: Figures for 1995 and 1996 exclude some vessels previously registered as recreational but now registered as commercial.
(Source: QT)

Table 5-19 Number of commercial vessels registered in Queensland

Category	1992	1993	1994	1995	1996
Passenger	1176	1174	649	609	596
Non-passenger	1810	1893	1607	1540	1834
Fishing (>10 m)	1430	1347	828	832	846
Hire	n.a	n.a	1562	1629	1355
Total	**4416**	**4414**	**4646**	**4610**	**4631**

Note: Numbers before 1993 are all registered vessels. Starting in 1993, numbers are current registered vessels.
(Source: QT)

The state of Queensland's coastal resources is discussed under the headings of the major biophysical resource groupings identified in table 5-1.

Where possible, quantitative environmental indicators of the quality or quantity of a particular resource have been identified and are used to measure the condition of the resource. Any change over time in the value of these environmental indicators, and therefore in the condition of the resource, is identified. Where possible, the significance of any such change is interpreted in terms of the actual or potential impact on the environmental values of the resource.

BEACHES AND DUNE SYSTEMS

More than any other feature of the Queensland landscape, beaches are synonymous with the Queensland lifestyle. They are major natural resources which have many values. The beaches and dune systems of the coastal zone are used extensively for recreation, support diverse vegetation types, are mined for valuable sands and provide a buffer to dissipate the destructive energy of the sea. The state (or condition) of Queensland beaches and dune systems is considered in terms of the status of coastal dune (heathland) vegetation, the extent of weed invasion in sandy shore plant communities and the physical state of the beach sand mass.

Coastal heathland

Indicator

Area of coastal heath vegetation remaining

Coastal heathland communities occur largely on the Quaternary dune systems and the coastal sand plains of south-east Queensland, the Burnett–Curtis coastal lowlands, the central Mackay coast and Cape York Peninsula. They consist of eight main vegetation types including *Banksia aemula* low shrubby woodland, *Eucalyptus conglomerata* shrubby woodland, open/dry heath dominated by *Banksia* spp., *Leptospermum* spp. and *Allocasuarina littoralis*, open heath and sedgelands.

In the past, coastal heathlands have been cleared extensively for urban development, agriculture, pine plantations and sandmining. This is particularly so in south-east Queensland. Information about the loss of heathlands is limited, however. On the south-east coast mainland about 33 percent of the area of heathland present in 1974 had been cleared by 1989 (Catterall and Kingston 1993). In 1989, approximately 27 km² of coastal heathland remained on the mainland and 173 km² on the major sand islands of Moreton Bay. Extensive clearing has continued around Caloundra, Maroochydore and Noosa, largely for urban development. Remnant areas such as Pine Ridge Conservation Park, the only remaining patch of heath on the Gold Coast, tend to be very small and isolated.

Table 5-20 National and conservation parks protecting coastal heathland vegetation on Queensland's east coast

Vegetation type	Protected area
Banksia aemula woodland	Great Sandy (4279 ha), Moreton Island (3140 ha), Eurimbula, Deepwater, Burrum Coast, Noosa, Bribie Island, Rodds Peninsula
Mallee shrublands	Moreton Island
Closed/wet heath	Great Sandy, Deepwater, Burrum Coast, Bribie Island, Noosa, Mooloolah River, Moreton Island, Rodds Peninsula, Byfield
Banksia open/dry heath	Great Sandy (16 500 ha), Noosa (1400 ha), Burrum Coast, Byfield, Blue Lake
Asteromyrtus open heath	Jardine River, Iron Range, Heathlands, Lakefield (126 980 ha in total)
Dwarf open heath	Jardine River, Cape Melville, Iron Range, Lakefield, Starcke (9600 ha in total)
Sedgelands	Eurimbula, Deepwater, Burrum Coast, Noosa, Great Sandy, Blue Lake
Eucalyptus conglomerata low woodland	Mooloolah River, Palmview, Glasshouse Mountains

Coastal heaths support at least 25 rare and threatened plant species including 7 vulnerable, 12 rare, and 6 endangered species — *Allocasuarina emuina*, *Eucalyptus conglomerata*, *Olearia hygrophila*, *Phaius australis*, *P. bernaysii* and *P. tancarvilliae*. One of the endangered species, *Olearia hygrophila*, is found only in areas that are not protected.

Open heaths are considered to be well conserved except on the mainland south of Noosa; dwarf open heaths are well conserved except for those on the sand plains at Cape Flattery; *Banksia aemula* woodland and closed heaths are moderately conserved; and sedgelands, mallee shrublands and *Eucalyptus conglomerata* low woodland are poorly conserved (table 5-20).

Coastal heath vegetation has been extensively cleared in the past. Available information suggests that those areas of coastal heath which are not protected in conservation reserves are increasingly threatened by sandmining, agriculture and urban/tourism development. The environmental values of this vegetation type have been adversely affected and are under threat.

Weed invasion

Indicator

Number and geographic distribution of introduced plant species

All introduced plant species, whether they originate from overseas or elsewhere in Australia, are considered to be weeds. Weed invasions and climate change have been listed as the processes most threatening to coastal zones (Batianoff et al. 1996). Highly invasive weeds, once established, have the potential to change the composition of dune vegetation significantly.

There are 185 exotic species established as weeds on the sandy shores of Queensland's east coast. These species can now be considered to be naturalised. They include 18 species of trees (9.7 percent), 31 species of low shrubs (16.8 percent) and 126 (68 percent) herbaceous species (Batianoff 1997). Naturalised exotic species now constitute 47.4 percent of sandy shore species. Table 5-21 lists the 35 most troublesome species.

Table 5-21 The 35 most troublesome 'weed' species occurring on Queensland's east coast sandy beaches and dunes

Scientific name	Common name	Origin
Agave sisalana	sisal	O
Agave vivipara	agave	O
Asparagus densiflorus	asparagus fern	O
Brachiaria mutica	para grass	E
Bryophyllum tubiflorum	mother-of-millions	O
Calotropis spp.	calotrop	O
Catharanthus roseus	pink periwinkle	O
Cenchrus echinatus	Mossman River grass	E
Centrosema pubescens	centro	E
Chrysanthemoides monilifera subsp. *rotundata*	bitou bush	E
Conyza bonariensis	flaxleaf fleabone	A
Digitaria eriantha subsp. *pentzii*	pangola grass	E
Euphorbia cyathophora	dwarf poinsettia	O
Gloriosa superba	glory lily	O
Helianthus argophyllus	dwarf sunflower	A
Ipomoea cairica	mile-a-minute	O
Lantana camara	lantana	O
Leucaena leucocephala	leucaena	E
Macroptilium atropurpureum	siratro	E
Melinis repens	red Natal grass	E
Oenothera drummondii	beach evening primrose	A
Opuntia stricta var. *stricta*	prickly pear	O
Panicum maximum var. *maximum*	guinea grass	E
Passiflora foetida var. *foetida*	stinking passion flower	A
Passiflora suberosa var. *suberosa*	corky passion flower	A
Psidium guajava	guava	E
Sansevieria trifasciata	mother-in-law's tongue	O
Schefflera actinophylla	umbrella tree	O
Schinus terebinthifolia	Brazilian pepperina tree	O
Senna pendula var. *glabrata*	Easter cassia	O
Stachytarpheta jamaicensis	Jamaica snakeweed	O
Stylosanthes guianensis	stylo	E
Stylosanthes scabra	shrubby stylo	E
Wedelia trilobata	Singapore daisy	O
Ziziphus mauritiana	Chinese apple	O

A: accidental; E: economic, agricultural or rehabilitation; O: ornamental/gardens
(Source: after Batianoff 1997)

The intentional introduction of exotic species as ornamental garden plants or economic agricultural plants is the major source of exotic weeds. Of the 35 most troublesome weeds on sandy shores, 30 (86 percent) were introduced intentionally (Batianoff 1997).

Weeds now invade sandy shore habitats along the entire east coast, although the number of species and the area infested are greatest in the south. In north Queensland, the cities of Townsville and Cairns are areas with significant weed introductions, due to human disturbance. McDonald (1984) recorded 123 vascular plant species along the Cairns sandy coast between Ellie and Buchan Points; of these, 80 (65 percent) were native and 43 (35 percent) were naturalised exotics. The most important weeds occurring along this coastline are guinea grass and Mossman River grass. More recent data are unavailable.

On the central coast between Bowen and Gladstone the most important and widespread weed species are guinea grass, prickly pear and para grass. Survey work on the Gold Coast (December 1996) and Sunshine Coast (January 1997) indicates a high proportion of weeds. Of 158 vascular plant species recorded on the Gold Coast, 101 (64 percent) are introduced. On the Sunshine Coast, of 226 species recorded between Noosa and Bribie Island, 130 (58 percent) are exotic species. The most important weed species are asparagus fern, glory lily, Brazilian pepperina tree and Singapore daisy (Batianoff 1997).

A comparison of survey results in 1982 (Batianoff and Elsol 1989) and 1997 (Batianoff 1997) from the same six locations on the Sunshine Coast indicates that 40 additional weed species became established at these sites in the intervening 15 years. A comparison of more comprehensive 1987 survey data (Batianoff 1987) with the 1997 data indicates an increase of 68 weed species. Introduced species comprised 40 percent (62 species) of dune species in 1987, increasing to 58 percent (130 species) in 1997.

Available data suggest a trend towards increasing numbers of introduced plant species on Queensland's sandy shores in recent years. The distribution of some species has also increased. The incidence of exotic weeds is highest around population centres, reflecting the role of urban development in the dispersal of such species. Weed invasion has adversely affected the environmental values of dune systems in localised areas. Current development trends in the coastal zone continue to present a threat to the environmental values of native dune vegetation.

Beaches

Beaches provide an effective buffer between the land and the sea, dissipating wave energy and protecting the land. The beach responds to differences in wave energy by changes in its width and/or depth. The beach and dune zone should be seen as a fluctuating zone — accreting (building up) when conditions are mild and eroding when conditions are rough.

Erosion due to natural beach processes does not permanently affect the form of a beach and hence its value as a public resource. However, it involves a landward shift in the location of the beach. Problems associated with beach erosion occur only when the shoreline recession threatens property and improvements. The problem is that development has

Table 5-22 Beach movement (metres) between 1890 and 1985 at locations between Point Vernon and the Burrum River, south-east Queensland

Location	1890–1910	1910–48	1948–54	1954–65	1965–75	1975–79	1979–81	1981–82	1982–85
Dundowran (eastern end)	–	–	–	–	–	–	−3	+2	−1
Dundowran (central section)	–	–	–	–	–	–	+1	−3	−1
Dundowran (western end)	–	–	–	–	–	–	+1	+2	+1
Toogoom (near O'Regan Creek)	–	–	–	–	–	–	0	0	−3
Toogoom East	–	–	–	–	–	–	0	−3	+5
Toogoom	–	–	+86	–	–	−6	–	–	–
Toogoom	–	–	+38	–	–	+6	–	–	–
Burrum Heads (near Beelbi Creek)	–	–	–	–	–	–	0	0	+1
Burrum Heads (central section)	–	–	–	–	–	–	−2	−1	−5
Burrum Heads (near township)	–	−8	–	−9	−8	−8	–	–	–
Burrum Heads (township)	−27	–	–	–	−2	−4	–	–	–
Burrum Heads	−38	–	–	−7	−3	Seawall built	n.a.	n.a.	n.a.

– indicates no data

(Source: BPA 1989)

occurred within the zone of natural beach fluctuations. Table 5-22 gives examples of historical shoreline movement.

In view of the dynamic nature of the beach environment, a summary statement on the overall condition of Queensland's beaches cannot be given. Instead, a case study examining issues affecting beaches is included to indicate the complexity of the beach system. This study focuses on recent coastal changes near the northern end of Bribie Island, 100 km north of Brisbane (see box 'Recent coastal changes near the northern end of Bribie Island').

CORAL REEF SYSTEMS

The Great Barrier Reef region, extending 2300 km from Bramble Cay to Lady Elliot Island, encompasses the shallow sea, islands and reefs of the continental shelf seaward to the outer reef. The region includes much of the marine environment under consideration in this report. Many issues discussed in the wider context of the coastal zone are directly relevant to the Great Barrier Reef region. In view of this, the state of the coral reef systems is presented as a summary of the major environmental issues affecting the Great Barrier Reef region (see box 'State of the Great Barrier Region'). Further detail is given in other sections of this chapter.

SOFT-BOTTOM SYSTEMS

Indicator

Area of soft-bottom habitats not subject to trawling

Soft-bottom habitats account for most subtidal benthic environments. Soft-bottom or inter-reef habitats comprise some 95 percent of the area of the Great Barrier Reef Marine Park, covering 225 000 km^2 of the region. In addition, such habitats are by far the dominant habitat type in the Gulf of Carpentaria (370 000 km^2), in Torres Strait and off the southern Queensland coast. These vast areas of seabed support a diversity of community types and species including many species of commercial significance. However, despite the extent and importance of such habitats, knowledge of their ecology is limited to the results of relatively few very localised studies and several large-scale studies.

Community sensitivity to disturbance, such as that resulting from trawling, and the long-term impacts of disturbance on productivity are largely unknown. Studies have shown localised adverse impacts associated with a high level of disturbance (high-frequency trawling) (Pitcher et al. 1996), but the significance of such impacts has not been examined. Consequently, the effect of human-related disturbance on soft-bottom communities remains unclear, as does the level of disturbance that can be sustained in the longer term.

Plants and animals found on the seabed are influenced by sediment type; species richness and diversity tend to increase in the coarser, sandier sediments and on rubble and bedrock. As many as 700–900 species more than 0.5 mm in length and at least as many less than 0.5 mm in length might live in the sediment, while up to 900 species live on the sediment surface (Pitcher 1997). In total, many thousands of species, most of them unnamed, live in association with bottom sediments.

The environmental values of these communities, including their biodiversity, level of endemism and ecological functions, might be threatened in localised areas as a result of human activities, particularly in the inshore lagoon of the Great Barrier Reef. Several long-term studies have been initiated, with the aim of eventually providing information to evaluate temporal changes.

COASTAL WETLANDS

Indicator

Area of coastal wetlands

The wetlands definition used in this report is based on that used in the Convention on Wetlands of International Importance Especially as Waterfowl Habitat 1971 (Ramsar Convention): 'areas of permanent or periodic/intermittent inundation, whether natural or artificial, static or flowing, fresh, brackish or saline, including areas of marine water the depth of which at low tide does not exceed six metres'.

Queensland's wetlands are of outstanding diversity, with all of Australia's 40 wetland classes except alpine and tundra

Bribie Island is a barrier island at the northern end of Moreton Bay. The island's northern tip, about 100 km north of Brisbane, is separated from Caloundra by the unstable northern estuary entrance to Pumicestone Passage (figure 5-8).

The northern end of Bribie Island consists of a narrow spit which is at present subject to ocean-induced shoreline erosion on the eastern shore, and channel erosion on the western shore. Historical changes are evident from aerial photographs.

The movement of Bribie Island's shoreline has been monitored by hydrographic surveys since 1970. Analysis of these surveys has shown an average annual recession of the ocean beach of about 2 metres. However, some annual erosion/accretion rates have been as high as 50 metres.

The northern spit of Bribie Island is also vulnerable to erosion by tidal channel changes in Pumicestone Passage. A 1987 study showed that erosion of the passage beach at the narrowest point of the island's spit was almost 2 m/year, although the average rate was almost zero. The island was then only 44 metres wide at this point and had an average annual erosion rate of 2.1 m/year. The erosion rate since has varied. Under present conditions, a breakthrough is expected within 20 years.

The Caloundra Bar entrance and the associated area of northern Pumicestone Passage are also dynamic. In the past, sediment has entered the passage to form intertidal banks near the entrance. These have reduced the tidal efficiency of the entrance and affected the tidal regime in Pumicestone Passage. However, the supply of offshore sediment has now declined and therefore major changes to the bar are not expected unless a breakthrough occurs, although channel relocations within the passage can be expected.

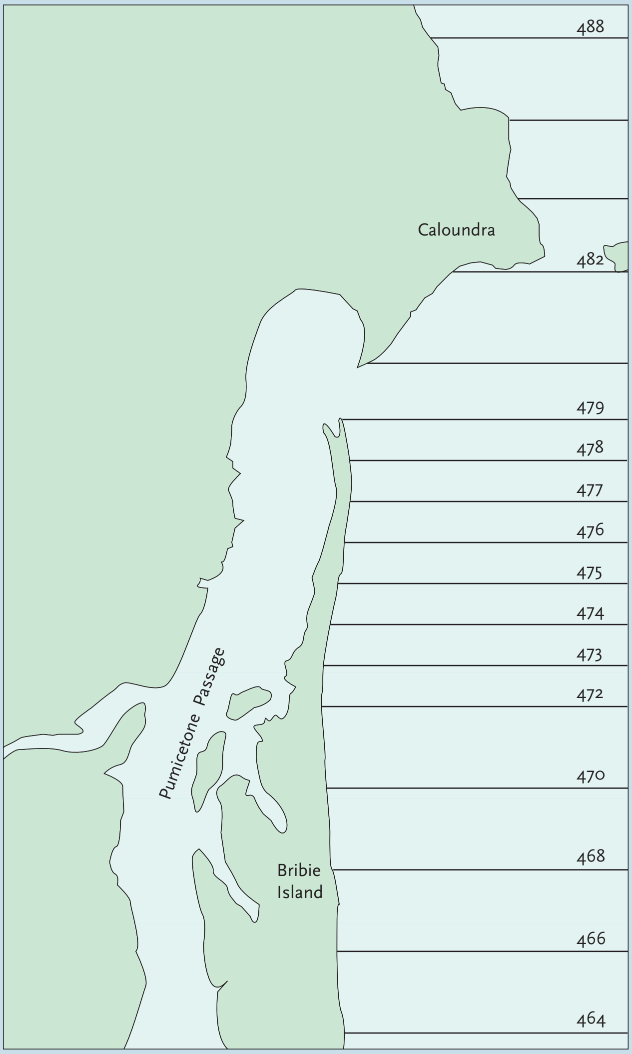
Photogrammetric data from 1940 to 1992 show trends in erosion at the northern end of Bribie Island. An analysis of island cross-sections, corresponding to survey lines 472 and 478 (figure 5-9), shows the following:

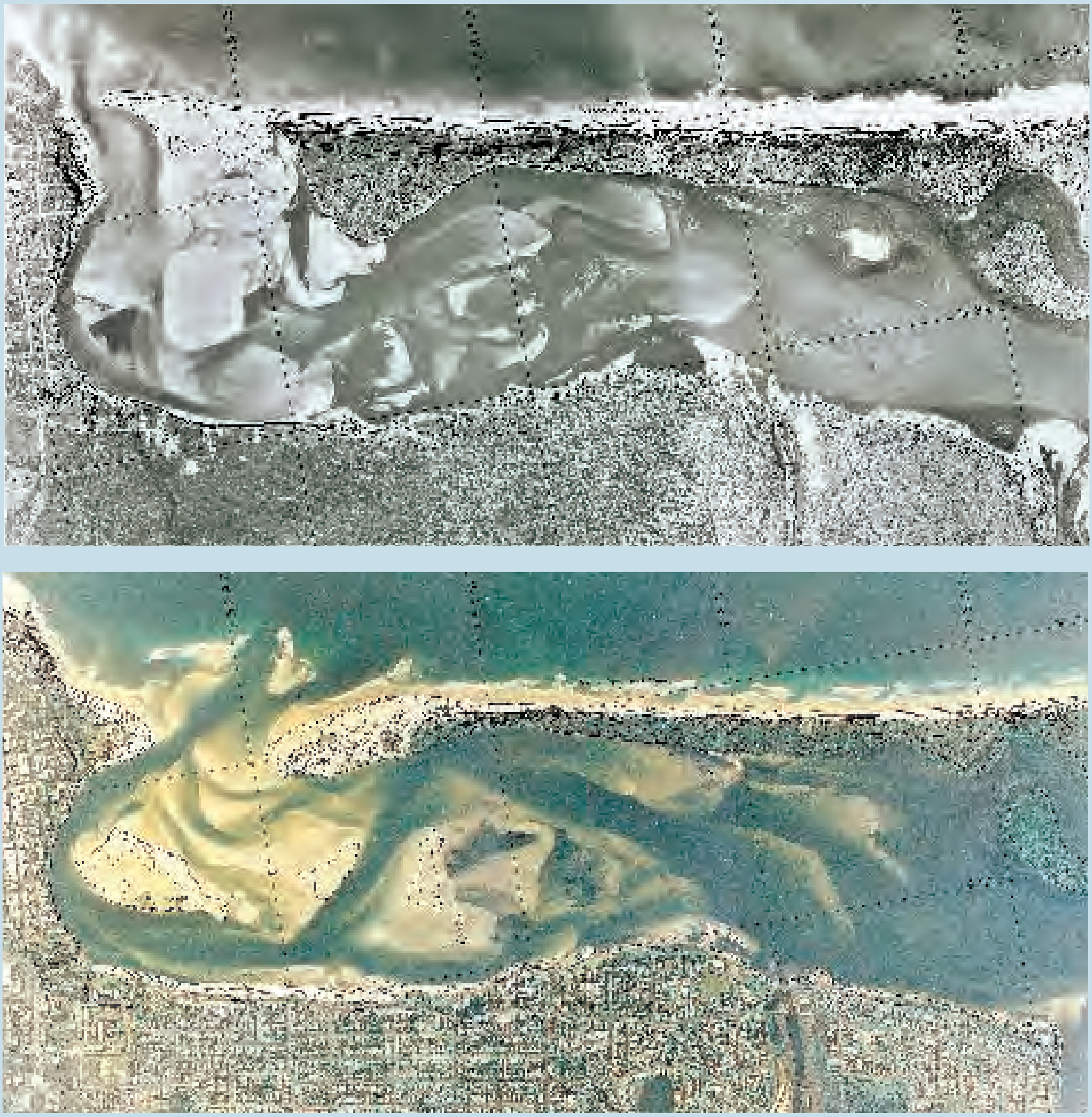
- Rates of erosion on the western edge of the island are low when compared with those of the wave-exposed ocean beach. The erosion rate on the western edge increases with distance northwards along the island.
- A general trend of ocean beach recession and dune height reduction over time exists for all profiles. At 0.0 m Australian height datum (AHD) the beach recession rate for the fastest eroding section (survey line 477) had an average rate of 1.1 m/year over the 52-year photogrammetry period, with a recent trend of 3.7 m/year between 1979 and 1992.

The recession rate is assumed to vary with time as a result of changing volumes of sand. However, a better measure of erosion is the volumetric erosion rate. This is shown in figure 5-10 for survey line 477, located near the narrowest section of Bribie Island. The figure shows the progressive volumetric erosion rate between 1940 and 1992. Since 1961 there has been a general trend of erosion.

The only other time when essentially no erosion occurred was during a period of beach recovery after a cyclonic period in 1971–72. However, the records still show a minor rate of erosion, suggesting a lack of available nearshore sediment to rebuild the beach. The cyclonic period of 1971–72 corresponds with the maximum annual volumetric erosion rate of 118 m^3 of sand for each metre of beach.

Figure 5-8 Location of Bribie Island





Changes to the shoreline of northern Bribie Island and the Pumicestone Passage entrance, 1940–92

Over the period of record, the average annual erosion rate at survey line 477 was 6.5 m^3 for each metre of beach. The more recent trend from 1961 to 1992 was 15.2 m^3 for each metre of beach. A continuation of this rate will result in breakthrough in approximately 15 years.

In general, it can be assumed that erosion will continue on the northern spit of Bribie Island in the near future, and the probability of an eventual breakthrough is very high. However, a single major event such as a large cyclone or heavy flooding could cause an immediate and dramatic change to the hydrodynamics of the entrance and of Pumicestone Passage generally. A breakthrough of Bribie Island would also have major implications for property and improvements located on the mainland in the vicinity of the breakthrough. In the absence of development, this would not normally be a problem.

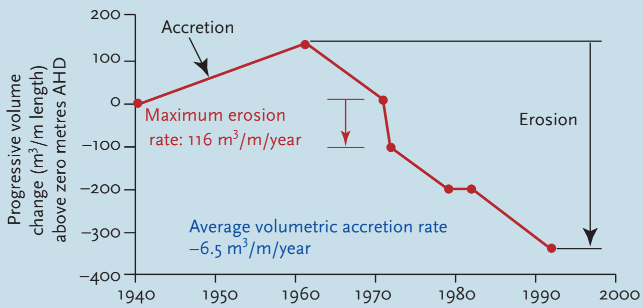


Figure 5-10 Progressive sand volumetric changes on north Bribie Island, 1940–92. These data show a general trend of erosion (negative volume change) since 1961, with accretion (positive volume change) occurring only before that time.

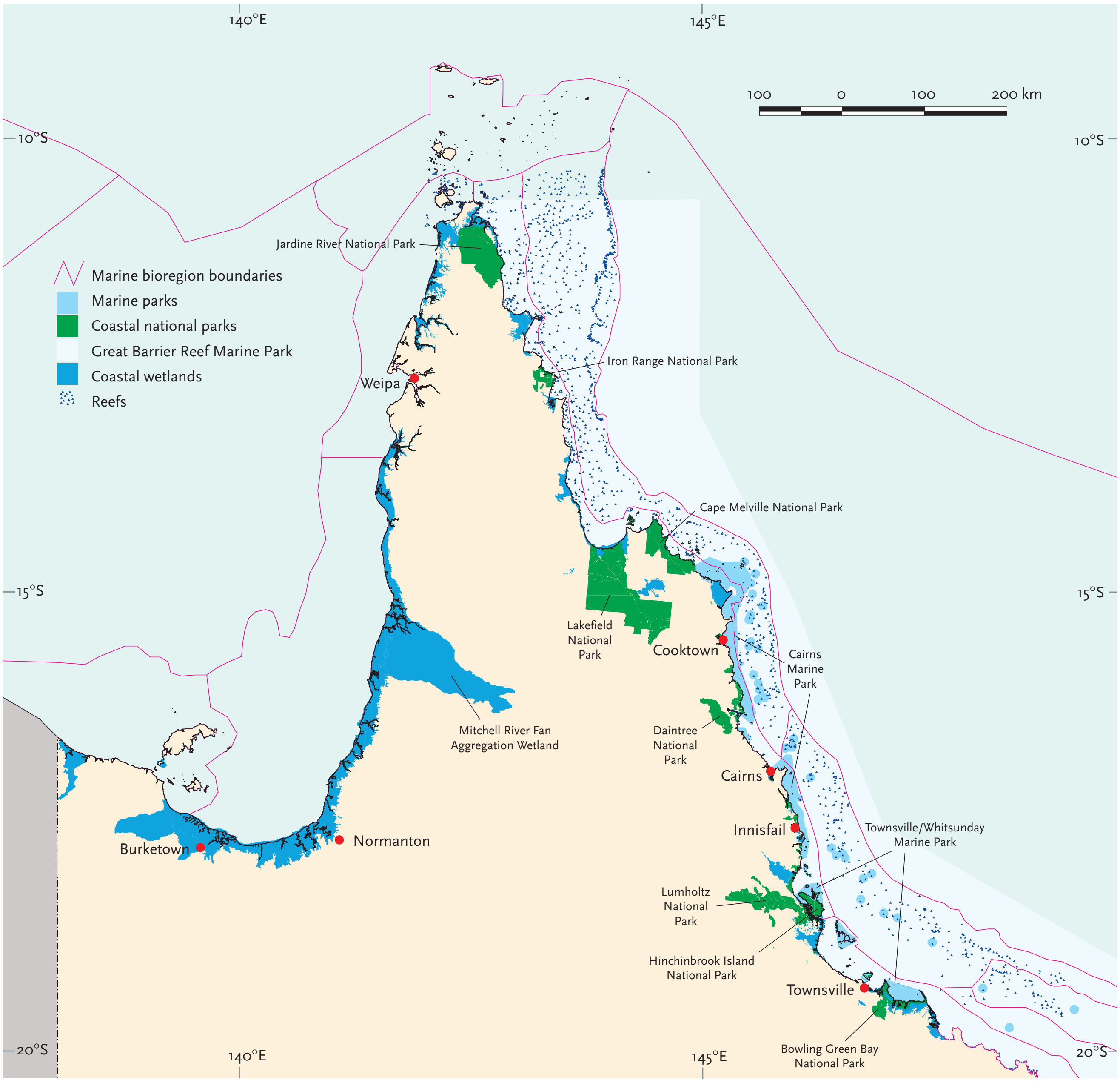


Figure 5-11 Extent of coastal and marine wetlands and protected areas — north Queensland

wetlands represented. In the coastal zone they range from small perched freshwater dune lakes, such as those on Fraser and Moreton Islands, to extensive systems of mangroves, saltflats, fresh and brackish sedgelands and saline lagoons such as Bowling Green Bay, north Queensland. The range of types and their distribution are reflected in the richness and diversity of wetland plants and animals. The extensive and highly productive seagrass beds and mangrove wetlands of Torres Strait and north Queensland are of critical importance as fisheries habitats. Some wetlands are of national and international significance as waterbird habitats. Bowling Green Bay, Shoalwater/Corio Bays, Great Sandy Strait and Moreton Bay are coastal zone sites listed under the Ramsar Convention. Other wetlands support rare or endangered species, or are themselves rare examples of particular wetland types.

Wetlands are vital for many ecological and physical processes and are therefore an important resource of the coastal zone. However, only relatively recently have the significance and values of wetlands been more widely recognised and understood. During the course of Queensland's development many

Criteria for wetlands of national importance

A wetland may be considered nationally important if it meets at least one of the following criteria:

- It is a good example of a wetland type occurring within a biogeographic region in Australia.
- It is a wetland which plays an important ecological or hydrologic role in the natural functioning of a major wetland system/complex.
- It is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions, such as drought, prevail.
- The wetland supports 1 percent or more of the national populations of any native plant or animal taxa.
- The wetland supports native plant or animal taxa or communities which are considered endangered or vulnerable at the national level.
- The wetland is of outstanding historical or cultural significance.

(Source: ANCA 1996)

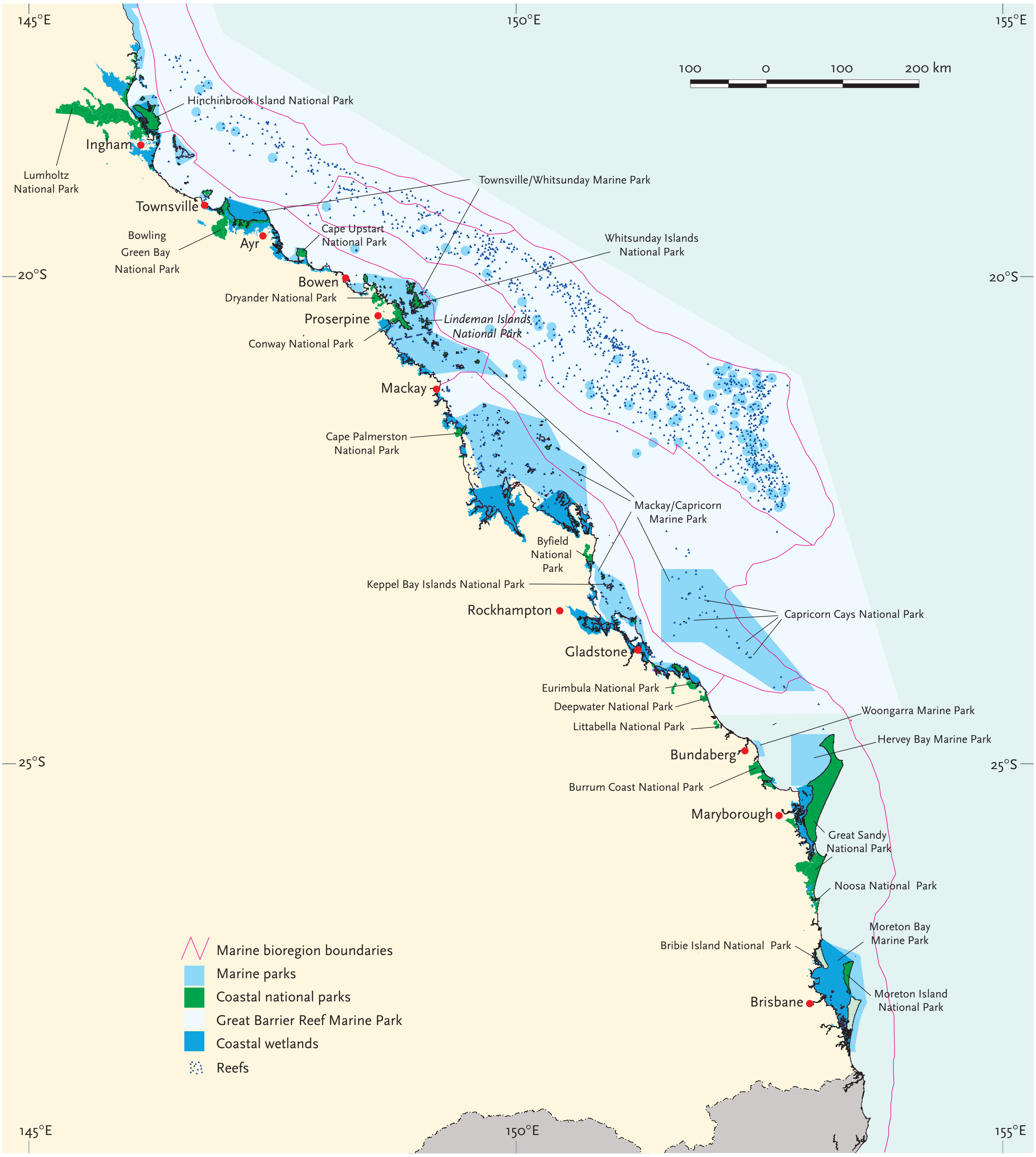
coastal wetlands have been affected to some degree by human activity including grazing, agriculture, urban development, aquaculture and ponded pasture.

Information here is based on several recent major studies (ANCA 1996; Blackman et al. 1996). However, data are still incomplete and therefore the characteristics and condition of all of Queensland's important coastal wetlands cannot yet be determined accurately.

Criteria for determining 'important' wetlands have been developed by the Australian Nature Conservation Agency (ANCA 1996) (see box 'Criteria for wetlands of national importance'). Some 165 important wetlands have been identified in Queensland; 83 of these are in the coastal zone (figures 5-11 and 5-12).

The presence of a wetland does not necessarily mean that the ecological integrity of the system remains intact. Presence or absence is merely an indication of the availability of the wetland resource.

Queensland's 83 important coastal wetlands cover 4 923 855 ha. The Great Barrier Reef Marine Park (34 076 800 ha) is additional. However, some of these systems contain significant areas of open water and therefore the total area of important wetlands does not necessarily reflect the area of wetland plant communities.



The Great Barrier Reef region encompasses most of the marine environment along Queensland's east coast seaward of low water. It includes (often overlapping) defined areas of the Great Barrier Reef World Heritage area, the Great Barrier Reef Marine Park, several Queensland marine parks, and undefined areas north of Cape York. Many factors affecting the region's ecological processes originate from outside these areas. Discussion on the state of the Great Barrier Reef region must, therefore, include consideration of such external factors.

Pressure

The Great Barrier Reef region is subject to a diverse range of human pressures. Probably the most significant pressure on the region is land-sourced pollution. The mainland is a source of potentially damaging inorganic sediments, organic matter, inorganic nutrients and toxicants. Over the past 100 years vast areas of land which drain to the region have been cleared, primarily for grazing and cropping. An estimated 32 million hectares of land is now under grazing and 1.2 million hectares under cropping, and clearing of coastal lowlands continues. The result has been an estimated two- to five-fold increase in the amount of sediment eroded from catchments and transported to coastal waters. A similar increase in the amounts of nutrients (principally nitrogen and phosphorus) flowing to nearshore waters might also have occurred. With continued development of the coastal zone, quantities of land-sourced pollutants entering coastal waters will increase.

Some pressures, such as fishing and construction activities, affect resources directly and are easily identifiable as potential causes of impact. The impact of others may be far less obvious but still significant. The interaction of human activity and natural events and influences must be considered. Studies have found that the ability of natural ecosystems to recover from devastating natural events such as cyclones can be impeded by human influences. Consequently, the impact of humans can extend beyond the immediate and obvious.

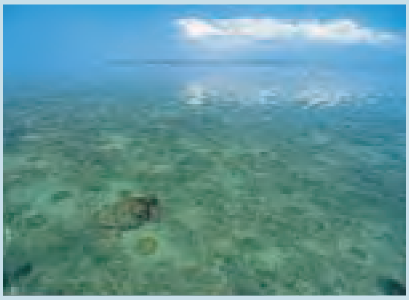
The intensity of commercial and recreational fishing pressure and increased access to previously remote areas constitute a significant pressure on Reef fisheries. While data are not conclusive, it appears that all commercially exploited species are fully exploited or over-exploited. In some areas, particularly those close to population centres, fishing pressure has reduced stocks. Fishing pressure, particularly from recreational fishers, continues to increase.

Growing numbers of tourists, and developments such as island resorts, marinas and floating pontoons supporting the tourism industry, are a major pressure on Reef resources. Large-scale development contributes to the loss of habitat and the incremental loss of wilderness and aesthetic values. The rate of growth of Reef tourism suggests that pressures caused by the industry will continue to increase, potentially eroding some of the Reef's environmental and World Heritage values.

Figure 5-13 The Great Barrier Reef — the largest system of coral reefs in the world — is internationally recognised for its outstanding biodiversity values. Most of the reef is within the Great Barrier Reef Marine Park, which has been divided into four administrative sections.

Coral cay

Angel fish



State

Populations of some of the region's rare and endangered species such as loggerhead turtles have declined rapidly over the past 15 or so years.

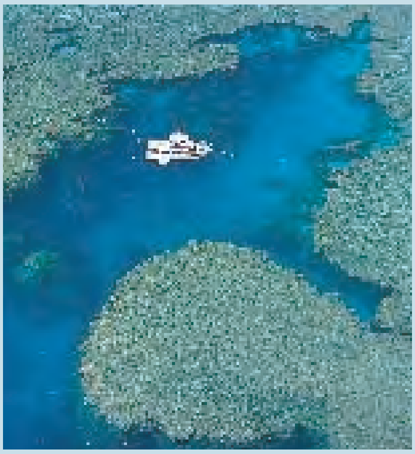
Some 215 species of introduced plants are now found on the continental islands of the Great Barrier Reef, and this number is rising. Their distribution is also widening, partly as a result of increased human visitation to once remote islands. Such species present a threat to the integrity of indigenous plant communities.

An estimated 3000 km² of shallow-water coastal seagrass habitat and at least 2000 km² of deepwater habitat have been mapped in the Great Barrier Reef region. Areas of shallow-water seagrass are being destroyed due to sedimentation associated with river runoff and by marina and port developments. Coastal development presents a continuing threat to inshore seagrass habitat.

The status of fish and prawn stocks is difficult to determine with accuracy due to year-to-year population fluctuations. The abundance of the eastern king prawn seems to have declined appreciably since the 1970s. There is localised depletion of coral trout and red-throat emperor in areas close to population centres and on reefs open to fishing. Spanish mackerel numbers have shown a marked and continuous decline since 1989, with recent studies indicating very low levels of spawning. The stock of the saucer scallop is also now so low as to suggest a threat to future spawning and recruitment.

The initial stages of what is believed to be another major crown-of-thorns starfish (COTS) outbreak episode have been detected on reefs in the Cairns section. Past outbreaks have been responsible for the greatest documented ecological impact on the Great Barrier Reef. Another major outbreak could have severe consequences for coral reefs. Following a decade of research, scientific understanding of the biology and ecology of COTS has advanced, but the cause of outbreaks is still unknown. Human activities have been implicated, but no conclusive evidence linking the two has been presented. Conversely, there is no conclusive evidence excluding human influence and proving that outbreaks are an entirely natural phenomenon.

Undoubtedly, quantities of nutrients entering inshore waters through river discharge have increased since



Increasing numbers of visitors to the Great Barrier Reef are placing pressures on coral reef ecosystems in some areas.

colonisation. This increase has the potential to significantly increase the growth of phytoplankton in the Great Barrier Reef lagoon. However, the biomass of phytoplankton present in the water column is highly variable, and any trend in relation to biomass is difficult to determine. Some scientists have suggested that the frequency and magnitude of phytoplankton blooms have increased as a result of nutrient enrichment. Others point to data which indicate no trend in average phytoplankton biomass, and discount bloom conditions as being potentially related to human activity (Brodie et al. 1996). High biomass frequently develops in the more sheltered inshore waters during summer months, but whether these incidents are more frequent or extensive than those in the past remains unclear.

Response

The Great Barrier Reef Marine Park was established in 1975. On 26 October 1981, in recognition of its outstanding natural, cultural and historical features and its integrity as a self-perpetuating ecological system, the Great Barrier Reef was inscribed on the World Heritage List. About 93 percent of the World Heritage Area lies in the Great Barrier Reef Marine Park.

By joint arrangement between the Commonwealth and Queensland Governments, park management is overseen by the Great Barrier Reef Marine Park Authority (GBRMPA).

Marine park management is based on zones in which different activities are allowed. About 79 percent of the marine park is zoned 'general use A', which allows virtually all activities including trawling and commercial collecting. Complete protection is given to 0.14 percent of the area in preservation zones. Some activities are also subject to approval through a permit system. Applications are assessed for their potential environmental effects.

In addition to dealing with the immediate needs of everyday management through these systems, GBRMPA places considerable emphasis on scientific research as a strategic management tool. There is a strong belief that credible management must be grounded in good information.

GBRMPA supports and funds, to varying degrees, a number of major research programs. Over the last decade, a multidisciplinary scientific research program has been investigating the crown-of-thorns starfish. A major water quality monitoring program is attempting to quantify nutrient inputs and assess their impact. Major studies are also under way on the effects of line fishing and trawling. Long-term management goals of the region are presented in the *25 Year Strategic Plan for the Great Barrier Reef World Heritage Area, 1994–2019*. This recognises the growing pressure on the region's natural resources.

In 1995, the Great Barrier Reef Marine Park Act was amended to require GBRMPA, in preparing management plans, to have regard to the protection of the World Heritage values of the marine park.

Table 5-23 Areas of wetland habitat types in three coastal catchments in north Queensland in 1951/1952 and 1992, determined from aerial photographs. The total decline for these areas averaged 47 percent. The exception is mangrove wetlands, which expanded due to saltwater inundation.

Mulgrave–Russell Rivers catchment			
Wetland type	**1952 area (ha)**	**1992 area (ha)**	**Change (ha)**
Mangrove	775	787	+12
Melaleuca	3 860	1 808	–2 052
Palm forest	1 766	738	–1 028
Rainforest	1 759	308	–1 451
Sedge swamp	1 077	562	–515
Mixed melaleuca	666	319	–347
Total	**9 903**	**4 522**	**–5 381 (–54%)**
Moresby River catchment			
Wetland type	**1951 area (ha)**	**1992 area (ha)**	**Change (ha)**
Mangrove	2 233	2 873	+640
Freshwater	3 363	1 175	–2 188
Total	**5 596**	**4 048**	**–1 548 (–28%)**
Johnstone River catchment			
Wetland type	**1951 area (ha)**	**1992 area (ha)**	**Change (ha)**
Mangrove	176	202	+26
Melaleuca	1 277	282	–995
Mixed melaleuca	462	258	–204
Palm forest	439	160	–279
Swamp	499	225	–274
Total	**2 853**	**1 127**	**–1 726 (–60%)**
Grand total	**18 352**	**9 697**	**–8 655 (–47%)**

(Sources: Russell and Hales 1993; Russell et al. 1996a, 1996b)

On a statewide basis, the area of the major wetland community types is not known with any certainty. Minimum estimates of saline wetland habitats are 189 500 ha (mangroves), 447 100 ha (saltpan), and 2 077 000 ha (seagrass), excluding 100 000 ha of seagrass recently destroyed in Hervey Bay and currently being recolonised. The seagrass area includes a large area in Torres Strait, some of which is outside Queensland waters. Not all mangrove and saltpan areas have been mapped accurately and additional areas of deepwater (>15 m) seagrass might yet be found. The area of freshwater wetlands is unknown.

In the past, some wetlands have been cleared extensively. Losses cannot be defined accurately on a statewide basis. However, detailed studies of past and present wetland distribution have been undertaken in several locations and provide an indication of the trend in wetland area (table 5-23).

Drainage of wetlands is also a source of environmental problems. Vital habitat is lost and acidic drainage waters can be produced, with severe effects on the ecosystems of receiving waters (see box ‘Acid sulfate soils’).

Mangroves

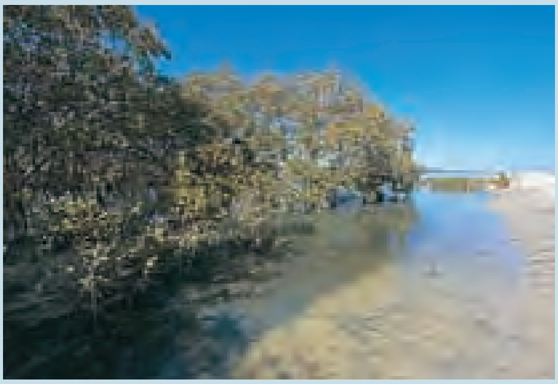
Indicator

Area of mangrove forests

Mangrove forests are diverse and highly productive communities of salt-adapted plants growing in the intertidal zone of relatively sheltered estuaries, bays and coastal foreshores of the tropics and subtropics. Such habitats are known to be critical to more than 75 percent of fish and crustacean species of value to commercial and recreational fishers. Cape York Peninsula has one of the highest mangrove species

Changes in mangrove forest cover

Although the change over time in the area of mangrove forest is not known on a statewide basis, attempts have been made to identify changes in specific areas. Results are useful in considering how mangrove cover has been affected by coastal development over the last five or six decades. Most studies have used historical and recent aerial photographs to determine coverage, with recent estimates verified by ground truthing.



Mangroves are highly diverse and productive ecosystems

Curtis Coast

Between 1941 and 1989 about 646 ha of mangrove wetland on the Curtis Coast were lost, almost exclusively in Port Curtis. The forested area declined to 24 908 ha. The principal cause has been clearing and reclamation for industrial and urban development (QDEH 1994).

Hinchinbrook Channel islands

Mangrove communities on the islands in Hinchinbrook Channel, north Queensland, have been relatively undisturbed by development. Between 1943 and 1991 the area of mangrove vegetation increased marginally from 3789 ha to 3836 ha (Ebert 1995).

Trinity Inlet, Trinity Bay

An estimated 600 ha of mangroves in Trinity Inlet was cleared in the 60–70 years to 1978, and an estimated 200 ha was created, giving a net loss of around 400 ha. The area of mangrove vegetation in Trinity Inlet and Bay was 4016 ha in 1918 and 3616 ha in 1978 (Olsen 1983). The loss was largely attributable to industrial development.

Moreton Bay

The coastal strip between Caloundra and Southport in south-east Queensland has been subject to the most intense urbanisation and development in Queensland. For the past three decades in particular, coastal wetlands have been under considerable pressure.

An estimated 1240 ha of mangrove habitat in Moreton Bay was destroyed between 1974 and 1989. Including low-density areas, the area declined from 17 512 ha to 16 272 ha (Quinn 1992). Losses also occurred before 1974, although accurate estimates are not available. Recent studies by Catterall et al. (1996) indicate that clearing is continuing, with an estimated 210 ha of mangroves and saltmarsh lost between 1987 and 1994.

Table 5-24 Estimated area of mangrove vegetation in Queensland coastal regions (regions based on Galloway 1982)

Coastal regions	Area of mangroves (km^2)		
	Galloway (1982)	Dowling and McDonald (1982)	Danaher (1995a, 1995b), Danaher and Stevens (1995)
1 Gulf of Carpentaria to Aurukun	1481	440	>304
2 Aurukun to Cape York	609	305	473
3 Islands of the Torres Strait	158	–	included in 2
4 Cape York to Evanson Point	354	395	240
5 Evanson Point to Bathurst Head (Princess Charlotte Bay)	93	10	99
6 Bathurst Head to Cardwell	243	230	>94
7 Cardwell to Lucinda (Hinchinbrook Island and Channel)	216	120	–
8 Lucinda to Clairview Bluff	645	365	>245
9 Clairview Bluff to Bustard Head	498	935	–
10 Bustard Head to Tweed Heads	285	335	–
11 Islands off the east coast	20	–	–
Total (approximate)	**4603**	**3135**	**>1455**

diversities in the world, having 36 of Queensland's 37 species. Nine species are found in south-east Queensland.

Until recently, the extent and diversity of Queensland's mangrove wetlands were very poorly known. However, through the work of the Department of Primary Industries (Danaher 1995a, 1995b) and the use of modern remote sensing techniques, mapping of these wetlands has advanced significantly. Estimates of the areas of mangrove wetlands are given in table 5-24. As can be seen from the table, differences in the mapping techniques used in the past have resulted in different estimates. To compare areas of mangroves now with those in the future, four locations have been selected for reporting here and in future reports (see box 'Changes in mangrove forest cover').

In the absence of reliable historical data, a clear trend in the total area of mangroves cannot be determined. It is apparent that in some areas significant losses of mangrove wetlands have occurred. Conversely, increases have been observed in other areas. The extensive wetlands of Cape York Peninsula remain virtually untouched by development. The environmental values associated with mangrove wetlands have declined in some areas on a local scale, although environmental values seem not to be threatened regionally and statewide.

Seagrass

Indicator

Area of seagrass beds

Seagrass beds are an important ecological and economic resource of the coastal zone. They represent a highly productive habitat and nursery ground of value to many marine species, including many commercially important fish and prawn species. They are also of critical importance to dugong, and play a role in stabilising bottom sediments.

On the east coast, seagrasses are found largely in relatively shallow waters (<30 m) near estuaries, in bays and inlets and in the lee of islands, reefs and shoals at protected sites. A total of 15 species of seagrass have been identified from the north-east coast of Queensland and 11 from the Gulf of Carpentaria. Seven species are found in Moreton Bay.

Over the past decade extensive studies have been undertaken by DPI to map the distribution and density of shallow-water seagrass communities. Seagrasses in deeper water (>15 m) are less well studied, and only recently have been found in large areas in the northern Great Barrier Reef region, Torres Strait and Hervey Bay (Lee Long et al. 1993). Aspects of seagrass biology and ecology, including the causes of seasonal and long-term changes in distribution and productivity, are also less well studied.

The most appropriate general indicator of the state of seagrass resources is the area of seagrass and the percentage cover present. From surveys of Cape York to Cairns (1984), Cairns to Bowen (1987), Bowen to Water Park Point (1987) and Water Park Point to Hervey Bay (1988), seagrass was estimated to cover a total area of 381 986 ha. Subsequently, about 100 000 ha of seagrass in Hervey Bay were lost after two major flood events and a cyclone, but recolonising is now occurring.

There are about 18 000 ha of seagrass in the Gulf of Carpentaria. Torres Strait, with 1 750 000 ha of habitat mapped, supports one of the largest seagrass areas in Australian waters though significant dieback was evident in north-east Torres Strait in the early 1990s.

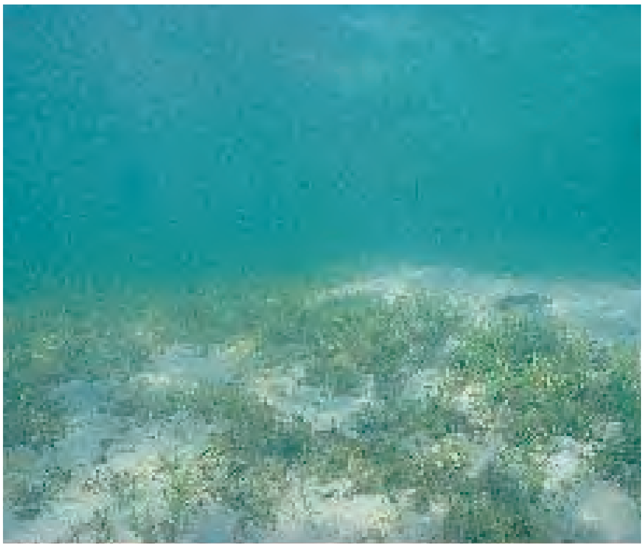


Table 5-25 Known changes in the area of melaleuca wetlands in south-east Queensland and several north Queensland coastal catchments

	Area of melaleuca wetland (ha)		Change (ha)
	1951–52	**1992**	
Russell–Mulgrave River catchment[a]	3 860	1 808	–2052
Moresby River catchment[a]	3 363	1 175	–2188
Johnstone River catchment[a]	1 277	282	–955
	1942	**1992**	
Tully–Murray catchment[b]	6 750	3 960	–2790
	1974	**1989**	
South-east Queensland[c]	16 500	8 250	–8250
	1820	**1982**	
Brisbane area[d]	13 000	<390	-12 610

[a] *(Source: Russell et al. 1996a, 1996b; Russell and Hales 1993)*
[b] *(Source: Skull 1996)*
[c] *(Source: Catterall and Kingston 1993)*
[d] *(Source: Catterall and Kingston 1993)*

The area of seagrass in south-east Queensland, including Moreton Bay, in 1987 was estimated at 14 368 ha dense to light, with 12 505 ha sparse to patchy. The marked decline in seagrass cover in the southern Broadwater from 72 ha in 1982 to 22 ha in 1992 is attributed to the building of the Gold Coast Seaway.

The areas described reflect the survey and mapping effort to date; additional seagrass resources might be discovered. Accordingly, the influence of human activity on the distribution or health of seagrasses cannot yet be estimated.

Other wetland systems

Melaleuca wetlands

Indicator
Area of melaleuca wetlands

In the past, coastal melaleuca wetlands have been cleared extensively, largely for agricultural development. More recently, losses resulting from urban sprawl and tourist development have been severe in the south-east, where about half of the melaleuca wetlands present in 1974 were cleared by 1989.

The area of melaleuca wetland remaining in Queensland is not known. Data for several localities show that the trend is one of significant losses and rapid decline, suggesting that the environmental values of melaleuca wetlands have been, and continue to be, adversely affected by human activity (table 5-25).

Saltpan

Indicator
Area of saltpan

Table 5-26 lists Queensland's known areas of saltpan habitat. Large expanses of saltpan occur in the Gulf of Carpentaria and on Cape York Peninsula. These areas are known to be of international significance as wetland habitat for migratory wader species. Changes to the area of saltpan habitat are not well documented, although reclamation and other activities are known to have reduced the area in some regions. For example, some 990 ha were lost from Port Curtis between 1941 and 1989 due to industrial development (QDEH 1994).

Table 5-26 Known areas of saltpan on the Queensland coast. The large expanses of saltpan in the Gulf of Carpentaria are recognised internationally for their significance as migratory wader habitat.

Coastal regions	Area (ha)
Gulf of Carpentaria to Aurukun	>262 600
Aurukun to Cape York and Torres Strait islands	58 000
Cape York to Evanson Point	26 100
Evanson Point to Bathurst Head (Princess Charlotte Bay)	42 000
Bathurst Head to Cardwell	>14 900
Cardwell to Lucinda (Hinchinbrook Island and Channel)	n.a.
Lucinda to Clairview Bluff	>26 600
Clairview Bluff to Port Alma	n.a.
Port Alma to Bustard Head	>16 900
Bustard Head to Tweed Heads	n.a.
Islands off the east coast	n.a.

(Sources: Danaher 1995a, 1995b; Danaher and Stevens 1995; QDEH 1994)

MID-WATER COLUMN SYSTEMS

The most significant feature of the water column is its abundance of plant and animal life. While the water column is not isolated from the seabed or coastal wetlands, for this report the water column is considered a discrete habitat with defined resources. Its major resources include fish stocks which support commercial and recreational fishing.

Fisheries resources

Indicators

Catch by unit effort (catch rate)

Stock status

The condition of Queensland's fisheries resources is of critical importance from both environmental and economic perspectives. From the environmental perspective, fish are an integral part of marine ecosystems and are therefore essential to the continued functioning of ecosystem processes. Changes in species diversity or relative abundance of a particular species harvested unsustainably can have profound ecological implications. From the economic perspective, continued productivity is clearly important, particularly at the local or regional level where a community relies heavily on income from fishing.

Maintaining fisheries stocks at levels which can sustain both harvesting and ecosystem processes is desirable. Excessive exploitation of a fishery can deplete the breeding stock rapidly, reducing production to the point of collapse in some cases. Signs of over-exploitation include declining catches and declines in catch rates.

Assessing the status of a fishery is often extremely complex. Natural factors such as climatic events and regional weather patterns influence fisheries recruitment. The time lag between a rainfall event and its impact on the spawning stock can complicate an assessment. Year-to-year variations in catch might be as much the result of natural factors as of fishing pressure. Consequently, caution must be exercised when interpreting catch trends. Since the introduction of catch logbooks in 1988, temporal trends in catches have been monitored. These data and other research data provide the basis for evaluating the status of Queensland's fisheries resources.

Table 5-27 gives a summary of the current status and catch trends of Queensland's major fishery resources.

Table 5-27 Summary of the stock status and catch trend of Queensland's major commercial fisheries

Species	Catch trend	Resource status
East coast trawl		
Banana prawns	Erratic	Unknown
Endeavour prawns	Variable	Probably stable
King prawns	Variable	Declining
Tiger prawns	Variable	Probably stable
Bugs	Increasing	Probably stable
Saucer scallops	Erratic	Declining
Stout whiting	Increasing	Probably stable
Squid	Erratic	Unknown
Subtropical inshore and estuarine		
Yellowfin bream	Declining	Stable
Swallowtail dart	Variable	Unknown
Dusky flathead	Declining	Probably stable
Sea mullet	Erratic	Probably stable
Tailor	Declining	Probably stable
Inshore whiting	Declining	Unknown
Tropical inshore and estuarine		
Barramundi	Declining	Probably declining
Blue salmon	Increasing	Stable
King salmon	Declining	Unknown
Reef line		
Coral trout	Declining	Probably declining
Red-throat emperor	Declining	Unknown
Crab		
Mud crab	Declining	Probably declining
Blue swimmer	Stable	Stable
Spanner crab	Increasing	Stable
Other finfish		
Snapper	Declining	Stable
Spanish mackerel	Declining	Declining
Sharks	Increasing	Unknown

(Sources: QFMA 1996b; DPI)

Freshwater inflows

Indicators

Annual discharge of major east coast rivers

Runoff-to-rainfall ratio of major east coast rivers

Queensland's east coast is drained by 46 major catchments covering about 448 000 km^2. The mean annual discharge from these catchments is 83.9 million megalitres (Wasson 1997).

Terrestrial freshwater runoff is important in the coastal zone's physical and ecological processes. Flood events, in particular, carry vast quantities of sediments, nutrients and organic matter. These inputs contribute to forming and shaping river deltas and also help maintain and stimulate marine productivity. Changes in the size or frequency of such inputs can change coastal productivity and sedimentation patterns.

River runoff is influenced by seasonal, yearly and decadal events including the El Niño Southern Oscillation (figure 5-14). Runoff might also be influenced by global warming, which could be changing rainfall patterns, and by human activity such as land clearing. Changes to vegetation cover and soil drainage characteristics through compaction can alter catchment hydrology, increasing the proportion of rainfall lost as runoff.

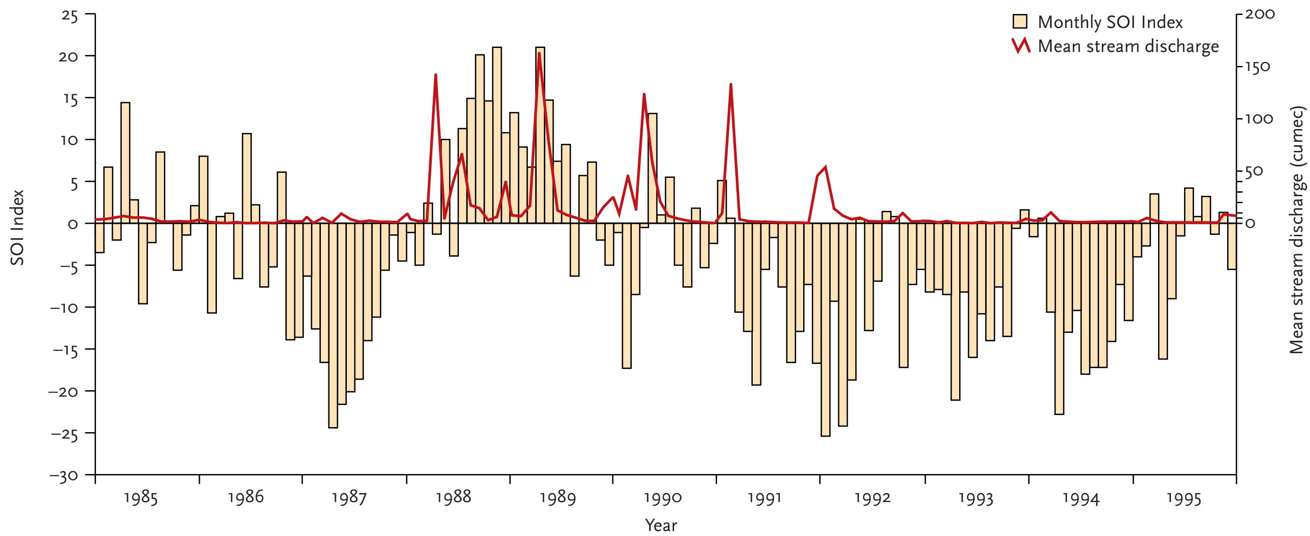


Figure 5-14 Monthly discharge (m^3/s) of the Logan River at Yarrahappini, south-east Queensland, 1970–96. The high variability in discharge and the influence of the El Niño drought between 1991 and 1995 are evident.

Table 5-28 Summary rainfall and flow statistics for some major Queensland east coast rivers and catchments

Basin*	Basin area (km²)	Mean annual runoff ('000 ML)	Mean annual rainfall (mm)	Runoff/ rainfall (%)
108 Daintree	2 125	3 560	2 576	65
109 Mossman	490	687	2 459	57
110 Barron	2 175	1 153	1 447	37
111 Mulgrave–Russell	2 020	4 193	3 233	64
112 Johnstone	2 330	4 698	3 405	59
113 Tully	1 685	3 683	2 970	74
114 Murray	1 140	1 628	2 485	57
116 Herbert	10 131	4 991	1 331	37
117 Black	1 075	509	1 510	31
118 Ross	1 815	372	1 071	19
119 Haughton	3 650	756	923	22
120 Burdekin	129 860	10 100	640	12
121 Don	3 885	689	1 022	17
122 Proserpine	2 485	1 431	1 562	37
124 O'Connell	2 435	1 668	1 705	40
125 Pioneer	1 490	994	1 418	47
126 Plane	2 670	1 370	1 499	34
127 Styx	3 055	825	1 157	23
128 Shoalwater	3 705	832	1 102	20
129 Waterpark	1 840	700	1 317	29
130 Fitzroy	142 645	7 127	702	7
132 Calliope	2 255	340	889	17
133 Boyne	2 540	401	1 031	15
134 Baffle	3 860	750	1 173	17
135 Kolan	2 980	464	1 162	13
136 Burnett	33 150	1 743	765	7
137 Burrum	3 340	718	1 104	20
138 Mary	9 595	2 309	1 158	21

*Basin numbers are after Australian Water Resources Council (see chapter 4).
(Source: Pulsford 1993)

Because Queensland's rainfall and runoff are highly variable, changes in runoff patterns due to factors other than natural variation are extremely hard to identify. Only with long flow records can changing flow patterns begin to be identified. Such records are not available for Queensland rivers, but an extensive flow-gauging system that will help identify trends over time is in place.

Summary rainfall and runoff data for some of Queensland's east coast river basins are given in table 5-28. The ratio of runoff to rainfall indicates the percentage of catchment rainfall which flows from the catchment as river discharge. The largest catchments, the Burdekin, Fitzroy and Burnett, produce the least runoff relative to rainfall (7–12 percent) while the smaller, tropical catchments which receive high rainfall produce the greatest runoff (57–74 percent). Percentages can change as a result of changes in catchment hydrology resulting from vegetation clearing or other forms of development. A more detailed discussion of rainfall patterns is presented in chapter 2, 'Atmosphere'. River flows are also discussed in chapter 4, 'Inland waters'.

Coastal and Estuarine Waters

Indicators

Concentration of nitrogen

Concentration of phosphorus

Coastal and estuarine waters are subject to inflows of a variety of contaminants associated with human activity which can affect water quality (see 'Pressure' section, under 'Contaminants'). Their influence is determined by factors such as quantities and types, available dilution, dispersion, degradation and toxicity. The interactions of these and other factors determine water quality.

There is considerable geographical variation in the degree of human influence on water quality in the coastal zone. A significant influence is apparent only in those estuaries and nearshore waters adjacent to major population centres. However, the extent of agricultural development in coastal catchments suggests that few estuaries or nearshore waters are free from some degree of human influence. Recent studies

Table 5-29 Median range guidelines for surface water quality indicators

Parameter	Region	Quality category Good	 Moderate	 Poor
Dissolved oxygen (percentage saturation)	Estuarine	81–109	60–80 and 110–120	<60 and >120
	Coastal	91–109	80–90 and 110–120	<80 and >120
Turbidity (NTU)	Estuarine	<30	30–80	>80
	Coastal	<10	10–30	>30
Oxidised nitrogen (µg/L N)	Estuarine	<40	40–300	>300
	Coastal	<25	25–80	>80
Total phosphorus (µg/L P)	Estuarine	<50	50–100	>100
	Coastal	<40	40–70	>70
Chlorophyll *a* (µg/L)	Estuarine	<7	7–15	>15
	Coastal	<3	3–6	>6

Quality category:
Good: indicative of quality in relatively undisturbed waters — i.e. waters not significantly affected by point discharges or catchment activity
Moderate: indicative of some minor level of disturbance, in most cases due to some aspect of catchment development
Poor: indicative of a significant disturbance either by major catchment development or by a point discharge

suggest that, of the human activities which affect the quantities of nutrients entering coastal waters, grazing activity is responsible for approximately 80 percent of inputs, sugarcane cultivation for 15 percent and sewage discharges for about 1 percent (Moss et al. 1993). Consequently, the water quality of all but the most remote waters can be expected to be subject to some degree of human influence.

The EPA carries out regular monitoring of water quality.

The Environmental Protection Agency monitors surface water quality at some 200 sites in coastal and estuarine waters throughout Queensland. Sampling is carried out monthly for a number of parameters. The sample sites shown in figures 5-15, 5-16 and 5-17 are concentrated in populated areas and/or near point sources of pollution. The pie charts summarise the data from sites in the mapped area where five or more water samples were collected. The median values from all sites were used to determine the proportion of sites rated as 'good', 'moderate' or 'poor' for each parameter, based on the ranges described in table 5-29. The total number of sites per parameter is indicated by the 'n' below each pie chart.

Coastal water quality

The terrestrial influence on coastal water quality is generally limited to a zone less than 15 km from the coast, although some substances can travel further (Brodie 1997). Only during major flood events, when river plumes extend further, is a water quality influence detectable some distance offshore.

While most scientists now acknowledge that nutrient and sediment inputs to coastal waters have increased substantially as a result of human activity, the significance of this increase is largely unknown. Water quality monitoring of the Great Barrier Reef region has increased over the last decade, but without historical data it is difficult to make comparisons or draw conclusions.

Water column nutrient concentrations are known to vary in response to river inputs and wave activity. Higher concentrations can occur with river plumes or resuspension of bottom sediments by wave action. Some variability in concentrations is therefore natural. How natural patterns have been affected by human activity is not known. Studies of the cross-shelf distribution of nutrients show higher concentrations in the shallow nearshore zone, where terrestrial inputs and resuspension are concentrated. Concentrations in open offshore waters are generally very low and relatively stable, with little evidence of change as a result of human activity.

Estuarine water quality

Water quality in estuaries is potentially affected by many activities in the catchment. These may be point-source pollution sources such as secondary treated sewage discharges or non-point sources such as agricultural activities.

Many estuaries in coastal Queensland are affected by point-source discharges as a result of coastal urban development. Impacts are generally greatest in estuaries associated with major population centres such as Cairns, Townsville, Proserpine, Rockhampton, Bundaberg and Brisbane. These impacts are characterised by moderate to high values for nutrients (nitrogen and phosphorus). As a response to these inputs, some estuaries show reduced concentrations of dissolved oxygen and to a lesser extent, increases in chlorophyll concentrations.

Non-point source inputs to estuaries result in increased turbidity associated with the transport of fine sediment from the catchment and increased nutrient concentrations, particularly under flood flow conditions.

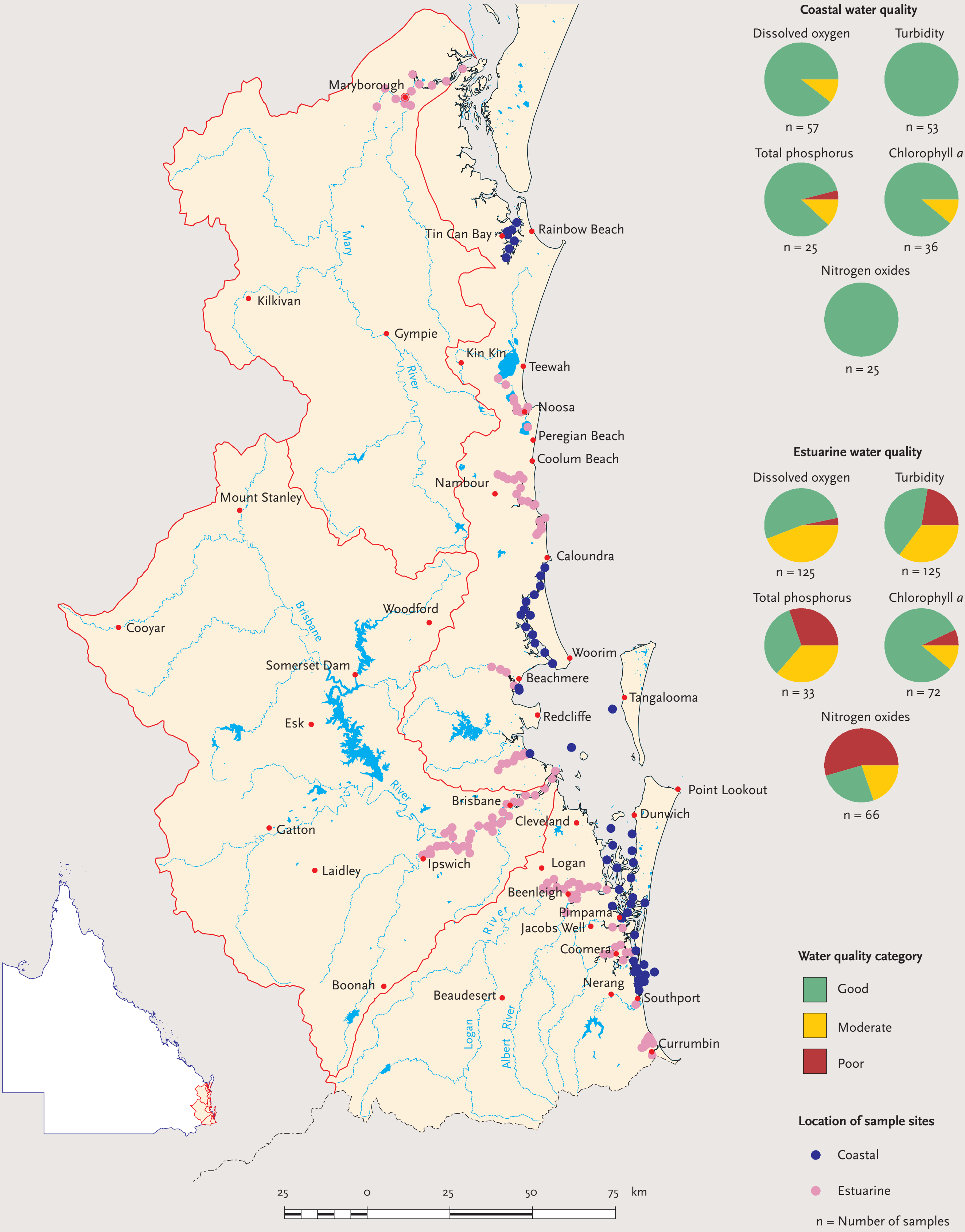


Figure 5-15 Water quality in the estuarine and coastal waters of the south coast. The region comprises a relatively small proportion of the State in area but contains over 80 percent of the total population. Due in part to population pressures, a large proportion of the land area of this region has been developed. Land use is diverse and includes major urban areas along the coast, some intensive agriculture, and grazing and forested areas in the ranges. Much of the coastal urban development is situated adjacent to estuarine waters and, as a result, many estuaries receive wastewater discharges. The majority of point-source discharges are due to secondary treated sewage. The impacts of treated sewage discharges are apparent in terms of moderate or high values of nitrate and total phosphorus in the estuaries of the Mary River, Maroochy River, Cabbage Tree Creek, Brisbane River and the Logan and Albert Rivers. Despite elevated nutrient levels, the chlorophyll data show that few estuaries exhibit algal blooms. High turbidity values occur in the Brisbane River estuary due to a number of factors, including the dredging of the river mouth for shipping and runoff from the surrounding greater Brisbane urban area and from upstream catchments.

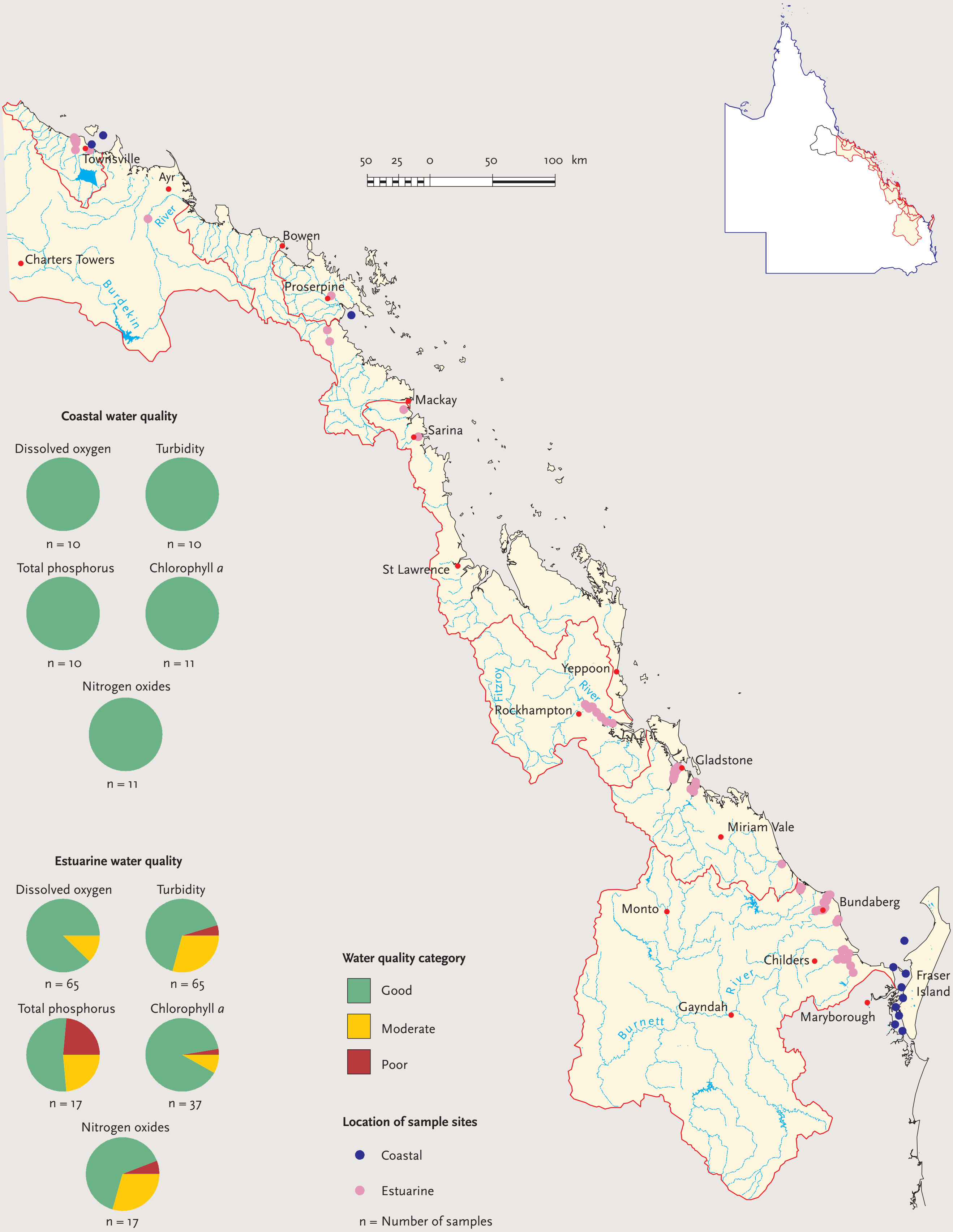


Figure 5-16 Water quality in the estuarine and coastal waters of the central coast. In general, rainfall is much lower than in the tropics, particularly in inland areas. Seasonality in rainfall is present but less pronounced and there is much greater annual variability. Streams in much of this region are slow-flowing with long periods of low or zero flows. The greater part of the area is used for grazing but intensive agriculture is important in several areas. Major irrigation areas include the Emerald, Callide, Dawson, Pioneer Valley and Eton, Proserpine and Bundaberg areas. There are a number of large open-cut coalmines which run in a broad north–south band through the mid-west. Water quality issues in the region include high salinity levels in streams between Theodore and Rockhampton and also in the Kingaroy district, acid drainage from mining developments, the potential impacts of a number of intensive irrigation areas, and the general issue of increased nutrient levels and the potential for algal blooms. Populations overall are low and tend to be concentrated at a few coastal centres.

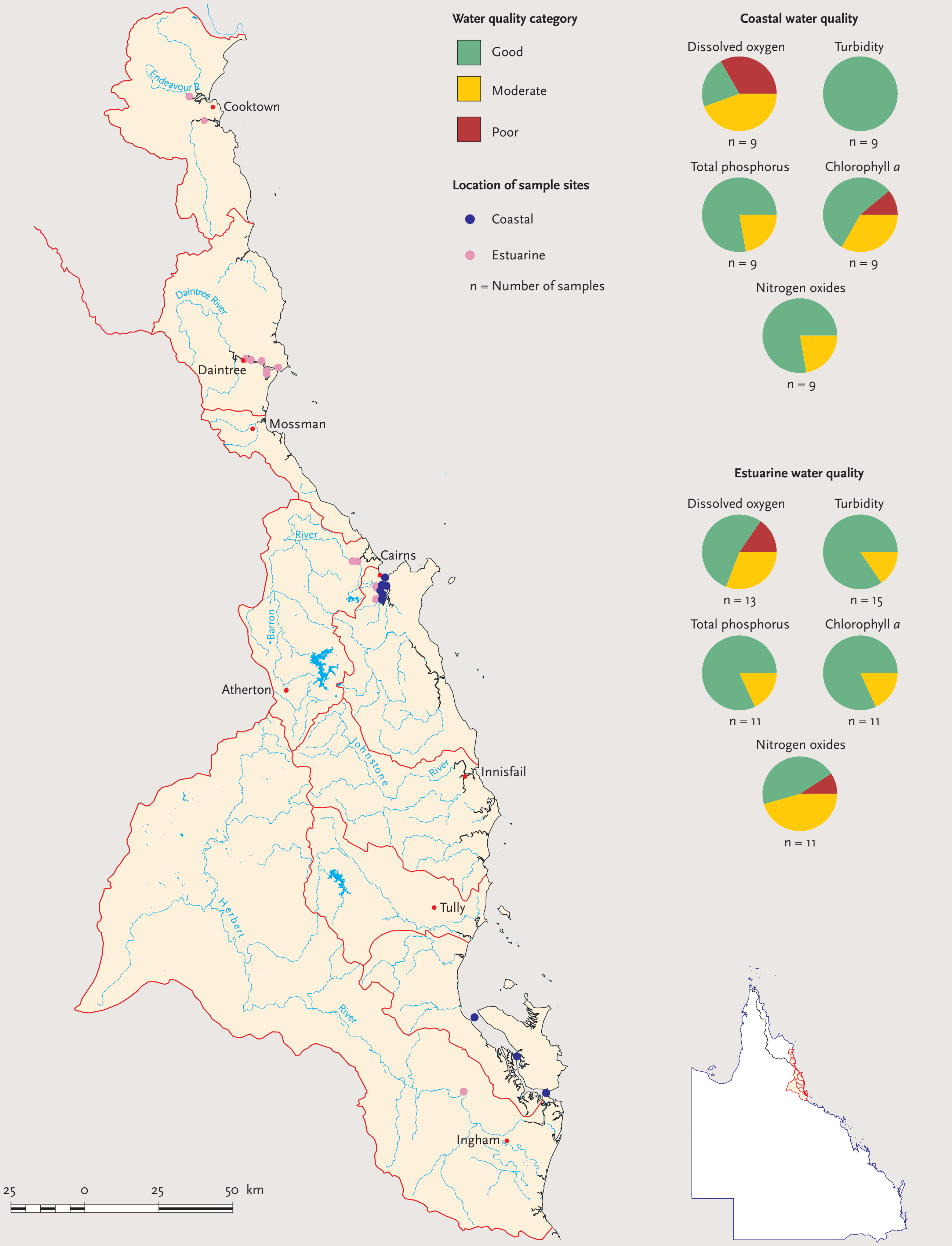


Figure 5-17 Water quality in the estuarine and coastal waters of the north coast. This region is characterised by short, steep nearshore ranges and confined coastal plains. The climate is tropical with high rainfall and a pronounced wet season, producing fast-flowing streams with low levels of turbidity. Estuaries are short and strongly influenced by freshwater inflows. The eastern Cape York section of the region north of Daintree is relatively undeveloped, with low-density cattle grazing, large national parks and Aboriginal reserves. South of Daintree there is intensive agriculture in the northern part of the Mareeba–Dimbulah Irrigation Area, while the ranges remain largely forested. Most of the population is located south of Daintree, mainly in small coastal centres. The main water quality impacts include intensive sugarcane cultivation, sugar mill discharges, and treated sewage discharges and urban runoff near urban areas. A significant proportion of this region has been set aside as the Wet Tropics Conservation Area.

Table 5-30 Area (hectares) and percentage of land according to consolidated zoning classes in local government areas of south-east Queensland at 1 July 1995

Local government area	Urban residential	Low-density residential	Commercial	Industry	Special use	Open space	Rural	Non-urban	Conservation	Roads, water-courses	Total area (ha)
Brisbane	28 515	3 859	1 366	6 989	17 131	28 535	18	14 969	1 169	12 279	114 830
	24.8%	3.4%	1.2%	6.1%	14.9%	24.9%	0%	13%	1%	10.7%	
Caboolture	4 567	8 221	208	5 385	23 442	4 598	69 204	4		6 831	12 2460
	3.7%	6.7%	0.2%	4.4%	19.1%	3.8%	56.5%	0%	0%	5.6%	
Caloundra	4 706	921	201	267	27 932	3 623	64 512	2253		5 300	109 715
	4.3%	0.8%	0.2%	0.2%	25.5%	3.3%	58.8%	2.1%	0%	4.8%	
Gold Coast	17 366	6 031	368	3 591	32 849	7 247	59 528			20 015	146 995
	11.8%	4.1%	0.3%	2.4%	22.3%	4.9%	40.4%	0%	0%	13.6%	
Logan	5 628	660	389	531	5 537	1 556	7 919	81		2 444	24 745
	22.7%	2.7%	1.6%	2.1%	22.4%	6.3%	32%	0.3%	0%	9.9%	
Maroochy	5 953	2 076	297	881	28 761	3 540	67 540	151		7 033	116 232
	5.1%	1.8%	0.3%	0.8%	24.7%	3%	58.1%	0.1%	0%	6.1%	
Noosa	1 594	2 460	23	109	25 685	3 327	40 382	628	3 368	9 682	87 258
	1.8%	2.8%	0%	0.1%	29.4%	3.8%	46.3%	0.7%	3.9%	11.1%	
Pine Rivers	7 645	8 910	287	1 066	18 281	1 422	34 574			5 159	77 344
	9.9%	11.5%	0.4%	1.4%	23.6%	1.8%	44.7%	0%	0%	6.7%	
Redcliffe	1 613		83	111	254	702		229		939	3 931
	41%	0%	2.1%	2.8%	6.5%	17.9%	0%	5.8%	0%	23.9%	
Redland	5 340	186	262	295	1 186	16 340	21 813	3 335		3 290	52 047
	10.3%	0.4%	0.5%	0.6%	2.3%	31.4%	42%	6.4%	0%	6.3%	

(Source: QDHLGP)

LAND

Indicator

Area of land allocated to different uses

Land is a valuable resource which is used for a variety of purposes. In the coastal zone it is used extensively for agriculture, human settlements, built infrastructure and conservation, in addition to being left in its 'natural' state. The resource is thus allocated to different uses in accordance with current economic, social and environmental priorities of the community and governments.

As priorities and needs change, the relative allocation of land to different uses can also change. Trends over time in the way land is used can thus be identified. These changes can be interpreted as reflecting a change in condition, for example from a natural state to a developed or highly developed state. Thus the state of coastal zone land can be expressed in terms of the area of land allocated for different uses.

Detailed information about land use allocation (zoning) is not available for all coastal local government areas. Recent data for south-east Queensland local government areas in table 5-30 show the variety of land uses.

Several studies have been carried out in recent years to analyse land use changes in south-east Queensland. In the Pumicestone Passage catchment land use changed significantly between 1974 and 1991 (table 5-31). The data show a very significant increase in land developed for urban use and a moderate increase in agricultural land. Nearly one-quarter (about 10 000 ha) of the natural vegetation present in 1974 was cleared by 1991.

Catterall and Kingston (1993) and Catterall et al. (1996) assessed change in the area of land under natural vegetation in the coastal south-east. Between 1974 and 1987 about 39 616 ha of bushland was cleared. Between 1987 and 1994 a further 13 014 ha was cleared. Land use changed from natural vegetation to primarily urban and built infrastructure.

Table 5-31 Major land uses and land use change in the Pumicestone Passage catchment, south-east Queensland, between 1974 and 1991

Land use	1974 hectares	1974 %	1991 hectares	1991 %	Change %
Agriculture/horticulture	8 845	12.4	11 454	16.2	+30
Urban/residential	2 207	3.5	5 146	7.2	+233
Plantation forestry	24 643	32.4	28 858	38.9	+17
Natural vegetation	40 244	51.7	30 480	37.7	−24

(Source: DPI 1993)

Over a larger area, major land use categories by catchment are shown in table 5-32. These 22 east coast catchments cover 375 250 km². By far the dominant land use is grazing (320 966 km², or 85.6 percent). 'Timber' covers 26 439 km² (7.1 percent), while 'pristine' accounts for 9337 km² (2.5 percent). These data show the developed nature of coastal catchments. While only 1.8 percent of the area can be classed as highly developed (urban), only 9.6 percent remains in a relatively undeveloped state (timber plus pristine categories).

In general, a trend towards increasing the intensity of development of coastal land is apparent along the major part of the Queensland coast. Land use is changing from natural to agriculture/mining, to urban/built infrastructure. This trend is most apparent in the south-east and near major coastal urban centres which have reached the most advanced stage of land development (table 5-33). More remote areas are progressing from a 'natural' state to a more developed state which supports agriculture, mining and tourism development.

Table 5-32 Estimations of major land uses in selected east coast catchments in 1995–96

River catchment	Area (km²)	Percentage of catchment				
		Timber[a]	Pristine[b]	Grazing	Crops	Urban[c]
Daintree	2 130	37.7	31.7	26.7	1.9	2.0
Mossman	490	30.4	11.0	44.6	10.1	3.9
Barron	2 180	36.4	2.0	47.7	6.8	6.9
Mulgrave–Russell	2 020	16.9	25.1	38.9	13.3	5.8
Johnstone	2 330	25.3	12.8	41.6	15.9	4.4
Tully	1 690	62.5	2.1	20.7	11.1	3.7
Murray	1 140	32.9	27.3	29.6	7.0	3.3
Herbert	10 130	9.5	9.7	71.1	7.0	2.7
Black	1 080	18.0	9.3	67.4	1.1	4.2
Haughton	3 650	0.8	10.8	74	10.9	3.5
Burdekin	129 860	1.0	1.3	94.8	1.0	2.0
Don	3 890	0.2	2.6	91.3	2.8	3.1
Proserpine	2 490	9.6	4.0	74.6	7.5	4.3
O'Connell	2 440	7.6	4.4	70.5	11.1	6.5
Pioneer	1 490	22.7	6.1	48.5	17.9	4.7
Plane Creek	2 670	4.3	2.9	67.4	21.0	4.4
Fitzroy	152 640	6.7	2.3	87.5	3.3	0.2
Baffle	3 860	12.2	4.4	75.9	0.9	6.7
Kolan	2 980	12.5	0.0	79.0	4.8	3.8
Burnett	33 150	12.9	0.4	79.9	3.6	3.2
Burrum	3 340	26.9	6.3	53.4	8.9	4.5
Mary	9 600	8.3	0.6	64.5	1.9	4.8
Total area	**375 250**	**26 439**	**9 337**	**320 966**	**11 763**	**6 745**
Total (%)		**7.1**	**2.5**	**85.6**	**3.1**	**1.8**

[a]Timber includes state forests and timber reserves. [b]Pristine includes national parks, national parks (scientific), conservation parks and resource reserves. [c]Urban includes dwellings, roads, railways, watercourses and aquaculture.
(Source: Rayment and Neil 1997)

Table 5-33 Area of bushland remaining in coastal local government areas of south-east Queensland in 1974, 1987 and 1994. With the exception of the large sand islands of Moreton Bay, the trend in bushland areas is one of rapid decline. In the past decade native vegetation has been cleared at rates in excess of 1000 ha/year in most local government areas.

Local government area	Area (ha)	1974 bushland area (ha)	1987 bushland area (ha)	1994 bushland area (ha)
Brisbane: total	113 879	43 339	37 402	35 691
mainland and small islands	96 649	28 106	22 326	20 551
large sand islands	17 230	15 233	15 076	15 076
Caboolture	120 618	43 374	36 788	35 119
Caloundra	109 094	44 150	38 619	36 969
Gold Coast: total	134 290	62 083	55 994	53 813
mainland and small islands	132 263	60 907	54 889	52 717
large sand islands	2 027	1 176	1 105	1 096
Logan	24 629	10 157	8 940	8 079
Maroochy	115 130	54 940	49 851	47 948
Noosa	86 284	42 098	38 396	37 258
Pine Rivers	76 360	33 660	30 086	29 121
Redcliffe	3 608	642	393	381
Redland: total	50 341	30 795	29 169	28 310
mainland and small islands	24 037	9 086	7 836	7 340
large sand islands	26 304	21 709	21 333	20 970

(Sources: Catterall and Kingston 1993; Catterall et al. 1996)

MINERALS AND SAND

Silica sands

Indicator

Defined silica sand resources (tonnes)

Silica sand is an economically valuable resource found in the Queensland coastal zone. Deposits of silica sand occur as unconsolidated sand masses along most of the coast. The major deposits occur on Fraser, Moreton and North Stradbroke Islands, and in the dune systems at Byfield, Shelburne Bay and Cape Flattery (table 5-34). Queensland's defined silica sand resources are estimated at about 300 million tonnes, with a further potential resource of about 1500 million tonnes (Carmichael and Cooper 1996). Extraction rates are currently less than 3 million tonnes/year.

Mineral sands

Indicator

Defined mineral sand resources (tonnes)

Rutile, ilmenite and zircon are the major commercially extracted components of mineral sand deposits. Such deposits occur in the Pleistocene to Recent coastal beach and dune systems along much of the east coast, although significant deposits of concentrated heavy minerals are more restricted in their distribution. Major deposits include Byfield (estimated 2.4 billion tonnes at 1.14 percent heavy minerals)

Table 5-34 Queensland silica sand resources

Mine/deposit	Contained material (million tonnes SiO_2)
Bribie Island (pot.)	8.00
Byfield	Undisclosed
Cape Flattery (P)	200.00
Colmer Point (pot.)	192.00
Coonarr Creek	Undisclosed
Fraser Island (pot.)	500.00
Iveragh (M)	10.00
Moreton Island (pot.)	407.00
Mourilyan (I)	10.74
North Stradbroke Island (Myora lease) (P)	45.00
Shelburne Bay (P)	8.72
Shelburne Bay (pot.)	143.00
Skardon	Undisclosed
Sunshine Coast (pot.)	30.00
Teewah/Cooloola (pot.)	20.00
Total	**>1574.46**

pot. = potential; P = proven; M = measured; I = indicated
(Source: Cooper 1993)

North Stradbroke Island is the base for major sandmining operations.

and Cape Clinton (37.5 million tonnes at 4 percent heavy minerals), both north of Rockhampton, and Fraser Island and North Stradbroke Island in south-east Queensland. Potentially one of the largest known ilmenite deposits in the world is located in the Goondicum area, west of Bundaberg. Resources total 4.08 million tonnes, according to the Department of Mines and Energy. Production is planned for 1999.

North Stradbroke Island resources will be substantially depleted within 20 years. Most remaining resources are now included in national parks where mining is not allowed.

CLIMATE

Indicators

Sea level

El Niño Southern Oscillation

Intensity and number of tropical cyclones

Storm surge height

Summer minimum temperature

An equable climate makes the coastal zone popular with Queenslanders and tourists. Temperature and humidity lie largely in the human 'comfort range', hours of sunshine are high and rainfall is generally low. The climatic regime is also an important factor in determining the diversity and abundance of coastal wildlife. Queensland's climate is conducive to supporting a diversity of marine life forms including temperature-sensitive reef-building corals.

While extreme climatic events occur, often with devastating consequences to natural and human systems, impacts are seldom irreversible. Natural ecosystems have adapted to tolerate some degree of climatic variability, and therefore recover after such events.

Climate can and does change over time scales of decades to thousands of years (see chapter 2, 'Atmosphere'). Climate is also subject to change as a result of human activity. The release of high concentrations of greenhouse gases by human activity is now widely believed to be causing global warming. This could result in a rapid change in the Queensland climate and a change in sea level, with potentially severe consequences.

To report on the Queensland climate and to help detect any climatic change, some climatic indicators have been developed (see also chapter 2, 'Atmosphere').

Sea level has been recorded at locations along the Queensland coast for many years. In 1991 the National Tidal Facility began the Australian Baseline Sea Level Monitoring Project, installing high-precision recorders at Rosslyn Bay, near Rockhampton, and Cape Ferguson, near Townsville.

Sea level trends for five Queensland ports calculated by the National Tidal Facility are given in table 5-35. All ports show a positive trend (rise), Brisbane having the highest trend estimate. Sea level trends at Rosslyn Bay and Cape Ferguson also show a positive trend, although 20 years of records are required before accurate trends can be forecast.

Year-to-year variability in Queensland's climate, particularly rainfall, is influenced to a considerable extent by the occurrence of El Niño and La Niña events (see chapter 2, 'Atmosphere'). These events influence cyclone activity and monsoonal activity, the summer monsoon being enhanced during La Niña events. While any particular trend in the Southern Oscillation Index cannot be identified, over the last 20 years El Niño events have tended to increase in frequency, resulting in lower-than-average rainfall and river flow over much of Queensland during this period.

Table 5-35 Sea level trends in Queensland, based on data to 31 December 1996

Location	Days of record	Trend (mm/year)
Brisbane	8 400	6.87
Bundaberg	10 673	0.05
Mackay	8 588	1.14
Townsville	13 642	1.23
Cairns	8 351	3.25

(Source: National Tidal Facility, The Flinders University of South Australia)

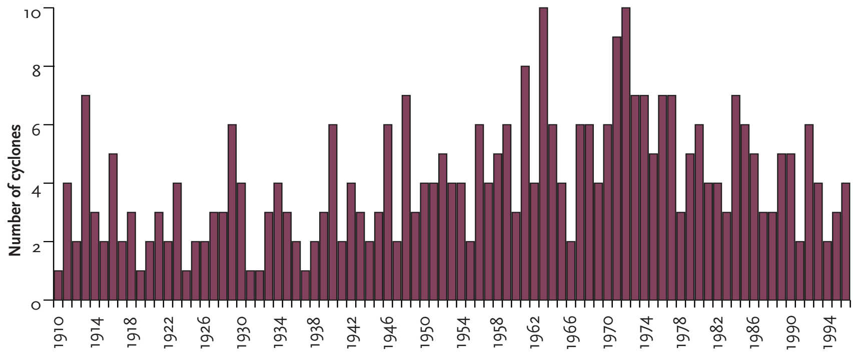


Figure 5-18 Number of cyclones recorded each year in Queensland, June 1909 to March 1996. The use of satellite technology since 1959 has improved the detection of cyclone activity and increased the reliability of information.
(Sources: Puotinen et al. 1997; BoM)

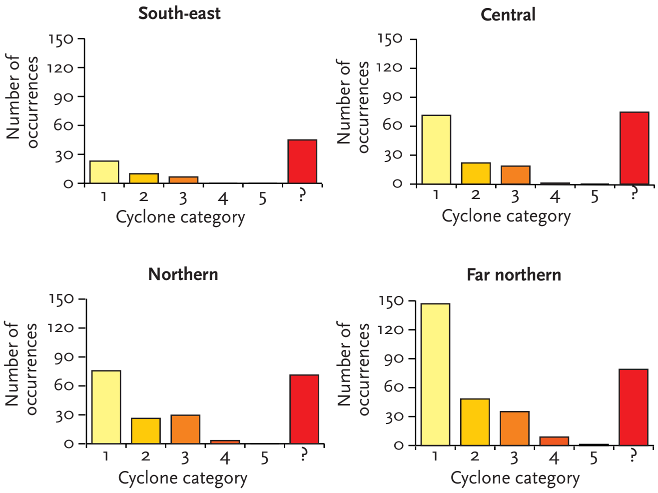


Figure 5-19 Frequency of occurrence and category of tropical cyclones by region along the Queensland coast, June 1909 to March 1996. Cyclone activity is clearly highest in the far northern region (between 11°S and 18°S).
? denotes 'uncategorised'
(Sources: Puotinen et al. 1997; BoM; EPA)

Table 5-36 Notable storm surges recorded on the Queensland coast

Year	Place	Cyclone	Estimated central pressure (hPa)	Surge height (m)
1884	Bowen		?	3.1
1887	Burketown		?	5.5
1896	Townsville	Sigma	?	>2.0
1899	Bathurst Bay	Mahina	914	14.0
1918	Mackay		935	3.7
1918	Innisfail		928	>3.0
1920	Cairns		988	>1.5
1923	Albert River	Douglas Mawson	974	>3.0
1934	Port Douglas		968	>1.8
1948	Bentinck Island		996	>3.7
1964	Edward River	Dora	974	5.0?
1971	Inkerman Station	Fiona	960	>4.0
1971	Townsville	Althea	952	2.9
1971	Edward River	Fiona	960	3.0
1972	Fraser Island	Daisy	959	3.0?
1976	Burketown	Ted	950	4.6?
1978	Weipa	Peter	980	1.2
1987	Karumba	Jason	970	2.0
1989	Ayr	Aivu	935	3.2
1995	Karumba	Warren	980	1.5
1996	Gilbert River	Barry	950	>4.0?

An analysis of cyclone activity in the Great Barrier Reef region between 1958 and 1992 indicates that during El Niño years an average of two tropical cyclones will occur in the region. During La Niña years activity increases, to about 7.5 tropical cyclones (Lough 1997). The annual occurrence of tropical cyclones in the Queensland region between 1909 and 1996 is shown in figure 5-18. The occurrence of cyclones by region and category is shown in figure 5-19.

Extreme events such as tropical cyclones are potentially very destructive to the coastal zone. Commonly associated with cyclones is the phenomenon of storm surge — where the sea level rises above the normal tidal level. The combination of storm surge with astronomical tide is known as storm tide. Increased frequency and height of storm surge height could be a result of climate change, and therefore monitoring such events can be a useful means of detecting trends in climate. Some notable storm surges recorded in Queensland are listed in table 5-36.

Average temperatures have increased significantly over the last century, particularly night-time minimum temperatures (Lough 1997; see also chapter 2, 'Atmosphere'). The full implications of such changes to human systems and natural ecosystems are not yet fully understood.

COASTAL BIODIVERSITY

Queensland's biodiversity is considered in detail in chapter 7, but some additional information about coastal and marine environments is provided here.

Biodiversity is a potentially useful indicator of ecosystem integrity and health. Changes in diversity may be a warning of adverse impacts and a threat to ecosystem integrity. The number of species in a particular area is one indicator of biodiversity. The population and/or distribution of a species are useful indicators as they provide information about the status (rarity) of the species.

The marine environment is extraordinarily rich in plant and animal life; many thousands of species have been formally described and named and even more are yet to be described. For example, the Great Barrier Reef supports some 2000 known species of fish, 350 species of echinoderms, 400 species of coral, 370 species of sponges and 4000 species of molluscs. Those species which are known to science tend to be the larger and more noticeable ones, and even then our understanding of their biology and ecology is very limited in most instances. The smaller, less noticeable species are largely unknown to science. Only a small percentage are described and even fewer have been studied in any detail.

The limited availability of information is itself a useful environmental indicator, as it reflects government and community priorities and attitudes to the natural environment and environmental resource management. The productivity of the sea depends on the integrity of estuarine and marine ecological systems, yet society's priorities are directed largely at exploiting such systems rather than first understanding them. A detailed understanding of the life cycle and biological requirements of species has proved essential in managing the productivity of commercially exploited species. However, the same level of research effort is not directed at other species or systems which are subject to 'indirect' exploitation and human impact (for example, from tourism activities or coastal development).

Data on the known diversity of species in the Queensland coastal zone are presented below. Where reliable records are available, population data are also presented for some species, although such records tend to be restricted to the megafauna (dugong, turtles).

Plants

Marine algae

Species of attached algae easily visible to the naked eye, including the larger filamentous species such as 'seaweeds', are known as macro-algae. Information about the diversity, distribution and ecological roles of the macro-algae of Queensland's coastal waters is very limited.

The few studies available indicate that the Great Barrier Reef region has a diverse macro-algal flora, reflecting the latitudinal extent, diversity of reef and substrate types, and consequent habitat diversity of the reef environment. On the basis of recent comprehensive survey work, McCook and Price (1997) estimate there are some 400–500 species of macro-algae on the Great Barrier Reef. Womersley (1990) estimated that 400 species occurred in Queensland. Cribb (1973), on the basis of intensive but exclusively intertidal sampling, reported 230 species from the Capricorn–Bunker Group of reefs.

Large-scale surveys of algal distribution and abundance are currently under way in the Great Barrier Reef region. Surveys of the abundance of about 125 taxa have already been undertaken at 583 sites on 77 reefs between Lizard Island and the Whitsunday Islands (McCook and Price 1997).

Marine plants

Worldwide there are about 69 species of mangroves, of which 38 occur in Australia and 37 in Queensland, although only *Lumnitzera × rosea* is more or less restricted to Queensland. The diversity of species tends to decrease from north to south, reflecting the importance of temperature in determining distribution. Twenty-seven species are found on the Olive River, thirteen at Port Clinton and seven in Moreton Bay.

Seagrasses are distributed along the entire Queensland coast and are represented by 15 species, although additional species are likely to be discovered. A new species, *Halophila capricorni*, was described in 1995.

Terrestrial plants

A number of site-specific and regional studies have provided comprehensive inventories of terrestrial plants. Such inventories provide a basis for future comparisons and are therefore useful for assessing the possible impact of human activity on botanical diversity.

Despite the apparently inhospitable nature of coastal dune environments, such systems support a diversity of species and plant communities. In a detailed study of 75 km of the Capricorn Coast between the Fitzroy River and Stockyard Point, Batianoff and McDonald (1978) described the flora of the foredunes, beach ridges, transgressive dunes and parabolic high dunes extending up to 2 km inland. In total, they recorded 504 species and varieties of plants, of which they found 118 species on the beach and frontal dunes. Of the 504 species, 80 (16 percent) were introduced. The authors noted that many pasture species had been introduced into swampy grasslands. As a result, native plants had been lost or partially replaced. The area has since undergone significant development.

In a recent detailed study of 28 500 ha of the Mackay coast, defined as the 5 km by 70 km coastal strip between Shoal Point and Salonika Beach, Batianoff et al. (1996) recorded 1009 species of vascular plants, of which 725 species (71.8 percent) were native, 268 (26.6 percent) were exotic and 16 (1.6 percent) were displaced Australian species not indigenous to the Mackay district. Two rare and threatened plants, *Atalaya rigida* and *Eucalyptus raveretiana*, were also found, in addition to 71 species which are considered locally rare and/or endangered.

Along 120 km of the Curtis Coast between Seventeen Seventy and Raglan Creek including Curtis Island (46 600 ha), 834 species of vascular plants have been recorded. Of these, 806 are flowering plants, 26 are ferns and two are conifers (QDEH 1994). Eight species are considered rare and one is considered vulnerable.

In a recent botanical inventory of the 552 continental islands in the Great Barrier Reef Marine Park, 2195 species of vascular plants were recorded: 2091 flowering plants, 97 ferns, five conifers and two cycads (see table 5-37). Of these, 215 species (10 percent) were introduced exotics, and 79 species are listed as rare or endangered, equal to 6 percent of Queensland's known rare plants.

Table 5-37 Botanical summary data for the 552 continental islands within the four sections of the Great Barrier Reef Marine Park (GBRMP). The Mackay–Capricorn Section (the most heavily visited) contains the highest percentage of exotic species (13 percent), while the Far Northern Section (the least visited) contains the lowest (5.5 percent).

	Far Northern	Cairns	Central	Mackay–Capricorn	Total GBRMP
Exotic species	47	57	152	163	215
Rare/endangered species	24	9	47	13	79
Exclusive regional species	168	43	456	361	1028
Other	617	591	779	715	873
All species	856	700	1434	1252	2195
Number of islands	139	47	161	205	552

Fauna

Queensland's tropical and subtropical coastal zone has a very high diversity of marine invertebrates, fish and birds. The region lies towards the centre of the most biologically diverse marine province on earth, the tropical Indo-Pacific region. However, of the 26 phyla known from Australia's marine waters only five or six are known in any detail, and even within them more species remain to be described. Even an approximation of the number of species of most phyla is impossible, particularly nematodes and other worms and the small crustaceans and molluscs.

Marine invertebrates

There are probably more than 100 000 species of invertebrates in Australian waters. Many thousands of species have been described from Queensland's coastal waters, reflecting the diversity of tropical and subtropical habitat types. The Queensland Museum has about 22 000 registered crustacean specimens (not species) on a computer catalogue, including extensive holdings from mangrove and reef habitats, and trawled shallow and deepwater habitats.

Some 374 species of sponges, 350 echinoderms and about 400 species of hard corals have been identified in the Great Barrier Reef region. On the fringing reefs of Cape Tribulation alone, 140 species of hard coral have been recorded. Dunning et al. (1994) recorded 21 species of cephalopods (squids and octopods) in the Gulf of Carpentaria. In the soft sediment areas off Townsville, 103 species of echinoderms and 196 species of molluscs have been recorded (Birtles and Arnold 1988). One hundred and thirteen species of barnacles and around 1030 decapod crustaceans are known from Queensland, including 22 species of prawns and 550 species of crabs.

The smaller invertebrate fauna of marine sediments is even more diverse. Long and Poiner (1994) recorded a total of 684 taxa of infaunal organisms (living in the sediment) from 105 seabed sites in the Gulf of Carpentaria. In reef environments, several hundred species might be found under one rock.

In the absence of accurate abundance data, the population status of the different species of invertebrates is largely unknown. With reference to molluscs, 44 tropical Cypraeidae (cowries) and 23 Conidae (cone shells) have been listed as potentially vulnerable and in need of monitoring to determine their status. The Heron Island volute *Cymbiolacca pulchra woolacottae* is restricted in distribution to Heron Island and nearby reefs where populations have been declining for many years.

No invertebrates are listed in the Nature Conservation (Wildlife) Regulation or the Endangered Species Protection Act. Various corals and giant clams are listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) and in Schedule 2 of the *Wildlife Protection (Regulation of Exports and Imports) Act 1982*.

Fish

About 2000 fish species have been identified in Queensland's coastal waters. Diversity tends to be greatest in association with reef systems and tends to decline in pelagic (mid-water column) environments. Some 960 species have been recorded from the reefs of the Capricorn–Bunker Group alone. In the Gulf of Carpentaria, Blaber et al. (1994a) recorded 197 species of fish from the Embley River estuary, while more than 300 species were recorded from deeper waters (>20 m) (Blaber et al. 1994b). In the Shoalwater Bay area on Queensland's central coast, 428 species of marine and estuarine fish have been recorded (Australian Government 1994).

The status of nearly all fish species is not known with any certainty. The International Union for the Conservation of Nature (IUCN) Red List contains three species of shark — the whale shark, listed as 'indeterminate status', and the great

Current status of turtle populations

The current status of turtle populations in Queensland reflects not only the impact of human activity in the Australian coastal zone, but the impact of activities in seas far from Australia.

Loggerhead turtle

The loggerhead turtle (*Caretta caretta*) breeds almost totally in the southern Great Barrier Reef region: on the mainland at Mon Repos and Wreck Rock; on Erskine, Wreck and Tryon Islands; and on the Swain Reefs cays. The nesting population in eastern Australia has declined by 50–80 percent since the early 1970s, from approximately 3000+ to 1000+.

Green turtles

Three separate globally significant breeding aggregations of green turtles (*Chelonia mydas*) occur in Queensland: southern Great Barrier Reef (including North West, Wreck and Hoskyn Islands); northern Great Barrier Reef (including Raine Island and Moulter Cay); and the Wellesley Group of islands (including Bountiful, Pisonia and Rocky Islands). Between 2000 and 7000 females are estimated to nest annually on Islands in the Wellesley Group.

Flatback turtle

The flatback turtle (*Natator depressus*) has a very limited geographic distribution and is effectively endemic to Australia. It occurs in northern Australian waters and nests along the Queensland coast, the largest rookery being located on Crab Island in Torres Strait. Population estimates are not available, but in excess of 2200 female flatback turtles were breeding at Crab Island during 1991. An estimated 1000–1500 nest on islands in the Wellesley Group in the Gulf of Carpentaria. Others nest at Peak and Wildduck islands off the central Queensland coast.

Olive ridley, leatherback and hawksbill turtles

Most Australian olive ridley (*Lepidochelys olivacea*) nesting occurs in the Northern Territory, with only sporadic nesting on the Queensland coast of the Gulf of Carpentaria. Nesting by the leatherback turtle (*Dermochelys coriacea*) is rare in Australia. Between 1968 and 1990, nesting was recorded 33 times, 29 of which were in Queensland. The northern Great Barrier Reef region is one of the remaing global strongholds for the hawksbill turtle (*Eretmochelys imbricata*), an estimated several thousand females nesting annually. A long-term population census project has been established at Milman Island to document population trends over time. This turtle is also known to nest on the Wessel and English Company Islands in the north-western Gulf of Carpentaria.

white and basking sharks, listed as 'insufficiently known'. The status of four species of sawfish found in tropical waters is listed by the Australian Society for Fish Biology as 'uncertain'.

Although some fish are less common than others, no marine species are listed under the Nature Conservation (Wildlife) Regulation as endangered, vulnerable or rare, or are in the Endangered Species Protection Act schedules. However, this might be a reflection more of the state of scientific knowledge than of the status of the species.

Reptiles

Six of the world's seven species of marine turtle breed in Queensland's coastal zone. Population monitoring and research have been undertaken at selected sites since 1968 and population status assessments are possible for some species. However, in view of the long life span, low reproductive rate and migratory behaviour of these species, accurate population status assessments are not yet possible (see box 'Current status of turtle populations').

About 22 species of sea snakes are found in Queensland waters; of these, two (*Hydrophis atriceps* and *H. belcheri*) are classed as rare. Before sea snakes became fully protected under the Nature Conservation Act in 1994, large numbers were harvested in northern Australian waters. The impact of such harvesting is unknown, as is the current population status of the species.

Although hunting is no longer a major threat to populations of the estuarine crocodile (*Crocodylus porosus*), increasing coastal development and improved vehicular access reduce habitat availability. Fishing activity, particularly gill netting, is a threat in some areas. 'Natural' factors such as floods and feral pigs also affect crocodile habitat.

Remaining areas of particular significance as crocodile habitat include the Jardine River wetlands, the Wenlock and Dulcie Rivers, Lakefield National Park and the Lockhart River mangrove wetlands. The waterways of the remote north-west of Cape York support the highest density of crocodiles. The available data and anecdotal evidence suggest that, since hunting was made illegal, populations have increased significantly and larger adults are becoming more common. In the eastern coastal plains region from Cape Melville to Rockhampton and in the Burdekin and Fitzroy River catchments, intensive agriculture, grazing and urban development are contributing to a probable overall decline in crocodile populations.

Marine mammals

Eighteen species of whales, ten species of dolphins, and the dugong have been sighted off Queensland. From perilously low numbers in 1963, the humpback whale population has shown a steady recovery. Shore-based counts of east Australian whales commenced in 1978 at Point Lookout, North Stradbroke Island. In 1996 the population of humpback whales migrating north along the east Australian coast was estimated to number 2500. This compares with an estimated population of less than 100 in 1962, 1100 in 1987 and 1900 ±250 in 1992.

Birds (waders and seabirds)

Waders comprise a variety of bird species which feed on coastal mudflats and saltflats. They include plovers, stilts, curlews, sandpipers, stone-curlews, and oystercatchers.

The extensive sand and mudflats of Queensland's coastal zone are important habitats for waders. Forty-six species have been recorded, including resident, regular migrant and occasionally recorded species. Many are listed under international migratory bird agreements aimed at protecting critical habitats.

In recent years a concerted effort has been made to document the distribution and numbers of waders on the Queensland coast (table 5-38). A total summer population of approximately 399 000 waders has been estimated (Driscoll 1996). Population changes over time are insufficiently known to provide any comment on population trends. The beach stone-curlew (*Burbinus neglectus*) is 'vulnerable'.

Seabirds include those species which depend on the sea and spend most of their time at sea — shearwaters, gulls, boobies, terns, cormorants and frigates. Seabird census data collected vary in terms of area studied, regularity of collection and methods used. The available data permit a reasonable assessment of seabird distribution, but knowledge of population trends is poor. Regular, long-term and reliable census data are required to assess population dynamics. Data of this quality are available for a limited number of species and colonies.

Islands off the Queensland coast are home to more than 1 159 000 breeding pairs of seabirds (table 5-39). Twenty-four species of seabird are known to breed in 58 major colonies and 20 minor colonies in the Great Barrier Reef Marine Park (Hulsman et al. 1997). The major colonies are mostly on cays (41) and continental islands (10), while the minor colonies occur mostly on vegetated sand cays and high continental islands.

Seabirds on Michaelmas Cay, far north Great Barrier Reef, were surveyed monthly by the Queensland Department of

Table 5-38 Estimated numbers (maximum) of the most common waders occurring on the Queensland coast (does not include adjacent freshwater wetlands). Numbers are for summer months only.

Common name	Total
Black-tailed godwit	55 057
Bar-tailed godwit	48 732
Whimbrel	16 940
Eastern curlew	18 478
Marsh sandpiper	1 735
Common greenshank	4 437
Terek sandpiper	11 431
Grey-tailed tattler	18 081
Ruddy turnstone	887
Great knot	92 711
Red knot	5 657
Red-necked stint	55 408
Sharp-tailed sandpiper	5 786
Curlew sandpiper	10 521
Broad-billed sandpiper	1 066
Pied oystercatcher	3 550
Black-winged stilt	3 150
Red-necked avocet	2 315
Pacific golden plover	4 619
Grey plover	1 550
Red-capped plover	8 745
Lesser sand plover	16 885
Greater sand plover	7 775

(Source: Driscoll 1996)

Table 5-39 Number of breeding pairs of seabird species recorded on islands within the Great Barrier Reef region, the Coral Sea and the Gulf of Carpentaria

Common name	Scientific name	Number of breeding pairs		
		Great Barrier Reef	Coral Sea	Gulf of Carpentaria
Wedge-tailed shearwater	*Puffinus pacificus*	351 276	99 417	0
Great frigatebird	*Fregata minor*	20	5 938	0
Lesser frigatebird	*Fregata ariel*	2 447	6 496	3 870
Brown booby	*Sula leucogaster*	18 611	5 900	4 400
Masked booby	*Sula dactylatra*	1 102	9 169	0
Red-footed booby	*Sula sula*	172	2 105	0
Australian pelican	*Pelecanus conspicillatus*	270	n.a.	50
Red-tailed tropicbird	*Phaethon rubricauda*	101	398	0
Caspian tern	*Hydroprogne caspia*	67	n.a.	50
Roseate tern	*Sterna dougallii*	7 307	n.a.	1 000
Crested tern	*Sterna bergii*	26 023	516	13 466
Lesser crested tern	*Sterna bengalensis*	6 341	n.a.	50
Little tern	*Sterna albifrons*	52	27	2
Black-naped tern	*Sterna sumatrana*	3 891	498	Common
Sooty tern	*Sterna fuscata*	48 000	161 283	n.a.
Bridled tern	*Sterna anaethetus*	13 887	2	Common
Common noddy	*Anous stolidus*	46 004	39 912	0
Black noddy	*Anous minutus*	210 240	67 900	0
Silver gull	*Larus novaehollandiae*	765	n.a.	142
White-bellied sea-eagle	*Haliaeetus leucogaster*	34	n.a.	n.a.
Osprey	*Pandion haliaetus*	61	n.a.	n.a.
Herald petrel	*Pterodroma arminjoniana*	3	n.a.	0
Black-winged petrel	*Pterodroma nigripennis*	1	n.a.	n.a.
Total		**736 675**	**399 564**	**23 030**

(Source: Hulsman et al. 1997; QDEH)

Environment and Heritage from 1984 to 1994. An analysis showed that populations of the common noddy decreased by 46 percent and sooty tern populations decreased by 26 percent. Reasons for these declines are not known with certainty, but increasing levels of human visitation are considered the most likely cause (Hulsman et al. 1997).

Detailed surveys of seabirds in the Swain Reefs, southern Great Barrier Reef, between 1982 and 1994 revealed a significant decline in the numbers of adults and nests of the brown booby, and in the number of adult silver gulls.

Eleven species of seabird are known to breed on the Wellesley Islands in the southern Gulf of Carpentaria. Four of these species mass in breeding colonies that are of international/national significance (Walker 1992). Breeding pairs are estimated as follows: crested terns 13 000–15 000; roseate terns 1000; brown boobies 6000–7500; and lesser frigatebird 1000–1500. The crested tern colony may be the largest known colony in the world. Seventeen seabird species have been recorded at sea during summer research cruises in the Gulf.

SEAFOOD QUALITY

Indicator

Concentration of heavy metals in selected seafood

Aquatic organisms can become exposed to various contaminants (pollutants) through contact with contaminated sediments, through exposure to contaminated water or by eating contaminated food. Contaminants can be absorbed and, to varying degrees, retained in the body tissues. In some instances, contaminants can reach relatively high concentrations. Ingestion of contaminated tissue by humans represents a potential health hazard.

Queensland Health and the Department of Primary Industries undertake intermittent testing of seafood caught in Queensland waters. Tests on fish, crustaceans and cephalopods taken from Moreton Bay in 1995 found that lead, inorganic arsenic, chromium and nickel concentrations were, in most cases, below the limit of detection. No sample contained a concentration of zinc, mercury, selenium or cadmium in excess of the maximum permitted concentration (MPC). More than half the crustaceans tested for copper exceeded the MPC, however. In the absence of long-term records from the same locations, conclusions about any trend in the level of contamination cannot be drawn.

Between July 1991 and June 1992, 54 shark and ray samples were collected from along the Queensland coast and tested for metal contamination. Fifty percent of samples tested for mercury exceeded the MPC of 0.5 mg/kg, and 11 percent of samples exceeded the standard for selenium (Queensland Health 1993).

Responses are those programs, activities and achievements by people and public authorities directed at resolving resource management issues or problems. Individuals, organisations, the community and governments are involved in managing the coastal zone in many ways.

The ways we use, conserve and manage the coastal zone are influenced by many laws and policies. In one way or another these are aimed at managing human activity and guiding our use and exploitation of coastal resources. They can be seen broadly as the community's response to coastal management issues and needs, an attempt to control and regulate use of the coastal zone to protect resources and lifestyles.

Responsibility for managing coastal resources extends across the three tiers of government, and involves numerous agencies and organisations and more than 30 Queensland Acts. International agreements and conventions also influence the way certain resources are managed or used (see box 'International treaties'). Responses therefore cover scales that range from local to global. Responses are also hierarchical, local actions often complementing and implementing national and international initiatives.

MAJOR COASTAL ZONE ISSUES

Coastal zone management and planning

Coastal zone planning and management involve all levels of government and many agencies and organisations. Given the often competing management aims of such bodies, integrating decision-making processes and identifying common management goals are difficult. The complexity of institutional arrangements for administering coastal resources has long been acknowledged. In recent years the need for a more coordinated approach to coastal zone management has been widely recognised. This has resulted in several major initiatives directed at facilitating a broader strategic approach to planning and management.

Through the Federal Coasts and Clean Seas Initiative, announced in May 1997, the Commonwealth Government is to provide $125 million by 2001–02 for a range of programs directed at protecting Australia's coastal and marine environments. Some $108 million of this funding is being provided through the Natural Heritage Trust. This new initiative supplements current Commonwealth funding for coastal resources management. Queensland is to benefit from a share of this funding.

Oceans Policy

In December 1998, the Commonwealth Government released Australia's Oceans Policy. The Policy focuses on the coordination and management of marine-based activities. It provides a strategic framework for the planning, management and ecologically sustainable development of fisheries, shipping, petroleum, gas and seabed resources while ensuring the conservation of the marine environment.

The Policy deals with the legislative, jurisdictional and institutional arrangements underlying the ocean's planning, management and use. It also deals with specific issues such as marine pollution, science, indigenous issues, shipping, conserving and managing marine biodiversity and international obligations and considerations.

Coastal and Marine Planning Program

The Commonwealth's Coastal and Marine Planning Program aims to stimulate coastal and marine planning that incorporates social, economic and environmental factors. The Program supports the development of strategic plans for areas experiencing pressure from competing uses, and aims to minimise impacts due to one-off and uncoordinated development in the coastal zone. The plans are developed through partnerships between Commonwealth, State and local governments, the community and industry. Funding of $7.6 million will be provided to 2000–01.

Coastcare

Coastcare is a program to promote community involvement in identifying and managing natural and cultural resources of the coastal zone. Established in 1995, the program is the result of a tripartite agreement between the Commonwealth and Queensland Governments and the Local Government Association of Queensland. The program provides grants for projects to protect or rehabilitate particular coastal environments (table 5-40).

Coastal Protection and Management Act

The *Coastal Protection and Management Act 1995*, administered by the Environmental Protection Agency, provides for the protection, conservation, rehabilitation, management and ecologically sustainable development of the coastal zone.

Achievement of these objectives is facilitated by a coordinated and integrated management framework, a key component of which is the State Coastal Management Plan. The plan, currently under development, must describe how the

Table 5-40 Queensland Coastcare applications, grants and total value

	1995–96	1996–97	1997–98
Applications received	52	82	101
Grants awarded	39	52	66
Total value	$539,314	$636,832	$888,000

International treaties

Many international treaties and conventions on protecting, conserving or managing coastal resources are in force. While the Commonwealth Government enters into such treaties in accordance with its constitutional authority, all tiers of government must observe the associated provisions and obligations. Provisions of international treaties, then, can directly influence Queensland's coastal zone management.

Through Commonwealth and State action in particular, provisions of treaties listed below are being implemented and obligations observed in Queensland.

United Nations Convention on the Law of the Sea 1982

The Convention on the Law of the Sea establishes a comprehensive framework for regulating the oceans, including the limits of national jurisdiction over the oceans. The treaty allows for natural resources in Australia's economic exclusion zone to be exploited, while obliging Australia to work towards preventing marine pollution from shipping and land-based sources, to undertake marine research, and to protect and preserve the marine environment.

Convention on Wetlands of International Importance Especially as Waterfowl Habitat 1971 (Ramsar Convention)

The Ramsar Convention provides the framework for intergovernmental cooperation in the protection and sustainable use of wetlands. At 30 June 1999, 53 sites in Australia and island external territories were Ramsar-listed. Queensland sites were:

- Currawinya Lakes (151 300 ha);
- Shoalwater/Corio Bays (239 100 ha);
- Moreton Bay (113 314 ha);
- Bowling Green Bay (35 500 ha); and
- Great Sandy Strait (93 000 ha).

While listing gives no extra legal protection to a site, it highlights its international significance to decision makers.

Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and Their Environment

This agreement, commonly known as the China/Australia Migratory Birds Agreement (CAMBA), seeks to protect those species which migrate between the countries by protecting critical wetland habitat. It lists 81 species of migratory birds. Many coastal wetlands, particularly those in the Gulf of Carpentaria, are important wetland habitats for CAMBA-listed birds.

Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds and Birds in Danger of Extinction and Their Environment

Commonly known as the Japan/Australia Migratory Birds Agreement (JAMBA), this agreement seeks to protect those species which migrate between the two countries by protecting critical wetland habitat. It lists species.

Convention for the Protection of the World Cultural and Natural Heritage

The objective of the World Heritage Convention is to establish an effective system for protecting the world's cultural and natural heritage of outstanding universal value on a permanent basis. The inscription of a site on the World Heritage List places an obligation on Australia to permanently protect the universal values of the area. Five Queensland sites are listed:

- Great Barrier Reef (listed 26 October 1981);
- Wet Tropics of Queensland (5 December 1988);
- Fraser Island (7 December 1992);
- Australian Fossil Mammal Sites (Riversleigh and Naracoorte) (12 December 1994); and
- Central Eastern Rainforest Reserves (12 December 1994).

Through cooperative funding and administrative arrangements, site management responsibility is shared between the Commonwealth Government and the Queensland Government.

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

CITES seeks to prevent the over-exploitation of endangered plants and animals including fish through import and export controls. Species identified as endangered are listed. The estuarine crocodile is among listed species found in Queensland's coastal zone.

United Nations Convention on Biological Diversity

The Convention on Biological Diversity seeks to conserve biological diversity, the sustainable use of its components, and fair and equitable sharing of benefits arising from using genetic resources. The Queensland Government has played an active role in developing national initiatives directed at implementing provisions.

International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention)

The purpose of this Convention is to control pollution of the sea caused by dumping.

International Convention for the Prevention of Pollution from Ships (MARPOL)

Through a series of protocols, the MARPOL Convention aims to preserve the marine environment by eliminating pollution by oil and other harmful substances and minimising the accidental discharge of such substances.

coastal zone is to be managed and can include a statement of the principles and policies of management.

The Act also provides for the development of regional plans. These can describe the principles, policies and requirements by which the coastal zone in a region will be managed, describe a scheme of coastal management works, and identify key coastal sites requiring special coastal management. The preparation of regional plans has commenced for the Wet Tropics Region, Cardwell–Hinchinbrook Region, Wide Bay Region and Southeastern Region. In 1997–98 the Queensland Government allocated $1.2 million as special funding to implement the Act.

Before this Act, several regional strategic plans were prepared for important and intensively used coastal areas, and they remain operational:

- The Trinity Inlet Management Plan defines the management objectives for Trinity Inlet and details complementary management strategies. The overriding principle of management is maintaining Trinity Inlet as an ecologically viable and sustainable ecosystem. The Cairns City

Council and several government agencies are responsible for implementing the plan.

- The **Moreton Bay Strategic Plan** provides for the ecologically sustainable use of Moreton Bay and for protecting its natural, recreational, cultural and amenity values. The Plan must be observed by State agencies and local governments but does not include management strategies relating to particular environments, activities or species.
- The purpose of the **Great Sandy Region Management Plan** is to protect natural, cultural and economic values. It identifies four outcomes to be achieved by 2010: a secure future for the natural and cultural environment, a secure community setting for residents, community access to resources and opportunities, and a basis for the sustainable use of renewable resources.

Coastal Protection Advisory Council

The Coastal Protection Advisory Council advises the Minister for Environment and Heritage about aspects of coastal management, including the following issues:

- areas of the coastal zone needing special coastal management;
- coastal plans and their relationship with other plans, prepared by a State agency or local government, for the coastal zone;
- appropriate preventive and remedial measures for coastal management;
- help for local government and other management agencies in applying coastal management techniques;
- public and community programs for coastal management;
- coastal management plans;
- monitoring the integration of coastal management plans; and
- Aboriginal and Torres Strait Islander liaison.

Queensland Acid Sulfate Soils Management Advisory Committee

This advisory committee represents a range of interests and seeks to coordinate acid sulfate soils issues such as awareness, information, advice, research and management options. It works within existing legislation.

Regional strategies

A number of regional strategies that affect the coastal zone have been prepared or are in preparation. These include: South East Queensland 2001 (SEQ 2001), FNQ 2010, Cape York Peninsula Land Use Strategy (CYPLUS), Wide Bay 2020, and the recently commenced projects based in Rockhampton (CQ — the new millennium) and Mackay (WHAM 2015).

These strategies establish a framework for decision making including appropriate policies and actions for guiding the use and development of land in the coastal zone.

Fishing and Fisheries

The *Fisheries Act 1994* provides the current legislative basis for managing and protecting Queensland's fisheries resources. Its objectives include ensuring that fisheries resources are used in an ecologically sustainable way, achieving the optimum community and economic benefits, and ensuring that access to fisheries resources is fair. The Act established the Queensland Fisheries Management Authority (QFMA) and the Queensland Fisheries Policy Council and set their powers and functions.

The QFMA's primary function is to ensure the appropriate management, use, development and protection of fisheries resources. This is to be achieved largely by regulations, management plans and declarations, having regard to the principles of ecologically sustainable development. With the assistance of six management advisory committees, the QFMA is developing a series of fisheries management plans.

Effects of Fishing Program

The Effects of Fishing Program is a multi-project collaborative research program focusing on the effects of trawl, line and gill net fishing in the Great Barrier Reef Marine Park. The primary objective is to gain a greater understanding of the impacts of fishing to ensure ecologically sustainable fishing, the protection of critical habitats and the protection of rare and endangered species. One component of a five-year study involves monitoring the impact on the seabed of trawling at different intensities.

Shark protection

As a result of a growing world trade in shark products, the conservation status of a number of shark species has been of some concern. Taking the grey nurse shark (*Carcharias taurus*) is now banned. The great white shark (*Carcharodon carcharias*) is protected from deliberate targeting, largely by recreational fishers.

National Fisheries Action Program

The National Fisheries Action Program aims to protect and restore fisheries habitats such as mangroves, estuaries and seagrass beds. The program also deals with issues such as aquatic pest control and the development of sustainable fishing practices and management plans. Commonwealth funding of $6 million over five years to 2001–02 has been provided. In 1996–97, 11 grants totalling $102,500 were made for projects in Queensland.

Indigenous Fisheries Strategy

In recognition of the interests of Aboriginal and Torres Strait Islander communities in coastal environments, the Commonwealth is funding development of an Indigenous Fisheries Strategy. This aims to ensure that indigenous fishing and marine resources interests are considered in coastal management. A separate integrated Natural Resources Planning Strategy is being developed to ensure the protection and sustainable use of the Torres Strait region's coastal, marine and cultural values.

Marine Pests

A recent Commonwealth Government initiative involves establishing a pilot community monitoring program aimed at the early detection and eradication of marine pests. The initiative involves Environment Australia, the CSIRO Centre for Research on Introduced Marine Pests, the Australian

Ballast Water Management Advisory Council and the Australian Quarantine Inspection Service (AQIS).

Australian Ballast Water Management Strategy

The Australian Ballast Water Management Strategy provides a framework for dealing with the management of ballast water to reduce the potential for introducing exotic marine organisms to Australian waters. In 1990 AQIS introduced a range of voluntary guidelines with the aim of minimising the potential for exotic introductions. These were subsequently reviewed and an implementation strategy was published in 1997. The Australian National Maritime Association reports that approximately 80 percent of ships entering Australian waters comply with the guidelines.

SHIPPING AND SHIP-SOURCED POLLUTION

The Environmental Policy for Queensland Ports guides port authorities in the operation and responsible environmental management of port areas.

Oil pollution

The National Plan to Combat Pollution of the Sea by Oil came into operation in 1973 and underwent a major review in 1991. Its purpose is to maintain a national capability to respond effectively to oil pollution incidents, in accordance with Australia's obligations under the International Convention on Oil Pollution Preparedness, Response and Co-operation 1990.

Complementary regional contingency plans detail the operational procedures, strategies and actions to be initiated in the event of an oil spill in waters off the Queensland coast. These include REEFPLAN, TORRES PLAN and the Queensland Coastal Contingency Action Plan.

Environmental protection

The Mandatory Ship Reporting System for the Torres Strait and Great Barrier Reef Inner Route aims to improve the safety of shipping operations in the hazardous waters of the Torres Strait and Great Barrier Reef regions.

The Australian and New Zealand Environment and Conservation Council Strategy to Protect the Marine Environment aims to reduce the impacts of shipping operations and enhance protection of the marine environment through improved waste management and reduced pollution from shipping. The Best Practice Guidelines for the Provision of Waste Reception Facilities at Ports, Marinas and Boat Harbours in Australia and New Zealand provide information about planning, establishing and managing waste reception services and facilities.

WATER QUALITY MONITORING

A comprehensive water quality monitoring program, operated by the Environmental Protection Agency, is in place for streams, estuaries and bays from Cooktown south. It covers 200 primary and 200 secondary sites. The aim of the program is to assess compliance with water quality objectives and to measure long-term trends in water quality. The program is limited to physico-chemical indicators of water quality, sampling at all sites being carried out monthly. The importance of biological indicators is recognised and the EPA is actively seeking to develop such indicators for estuaries and bays. Data for 1992–96 have been collated and a comprehensive report on water quality in coastal waters has been published.

Additional site-specific water quality studies are in progress. One study seeks to develop a water quality management strategy for the Brisbane River and Moreton Bay region. The study involves a large program of scientific measurements. Results will be used to develop and calibrate a predictive water quality model.

Another study seeks to assess the level and significance of heavy metal and toxicant contamination in estuaries and inshore coastal areas. In a pilot program, the use of a range of crab species as bio-indicators was assessed. The methodology has been established and monitoring has begun at selected sites.

The bacteriological quality of waters at several major bathing areas in south-east Queensland is monitored over the summer months each year. The work is carried out cooperatively by the EPA and local governments in some areas and by local governments alone in others. Monitoring sites are located in the shires of Noosa, Maroochy and Caboolture, and in the cities of Caloundra, Redcliffe and Gold Coast. The sites include open beaches, river and creek estuaries and waters close to stormwater drain outlets.

Faecal coliform counts are compared with guidelines for primary contact recreation — that is, swimming, surfing, waterskiing and diving.

The monitoring programs generally show that sites in open beach waters are within the guidelines. Sites within estuaries or creeks sometimes fail to comply, while sites in or near stormwater drains regularly fail. Wet weather runoff can adversely affect most sites temporarily except those on open beaches.

COASTAL AND MARINE RESERVES

Marine reserves

One of the most significant institutional responses aimed at protecting certain coastal resources is declaring reserves. Declarations of marine reserves in Queensland's coastal zone are made under three Acts (table 5-41). Several types of reserve are provided for, depending on the level of protection required and the particular resources or attributes to be protected.

The early focus of the reserve system was to protect commercial resources, not representative habitat types. Consequently, the existing marine reserve estate does not reflect the optimum in terms of the representativeness of different habitat types. However, deficiencies in the process of selecting reserves are being dealt with and a more rigorous assessment of conservation needs and priorities is now practised.

The Capricornia Section of the Great Barrier Reef Marine Park was declared in 1979. Other declarations followed. The Great Barrier Reef Marine Park today covers 34 076 800 ha.

Table 5-41 Functions of legislation for declaring marine reserves

Title of Act	Function of Act
Great Barrier Reef Marine Park Act 1975 (Cwlth)	Provides for the protection and conservation of the Great Barrier Reef Marine Park. Provides for the development of zoning plans to regulate use of the marine park.
Marine Parks Act 1982	Provides for the declaration of marine parks over Queensland tidal waters or tidal land and development of zoning plans to regulate use.
Fisheries Act 1994	Provides for the management, use, development and protection of fisheries resources and fish habitats, and for the declaration of fish habitat areas.

By 1998, 79 fish habitat areas covering 603 000 ha had been declared, replacing existing fish habitat and wetland reserves. A progressive expansion is apparent in the area of the marine reserve estate. However, the level of protection afforded to a particular area can differ according to the type of reserve. In addition, depending on provisions of management plans or zoning plans, different areas can be protected to different degrees, ranging from negligible to total protection. Consequently, while the total area of marine reserves has increased in recent years, this does not mean that the level of protection of marine resources has increased correspondingly.

About 80 percent of the Great Barrier Reef Marine Park is zoned 'general use A'. In this zone virtually all activities, including trawling, commercial collecting and line fishing, are permissible. Some activities require a GBRMPA permit. The level of protection provided to marine resources in this zone is thus limited. A further 15 percent of the area is zoned 'general use B', the difference being that trawling is not permitted (see table 5-43).

Marine national park and other zonings which restrict fishing, collecting and other activities potentially affecting marine resources cover the remaining 5 percent of the marine park. Preservation zones, which provide for complete protection, cover 0.12 percent of the marine park area. Such zones are distributed throughout the marine park, usually as isolated single reefs. Of about 100 reefs in the Hardy Reef area of the Central Section, only Jacqueline Reef is zoned as a preservation area.

A different zoning system is used in Queensland marine parks. In the Moreton Bay Marine Park, for example, five zones are defined:

- general use (61 percent, or 343 595 ha);
- habitat zone (27 percent);
- conservation zone (11 percent);
- buffer zone (0.01 percent); and
- protection zone (0.5 percent).

More than 95 percent of marine waters in marine parks remain virtually unprotected from human pressures, commercial fishing being allowed by permit in some protection zones.

When assessing the effectiveness of marine reserves, the level of representation of habitat types in reserves must also be considered. Representation can differ widely. Consequently, an important indicator is the level of representation of different habitat types.

In combination, Queensland and Commonwealth marine parks cover an estimated 25 million ha (42 percent) of the 59 443 000 ha which comprise the total area of Queensland's 14 marine biophysical regions (bioregions). However, representation of the bioregions in marine parks varies widely (table 5-44).

Table 5-42 Queensland marine parks. All fall within IUCN's Category V — protected land/seascapes.

Name	Locality	Area (ha)*	Original gazettal
Cairns	Jeannie River south to Mission Beach/Dunk Island	697 366	18/2/89
Townsville/Whitsunday	Mission Beach/Dunk Island south to Repulse Bay	637 671	3/10/87
Mackay/Capricorn	Repulse Bay south to Broadwater Creek	3 317 372	27/8/88
Hervey Bay	West of Fraser Island	197 758	16/9/89
Woongarra	Between Burnett and Elliot Rivers	10 706	14/12/91
Moreton Bay	North of Bribie Island to south of South Stradbroke Island	343 787	30/1/86

*Areas are approximate and exclude the area of islands within the boundaries.

Table 5-43 Areas of zones in Great Barrier Reef Marine Park sections at April 1999 (km²)

	Far Northern	Cairns	Central	Mackay–Capricorn	Totals/percentages of whole GBRMP
General use A	63 063	25 894	58 181	121 529	268 667 (78.84%)
General use B	10 368	8 342	15 178	19 378	53 266 (15.63%)
Marine National Park A	129	153	668	95	1 045 (0.31%)
Marine National Park buffer	129	358	–	–	487 (0.14%)
Marine National Park B	11 119	631	1 759	1 967	15 476 (4.54%)
Scientific Research	31	–	3	27	61 (0.02%)
Preservation	236	106	49	82	473 (0.14%)
Islands (not zoned)	80	16	841	356	1 293 (0.38%)
Totals	**85 156**	**35 500**	**76 678**	**143 434**	**340 768**

(Source: GBRMPA)

Table 5-44 Representation of Queensland marine bioregions in marine parks

Marine bioregion	Total area (excluding islands) (ha)	Percentage area in Queensland marine parks	Percentage area in all marine parks
Carpentaria	10 833 636	0	0
Central Reef	3 138 893	4.4	100
East Cape York	1 445 810	9.3	83.8
Karumba–Nassau	5 614 000	0	0
Lucinda/Mackay Coast	1 510 224	45.2	100
Mackay/Capricorn	5 491 166	20.7	100
Pompey–Swains	5 637 320	9.3	100
Ribbons	4 781 184	5.1	89.2
Shoalwater Coast	2 030 063	58.9	100
Torres Strait	3 575 000	0	0
Tweed/Moreton	3 364 005	16.8	29
Wellesley	2 164 021	0	0
West Cape York	2 166 300	0	0
Wet Tropic Coast	581 468	46.7	100

The five bioregions located in the Gulf of Carpentaria and Torres Strait are not represented in marine parks, although areas are included in fish habitat areas.

Terrestrial reserves

Many protected areas declared under the *Nature Conservation Act 1992* are in the coastal zone on the mainland and islands. Major national parks along the coast include Jardine River National Park (237 000 ha), Iron Range National Park (34 600 ha), Lakefield National Park (537 000 ha), Cape Melville National Park (137 000 ha), Daintree National Park (76 000 ha), Wooroonooran National Park (79 800 ha), Lumholtz National Park (168 000 ha), Bowling Green Bay National Park (55 400 ha), Conway National Park (22 500 ha), Eurimbula National Park (12 500 ha), Burrum Coast National Park (23 100 ha), and Great Sandy National Park (219 555 ha).

Several hundred Queensland islands are national park. They include Hinchinbrook Island National Park (39 900 ha), Magnetic Island (2790 ha), Gloucester Island National Park (2960 ha), Whitsunday Islands National Park (17 000 ha), and Moreton Island (16 800 ha). See figures 5-11 and 5-12 for location of major coastal protected areas.

Significant additions to the protected area estate have been made in recent years, reflecting a positive response to increasing concern over the conservation status of coastal habitats. Nevertheless, in the context of the size of the coastal zone, the area reserved is small. The five national parks of more than 100 000 ha account for much of the protected area. Consequently, the protected area estate of the coastal zone is characterised by a dozen large national parks and many small to very small national and conservation parks.

The lack of protection of wetland habitats in reserves is particularly evident. While initiatives are under way to improve the conservation status of important wetlands (see below), many of the 83 important coastal wetlands, most notably those of the Gulf of Carpentaria and the central coast between Rockhampton and Mackay, are not protected in reserves.

WETLANDS

The Australian Wetlands Policy, commenced in early 1997, comprises a series of objectives, principles and strategies to guide the Commonwealth Government's actions relating to the 'wise use' of wetlands in Australia, and sets a framework for the Commonwealth Government to work cooperatively with State and Territory Governments. Funding of $1.8 million was provided by the Natural Heritage Trust in 1997–98 and $11 million will be provided until 2001–02 to support locally based efforts to rehabilitate degraded wetlands. The policy covers coastal and inland wetlands.

Five of Queensland's major wetland areas are declared under the Ramsar Convention (see box 'International treaties').

MARINE RESEARCH AND MONITORING

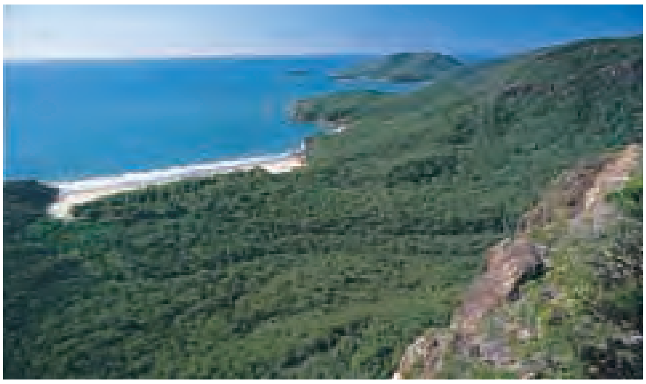
The work of the Australian Institute of Marine Science (AIMS) in Townsville is particularly relevant to the Queensland coastal zone. Research is conducted in the strategic areas of:

- the ocean environment — understanding the circulation of water, nutrients and sediments;
- marine biodiversity — characterising species richness and genetic variety;
- marine living resources — identifying valuable marine organisms;
- ecologically sustainable development — understanding natural changes and human impacts; and
- technological innovation — developing advanced instruments and techniques.

In addition, the Cooperative Research Centres (CRC) Program provides about $12 million a year for marine-related research. The CRC for Ecologically Sustainable Development of the Great Barrier Reef, Townsville, undertakes an integrated program of research and development to expand Reef-based industries and provide information for better science-based management. The CRC, AIMS and GBRMPA are all involved in extensive monitoring programs of the Reef environment.

DATA COLLECTION AND COLLATION

Several initiatives are directed at improving coordination of marine and coastal data and information. Access to data is being enhanced through better electronic management



information systems and databases. These include the development of a coastal atlas and the continuing development of the National Marine Information System, which includes data on all aspects of the marine environment including fisheries, mineral resources, ocean currents and the distribution of marine life. The system will also include a Collaborative Australian Protected Area Database on marine protected areas.

Coral Reefs

In 1996, the Global Coral Reef Monitoring Network was established. Its seven member nations include Australia and the USA. Its inaugural head is Dr Cliff Wilkinson of AIMS, Townsville. The network is monitoring the occurrence of coral bleaching incidents and human-related impacts on coral reefs, including pollution, sedimentation and overfishing.

Great Barrier Reef Marine Park Authority

The *Great Barrier Reef Marine Park Act 1974* (Cwlth) provided for the establishment, control, care and development of the Great Barrier Reef Marine Park and established GBRMPA.

Zoning plans regulate the purpose for which areas of the marine park can be used or entered in accordance with the following objectives:

- conservation of the Great Barrier Reef;
- regulation of use of the marine park to protect the Great Barrier Reef, while allowing the reasonable use of the Great Barrier Reef region;
- regulation of activities that exploit the resources of the Great Barrier Reef region to minimise the effect of those activities on the Great Barrier Reef; and
- preservation of some areas of the Great Barrier Reef in their natural state undisturbed except for the purposes of scientific research.

Marine Conservation Strategy

A Queensland Marine Protected Areas Strategy is being prepared. A policy framework is to be developed for finalisation in 1999. The strategy will include proposals for a comprehensive system of marine protected areas for the whole of Queensland. This process will link with Commonwealth Government initiatives for a national system of marine protected areas by the year 2000.

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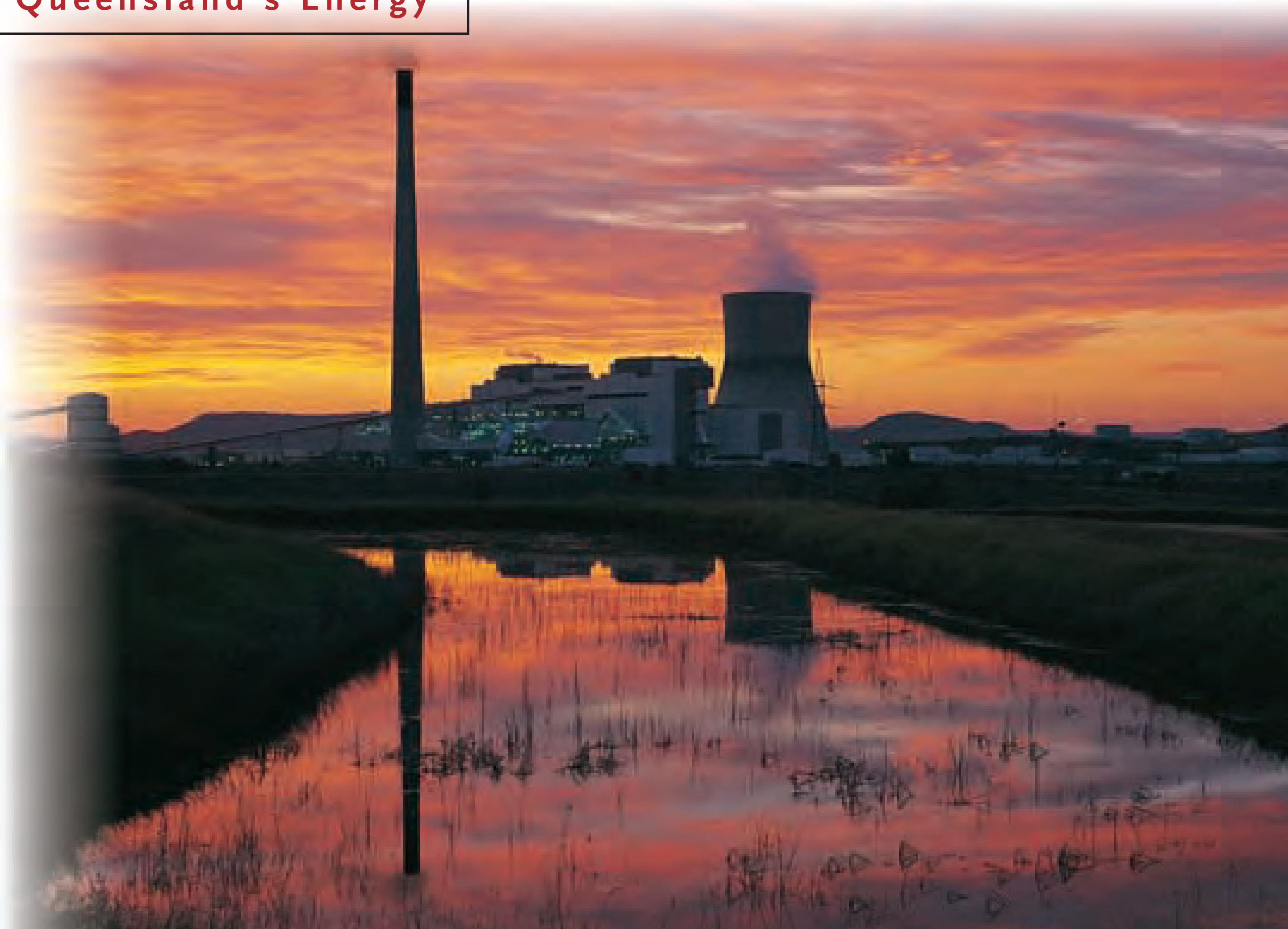
CHAPTER 6

QUEENSLAND'S ENERGY

Queensland's Energy



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CONTENTS

Key issues and findings

Queensland is a resource-rich State with extensive coal and oil shale reserves. Coal supports a major export industry and the State's electricity generation system. In contrast, the State has modest reserves of crude oil and natural gas. The State's transport sector depends almost entirely on energy refined from imported crude oil.

Queensland's energy requirements are based almost entirely on non-renewable coal, oil and natural gas. Energy consumption is increasing steadily, with a consequent decline in energy resources. Queensland's large area and dispersed and rapidly growing population contribute to increasing energy demands.

Queensland's reliance on non-renewable energy resources to meet its energy requirements has been challenged by recent international agreements and national strategies designed to reduce greenhouse gas emissions. There is a need to move towards more efficient use of non-renewable energy and the use of renewable energy.

While non-renewable energy resources are being depleted, when resources will be exhausted cannot be forecast with any reliability due to the discovery of new reserves, technological advances and changing consumption rates.

- Queensland's estimated 34.2 billion tonnes of coal account for 99 percent of the State's non-renewable fossil fuel reserves, excluding oil shale. Of the 18 million tonnes used annually, 85 percent is used for electricity generation. Queensland's total reserves of coal are equivalent to about 350 times current annual production. However, only about one-third of reserves could prove to be economically recoverable.
- State crude oil reserves and production have been declining since the late 1980s. Even when oil production peaked around 1987, production was equivalent to less than 30 percent of Queensland's consumption of oil products. By 1995 oil production had declined, consumption of oil products had increased, and the State's overall self-sufficiency in oil products fell to 11 percent. Queensland is becoming progressively more reliant on imported oil.
- Queensland has substantial oil shale resources, equivalent to 4717 gigalitres of oil.
- Estimated proven and probable natural gas reserves at June 1995 were 56.5 billion cubic metres, representing an increase of almost 48 percent since 1989. Substantial new natural gas reserves have been discovered in south-west Queensland in recent years.
- Reserves of coal seam methane in the Bowen Basin are potentially enormous; a preliminary estimate places reserves at 4000 billion cubic metres. In 1996–97, 36 coal seam gas wells were drilled and 29 gas discoveries were made.
- Significant sources of renewable energy available in Queensland include solar, wind, biomass and biogas. Although renewable energy sources currently meet only a small portion of Queensland's energy needs, they could be important in the long term in reducing the State's dependence on fossil fuels.
- Queensland's per capita energy consumption, at 286.1 gigajoules (GJ) in 1995–96, was high relative to the Australian average (269.4 GJ). The State's annual energy consumption increased by more than 360 petajoules between 1980–81 and 1995–96.
- Domestic demand for coal rose from 7.1 to 18 million tonnes a year between 1980 and 1997. Coal consumption grew by 31 percent between 1990 and 1996. Coal exports, primarily to Japan, increased from 45 million tonnes in 1984–85 to 79 million tonnes in 1996–97. To meet domestic consumption and exports, production of raw coal rose from 84.6 million tonnes in 1987–88 to 128.9 million tonnes in 1996–97.
- Consumption of electricity rose from 74 petajoules in 1985 to 122 petajoules in 1995, an increase of 65 percent. Installed electricity generating capacity is about 7500 megawatts, 97 percent of which is coal-based. Coal-fired generating plants will continue to provide most of the State's electrical energy needs for the foreseeable future.
- Consumption of petrol in 1995–96 was approximately 3600 megalitres, an increase of 850 megalitres since 1985–86, with a significant shift towards the use of unleaded petrol. Consumption of diesel fuel increased by almost 39 percent over the same period and sales of motor spirit (petrol) increased by 28 percent. Local production of crude oil meets less than 10 percent of the State's annual demand for oil products, which totals about 8800 megalitres.
- Consumption of natural gas has more than doubled in the last decade and this is likely to increase as new applications develop. Since the 1990s the availability of natural gas has increased greatly due to pipeline extensions, with corresponding rises in gas production. However, there has been a parallel rise in demand for natural gas.
- Energy production and consumption are the most significant sources of greenhouse gas emissions in Australia. The National Greenhouse Strategy was developed to meet Australia's commitments to limit greenhouse gas emissions. This is being achieved through market reforms, improving the economic efficiency of energy supply and use and the promotion of renewable energy technologies.
- In December 1998 the Queensland Government established the Office of Sustainable Energy. Its functions include the provision of information on energy efficiency and renewable energy, and facilitation of increased commercial application of sustainable energy technologies. Key initiatives include the Solar Hot Water Rebate Scheme, an energy efficiency advisory service (energyWise), the Householder Remote Area Power Rebate, the Sustainable Energy Innovation Fund and funding of advanced bagasse technology development.

Pressure

Production and consumption of non-renewable energy resources

Production of oil, compared with total consumption of oil products

Total annual production of natural gas

Total annual consumption of natural gas

Total annual production of raw coal

Total annual consumption of raw coal

Total electrical energy consumed

State

Reserves of non-renewable resources

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INTRODUCTION

Energy plays a vital role in all aspects of modern society, driving those processes and activities that underpin living standards and generate material wealth. In Queensland, the energy requirements of an expanding industrial base and a growing population are met through a well-developed energy infrastructure based almost entirely on non-renewable sources of energy — coal, oil and gas.

NON-RENEWABLE ENERGY RESOURCES

In Queensland, the predominant energy resource is coal, which accounts for 99 percent of the State's non-renewable fossil fuel reserves excluding oil shale. Queensland's coal resources are estimated at 34.2 billion tonnes. Of the 18 million tonnes of coal used annually in Queensland, 85 percent is used for electricity generation.

Over 97 percent of total electricity generated in Queensland comes from coal. Electricity generation infrastructure is based mostly on coal-fired power stations; only minor contributions come from hydro-electric, natural gas and diesel generators in remote townships.

Industrial use and transport are the main end uses of energy resources. Queensland's mineral processing industries are on a world scale and are highly energy-intensive. Industrial and commercial applications account for 70 percent of electricity consumption, 96 percent of natural gas consumption and virtually all coal used directly in Queensland.

A significant part of electricity production is used to produce alumina and aluminium, much of which is exported. The majority of energy produced at Gladstone power station is used to meet the requirements of the Comalco alumina refinery and the Boyne Island aluminium smelter (see table 6-1).

Queensland depends largely on crude oil imported from overseas and interstate. Local reserves of crude oil have never been significant, and production has been declining steadily during the past decade. Local production is sufficient to supply less than 10 percent of Queensland's annual demand for oil products, which totals about 8800 ML. Known reserves of crude oil and condensate are equivalent to only about one year's consumption of oil products.

The State's transport sector operates almost exclusively on oil products, and accounts for the predominant share of oil product consumption (figure 6-1). The only significant transport applications that do not depend entirely on

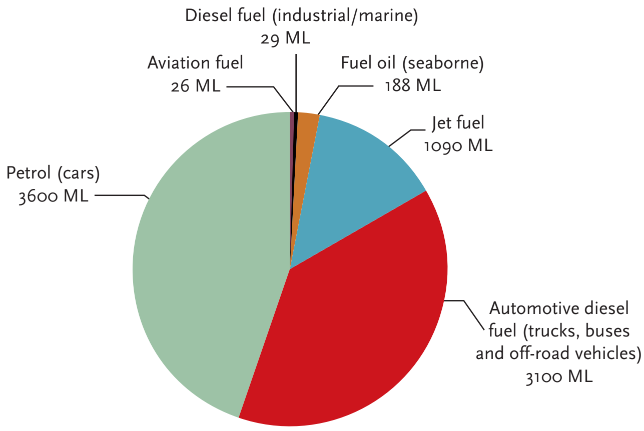

Figure 6-1 Use of oil products by Queensland's transport sector
(Source: AIP 1997)

Table 6-1 Major electricity generating stations in Queensland, with their capacities (megawatts), energy sources and operators

Major generating station	Capacity (MW)	Energy source	Operator
Gladstone power station	1650	coal	Comalco/NRG
Tarong power station	1415	coal	Tarong Energy
Swanbank power station	908	coal	CS Energy
Callide A power station	120	coal	CS Energy
Callide B power station	700	coal	CS Energy
Collinsville power station	180	coal	NRG Australia
Stanwell power station	1400	coal	Stanwell Corp.
Mica Creek power station	198	coal*	MIM/CS Energy
Kareeya power station	72	hydro-electric	Stanwell Corp.
Barron Gorge power station	60	hydro-electric	Stanwell Corp.
Queensland Alumina	25	co-generation (coal)	QAL
Sugar mills	194	co-generation (bagasse)	sugar mills
Wivenhoe pumped storage	500	hydro-electric (storage only)	Tarong Energy
Barcaldine gas turbine	37	natural gas	Energy Equity

* Mica Creek Power Station is being converted to operate on natural gas.
Note: In May 1998, Tarong Energy, MIM Holdings and Energy Corporation announced plans to expand the Tarong power station by 800–850 MW and to build a 750 MW power station at Wandoan. CS Energy and Shell Coal announced plans to build two 420 MW generators next to the existing Callide power stations.
(Source: ESAA 1997)

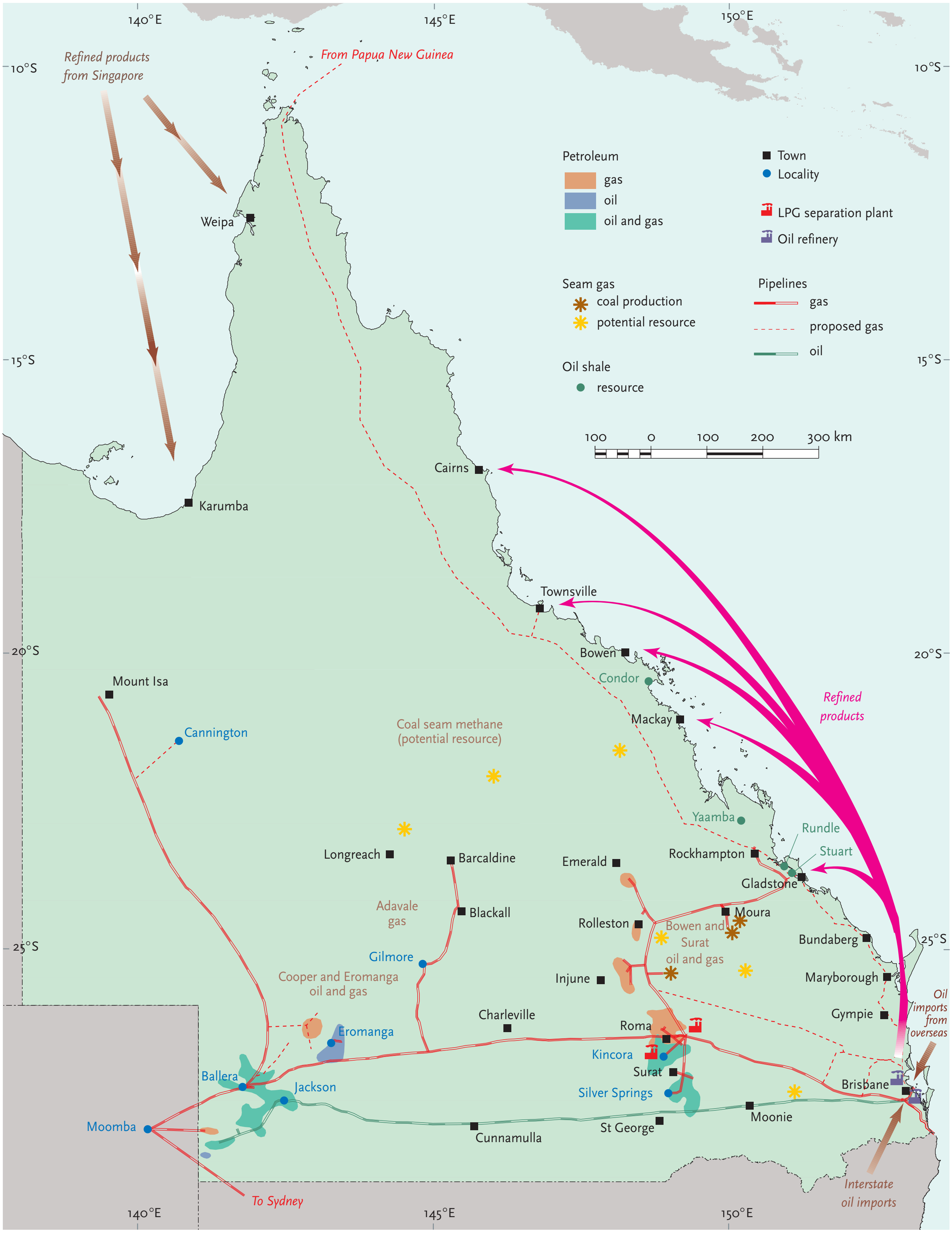

Figure 6-2 Sources and distribution of petroleum products in Queensland
(Source: DME)

oil products are electrified railways including coal export trains, vehicles operating on LPG and bicycles.

Natural gas is used primarily as an industrial fuel. Until the 1990s, availability of natural gas was geographically restricted to Brisbane and along the pipeline corridor from Roma, and consumption was relatively limited. However, new pipelines have greatly extended the availability of natural gas, and production and consumption have risen accordingly. During 1989 the pipeline distribution system was extended to Gladstone, and then to Rockhampton. In 1997, a pipeline was built linking gas consumers to reserves in the Cooper and Eromanga Basins in south-west Queensland, to provide the growing pipeline distribution system with significant new reserves. In the same year, a pipeline was built to supply natural gas from south-west Queensland to Mount Isa.

Substantial amounts of natural gas are used for fertiliser production by Incitec, for alumina refining by Queensland Alumina Limited and for production of magnesia by Orica Australia. The Mount Isa pipeline will supply natural gas for the Mica Creek power station and for mineral processing. Other companies are expected to use natural gas for electricity generation, possibly transporting natural gas by pipeline from Papua New Guinea (see figure 6-2).

Fossil fuels are considered primary energy sources. When primary energy sources are used to provide heat, as much as 100 percent of the energy content of the fuel can be converted to heat energy. However, only a fraction of the heat energy can be converted into mechanical power which can turn an electrical generator. Conversion of heat into mechanical power is inherently inefficient. Most engines can convert only about one-third of the fuel energy into mechanical power and then into electricity. The rest is dissipated as waste heat.

Electricity is a derived form of energy. Like primary energy sources, electricity can be converted to heat with nearly 100 percent efficiency. There is no inherent limitation restricting conversion of electricity to mechanical power (or any other type of energy): in principle, as much as 100 percent of electrical energy can be converted to mechanical power, light, sound or chemical energy. In practice, electric motors have some efficiency losses due mainly to friction and air resistance, so that about 80–90 percent of electrical energy input is converted to mechanical power.

Queensland Rail

Queensland's electrified rail network is one of only a few transport applications not dependent entirely on oil products.

Stanwell Corporation

When operating at full load, Stanwell power station burns about 4 million tonnes of coal a year.

Wind generator at Mount Mee, near Brisbane

RENEWABLE ENERGY RESOURCES

Renewable energy resources are those that are continually being produced and replenished. Renewable energy resources are essentially inexhaustible. Queensland potentially has significant renewable energy resources. Prominent among them are:

- hydro-electricity — electricity produced from flowing water, ultimately derived from solar energy;
- solar energy — heat or electricity produced from sunlight;
- wind energy, originating from sunlight on the Earth's surface;
- biomass — plant matter whose energy is derived from sunlight by photosynthesis;
- geothermal energy, derived from heat produced by radioactive decay deep within the Earth;
- tidal energy, ultimately derived from the motion of the Moon orbiting the Earth; and
- wave energy, which is sustained by wind energy.

Student at Renewable Energy Centre, Brisbane, with photovoltaic cells

Hydro-electricity is the main renewable energy resource being used commercially in Queensland. In 1995–96 the Kareeya and Barron Gorge power stations accounted for 880 000 megawatt hours (MW h), or about 2.6 percent of the total electrical energy generated in the State.

Solar radiation received over Queensland is a potentially huge energy resource. Most areas have clear weather during much of the year. Each hectare of land receives enough sunlight to generate about 4000 MW h of electricity each year. An area of 70 km^2, roughly equivalent to the roof area of all houses in Queensland, could meet the State's entire electrical energy requirements.

Wind energy is also a large, widely distributed resource. Wind velocity and availability throughout the year depend markedly on the particular site. Islands and coastal areas are the best prospective sites for commercial wind generation, although wind power is considered a viable alternative to diesel generation for many inland areas.

The fibrous residue of sugarcane processing, known as bagasse, is potentially an important fuel for electricity generation. Most sugar mills use bagasse to generate steam and electricity, with 194 MW of generating capacity installed in Queensland. However, sugar mill boilers have been designed mainly to dispose of the bagasse so that this electricity generation is generally inefficient, mills operating to optimise sugar production rather than maximise electricity generation.

Geothermal energy, tidal energy and wave energy are not yet being used commercially in Queensland.

SCOPE

This chapter considers Queensland's energy resources, the pressures on and status of these resources, the State's requirements for energy, and society's responses to the changing status of resource stocks. The chapter also discusses the potential for further exploitation of the State's vast renewable energy resources.

ENERGY CONSUMPTION

Energy-intensive industries account for a major share of Queensland's requirements for electricity, coal and natural gas. These include alumina refining, mining and mineral processing, fertiliser production and agriculture. Much of the output of these industries (and, in effect, much of the energy used) is exported. Further, the State's large size and dispersed population lead to high use of transport fuel. These factors contribute to an overall level of energy consumption which is very high by Australian and international standards. Accordingly, Queensland's fossil energy resources are under considerable pressure.

In 1995–96, Queensland's energy consumption per capita was 286.1 gigajoules (GJ). This exceeded the Australian average for the same period (269.4 GJ). Queensland's total annual energy consumption increased from about 500 petajoules (PJ) in 1980–81 to about 860 PJ in 1995–96 (figure 6-3). This represented 19.2 percent of Australia's total energy consumption (ABARE 1997). Table 6-2 shows energy consumption by sector.

A rapidly growing population, changing lifestyles and rising living standards are also causing energy demand to rise. For example, central air conditioning is now considered normal and is expected in shopping centres, public facilities and offices, and is increasingly being promoted to householders. As a result, electricity demand reaches a peak on hot summer days. Until recently, peak electricity demand occurred on winter evenings when heaters were used.

Energy consumption affects the environment in two main ways:

- combustion of fossil fuels releases pollution and greenhouse gases into the atmosphere, producing local, regional and global effects (see chapter 2, 'Atmosphere', for details); and
- consumption of non-renewable fossil fuels depletes finite resources, potentially depriving future generations of the most accessible and low-cost sources of energy and petrochemicals.

Many secondary impacts result from production, refining, transport and use of energy resources:

- production of energy resources, coalmining in particular, affects land use and water catchments (see chapter 3, 'Land', and chapter 4, 'Inland waters');

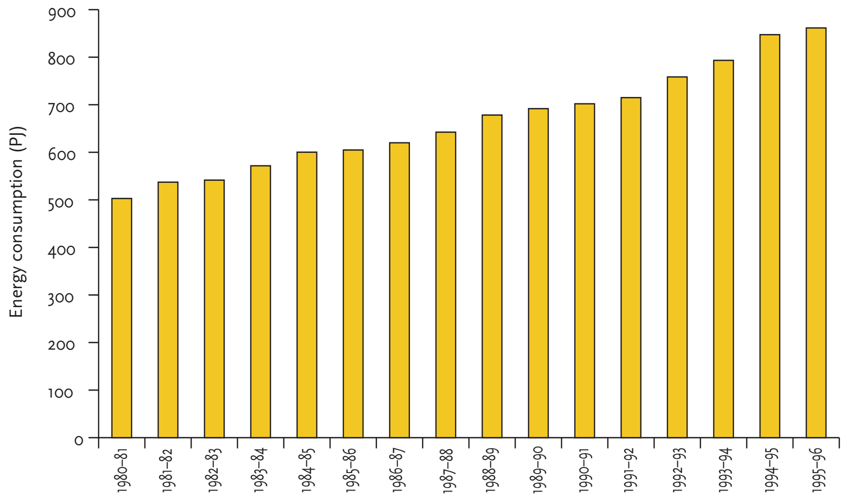

Figure 6-3 Total annual energy consumption in Queensland, 1980–81 to 1995–96
(Source: ABARE 1997)

Table 6-2 Energy consumption (petajoules) in Queensland by sector, 1984–85 to 1995–96

Year	Agriculture	Mining	Manufacturing	Electricity generation	Construction	Transport and storage	Commercial	Residential	Other	Total
1984–85	17.4	14.0	192.9	159.0	9.0	155.9	14.6	28.0	9.5	600.3
1985–86	17.4	15.1	191.0	156.2	10.0	160.5	16.3	28.6	9.8	604.8
1986–87	17.9	16.9	196.8	156.7	10.2	164.8	17.7	29.2	9.8	620.0
1987–88	17.8	18.5	202.4	158.2	13.0	172.8	19.2	30.4	10.0	642.4
1988–89	18.1	19.8	213.4	165.0	13.3	185.5	21.0	31.5	10.6	678.3
1989–90	17.6	20.9	213.6	171.0	13.6	188.7	22.0	33.4	11.0	691.8
1990–91	18.1	21.7	213.8	175.3	12.7	191.7	23.2	34.5	10.9	702.0
1991–92	18.5	23.4	206.1	185.9	13.6	197.4	24.2	35.4	10.5	715.0
1992–93	19.3	25.7	220.6	198.6	14.1	206.3	25.1	37.3	11.6	758.5
1993–94	19.8	27.5	235.2	201.0	14.8	218.0	26.2	38.2	12.5	793.2
1994–95	20.4	29.3	245.2	218.5	15.6	236.8	28.8	39.5	13.3	847.3
1995–96	20.9	30.6	242.3	228.3	16.4	240.1	29.8	39.8	13.3	861.5

(Source: ABARE 1997)

- transport of energy resources and refined products presents the hazards of spills and contamination of waterways (see chapter 5, 'Coastal zone'); and
- production and processing of coal produce waste by-products (coal washery reject and gas), the disposal of which can present the significant environmental hazards of fire, air pollution and watercourse contamination.

Energy plays a vital role in modern society, and the export of energy resources — principally coal — makes a major contribution to the State's economy. Queensland industries want the cheapest possible source of energy supplies, and consumers can exert downward pressure on energy prices in an increasingly competitive market. However, low energy prices could undermine initiatives to adopt more efficient energy technologies and practices.

Adoption of new technologies is crucial if Australia is to moderate growth in energy consumption and greenhouse gas emissions, and if Australian industries are to withstand overseas competition when unlimited access to cheap energy is no longer available.

DEPLETION OF NON-RENEWABLE ENERGY RESOURCES

The least expensive energy resources to exploit are generally those that are most accessible to existing markets and facilities, and most readily recovered using existing technology. Unless geographically and technologically accessible major new resources are discovered, the cost of recovering existing resources is likely to rise.

Oil and petroleum products

Petroleum comprises a series of hydrocarbon compounds. The first compounds are methane (CH_4) and ethane (C_2H_6). Methane and ethane are gaseous, and remain so even when compressed to high pressure. These are the primary components of natural gas.

The next two compounds are propane (C_3H_8) and butane (C_4H_{10}). These compounds are gases at normal atmospheric temperature and pressure, but can be easily liquefied by compression to high pressure. These compounds comprise liquefied petroleum gas (LPG). Propane and butane are also produced during refining of crude oil, providing an alternative source of LPG.

LPG is used as a transport fuel for cars (especially taxis), light commercial vehicles, buses and trucks, and for a wide range of domestic and commercial applications where bottled gas is required. Consumption of LPG has grown steadily in Queensland over recent years, particularly in the transport sector (see figure 6-8). Production of LPG has expanded rapidly in Queensland in the past few years.

Natural gas consists mainly of methane, but can also contain other light hydrocarbons. It can also contain the heavier hydrocarbon compounds pentane (C_5H_{12}) and hexane (C_6H_{14}). These compounds are liquid at atmospheric pressure and room temperature, but evaporate readily and have low boiling points. Pentane and hexane are used as constituents of motor spirit (petrol), especially in winter because their high volatility aids starting in cold weather. These compounds are called condensate.

Liquid hydrocarbons are the most commonly used transport fuels since they can be stored conveniently in fuel tanks. By far the most important resource for the production of transport fuels is crude oil. However, condensate can be added as a component of motor spirit, and LPG (stored as a liquid in pressurised tanks) is also used as motor fuel.

Consumption of petrol in Queensland increased steadily between 1985–86 and 1995–96 (figure 6-4). Since 1986, when the use of unleaded petrol was made compulsory for new cars, the use of leaded petrol has been declining as older vehicles are gradually replaced.

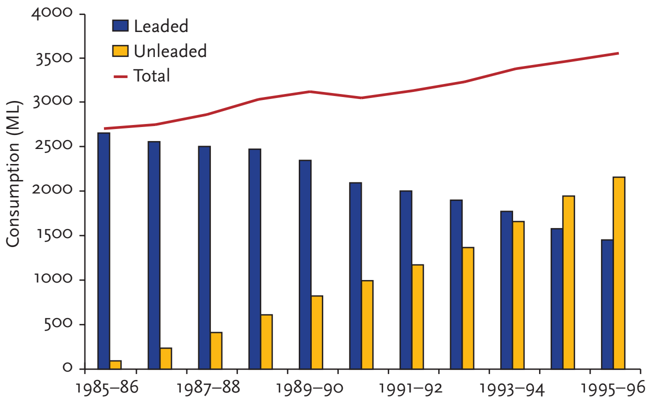

Figure 6-4 Consumption of petrol in Queensland, 1985–86 to 1995–96
(Source: ABARE 1997)

Indicators

Production of oil, compared with total consumption of oil products

Total annual production of natural gas

Total annual consumption of natural gas

Queensland's crude oil reserves and production have been declining since the late 1980s (see figure 6-5). Even when oil production peaked around 1987, it was equivalent to less than 30 percent of total consumption of oil products. By 1995, oil production had declined, consumption of oil products had

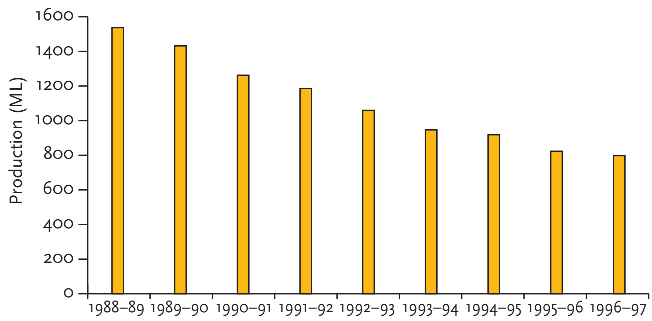

Figure 6-5 Crude oil production in Queensland, 1988–89 to 1996–97
(Source: DME)

Table 6-3 Queensland imports of petroleum (megalitres) by type, 1988–89 to 1995–96

Year	Crude	Other refinery feedstock	Petrol	Automotive diesel oil	LPG	Aviation turbine fuel	Other	Total imports
1988–89	1053.9	62.4	113.5	169.1	5.3	15.1	165.5	1584.9
1989–90	1016.2	517.0	34.6	150.6	12.3	12.8	103.2	1846.6
1990–91	2596.7	295.8	71.6	69.2	35.6	40.4	71.4	3180.8
1991–92	3113.7	12.8	89.2	38.0	36.7	14.6	77.6	3382.6
1992–93	3380.9	133.1	54.9	67.3	67.4	2.4	114.4	3820.4
1993–94	4625.6	300.9	16.3	186.5	58.5	34.8	113.6	5336.1
1994–95	4068.4	598.8	29.2	257.5	104.0	126.2	119.9	5304.1
1995–96	6236.0	439.5	16.1	88.4	134.6	38.5	138.0	7091.1

(Source: ABARE 1997)

CALTEX/AMPOL

Ampol oil refinery at Lytton

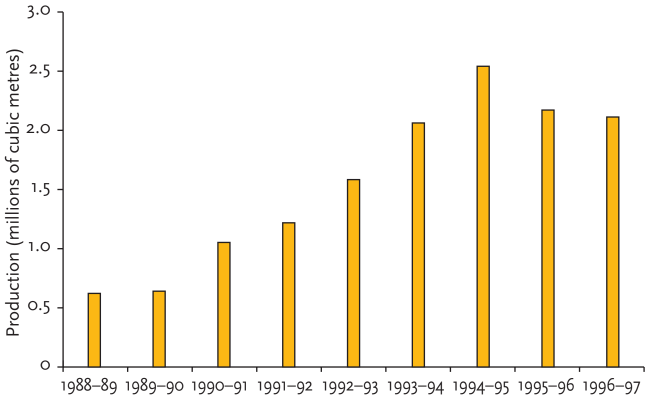

Figure 6-6 Wellhead gas production in Queensland, 1988–89 to 1996–97
(Source: DME)

increased, and the State's overall self-sufficiency in oil products had fallen to 11 percent. The trend in declining oil reserves and production is expected to continue, because recent discoveries of oil are failing to keep pace with production. Accordingly, Queensland is expected to become progressively more reliant on imported oil.

Australian oil production is currently 535 000 barrels (about 84 ML) a day, equivalent to about 70 percent of the nation's consumption of petroleum products. Australia contains only 0.2 percent of the world's known reserves of conventional crude oil.

Because crude oil production is insufficient to meet demand, Queensland imports significant quantities of crude oil and other refinery feedstocks (see table 6-3). Imported and local sources of crude oil are refined at the BP and Ampol refineries in Brisbane, which meet most of Queensland's requirements for refined oil products.

Past predictions of oil reserve depletion have proven premature because more reserves have been discovered, recovery rates have improved, and technological innovation has increased efficiency and reduced consumption growth. Meanwhile, sales of motor vehicles, appliances and energy-consuming services continue to grow.

Whether huge amounts of energy will still be required for transport, goods and services in the future is open to question. The main issue is how and when oil-based transport fuels will be replaced or phased out — by using renewable or alternative fossil fuels, or by changing lifestyles in the twenty-first century.

Substantial new natural gas reserves have been discovered in south-west Queensland, Papua New Guinea and the Timor

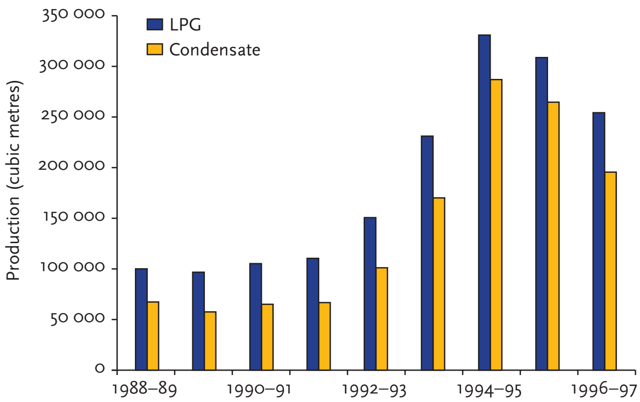

Figure 6-7 LPG and condensate production in Queensland, 1988–89 to 1996–97
(Sources: DME; ABARE 1997)

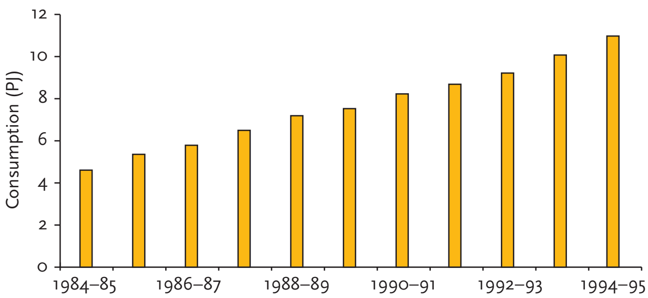

Figure 6-8 Queensland consumption of LPG, 1984–85 to 1994–95
(Source: ABARE 1997)

Table 6-4 Queensland natural gas consumption (petajoules) by sector, 1984–85 to 1994–95

Year	Manufacturing	Mining	Electricity generation	Transport and storage	Commercial	Household	Gas production	Total
1984–85	14.35	1.00	0.63	0.53	0.29	0.63	1.47	18.90
1985–86	14.46	1.40	0.50	0.66	0.30	0.61	1.56	19.49
1986–87	14.83	1.47	0.04	0.72	0.34	0.61	1.78	19.79
1987–88	17.71	2.23	0.03	0.76	0.42	0.72	1.60	23.47
1988–89	15.86	1.98	0.03	0.84	0.43	0.73	1.48	21.35
1989–90	16.42	1.81	0.05	0.90	0.44	0.73	1.51	21.86
1990–91	31.41	1.74	0.05	0.98	0.45	0.74	1.54	36.91
1991–92	32.33	2.88	0.05	1.04	0.47	0.72	1.52	39.01
1992–93	31.78	3.67	0.05	1.08	0.51	0.71	1.45	39.25
1993–94	35.66	4.76	0.05	0.83	0.52	0.70	1.50	44.02
1994–95	36.05	4.86	0.05	0.73	0.47	0.67	1.46	44.29

(Source: ABARE 1997)

Sea in recent years, and considerable scope remains for new gas reserves to be discovered and developed (see figures 6-6 and 6-7). Meanwhile, consumption of LPG more than doubled in the period 1984–85 to 1994–95 (see figure 6-8), and major new applications for gas are expected to develop soon.

Consumption of natural gas in Queensland has risen significantly, from approximately 19 PJ in 1984–85 to 44 PJ in 1994–95 (see table 6-4).

Coal

Indicators

Total annual production of raw coal

Total annual consumption of raw coal

Queensland's coal reserves (measured and indicated) are estimated to be 34.2 billion tonnes, or equivalent to about 350 times current annual production. However, this does not necessarily mean production can be sustained for 350 years. Recovery of only a fraction, perhaps one-third, of reserves will prove to be economically and technologically feasible. Further, production rates cannot be projected decades into the future with a high degree of reliability. It would have been difficult to foresee in 1977 that Queensland's coal production would quadruple within 20 years. If coal production continues to expand by 4 percent annually, as it has in the past decade, output will quadruple again by the year 2030.

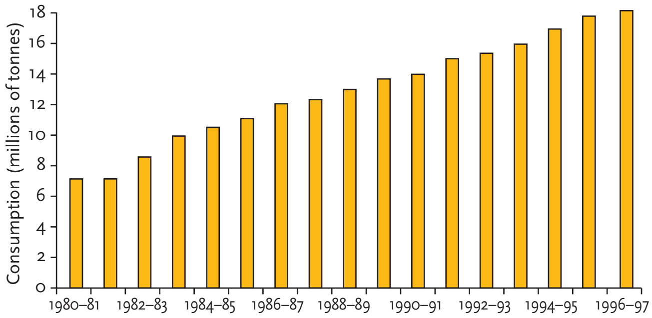

Figure 6-9 Queensland's domestic consumption of coal, 1980–81 to 1996–97
(Sources: ABARE 1997; QCB)

Domestic consumption and exports have created demands for production, processing and transport of coal on a huge scale. Production of raw coal increased from 84.6 million tonnes in 1987–88 to 128.9 million tonnes in 1996–97 (table 6-5).

Domestic demand for coal has grown strongly since the 1950s, reflecting population growth and electricity use. Between 1980 and 1997 coal consumption rose from 7.1 to 18 million tonnes a year (see table 6-6 and figure 6-9). Increasing domestic coal consumption reflected growth in the use of electricity. Coal consumption for electricity generation grew by 31 percent between 1990 and 1996. Queensland also supplies coal interstate (mainly coking coal), although the amounts involved are relatively small (250 000–500 000 tonnes per year).

Table 6-5 Queensland production of raw and saleable coal (millions of tonnes), 1987–88 to 1996–97

Year	Raw coal production			Saleable coal production			
	Underground	Open-cut	Total	Underground	Open-cut	Tailings recovery	Total
1987–88	4.640	80.012	84.652	3.369	62.450	–	65.819
1988–89	5.531	89.950	95.481	4.011	70.107	–	74.118
1989–90	7.336	87.960	95.296	5.758	69.172	–	74.930
1990–91	8.624	91.270	99.894	6.676	71.148	0.538	78.362
1991–92	9.826	98.495	108.321	7.651	75.922	0.510	84.083
1992–93	10.696	100.238	110.934	8.484	76.566	0.250	85.300
1993–94	13.119	98.005	111.124	9.880	75.855	0.003	85.738
1994–95	16.506	103.463	119.969	12.620	81.867	0.008	94.495
1995–96	13.584	106.656	120.240	10.432	83.330	–	93.762
1996–97	18.161	110.753	128.914	13.074	86.362	–	99.437

(Source: QCB)

Table 6-6 Queensland domestic coal consumption (millions of tonnes) by sector, 1990–91 to 1996–97

Year	Electricity	Metal processing	Building and materials	Paper pulp, board and wood products	Chemical and coke works	Food processing	Others	Total
1990–91	11.5	1.57	0.24	0.086	0.081	0.15	0.23	13.87
1991–92	12.4	1.67	0.23	0.092	0.079	0.15	0.24	14.89
1992–93	12.7	1.69	0.24	0.080	0.067	0.17	0.24	15.24
1993–94	13.4	1.70	0.25	0.083	0.045	0.20	0.19	15.83
1994–95	14.2	1.73	0.24	0.084	0.067	0.22	0.25	16.81
1995–96	15.1	1.64	0.22	0.085	0.066	0.27	0.24	17.65
1996–97	15.4	1.73	0.25	0.100	0.067	0.27	0.25	18.01

(Source: QCB)

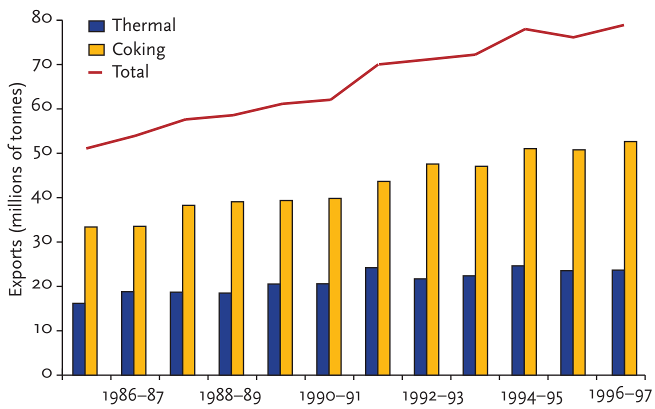

Figure 6-10 Queensland coal exports by type, 1985–86 to 1996–97
(Source: QCB)

Mount Isa Mines Ltd

Open-cut mine, Newlands Coal, central Queensland

In the early 1960s Queensland began exporting coal to Japan, and coal exports grew rapidly. While Japan is still the largest customer for Queensland coal, many other countries bought coal from Queensland during the past decade. Exports of coking coal (for steel production) and thermal coal (mainly for electricity generation) increased from 51 million tonnes in 1985–86 to 79 million tonnes in 1996–97 (see figure 6-10).

Electricity

Indicator

Total electrical energy consumed

Electricity plays a vital role in Queensland's industrial, commercial, agricultural, mining and household sectors. Electricity, derived from primary energy sources, provides a versatile and convenient form of energy that can be used for lighting, heating, cooling, motive power and communications. The convenience and versatility of electricity have led to a steady rise in its consumption in all sectors. Across Queensland, consumption rose from 74 PJ in 1984–85 to 122 PJ in 1994–95, an increase of 65 percent.

Queensland's total installed generating capacity is about 7500 MW. This is based overwhelmingly on coal, which accounts for 97 percent of electricity produced. Converting coal (or any fuel) into electricity, however, involves a considerable loss of energy as waste heat (figure 6-11).

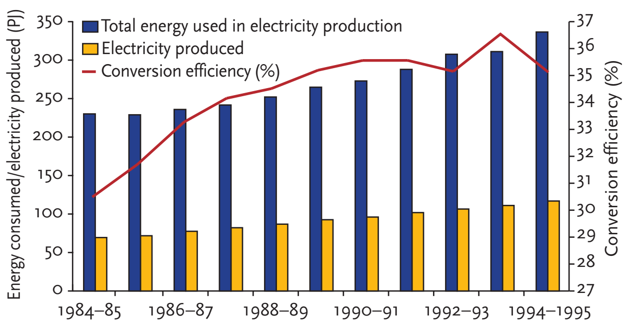

Figure 6-11 Total energy used to produce electricity, electrical energy produced, and percentage conversion efficiency, 1984–85 to 1994–95
(Source: DME)

NON-RENEWABLE RESOURCES

The status of energy reserves, production, consumption and exports varies greatly for the different types of energy resources that are important to Queensland's economy.

Coal

Indicators

Reserves of coal (measured and indicated)

Estimated recoverable reserves of coal

Queensland has coal reserves of approximately 34.2 billion tonnes (measured and indicated). Commercially significant reserves are restricted to deposits laid down in the Jurassic, Triassic and Permian ages, with the Permian accounting for approximately 80 percent of deposits (DME 1998). Of the Permian coal basins, by far the most important is the Bowen Basin in central Queensland. It contains almost all the reserves of coking coal (see table 6-7 and figure 6-12).

Reserves may not be recoverable, for economic or technical reasons. For example, recovery of coal resources contained in thin seams or located at great depth may not be economically feasible. 'Raw coal' often contains substantial amounts of ash-forming minerals which must be removed by washing to meet customers' specifications. Only about three-quarters of raw coal produced is used in saleable coal products.

Petroleum

Indicator

Proven reserves of crude oil, condensate and LPG

Queensland's total petroleum reserves comprise crude oil, condensate and LPG. Proven and probable remaining reserves of recoverable liquid petroleum at 30 June 1995 totalled 14 060 ML, consisting of 4114 ML of crude oil, 4130 ML of condensate and 5816 ML of LPG.

Queensland's total reserves of oil, condensate and LPG have increased since 1989, mainly because of successful exploration and development of gas resources containing a substantial content of condensate and LPG. However, crude oil reserves and production have been declining since the late 1980s.

Queensland's known petroleum reserves occur in four main geological and geographic regions — the Bowen and Surat Basins and environs in the St George–Roma–Moonie region of south-east Queensland; the Bowen and Surat Basins in the Denison Trough region between Injune and Emerald; the Cooper and Eromanga Basins and environs in far south-west Queensland; and the Adavale Basin south-west of Blackall (see table 6-8). Other regions including offshore have potential for further discoveries, although environmental concerns currently prevent offshore exploration.

Table 6-8 Liquid petroleum reserves (megalitres) at 30 June 1995

Region	Oil	Condensate	LPG
Cooper and Eromanga Basins	3 815	3 795	5 409
Bowen and Surat Basins	299	335	407
Total	**4 114**	**4 130**	**5 816**

(Source: DME)

Table 6-7 Proven black coal resources (millions of tonnes) by type and by basin in Queensland, 1994

Basin	Coking coal		Thermal coal		Total reserves
	Open-cut	Underground	Open-cut	Underground	
Bowen	2 564	10 451	2 689	9 075	24 779
Galilee	–	–	2 585	–	2 585
Callide	–	–	203	553	756
Ipswich	–	–	4	569	573
Moreton	–	–	2 201	6	2 207
Mulgildie	–	–	110	–	110
Surat	–	–	2 650	–	2 650
Styx	–	–	–	4	4
Tarong	–	–	411	–	411
Laura	–	157	–	–	157
Total	**2 564**	**10 608**	**10 853**	**10 207**	**34 232**

(Source: DME)

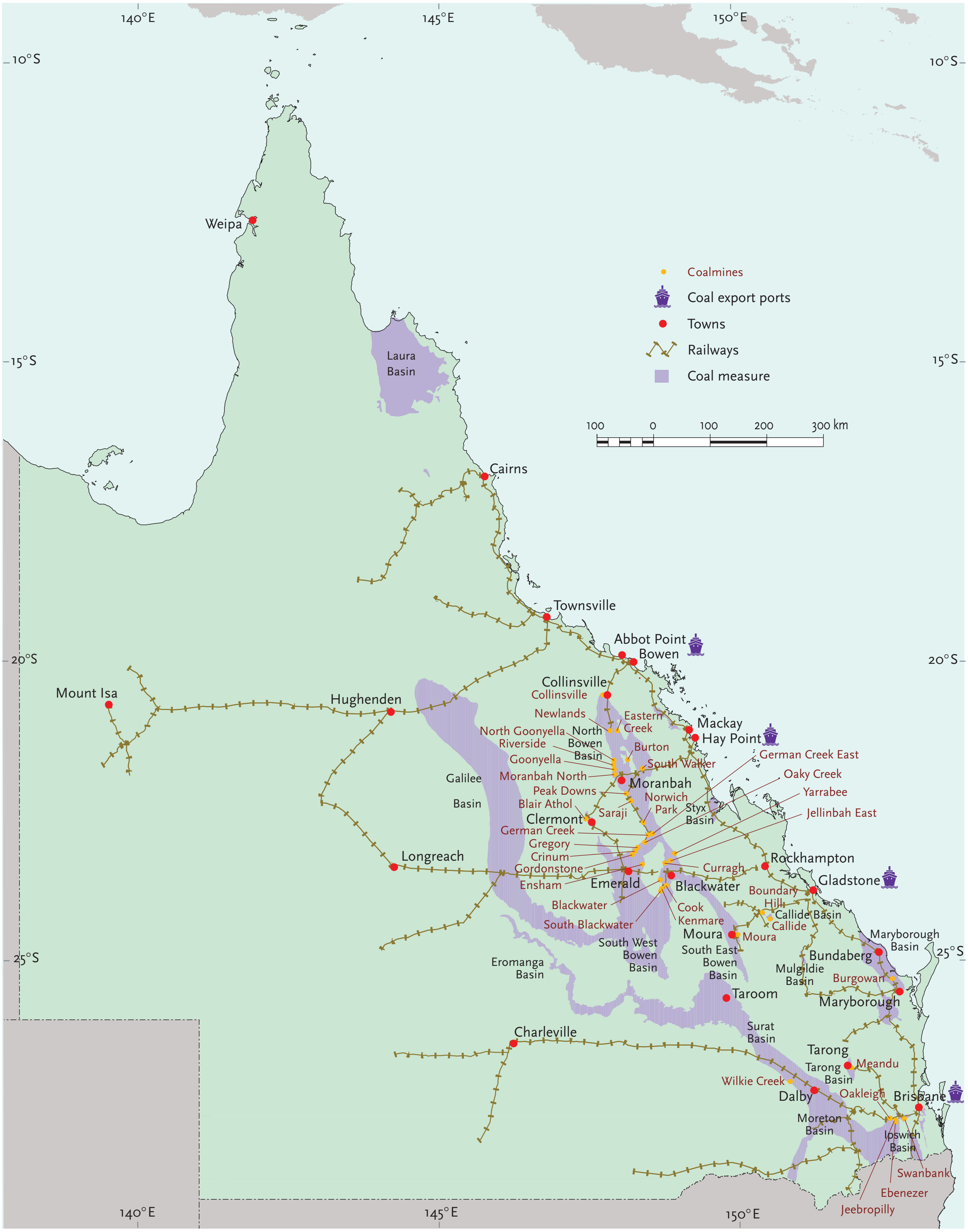

Figure 6-12 Sources and distribution of coal in Queensland
(Source: DME)

Oil shale

Indicator

Total proven reserves of oil shale

In contrast with very limited resources of conventional crude oil, Queensland has major reserves of oil shale, a sedimentary deposit containing hydrocarbon compounds that can be refined into a synthetic crude oil.

Oil shale deposits in New South Wales were developed as an alternative source of liquid transport fuels during World War II, although these operations were abandoned when cheap oil became widely available during the postwar period. Interest in the commercial development of oil shale resources was rekindled by the world oil crisis in the 1970s.

Most of Queensland's oil shale resources are in nine small basins adjacent to the eastern coastline. Oil shale is also found in the Bowen, Galilee and Alpha Basins and the Eromanga and Carpentaria Basins (see table 6-9).

Extensive studies have been undertaken to examine the feasibility of recovering oil shale by open-cut mining, and retorting the material to extract hydrocarbon fractions suitable for use as motor spirit, diesel fuel and other fuels normally derived from crude oil.

Oil shale is well placed to contribute to Australia's petroleum production. Queensland contains the majority of the currently identifiable oil shale resources in Australia. Reserves totalling more than 4700 GL, or about 30 billion barrels, have been identified.

Table 6-9 Oil shale reserves (gigalitres — measured, indicated and inferred) by basin, 1998

Deposit	Reserves (GL)
Alpha	14.2
Condor	1543.0
Duaringa	591.0
Herbert Creek	243.0
Julia Creek	238.0
Lowmead	64.7
Mt Coolon	27.6
Nagoorin	421.0
Nagoorin South	34.0
Rundle	421.0
Stuart	461.0
Yaamba	658.0
Total	**4717.0**

(Source: DME 1998)

Natural gas

Indicator

Total proven and probable reserves of natural gas in Queensland, and reserves accessible to Queensland by pipeline

Gas was first discovered in Roma in 1900, and subsequent discoveries were made in the Bowen and Surat Basins. The first commercial use of natural gas was undertaken in 1961 (for electricity generation for the hospital and abattoir in Roma). The transport of gas to Brisbane by pipeline began in 1969. Exploration identified gas reserves in the Denison Trough and the Adavale, Cooper, Eromanga, Bowen and Surat Basins.

In 1981, the Jackson oilfield was discovered in the Eromanga Basin, prompting further exploration for oil and gas reserves and development of pipelines and other supporting infrastructure. Significant discoveries of natural gas have been made, but there has been less success in making new discoveries of crude oil.

Estimated remaining proven and probable gas reserves at 30 June 1995 were 56.5 billion cubic metres, with most located in the Cooper and Eromanga Basins (table 6-10). Levels of proven and probable reserves have increased by almost 48 per cent since 1989, reflecting new discoveries. The increase in reserves has paralleled a rise in demand, with most conventional reserves already committed to long-term contracts.

Table 6-10 Remaining recoverable reserves of natural gas (millions of cubic metres) by region, 1995

Region	Remaining recoverable reserves
Adavale Basin	570
Denison Trough	3 373
Cooper and Eromanga Basins	49 989
Bowen and Surat Basins	2 617
Total	**56 549**

(Source: DME)

Most condensate produced in Queensland is currently exported to South Australia by pipeline; only relatively small amounts are sent to Brisbane.

All of onshore Queensland remains sparsely explored, with a drilling density of one well in 550 km². This is a result of the pre-1970s reluctance of exploration companies to move away from established petroleum sources into more high-risk areas. The discovery of oil in south-west Queensland in the early 1980s and the building of the Jackson–Moonie pipeline created a renewed interest in oil and gas exploration.

Forty-one conventional petroleum exploration wells drilled in 1996–97 resulted in two oil and 14 gas discoveries. Of 46 petroleum appraisal and development wells drilled in the year, 20 confirmed resources of oil and 18 tapped gas.

Coal seam methane

Indicator

Total proven and probable reserves of coal seam methane

Coal seams often contain trapped methane gas, which is liberated during fracturing or mining. Coal seam methane has been regarded as a major threat to underground coalmining operations because it forms explosive mixtures with air. It is now recognised as an important potential source of fuel gas. Although the total extent of the resource has not yet been accurately determined, Queensland clearly has enormous potential reserves of coal seam methane in the Bowen Basin.

Total reserves of coal seam methane in Queensland have been estimated to be as much as 4000 billion cubic metres — three times those of the North-West Shelf off Western Australia. However, these estimates are preliminary and further work is needed to confirm the size of the resource and its commercial viability. Technical difficulties associated with gas extraction will also have to be overcome.

In 1996–97, 36 coal seam gas wells were drilled, and 29 gas discoveries were made.

RENEWABLE RESOURCES

Indicator

Installed capacity and estimated energy production by renewable resources in Queensland

Significant sources of renewable energy are available in Queensland. Renewable resources are, by definition, available for exploitation on a continuing basis, so production can be sustained indefinitely.

Hydro-electricity

Hydro-electric schemes play a small role in meeting Queensland's energy needs: 60 MW generating capacity is installed at Barron Gorge, 72 MW at Kareeya and 4 MW at Somerset Dam.

Over recent years, the relative contribution made by hydro-electricity has diminished due to a steady increase in use of fossil fuels for electricity generation. The potential for further large-scale hydro-electricity development in Queensland is limited due to rainfall, topography and environmental constraints. However, potential exists for development of small hydro-electric projects on existing water storage dams, such as Somerset Dam.

Solar energy

A huge and effectively inexhaustible supply of solar energy is available in Queensland, although only a minute fraction is currently captured for use. Nevertheless, solar energy makes a significant contribution to the lifestyle of Queenslanders through its use for:

- solar water heating (accounting for about 4.8 percent of domestic water heaters);
- pool heating;
- natural lighting;
- passive solar house design to optimise comfort; and
- electricity generation for telecommunications, water pumping, navigation beacons, electric fencing and household power, especially in remote areas where providing mains power is very costly.

Solar radiation received in Brisbane, Cairns and Longreach is presented in tables 6-11, 6-12 and 6-13 respectively. Data are all statistical mean values that account for reductions caused by actual cloud conditions. Average daily irradiation for a vertical wall facing north is also pertinent for the winter months of June, July and August. Levels in Brisbane are 15.6, 15.1 and 16.1 MJ/m^2 respectively. Levels for Longreach are 20.3, 21.1 and 19.4 MJ/m^2.

For a typical solar water heater, solar radiation in Brisbane is sufficient to supply 180 litres of water per day at 60°C for 80 percent of the time. An energy-efficient house might also require 6 kWh of power a day. This could be provided by a 1.2 kW photovoltaic array and storage system. At current prices, this costs about $10,000 plus installation (costs supplied by Renewable Energy Centre, Brisbane Institute of TAFE).

Table 6-11 Average daily total irradiation (MJ/m^2) at Brisbane. The seasonally adjusted irradiation for an east–west tracking plane is 20.9 and for full sun tracking 25.8.

Month	Typical 20° inclination	Optimal 40° inclination
January	23.5	20.7
July	15.0	17.3
Annual	19.6	19.6

(Source: ERDC)

Table 6-12 Average daily total irradiation (MJ/m^2) at Cairns. The seasonally adjusted irradiation for an east–west tracking plane is 20.6 and for full sun tracking 25.3.

Month	Typical 10° inclination	Optimal 30° inclination
January	20.4	17.9
July	15.3	18.2
Annual	19.1	19.1

(Source: ERDC)

Table 6-13 Average daily total irradiation (MJ/m^2) at Longreach. The seasonally adjusted irradiation for an east–west tracking plane is 25.9 and for full sun tracking 33.4.

Month	Typical 20° inclination	Optimal 40° inclination
January	24.2	20.4
July	21.7	24.9
Annual	23.9	23.6

(Source: ERDC)

Wind

For many years, wind power has been used to pump water from an estimated 70 000 wells and bores in rural areas. More recently, wind has been used to augment solar photovoltaic power production to provide electricity in remote areas.

The amount of wind energy potentially available in Queensland is limited by geography and prevailing weather patterns. Northern coastal areas and parts of inland Queensland appear to have some potential for wind to be harnessed as an energy resource. Wind conditions have been monitored at a number of sites throughout Queensland to identify suitable locations for wind turbines to generate electricity. Overall, Queensland is not particularly well endowed with wind resources, relatively few sites having an average wind velocity exceeding 6 metres a second, the level considered necessary for wind turbines to be economically viable (table 6-14).

Table 6-14 Results of wind monitoring trials

Location	Wind velocity (average m/s)
Stradbroke Island	5.7
Lowood	4.7
Mt Wolvi (near Gympie)	5.0
Dudgeon Point (near Mackay)	5.1
Archer Point (near Cooktown)	6.0
Thursday Island	7.5

(Source: Queensland Transmission and Supply Corporation)

Biomass

Indicator

Total biomass resources used for energy production

Plants use sunlight in photosynthesis to produce sugars, which they convert into starches and cellulose. Cellulose, the main structural material of plants, can be used effectively as a fuel to produce heat. Many plant products, including tree branches, bark and offcuts, sugarcane bagasse and nut shells, have a high cellulose content and are excellent fuels for cooking, domestic heating or even industrial applications.

Wood was the dominant energy resource for households and industry until the Industrial Revolution. Wood continues to play a vital role in meeting energy needs in many developing countries.

In Australia today wood continues to be used as a source of energy, although the amount used is difficult to ascertain. One estimate is that wood provides about 8 petajoules of energy a year, primarily for domestic heating, although this figure might underestimate the amount of wood that is actually used as fuel. Estimated timber residues in Queensland are 1.9 million tonnes from finished production, 2.8 million tonnes forest residue and 1.4 million tonnes sawmill waste. While some timber residue is used in the horticultural industry, a considerable resource remains.

Sugarcane is highly efficient at using solar energy to create biomass in the form of raw sugar and bagasse. Bagasse is used as an energy source in Queensland's 25 sugar mills, where it is burnt to produce process heat and to generate electricity. Some electricity not needed at that time is transmitted to the State grid.

Each sugar mill generates biomass quantities far in excess of those attainable by any other source. The sugarcane harvest each year yields on average more than 10 million tonnes (wet basis) of bagasse, with an energy content of more than 100 petajoules. However, about the same quantity of equivalent bagasse (as leaves, trash and tops) is left in the field. Research indicates that about 80 percent of this could be recovered and used for co-generation (Dixon 1997).

In January 1998, a consortium of five mills began supplying electricity to the State grid on a stand-by/on-demand basis. A 10-year agreement is for an initial supply of a minimum 49 MW, not only in the crushing season but throughout the year. Up to 60 MW might be available, and there is a possibility of supplying up to 200 MW subsequently (ASMC 1998). In the longer term, with new technologies, it will be possible to generate far larger quantities of electricity from bagasse.

Annual estimates have been made of other biomass resources which could be burnt to generate process heat and electricity (Juniper and Joseph 1996):

- cotton trash (17 700 tonnes);
- macadamia nut shells (10 500 tonnes);
- cattle dung (70 000 tonnes);
- fruit pips (3000 tonnes);
- tomato refuse (1500 tonnes); and
- Brisbane municipal waste (630 000 tonnes).

Biogas

When vegetable matter decays in the absence of air, anaerobic bacteria decompose organic compounds into simpler molecules. In particular, a gaseous mixture of methane and carbon dioxide termed 'biogas' is produced. This mixture can be refined to produce a fuel gas that can replace natural gas.

Biogas is produced naturally whenever organic matter is allowed to decompose in the absence of air. Landfill and sewage are therefore potential resources for biogas production.

Methane is produced in landfill sites whether it is used or not. Since methane is believed to contribute to the enhanced greenhouse effect approximately twenty times more than carbon dioxide, unused biogas escaping into the atmosphere adds to the problem of global warming.

Energy Developments Limited (EDL) owns and operates 14 landfill gas-fuelled power plants in Australia with a capacity of 67 MW. These reduce greenhouse gas emissions by about three million tonnes per year of carbon dioxide equivalents. The EDL power station at Browns Plains, Logan City, exports 1 MW of power almost continuously. Since opening in January 1997, the power station is estimated to have used more than one million cubic metres of landfill gas and reduced greenhouse gas emissions by more than 20 000 tonnes (carbon dioxide equivalents). The plant generates some exhaust gases but generally eliminates odours and reduces fire hazards. The rate of rehabilitation of the landfill site is also increased.

Methane is also produced by the breakdown of organic sewage wastes. The Luggage Point treatment plant, operated by the Brisbane City Council, uses biogas produced during sewage treatment to operate a 3.2 MW generator. This provides 70 percent of the electricity needed to run the plant, as well as hot water used to heat anaerobic digesters.

Many sewage treatment plant operators make no attempt to use biogas, which is flared or simply escapes to the atmosphere, where it contributes to the enhanced greenhouse effect.

Geothermal energy

There is some potential to use geothermal energy in Queensland. In 1994 a small demonstration plant used bore water at near boiling point to drive a 120 kW generator at Birdsville. While technical problems forced the plant to be shut down, geothermal energy could possibly be harnessed to generate electricity in a number of remote locations. Remote homesteads use bores as a source of hot water, but the extent is largely unknown.

Waves and tides

High-energy waves occur only off the south Queensland coast. Other parts of the Queensland coast have reduced or variable waves. The Brisbane Waverider buoy off Point Lookout, Stradbroke Island, recorded significant wave heights of one metre for 99 percent of the time from 1976 to 1994 but three-metre waves for only three percent of the time.

The Queensland coast from St Lawrence to Mackay, particularly Broadsound, has a tidal range of about seven metres.

Response

Queensland's reliance on coal and imported fossil fuels to meet its energy requirements has been challenged by recent international agreements and national strategies designed to reduce greenhouse gas emissions. There is evidence of trends towards more efficient use of conventional energy sources and the promotion of renewable energy at the State and national levels.

State Government initiatives are playing a role through setting efficiency standards for appliances and providing information on efficient and sustainable energy technologies. Education campaigns and cash incentives are being used to reduce energy consumption in industrial, commercial and domestic markets.

As the State's population and economy grow, demand for energy continues to rise strongly. To meet these needs new infrastructure is being constructed, including the interconnector which will link the Queensland and New South Wales electricity grids. The construction of a pipeline from Papua New Guinea to Queensland is also under consideration. Should the pipeline proceed, it will bring large volumes of gas as far south as Gladstone to support resource development projects along Queensland's coast.

International agreements/conventions

Climate change

As a signatory of the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, Australia has agreed to the goal of limiting net emissions of greenhouse gases to 108 percent of 1990 levels by 2008–12. The overall target for developed countries is to reduce net emissions by 5 percent of 1990 levels in the same period.

The largest single source of Australia's greenhouse gas emissions is the production and consumption of energy (AGO 1998). The burning of fossil fuels for the purpose of energy production accounts for approximately 53 percent of these emissions. Domestic road transport accounts for another 14 percent (King et al. 1996). Meeting the UNFCCC commitments will require fundamental changes to the way energy is produced and used in Australia.

National and State policy statements/strategies

National Greenhouse Strategy

The National Greenhouse Strategy (NGS) was developed by the Commonwealth and State and Territory Governments to meet Australia's commitments under the Kyoto Protocol to reduce greenhouse gas emissions. Under the NGS, energy market reforms will be accelerated to improve the economic efficiency of energy supply and use. Energy performance codes and standards related to domestic industrial equipment and residential and commercial buildings will be tightened. Targets will be developed for efficiency standards for fossil fuel electricity generation and the use of renewable energy in the electricity market. The NGS will provide support for the development of renewable energy technologies and manufacturing (AGO 1998).

National energy policy

The Sustainable Energy Policy for Australia (Commonwealth of Australia 1996a) is a Green Paper that provides a consistent approach to national energy policy. It promotes competition within the energy market, more transparent pricing structures, technological development and reduced impediments to the entry of renewables.

Energy efficiency

In December 1998 the Queensland Government established the Office of Sustainable Energy (OSE) within the Department of Mines and Energy. Its functions include providing reliable and independent information on energy efficiency and renewable energy, facilitating increased commercial applications of sustainable energy technologies, and managing a number of rebate schemes and programs.

One of the key programs OSE administers is the Solar Hot Water Rebate Scheme, launched in September 1998. This scheme provides a $500 rebate for two-panel solar hot water systems and $300 for single-panel systems. A grant of up to $200 is also available for replacement components of existing systems.

To promote energy-efficiency measures in households and small to medium-sized businesses, OSE launched energyWise, an energy efficiency advisory service. EnergyWise provides a number of services, including a free or local call telephone service, Internet access and information mail-outs, and plans to include a schools program in the future.

New energy-efficiency initiatives of the Queensland Government include:

- developing guidelines for energy-efficient and sustainable building development;

- expanding annual reporting systems for energy auditing and conservation initiatives undertaken by the Queensland Government;
- developing energy rating standards for public housing;
- encouraging the adoption of energy conservation technologies and renewable energy supplies for government-owned buildings; and
- promoting the adoption of energy performance contracting.

OSE launched the Householder Remote Area Power Rebate scheme in December 1998. This scheme provides rebates to people who install renewable energy components in their household electricity generation systems.

OSE also has responsibility for the Sustainable Energy Innovation Fund. In the longer term, OSE will have responsibility for promoting and supporting sustainable energy innovation, developing projects and partnerships with industry and universities, and maximising awareness of the benefits of energy efficiency. DME will contribute significant funding to advanced bagasse technology development.

The publication *Energy Efficiency for SMEs* evaluates opportunities for small to medium-sized enterprises (SMEs) to use energy more efficiently (Commonwealth of Australia 1996b). It investigates common impediments to proposals for investment in energy efficiency by smaller firms, and offers solutions that could help overcome them. It suggests policy proposals for governments to help firms and households invest in energy efficiency.

The publication *Site Planning in Australia: Strategies for Energy-efficient Residential Planning* is an initiative of the National Energy Efficiency Program of the Department of Primary Industries and Energies (King et al. 1996). It was designed to help design professionals, consultant advisers, local government officers and others to better understand the energy and environmental issues associated with new and existing housing developments. Topics covered include:
- street layouts, allotment dimensions and shape, and landscaping to maximise the solar energy available for water and space heating;
- management of wind movement to shield from cold winter winds and encourage cooling breezes in summer; and
- the design of transport networks, street design, residential density and public services to minimise the dependence on private motor vehicles for transport.

Energy market reform

The National Electricity Market commenced in December 1990. This introduced a competitive market for the wholesale supply and purchase of electricity and an open access regime for the use of electricity networks across the eastern States (excluding Tasmania).

In February 1999, the State Government announced that the Government-owned sector of Queensland's electricity industry would be restructured so that the six regional electricity distribution corporations would be merged into a single corporation, Ergon Energy. The three generation corporations (Tarong Power, CS Energy and Stanwell Corporations) will not be amalgamated. The restructure aims to provide better community service and improve the reliability of the State's electricity system.

RELEVANT PROTOCOLS/REPORTS

ANZMEC

In August 1996 the Australian and New Zealand Minerals and Energy Council committed to undertake regular assessments of national energy production and use against the criterion of achieving cost-effective and competitive delivery of energy services (ANZMEC 1998). The Council concluded that it was too early to determine the full impact of energy market reforms on the energy industry, but that early signs were encouraging. Two relevant trends were noted:
- increased competitiveness was producing lower overall energy prices for consumers; and
- the shift to natural gas, co-generation and an emphasis on more efficient use of resources were producing positive environmental outcomes nationally.

INDUSTRY RESPONSES

Greenhouse Challenge

The Greenhouse Challenge is a joint effort by Australian industry and the Commonwealth Government to reduce gas emissions by improving energy and industrial process efficiency. Individual companies or industry associations voluntarily agree to abide by a set of principles that involves conducting a greenhouse gas inventory, developing an action plan to reduce emissions, and conducting regular monitoring and public reporting of the undertakings contained in the agreement. Nearly 50 companies and industry associations that have signalled their intention to take up the challenge are from energy- or mining-related organisations.

Electricity market

The Australian electricity supply industry has recently been reformed to increase competition. In a centrally coordinated process, the National Electricity Market Management Company (NEMMCO) uses the offers and bids provided by generators to schedule the generators into production to meet forecast electricity demand. In normal circumstances, NEMMCO starts with the generator with the lowest price offer and then, in sequence of price offers, schedules enough generation to meet demand. Typically, at any given time, the offer price of the last generator brought into production sets the pool price (NEMMCO 1998). Generally, consumers who purchase their electricity directly from the pool and use it during off-peak times pay less than consumers who use electricity during peak periods.

The 'earth's choice' program is a new initiative of Energex (a corporatised, Queensland Government-owned energy supplier) focused on facilitating the reduction of greenhouse gas emissions. The program offers business and residential consumers the choice of having future energy supplied from renewable sources such as hydro, solar, wind and landfill gas or biomass. The cost to the consumer is 2c extra per kilowatt hour. Over 6000 south-east Queensland residential households joined the program in its first eight months of operation, the most successful take-up rate per capita worldwide for a renewable energy program of this type.

Acknowledgements

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CHAPTER 7

QUEENSLAND'S BIODIVERSITY

Biodiversity

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Contents

Key Issues and Findings

Australia supports such a rich diversity of life that it is classified as one of twelve megadiverse countries on Earth. These countries collectively support 75 percent of total global biological diversity (biodiversity). Queensland supports the greatest level of Australia's continental biodiversity. The maintenance of healthy, functioning ecosystems and ecological processes is critical to sustaining all life and providing essential resources and socio-cultural benefits to humans. Biodiversity in Queensland has suffered losses since European settlement and many ecosystems and species are under threat from human activities.

- A hierarchy incorporating the landscape, ecosystem, species and genetic levels of biodiversity provides a regional approach to the assessment and protection of biodiversity in Queensland. Queensland's 13 terrestrial bioregions and 14 marine bioregions form part of a national biogeographic regionalisation for Australia.
- Of 1085 regional ecosystems identified across all bioregions, 107 are classified as 'endangered' and 243 as 'of concern'. Endangered ecosystems are associated mainly with the extensively cleared agricultural areas, wetlands, riparian zones and rainforest types on the Wet Tropics and Central Queensland Coast lowlands.
- Detailed data on the status of many marine ecosystems are unavailable. While more than 70 percent of mangroves, seagrasses and other intertidal habitats have been mapped to some extent, our knowledge of the types of benthic habitats and their extent is very poor.
- Queensland's wetlands are of outstanding diversity but their representation in the protected area estate at the bioregional level is incomplete. While 47 percent of the 165 listed nationally important wetlands have partial protection, very few have total protection. Grazing, the most widespread pressure, affects 53 percent of important wetlands. Riparian vegetation is in a poor to very poor condition throughout seven major catchments surveyed and its condition has been identified as the most significant management issue in State of the Rivers reports.
- Knowledge of invertebrate animal, non-vascular plant, fungal and micro-organism diversity in Queensland is generally poor in comparison with knowledge of vascular plant and vertebrate diversity. Insufficient information is available to accurately determine total species numbers and distribution patterns within most bioregions.
- Approximately 2000 marine fish, 173 freshwater fish, 120 frog, 442 reptile, 615 bird and 226 mammal species and more than 8000 plant taxa occur in Queensland, and new species are still being described. The Wet Tropics World Heritage Area, one of the most species-diverse areas in Australia, is of great importance to the conservation of relict and endemic species.
- The *Nature Conservation (Wildlife) Regulation 1994* lists 21 plant and 6 animal species as presumed extinct in Queensland. A further 63 mammals (28 percent of Queensland mammals), 64 birds (10 percent), 83 reptiles (19 percent), 45 frogs (38 percent), 5 fish (3 percent), 17 butterflies (5 percent) and 1017 plants (13 percent) are listed as endangered, vulnerable or rare.
- The threatened species list is biased towards vertebrates and vascular plants, reflecting in part the paucity of knowledge of many of the less well known taxonomic groups. The list also masks the extent of regional extinctions and continuing regional declines for many species. There are insufficient data on historical distributions to determine the extent of regional declines for most species.
- Many species have been reduced to small remnant populations, with a consequent loss of genetic diversity. While genetic studies have provided an insight into amounts and distribution of genetic diversity for some species, there are insufficient data to assess genetic diversity across bioregions. No coordinated monitoring of genetic diversity occurs.
- The demands, both economic and lifestyle-related, that an increasing human population places on natural resources are underlying pressures on biodiversity. Pressures on land and sea resources result in the clearing and degradation of ecosystems, introduction of non-native species, overgrazing and pollution, directly threatening biodiversity.
- The protection and sustainable management of biodiversity in Queensland are made difficult by the paucity of information about biodiversity, its extent, the processes that maintain it and the impacts of human activities on it. Insufficient knowledge about the current status of biodiversity means that some of it may be lost before it is even documented.
- Clearing of native ecosystems is the factor contributing most to the loss of biodiversity in Queensland. Since European settlement, more than half of Queensland's original 117 million hectares of woody vegetation has been cleared. The average annual clearing rate is currently approximately 289 000 hectares, with clearing concentrated in the Brigalow Belt, Mulga Lands and Desert Uplands bioregions. Approximately 54 percent of clearing is occurring on leasehold land and 44 percent on freehold land.
- Clearing threatens 31 percent of regional ecosystems in the Southeast Queensland bioregion, 26 percent in the Brigalow Belt and 23 percent in the Mulga Lands. Habitat clearance is the major cause of, or a cause contributing to, the decline of at least 44 threatened vertebrate species.
- Much remnant vegetation is fragmented into small patches that may be inadequate for long-term protection of biodiversity. In the Southeast Queensland bioregion, 99 percent of habitat fragments are under 50 hectares; 10 fragments exceed 50 000 hectares. Comprehensive data on the impact of habitat fragmentation throughout Queensland are not available.
- The introduction and spread of exotic species pose a serious threat to native biodiversity. At least 19 exotic mammals, 11 birds, 11 fish, 2 reptiles, 1 amphibian and unknown numbers of invertebrates and micro-organisms have established breeding populations. Declines in at least 17 species of threatened fauna have been attributed to predation by foxes and cats. The cane toad and some exotic fish species are increasing their ranges.

- At least 1166 introduced plant species, 13 percent of Queensland's total flora, have become naturalised. Approximately 300 of these are or could become environmental weeds that invade and compete with native vegetation. Of sixteen serious weeds identified, the most invasive include prickly acacia (*Acacia nilotica*), covering 7 million hectares of the Mitchell grasslands, and rubber vine (*Cryptostegia grandiflora*), densely infesting 700 000 hectares of mostly riparian habitat.
- Grazing by sheep and cattle occurs across 87 percent of the State. Unsustainable grazing practices in combination with grazing by feral and native species, the planting and spread of exotic pasture species, woody weeds and changes in fire regimes have contributed to the deterioration and degradation of 85 million hectares, or 58 percent of the native pasture area.
- Changes in fire regimes following European settlement are altering habitats. Between 1943 and 1992, 48 percent of the wet sclerophyll forests of north Queensland was affected by rainforest encroachment; the remainder is under threat. On Cape York Peninsula, the invasion of grasslands by woody species has contributed to contraction of the endangered golden-shouldered parrot's range.
- Pollutants, originating largely from land-based human activities, constitute a threat of unknown magnitude to aquatic biodiversity. Most monitoring programs centre on the use of physico-chemical indicators of water quality and limited long-term monitoring of ecological impacts. Excessive sediment and nutrient levels have resulted in significant seagrass losses and algal blooms in some inshore areas.
- Impacts of fishing, such as species loss, seabed disturbance and the taking of bycatch, affect marine ecosystems in ways that are largely unknown. A number of Queensland's major commercial fisheries, due to economic and environmental effects, appear to show signs of over-exploitation although clear trends are difficult to identify. Recreational fishing catch, unlike commercial catch, has generally not been regulated and quantified for many species.
- Timber harvesting can have measurable effects on forest biodiversity, including changes to forest structure and ecological processes. Commercial harvesting of native trees occurs on both private and State forest and timber reserves tenures. From 1993 to 1997, 48 percent of all native timber harvested was removed from private forests. Unlike State lands, private lands are subject to limited harvesting controls, and very little summary information on harvesting extent or methods of operation is available.
- Queensland is committed to the protection of biodiversity and its sustainable use and is implementing national policies and strategies such as the National Strategy for the Conservation of Australia's Biological Diversity and the National Forest Policy Statement.
- Many legislative and policy initiatives influence the management of biodiversity. The *Nature Conservation Act 1992* has statutory provisions for biodiversity conservation and is the most significant piece of Queensland legislation in this regard. No overall State biodiversity strategy exists to integrate and coordinate government and community efforts.
- Bioregional planning is dependent on a statewide review of bioregional issues and is yet to be fully developed and implemented. A Regional Forest Agreement currently under development for Southeast Queensland provides for the establishment of a comprehensive, adequate and representative forest conservation reserve network for the region. A model framework for bioregional management of the Mulga Lands has been developed. Regional natural resource management strategies incorporating biodiversity considerations are currently under development.
- Many community groups and organisations in Queensland take part in projects to monitor, protect, rehabilitate or restore biological diversity. Bushcare and other Natural Heritage Trust programs are significant sources of funding for community conservation projects. No data are available on the extent of community involvement in conservation across Queensland.
- Queensland's biodiversity is afforded some protection through the protected area estate. Terrestrial protected areas total seven million hectares, or 4 percent of the State. Marine parks cover approximately 47 percent of marine bioregions, although most of this area is managed for multiple uses. Five World Heritage areas and five internationally significant Ramsar wetlands are within Queensland.
- While 69 percent of terrestrial regional ecosystems are represented in protected areas greater than 1000 ha, only 39 percent are represented more than once. Eleven of Queensland's 20 IBRA bioregions are under-represented in the National Reserve System. Current zoning of marine parks provides for less than 5 percent of marine and estuarine waters to be fully protected. Major deficiencies in the comprehensiveness, adequacy and representativeness of the land and marine protected area system are now being dealt with.
- Much biodiversity exists outside formal protected areas under tenure that affords varying degrees of protection and controls on its use. The State Government, local governments and community organisations are working with landholders to integrate nature conservation into the management of land across all tenures. Effective incentive schemes to foster off-reserve conservation have yet to be comprehensively applied in Queensland, but the development of mechanisms such as rate rebates and conservation agreements has so far been successful. The number of nature refuges increased from one (42 ha) in 1995 to 37 (12 099 ha total area) in 1999.
- A comprehensive program for ecologically sustainable forest management is in place for State forest and timber reserves, and for some forest management activities on leasehold land.
- Rare and threatened species are listed and protected by legislation. Resource constraints have limited the development of recovery or conservation plans for many of these species. Currently, programs are being implemented for 23 percent of threatened species.
- A Broadscale Tree Clearing Policy and associated Local Tree Clearing Guidelines regulate clearing of native vegetation on leasehold lands. Under these guidelines, tree clearing permits prohibit clearing of endangered ecosystems and those that would result in a downgrading of conservation status. Local government tree protection laws are the main regulatory mechanisms currently used to control tree clearing on freehold land. The State Government is considering the development of a comprehensive framework for vegetation management to cover all tenures.
- A vegetation mapping program has so far mapped pre-clearing and remnant extent of ecosystems for about 60 percent of the State. The Statewide Landcover and Trees Study provides data on land cover and trends in land clearing.

INDICATORS

Pressure

Clearing and fragmentation of native habitat

Extent and rate of clearing of native vegetation by bioregion

Extent and rate of marine habitat disturbance by bioregion

Extent and rate of clearing of native vegetation by land tenure

Extent and rate of clearing by ecosystem type

Extent of fragmentation of remnant vegetation and marine habitat by bioregion

Frequency and areas of remnant vegetation patches in specified class areas

Number of river structures per kilometre of river length by catchment

Introduced species

Distribution and abundance of exotic species by bioregion

Rate of spread of exotic species by bioregion

Number of translocated species and sites of translocation by bioregion

Grazing

Extent of native grasslands grazed by bioregion

Extent of naturalised, non-native grasses and legumes by bioregion

Altered fire regimes

Extent of altered fire regimes by bioregion

Harvesting of native species

Species and quantity of fish harvested commercially and recreationally

Ratios of bycatch to target species and amount of bycatch discarded

Tree species and quantity harvested commercially during forestry operations

Area of forest in which logging and thinning operations have occurred each year

State

Ecosystem diversity

Number and extent (current and pre-clearing) of regional ecosystems by bioregion

Number of threatened (endangered and of concern) regional ecosystems by bioregion

Comprehensiveness, adequacy and representativeness of the protected area system

Extent of broad vegetation types by bioregion

Extent of broad vegetation types within protected areas by bioregion

Number and extent of wetlands by bioregion

Number and extent of wetlands represented in protected areas by bioregion

Condition of riverine habitats by catchment

Number and extent of cave and lava tube systems of biodiversity significance by bioregion

Extent of cave and lava tube systems in protected areas by bioregion

Species diversity

Number of known species by taxon by bioregion

Number of species by taxon presumed extinct, endangered, vulnerable or rare by bioregion

Genetic diversity

Numbers of discrete populations, location of populations and population numbers for selected species

INTRODUCTION

Biological diversity, or biodiversity, is the variety of all life forms: plants, animals and micro-organisms, the genes they contain and the ecosystems and ecological processes of which they form a part. Biodiversity is dynamic, changing through time as a result of natural evolutionary processes.

Australia supports such a rich diversity of life that it is classified as one of twelve megadiverse countries on Earth; collectively, these countries account for 75 percent of total global biodiversity. Queensland supports the greatest levels of Australia's continental biodiversity. Its diverse landscapes include arid dunefields, open grasslands, wetlands, coral reefs, sand islands and rainforests. They support more than 1000 ecosystem types, habitat for approximately 89 percent of Australia's known freshwater fish species, 58 percent of its frog species, 55 percent of its reptile species, 79 percent of its bird species, 65 percent of its mammal species and 47 percent of its vascular plant species. (In this chapter, the term 'landscapes' encompasses both landscapes and seascapes.)

Humans have probably been part of the Queensland landscape for at least 60 000 years. In the past 200 years, intensive agricultural, pastoral and urban developments have substantially altered this landscape. Native ecosystems have been cleared, fragmented and modified through altered fire regimes, introduced species, grazing pressures, harvesting and pollution. These pressures, alone or in combination, have contributed to losses and declines in Queensland's biodiversity.

The international Convention on Biological Diversity and Australian instruments — the National Strategy for the Conservation of Australia's Biological Diversity, the Intergovernmental Agreement on the Environment, the National Strategy for Ecologically Sustainable Development and the National Forestry Policy Statement — all stress the importance of conserving biodiversity. These and other strategies and policies are implemented through many interdependent government programs and legislative requirements.

This chapter examines the pressures on Queensland's biodiversity as well as its current condition, or state, and reports on society's responses to the pressures and state. Regular reporting on pressure and state indicators could identify trends that can be used to guide future management. For many indicators, insufficient data are available at present to provide any clear trends.

SCOPE

Biodiversity can be understood, conserved and managed at a range of spatial and temporal scales. A hierarchy incorporating the regional, ecosystem, species and genetic levels of biodiversity is recognised in Queensland and provides an integrated, systematic and holistic framework for the protection and management of biodiversity in the State. The importance of this approach has been affirmed in the *Nature Conservation Act 1992*, the first Queensland legislation to define biodiversity at the four levels.

- Regional diversity is the diversity of the landscape components of a region and the functional relationships that affect environmental conditions within ecosystems.
- Ecosystem diversity is the diversity of the different types of communities formed by living organisms and the relations between them.
- Species diversity is the diversity of species.
- Genetic diversity is the diversity of genes within each species.

Planning for the protection and management of biodiversity begins at the broad regional landscape level, represented by biogeographic regions, or bioregions. Terrestrial bioregions are based on broad landscape patterns and are distinguished by combinations of climate, geology, landforms, vegetation, plants, animals and land use. Similarly, marine bioregions are recognised on the basis of biological and physical characteristics.

Thirteen terrestrial bioregions are identified in Queensland (figure 7-1). The national Interim Biogeographical Regionalisation of Australia, or IBRA (Thackway and Cresswell 1995), incorporates the Queensland bioregions but identifies parts of seven as small extensions of bioregions in New South Wales, South Australia and the Northern Territory. In addition, under IBRA, the Brigalow Belt has been divided into two bioregions. The marine environment in Queensland is divided into 14 bioregions under the Interim Marine and Coastal Regionalisation for Australia (IMCRA Technical Group 1998).

Where data exist, this chapter will report on ecosystem, species and genetic diversity at a bioregional level. This allows assessment of biodiversity from both a statewide and a bioregional perspective. In most cases, data are provided for Queensland's 13 terrestrial and 14 marine bioregions and, where applicable in a national context, for the 20 IBRA bioregions. Pressures on biodiversity are assessed in terms of their impacts on regional, ecosystem, species and genetic diversity.

VALUES OF BIODIVERSITY

Biodiversity is essential in the maintenance of all life on Earth, and scientists have long acknowledged that the preservation of biodiversity is, by definition, vital for an ecologically sustainable society. The maintenance of healthy, functioning ecosystems and ecological processes is essential for clean air and water and fertile soils. Apart from the ecological benefits, biodiversity provides essential biological resources and socio-cultural benefits for humans (table 7-1).

Humans derive all their food and many medicines and industrial products from biodiversity; its loss could mean the loss of new strains of agricultural crops and agents for biological control of pest species. Maintenance of biodiversity is critical for many of Queensland's industries; forestry, agriculture,

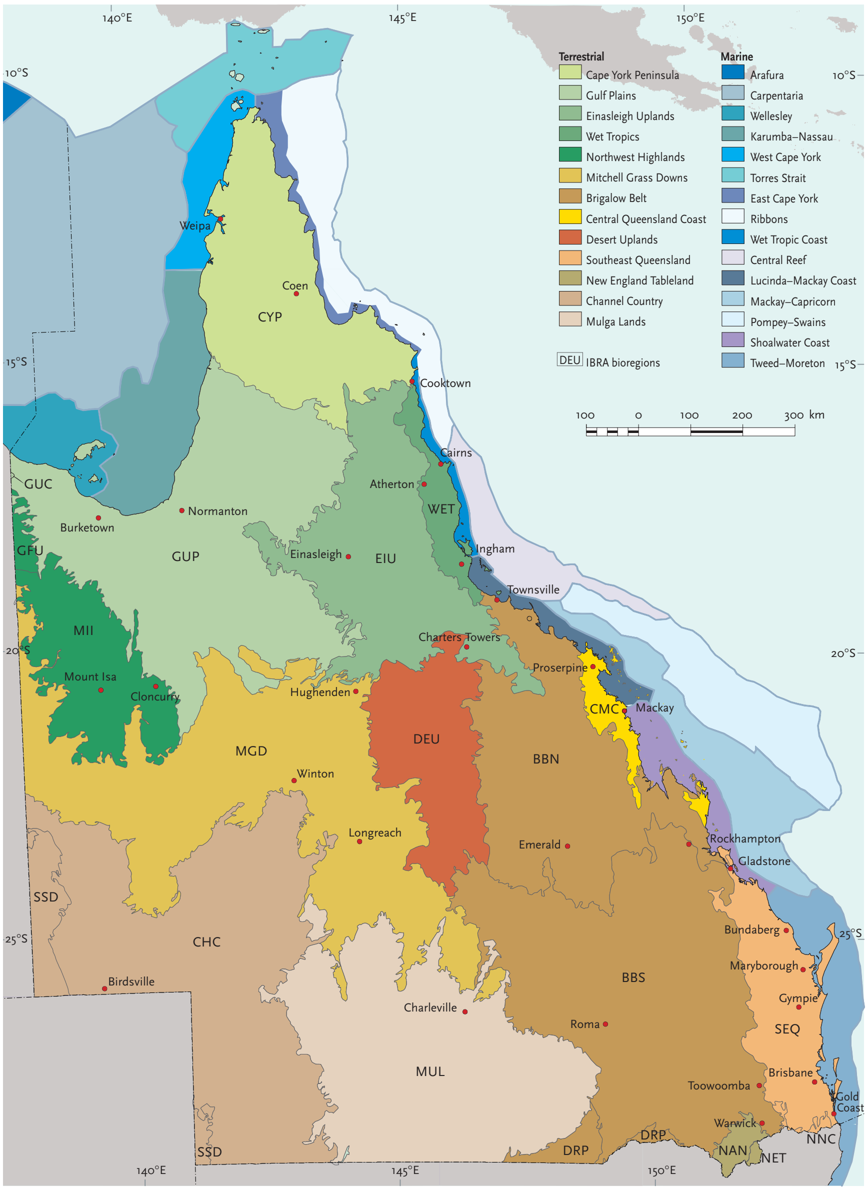


Figure 7-1 Queensland terrestrial and marine bioregions support a great diversity of ecosystems, habitat for many thousands of species. (For list of IBRA bioregions, see table 7-14.)

Arid Queensland landscape, Simpson Desert National Park

Coral cay, Great Barrier Reef

Masked boobies, on Raine Island

Table 7-1 Values of the biological environment and benefits obtained from it

Ecosystem services	Biological resources	Social benefits
Protection of water resources	Food	Cultural values
Regulation of atmospheric processes	Medicinal resources	Aesthetics
Soil formation and protection	Wood and industrial products	Recreation
Nutrient storage and cycling	Ornamental plants	Education
Pollution breakdown and absorption	Breeding stocks, population reservoirs	Income
Contribution to climate stability	Resistance to certain pests	
Maintenance of ecosystems		

(Source: DEST 1993)

fisheries and tourism contribute significantly to the State's economic development. Fisheries resources, for example, support commercial harvesting valued at $300 million (Zeller 1998). About 6000 tourism jobs depend largely on the State's national parks. Visitors to these parks spend more than $600 million in association with their visits: the total direct and indirect output effect in the Queensland economy is about $1.2 billion (Kinhill Economics 1998).

Aesthetic and ethical arguments can also be made for conserving biodiversity. The natural environment contributes to the emotional wellbeing of society and offers many recreational benefits. It has great spiritual, economic and social significance for Aboriginal and Torres Strait Islander peoples, and is central to the maintenance of their cultural identity. Many people also put forward moral reasons for conserving biodiversity: they hold that all species have an innate right to exist.

The conservation of biodiversity is a cornerstone of ecologically sustainable development (ESD). A fundamental principle of ESD is that biodiversity belongs to the future as well as to the present and that no generation has the right to deplete it.

One of the greatest barriers to biodiversity conservation is an acute lack of knowledge about biodiversity and the processes that maintain it. Even a basic inventory of Queensland's animal, plant and micro-organism diversity is far from complete. The paucity of information about the current status of biodiversity makes it inappropriate to consider any habitat type not worth saving or any species, species interaction, behaviour or natural product not worth conserving (Beattie 1993). This precautionary approach to biodiversity conservation is a key principle of the National Strategy for the Conservation of Australia's Biological Diversity. Lack of knowledge means that we may lose attributes of biodiversity without even knowing they existed. Few of our land and water use practices have been evaluated fully in terms of their impact on the environment, so the impacts of our activities on biodiversity values remain largely unknown.

The multiple demands that human activities place on biodiversity can be considered pressures removing, altering or affecting it in some way. These pressures often modify natural landscapes to the extent that there is an irretrievable loss of ecosystem, species and genetic diversity. Although some extinctions and declines in biodiversity are part of natural evolutionary processes, human-induced acceleration of these is contrary to the goal of achieving ecological sustainability.

While activities such as land clearing directly contribute to biodiversity loss in Queensland, they arise from the demands — economic, resource and lifestyle-related — of an increasing population. These demands, underlying pressures on biodiversity, are very complex and are embedded in society's social, economic and value systems. Underlying pressures lead to use of land, water and associated biological resources, placing direct pressure on biodiversity (figure 7-2).

Issues related to population and settlement and appropriate indicators are discussed in detail in chapter 8, 'Human settlements'. Queensland's estimated resident population on census night in 1996 was 3 339 100. This figure represented a growth of 13 percent since the 1991 census, the largest experienced by any Australian State or Territory. Population growth occurred mainly in the State's eastern coastal regions and was most pronounced in the south-east corner. The Southeast Queensland bioregion, with 61 percent of the State's population, has the highest population density — 25 people/km^2 (figure 7-3). In 1996, 69 percent of the population lived in 26 urban centres of more than 10 000 residents (QDLGP 1997). Eighty-five percent of the population lives within 50 kilometres of the coastline, mainly in urban centres located on harbours and estuaries with considerable biodiversity and habitat richness.

Interpreting human consumption patterns and their impacts on biodiversity is very difficult. The pressures on biodiversity that result from human demands on natural resources are not necessarily greatest where human population density is highest. For example, the pressures of clearing and grazing can be substantial in the extensive pastoral zones where human population density is low.

The concept of an 'ecological footprint' is being developed to provide a measure of human pressures on the environment (see chapter 8 for detail). The ecological footprint is the area of ecologically productive land needed to produce the natural resources that the population consumes and to assimilate the waste that the population generates. It has been estimated that, in 1991–92, Queenslanders appropriated nearly 6 ha of land per capita in the consumption of food, energy, goods and services (Simpson et al. 1998). Of this total, each individual required, on average, 2.6 ha of pasture for the production of meat, dairy and wool products and 2.2 ha of forest to assimilate the carbon dioxide produced during the combustion of fossil fuel.

Economic systems in Australia have generally failed to fully value biodiversity in decision making. Products and services derived from biodiversity are often grossly undervalued in environmental accounting and cost–benefit analyses. Natural areas are converted to other land uses even when the net effect to society may be negative. This is due, in part, to

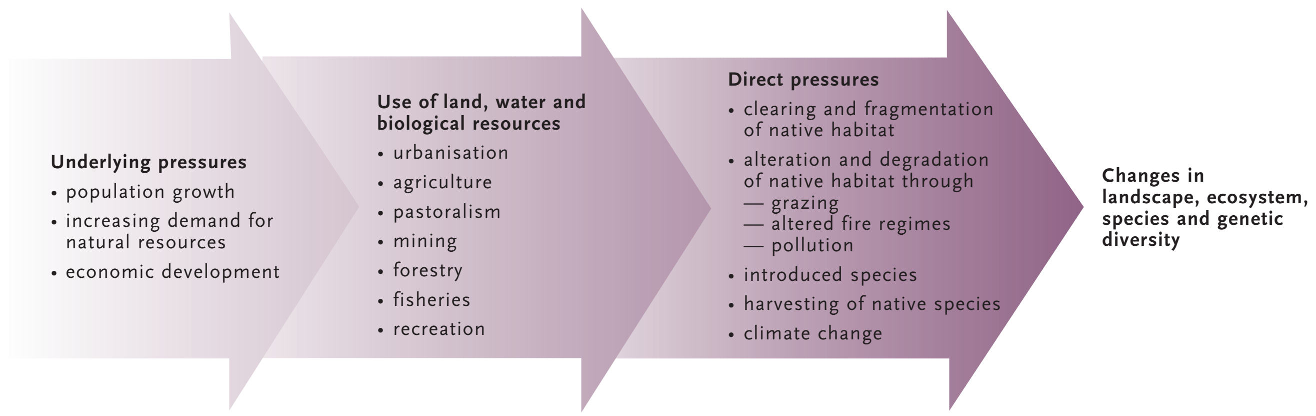


Figure 7-2 Underlying pressures create demand for land, water and biological resources that result in activities that directly threaten biodiversity.

market values for which the land is used being easily recognised while conservation values are hidden or too difficult to quantify. There is growing recognition that cost–benefit analyses must recognise biodiversity loss as a cost to the community and biodiversity conservation as a benefit.

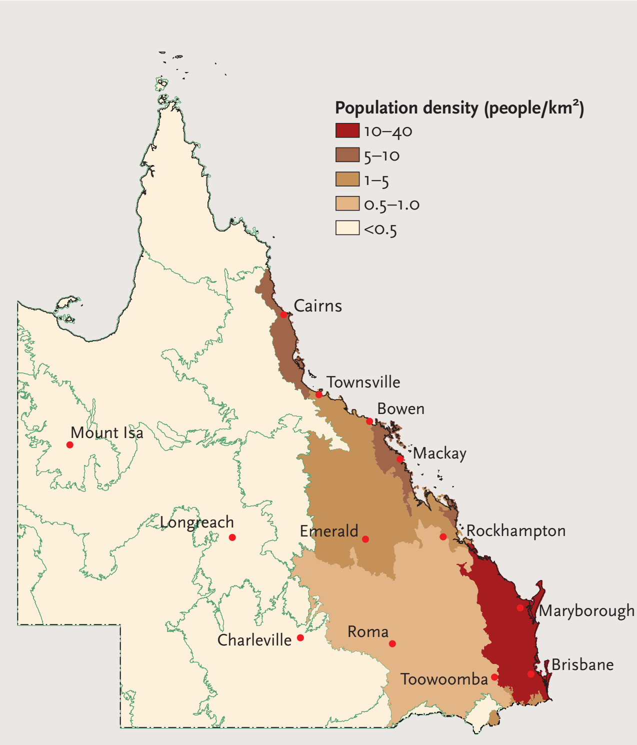


Figure 7-3 The Southeast Queensland bioregion is home to most of Queensland's population.

Land uses and water uses in Queensland vary considerably in extent, as do the pressures on biodiversity associated with them. Approximately 87 percent of the State's land area is managed for pastoral activities: associated pressures include clearing, grazing, introduced species and changed fire regimes. Although urban and mined areas occupy only a small total area in Queensland, they can have severe impacts on biodiversity, both locally and over broader areas. For example, the release of pollutants from point sources into aquatic ecosystems can affect biodiversity considerable distances downstream.

Ecological processes and the ways human activity can influence them are complex, and simple cause-and-effect relationships linking loss or decline in biodiversity with a pressure can be difficult to identify. For example, the state of riverine ecosystems might be affected by the combined pressures of nutrient enrichment, sedimentation, industrial effluent and loss of riparian habitat. No one pressure is solely responsible for any observed change in river biodiversity.

Recognising that biodiversity losses are often a result of multiple, interacting pressures, major direct pressures on Queensland's biodiversity that have or might have significant adverse impacts on its conservation are described under broad groupings of processes and activities. Indicators correspond to major threatening processes described in the National Strategy for the Conservation of Australia's Biological Diversity (DEST 1996). Where evidence exists, reasons for losses or declines in biodiversity are linked to these major pressures (or threats) — see table 7-2 for examples.

Table 7-2 Known or suspected threats to the current status of Queensland's animal species listed as endangered or vulnerable under the *Nature Conservation Regulation 1994*

Pressure	Mammals		Reptiles		Birds		Frogs		Freshwater fish		Butterflies	
	K	S	K	S	K	S	K	S	K	S	K	S
Habitat clearance/fragmentation	8	7	5	5	20	2	1	1	2		8	7
Habitat alteration/degradation												
grazing	1	8	2	9	5	6		2	2	1		
changed fire regimes	1	8		2	5	8					1	
aquatic habitat degradation/pollution	1	1	6	3				2	2			
pasture development/cropping				4								
hydrological changes	1			1		1	1		1	2		
mining disturbances	3	3		1								2
Introduced species												
predation	5	15	6	3	6	3		1				
competition	3	4				1			2	2		1
environmental weeds		1		1		2					1	
cane toad poisoning		1		1		1						
Harvesting activities												
forestry operations	1	3		1	2	3						
fishing nets/bycatch	1		5	1								
poaching, trapping, collecting			1		6	3			1	1		2
Visitor disturbances	3		3	1	1	3			1			
Pesticides/poisoning						2		1				2
Disease		1										
Loss of genetic diversity	1	1										
Vehicle accidents (cars, boats)	2		4	1	1							
Unknown	3		1		4		14					

K = known threat; S = suspected threat
The column figures are the number of species at risk from each threat. A species can be at risk from more than one threat.
(Sources: Cogger et al. 1993; Duncan et al. 1999; Garnett 1992; Lee 1995; Maxwell et al. 1996; McFarland 1998; Tyler 1997; Wager and Jackson 1993; EPA databases)

CLEARING AND FRAGMENTATION OF NATIVE HABITAT

The factor contributing most to the loss of biodiversity in Queensland has been and continues to be the destruction of native habitat by broadscale land clearing. Immediate effects on biodiversity include the removal or killing of species, the most obvious being plants, and the rapid reduction in habitat for other species. Habitat loss is a major factor in loss of woodland bird diversity in Australia: it has been estimated that 1000–2000 birds die for every 100 ha of native bushland cleared (Bennett 1993). Broadscale land clearing not only reduces the extent and diversity of natural ecosystems but also fragments them into remnant patches that, in many cases, are too small and too isolated to maintain viable populations of species.

Clearing

Mapping of pre-clearing and remnant extent of regional ecosystems in the Mulga Lands, Mitchell Grass Downs, Brigalow Belt and Southeast Queensland bioregions has indicated large numbers of endangered and of concern ecosystems currently threatened by tree clearing (table 7-3). These ecosystems have been reduced to less than 30 percent of their pre-clearing extent.

Table 7-3 Numbers of endangered and of concern regional ecosystems threatened by tree clearing in the Mulga Lands, Mitchell Grass Downs, Brigalow Belt and Southeast Queensland bioregions

Bioregion	Endangered	Of concern	Total	Percentage of total in bioregion
Mulga Lands	4	11	15	23
Mitchell Grass Downs	1	3	4	8
Brigalow Belt	19	23	42	26
Southeast Queensland	11	33	44	31

(Source: Wilson 1998)

Habitat clearance is the most serious threat to Queensland's threatened butterflies. The original distribution of the vulnerable Richmond birdwing butterfly (*Ornithoptera richmondia*) has been reduced by two-thirds due to clearing of its coastal rainforest habitat in south-east Queensland.

Habitat clearance is the major cause of decline or a factor contributing to the decline of at least 44 threatened animal species in Queensland — 35 percent of the total number listed as endangered or vulnerable. The disappearance of eight mammal species (Gordon 1984) from the Brigalow Belt bioregion and the threatened status of nine reptile species (Covacevich 1996) mainly confined to the region have been attributed to clearing and the replacement of native groundcover by exotic pasture species.

Indicators

Extent and rate of clearing of native vegetation by bioregion

Extent and rate of marine habitat disturbance by bioregion

Extent and rate of clearing of native vegetation by land tenure

Extent and rate of clearing by ecosystem type

Scanlon and Turner (1995) estimated that at European settlement about 117 million ha of what is now Queensland (68 percent of the total land area) supported woody ecosystems — forests, woodlands and shrublands. Over the past 200 years more than half of this area has been cleared, mainly in the most fertile and accessible parts in the coastal, subcoastal and central inland regions. Clearing has been most extensive in the Brigalow Belt, Mulga Lands and Southeast Queensland bioregions. About 95 percent of the original 6 million ha of those ecosystems comprising brigalow (*Acacia harpophylla*) in semi-arid Queensland has been cleared, thinned or degraded. In the heavily populated SEQ 2001 area (2.25 million ha centred on Brisbane), 64 percent of the total bushland was cleared between 1820 and 1987 and a further 1 percent in the period 1987–94 (Catterall et al. 1997).

Factors such as topography and land tenure have influenced clearing. In the SEQ 2001 region, 84 percent of the lowland areas had been cleared by 1993, primarily for urban expansion and intensive agricultural purposes, while only 28 percent of land at higher elevations had been cleared (figure 7-4). As a result, ecosystems restricted to lowland areas, including melaleuca wetlands, lowland rainforest, eucalypt-dominated associations of river basins and coastal heathlands, have in particular been subject to high rates of clearing.

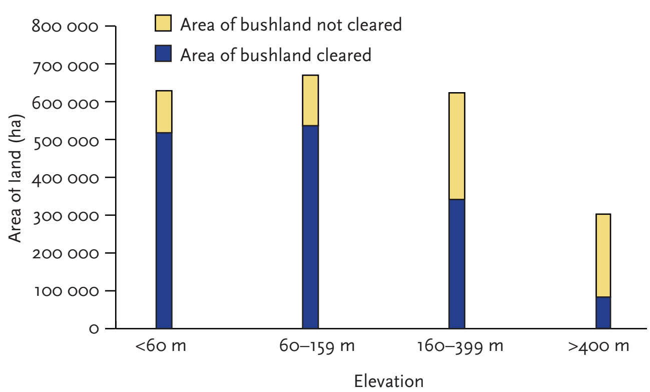


Figure 7-4 Area of bushland cleared by elevation category in the SEQ 2001 area of the Southeast Queensland bioregion. Topography has a strong influence on patterns of bushland loss in the area.
(Source: Catterall and Kingston 1993)

Clearing rates by bioregion (table 7-4) and province (figure 7-5), catchment, local government area and tenure have been calculated as part of the Statewide Landcover and Trees Study (SLATS) project. Recent SLATS calculations indicate that the average annual clearing rate in the period 1991–95 was approximately 289 000 ha/year (DNR 1999a).

A SLATS report on land cover change in south-east Queensland (an area encompassing all coastal catchments from the Queensland/New South Wales border to Double Island Point) reported an average annual clearing rate of 60 000 ha/year for 1988–97 (DNR 1999b). Within the large Brisbane River catchment, an average of 1960 ha/year was cleared within this period.

Preliminary data suggest that the overall rate of tree clearing declined by approximately 21 percent between 1988–91 and 1991–95. Further analysis of the 1995–97 period is needed to confirm any statewide trends. In south-east Queensland the most recent 1994/95–97 clearing rate is 7 percent higher than the 1988–91 and 1991–94/95 figures (DNR 1999b). Regrowth in south-east Queensland is occurring at a rate equal to approximately 15 percent of the clearing rate; the majority of this regrowth is planting of plantations or regrowth following harvesting within State forest (DNR 1999b).

Approximately 92 percent of woody vegetation change is clearing of woody vegetation for pasture for grazing (table 7-5). The proportion of clearing that is re-clearing of cleared areas is unknown.

At present the highest rate of tree clearing in Queensland takes place in the more marginal production areas including parts of the Brigalow Belt, Mulga Lands and Desert Uplands bioregions, and, to a lesser extent, the southern treed portion of the Mitchell Grass Downs bioregion. In the period 1991–95, the Upper Belyando Floodout province in the Desert Uplands bioregion recorded the highest clearing rate of any province: on average, 2.5 percent of the total area was cleared each year.

While just over half (54 percent) of all clearing in Queensland has occurred on leasehold land, the relative rate of clearing on freehold land is significantly higher (table 7-5). Rates of bushland clearing on freehold land in coastal south-east Queensland have been very high: about 40 percent of privately owned bushland was cleared in the period 1974–89 (Catterall and Kingston 1993).

Clearing in north Queensland coastal wetland areas for agricultural development has contributed to extensive losses of freshwater (non-tidal) wetland habitats (figure 7-6). Skull (1996) reported a 40 percent reduction of melaleuca wetland in the Tully–Murray River catchments, from 6750 ha to 3960 ha in the period 1942–92.

Marine habitat loss has occurred as a result of dredging, land reclamation and bottom trawling in some fisheries. Measurement of marine habitat loss through clearance or disturbance is difficult and few detailed studies of change in marine habitat over time have been made. Intertidal areas have been

As a result of preferential clearing, the more fertile lowlands have lost more types of ecosystems than other parts of Queensland.

Table 7-4 Average annual clearing by bioregion, 1991–95

Bioregion	Clearing rate (ha/year)	Clearing as percentage of bioregion area/year	Clearing as percentage of Queensland's total clearing area
Brigalow Belt	150 552	0.4	52.1
Cape York Peninsula	967	<0.1	0.3
Central Queensland Coast	1 770	0.1	0.6
Channel Country	161	<0.1	<0.1
Desert Uplands	36 251	0.5	12.5
Einasleigh Uplands	2 037	<0.1	0.7
Gulf Plains	1 091	<0.1	0.4
Mitchell Grass Downs	18 081	0.1	6.2
Mulga Lands	63 335	0.3	21.9
New England Tableland	1 343	0.2	0.5
Northwest Highlands	33	<0.1	<0.1
Southeast Queensland	9 736	0.1	3.4
Wet Tropics	3 583	0.2	1.2

(Source: DNR)

Table 7-5 Average annual clearing by tenure type and by replacement land cover, 1991–95

Tenure Type	Tenure Area (ha)	Clearing rate by replacement land cover (ha/year): Pasture	Crop	Forest	Mining	Infrastructure	Settlement	Total	% tenure type area cleared in Qld per year	% of total clearing in Qld per year
Leasehold	118 443 500	149 900	2 600	200	900	1400	200	155 200	0.13	53.7
Freehold	42 464 100	112 900	9 700	500	400	900	2 100	126 500	0.30	43.8
Other tenures*	2 329 200	1 000	100	0	300	100	0	1 500	0.06	0.5
Reserves†	11 401 700	1 600	100	4 100	0	100	100	6 000	0.05	2.1
Totals	**174 638 500**	**265 400**	**12 500**	**4 800**	**1 600**	**2 500**	**2 400**	**289 200**	**0.10**	**100.0**

*Other tenures include Commonwealth lands, mining tenure, main roads, railways and ports. †Reserves include State forests, timber reserves and national parks.
(Source: DNR)

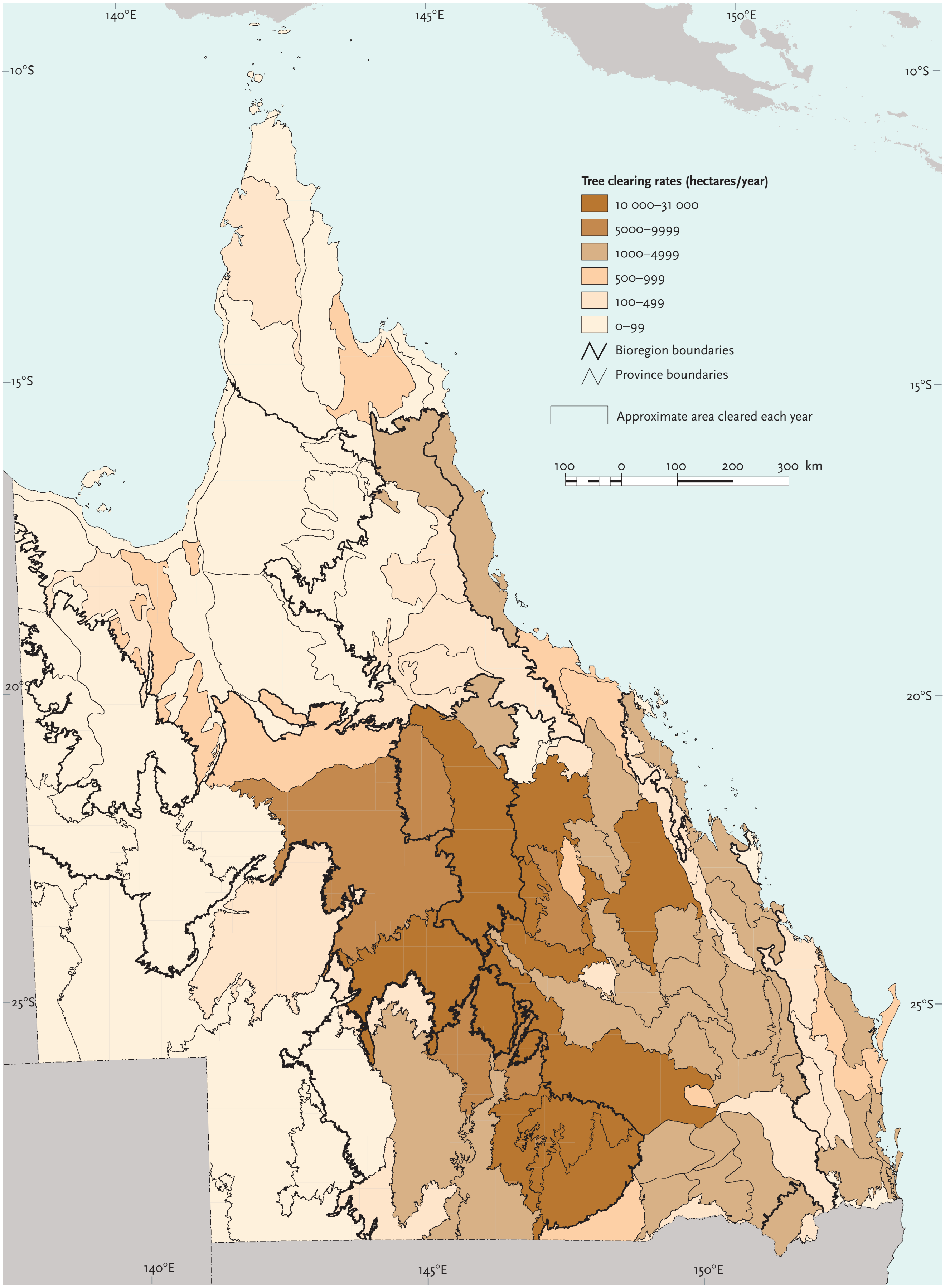


Figure 7-5 Average annual clearing rates in biogeographic provinces, 1991–95, including State forest clearing
(Source: DNR)

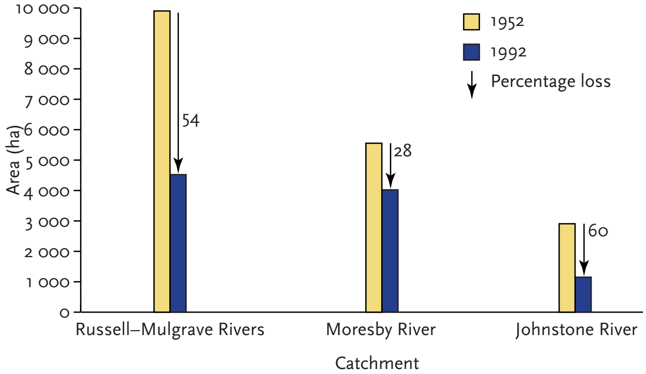


Figure 7-6 Clearing and draining were the principal causes of changes in wetland area of three north Queensland coastal catchments, 1952–92.
(Sources: Russell and Hales 1994; Russell et al. 1996a, 1996b)

cleared and reclaimed for urban, tourism, industrial, port expansion and agricultural purposes. Between 1941 and 1989 about 646 ha of mangrove wetland on the Curtis Coast was lost, primarily through clearing and reclamation for industrial and urban development (QDEH 1994). An estimated 1240 ha of mangrove habitat in Moreton Bay was destroyed between 1974 and 1989 (Quinn 1992), while an estimated 210 ha of mangroves and saltmarsh was lost between 1987 and 1994 (Catterall et al. 1996).

Under the *Fisheries Act 1994* all marine plants are protected and can only be removed under approved permits. Permit records from DPI Fisheries indicate that, from 1990 to 1996, almost 2500 ha of tidal land supporting marine plants was disturbed. This area comprised 222 ha supporting mangroves, 14 ha of seagrass, 33 ha of saltmarsh and 2230 ha of mixed communities (Zeller 1998). While most permits issued result in localised small disturbances, port expansion, tourist developments and marinas/boat harbours result in the greatest disturbance of tidal land and associated loss of marine plants.

Activities such as dredging and trawling have the potential to significantly affect seabed habitats through physical disturbance. Disturbance can remove or destroy sessile benthic organisms and alter the composition and diversity of benthic ecosystems. The effects of prawn trawling on benthic communities were documented in a five-year study by CSIRO and DPI in the Far Northern Section of the Great Barrier Reef. Preliminary analyses of the effects of trawling at different frequencies indicated that each trawl removed roughly 5–20 percent of the available living, immobile organisms growing on the seabed. Some 70–90 percent of the initial living biomass was removed after 12–13 trawls. At low trawl frequencies, impacts may be undetectable, but the cumulative effect of frequent trawls over the same grounds may be substantial (Pitcher et al. 1996).

While trawling occurs along most of the east coast, more than half the commercial fisheries catch is taken from less than 30 percent of the coastline. Trawl effort is most concentrated in Moreton Bay, the Curtis Channel off Gladstone, the Bowen region and Princess Charlotte Bay in north Queensland (see figure 5-7, chapter 5).

Habitat fragmentation

As native vegetation clearing continues, ecosystems are becoming increasingly restricted to relatively small remnant areas, isolated from one another by a matrix of different vegetation and/or land uses (figure 7-7). Roads, powerlines, canals, plantations and open agricultural land can create barriers between remnants. Such barriers can stop or restrict the movement of species between fragments.

The species most likely to be affected include those with large home ranges, patchy distributions and poor dispersal abilities. Arboreal animals such as the yellow-bellied glider (*Petaurus australis*) are unlikely to cross open ground and are therefore particularly sensitive to fragmentation. Barriers can also alter historic natural patterns of gene flow among populations, which may have serious consequences for long-term preservation of genetic diversity.

If habitat fragments are too small, they may not support long-term viable populations of species, particularly those with large area requirements and extensive geographic ranges. For example, a minimum of 9750 ha of unfragmented forest habitat has been assessed as necessary to maintain a viable population of the yellow-bellied glider (Goldingay and Possingham 1995). The creation of habitat fragments also results in greater isolation of subpopulations of species and a reduction in their size. Small population size increases the risk of extinction of a species and is a threat to genetic diversity (see box 'The northern hairy-nosed wombat').

A fragmented landscape also greatly increases the total length of remnant edges, making remnants more vulnerable to external disturbances such as fire and invasion by non-native species. The impacts of clearing are often not just confined to the cleared area itself, but can extend well into the surrounding vegetation. Powerline easements can adversely affect bird diversity up to 125 m beyond the cleared area (Baker et al. 1998). In the Wet Tropics World Heritage Area, while 0.22 percent of the area has been directly affected by clearing associated with the network of powerlines and roads, it has been estimated that upwards of 1.5 percent of the area (about 12 960 ha) may potentially be affected to some extent by these clearings (WTMA 1998).

Roads can act as barriers to wildlife movement and are also a cause of mortality for wildlife.

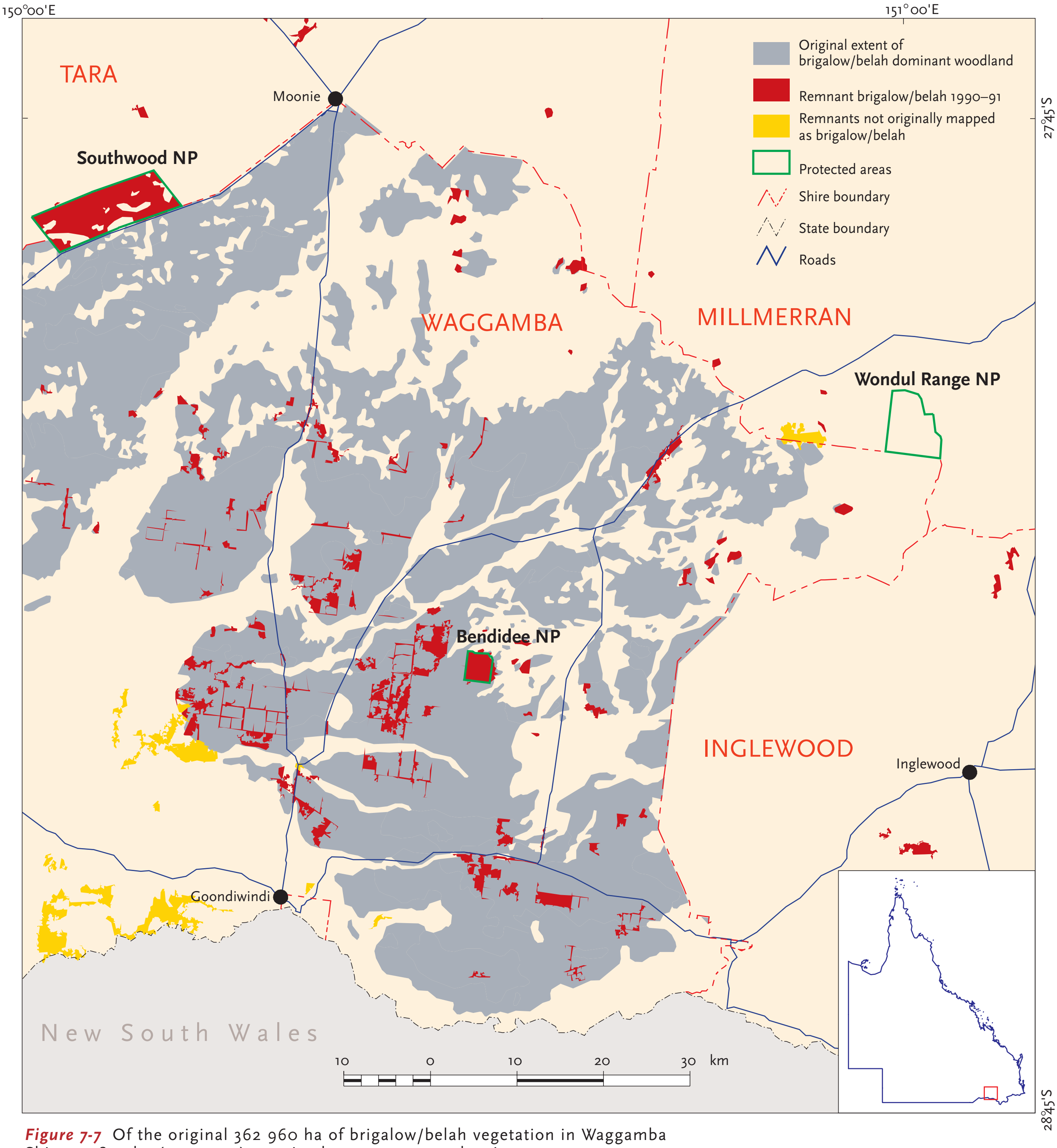


Figure 7-7 Of the original 362 960 ha of brigalow/belah vegetation in Waggamba Shire, 15 819 ha (4 percent) remained as remnant patches in 1990–91.

Fragmentation of native habitat is now recognised as one of the major threats to biodiversity (Saunders et al. 1991). It is believed to be one of the reasons for the decline of birds in Australian woodlands (Barrett et al. 1994). Research in the Wet Tropics has yielded important insights into the responses of rainforest mammals to habitat fragmentation: the most vulnerable species are disappearing or declining rapidly (Laurance 1997). On the southern Atherton Tableland, the lemuroid ringtail possum (*Hemibelideus lemuroides*) is known to have disappeared from a small rainforest fragment in only 3–9 years and from two larger fragments in 35–60 years (Laurance 1990). The habitat of the endangered mahogany glider (*Petaurus gracilis*) has been reduced to 20 percent of its original extent and the species is now fragmented into a number of small populations (Blackman et al. 1994).

Indicators

Extent of fragmentation of remnant vegetation and marine habitat by bioregion

Frequency and areas of remnant vegetation patches in specified class areas

Number of river structures per kilometre of river length by catchment

While case study data exist, there is a lack of comprehensive data to allow measurement of the extent of fragmentation across all bioregions and its impact. No data exist for marine habitats. No common measures of fragmentation are available yet, but they are being developed. While progressive mapping of fragments by the Department of Natural

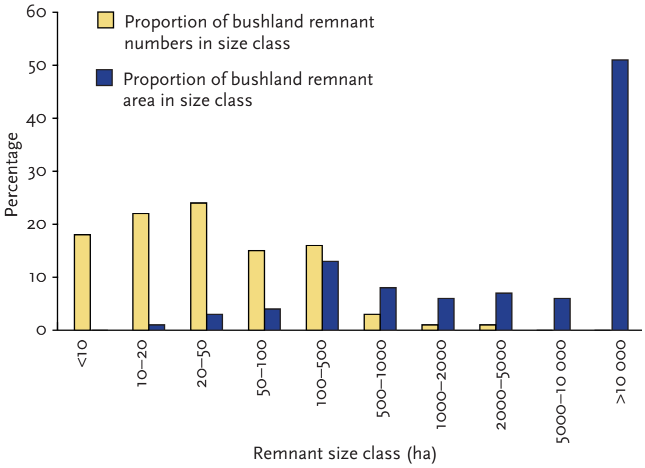


Figure 7-8 Degree of fragmentation of bushland in the SEQ 2001 area, Southeast Queensland bioregion
(Source: Catterall and Kingston 1993)

Resources (DNR) and the Environmental Protection Agency (EPA) will provide information on remnant size, shape and location, selection of suitable measures to quantify deleterious impacts of fragmentation on biodiversity is far more complex and uncertain.

An assessment by DNR of remnant forest fragments in the Southeast Queensland bioregion has revealed that 99 percent of the 524 630 forest fragments are less than 50 ha in size; only 10 are greater than 50 000 ha. In the SEQ 2001 area, Catterall and Kingston (1993) found that while 64 percent of mapped bushland remnants were less than 50 ha in size, the one large remnant patch of some 10 000 ha accounts for just over half of all native bushland in the study area (figure 7-8).

Even within large and seemingly continuous tracts of native habitat, fragmentation can occur at a finer scale. Timber harvesting and grazing can disrupt habitat continuity within a forest, resulting in a mosaic of disturbed and undisturbed habitat (figure 7-9). The extent to which these smaller 'within-forest' fragments disrupt ecological processes is unknown.

Artificial barriers such as dams, weirs and tidal barrages fragment rivers, resulting in discontinuous aquatic habitat and

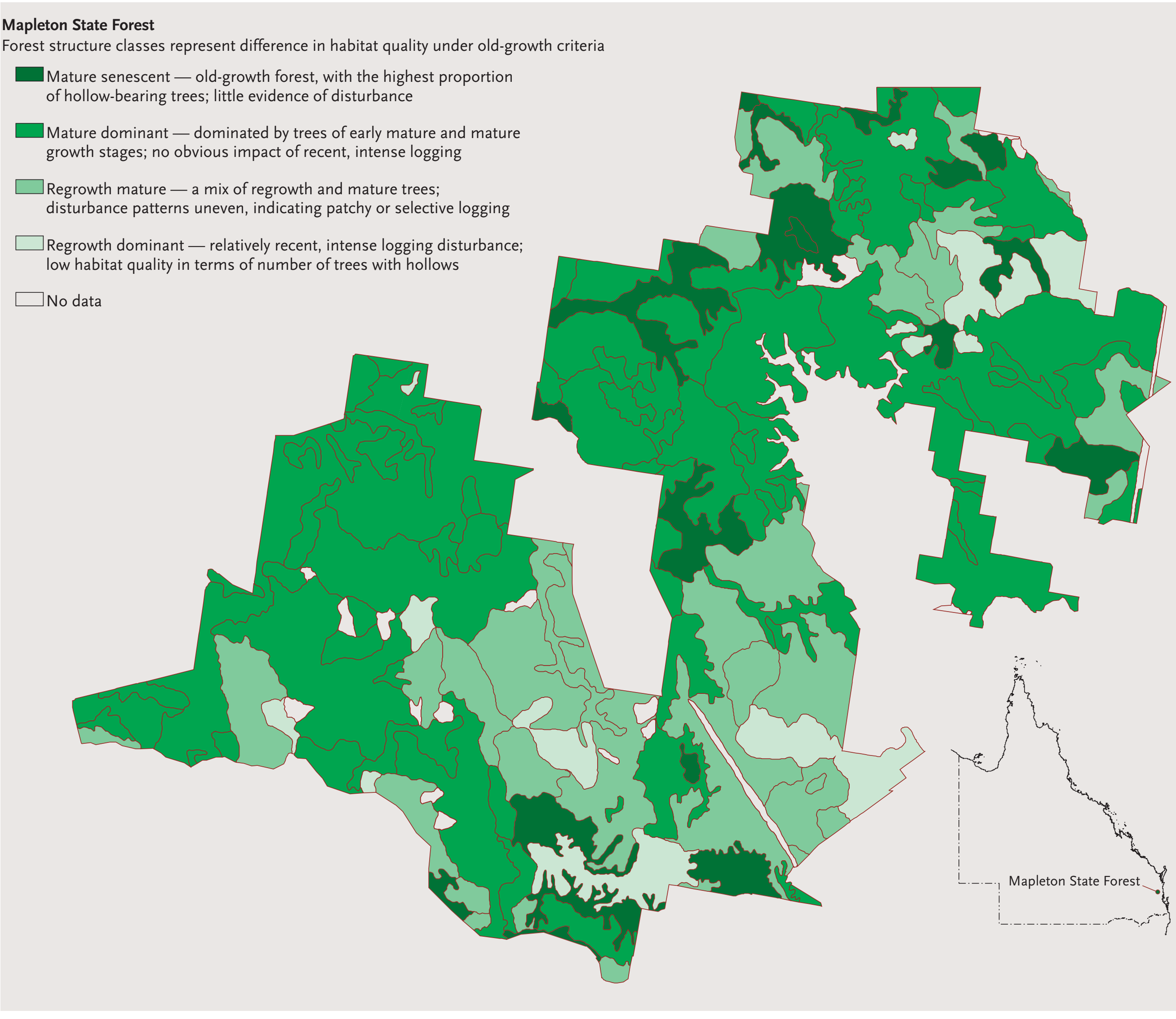


Figure 7-9 Some forested areas, when viewed at a landscape level, may appear as a single large remnant patch. However, fragmentation can occur at a smaller scale within the remnant. This 'within-forest' fragmentation has been mapped in Mapleton State Forest.
(Sources: DNR and Department of Geographical Sciences, The University of Queensland)

disruption of many ecological processes. Many of Queensland's freshwater and marine fish species are known to migrate at some stage in their life cycle to breed, to disperse into new habitats or to find feeding or rearing areas. Fragmentation of rivers can prevent such migrations and, in the long term, affect distribution and abundance of species and the genetic composition of individual species and populations.

Most river basins in Queensland have been regulated by artificial impoundments to some extent. DNR manages 114 major dams and weirs and many others are managed by local authorities. Few of these have been built with consideration of the migratory habits of native aquatic fauna; 26 devices to assist the passage of fishes through artificial instream barriers have been constructed in Queensland (Zeller 1998). The numbers of artificial barriers provide an indication of the extent of fragmentation of riverine habitats (table 7-6).

Table 7-6 Number of dams, weirs and barrages per 1000 km of river length within the major drainage basins in Queensland. These data are based on number of structures sited on major rivers and streams only.

Drainage basin*	Number of dams, weirs and barrages per 1000 km of river length
Carpentaria	0.5
Central Coastal	3.3
Lake Eyre	0.3
Murray–Darling	4.3
Northern Coastal	3.6
Southern Coastal	16.0

*For location of drainage basins see figure 4-1, chapter 4. Analysis is based on data supplied by DNR.

INTRODUCED SPECIES

Many exotic organisms have been introduced, both deliberately and unintentionally, to Queensland since European settlement. At least 1166 vascular plant taxa and 19 mammal, 11 bird, 11 fish, 2 reptile and 1 amphibian species have established breeding populations in the State and become naturalised. Unknown but probably large numbers of invertebrates, fungi and bacteria, including many organisms that cause commercially destructive diseases, have also become established as a consequence of human actions. Indicators on distribution, abundance and rate of spread are important because introduced species exert considerable pressure on native biodiversity.

Indicators

Distribution and abundance of exotic species by bioregion

Rate of spread of exotic species by bioregion

Vertebrates

Foxes (*Vulpes vulpes*) and cats (*Felis catus*) prey on a wide range of native species and have been implicated in the decline, and possible local extinction, of at least 17 vertebrate species listed as endangered or vulnerable. A further 22 threatened vertebrate species are thought to be at risk from these predators (table 7-2). The eastern Simpson Desert in south-west Queensland is part of the large central sandy desert region of Australia identified as a major 'hot spot' area where five mammal and one bird species are at risk from these predators (Newsome et al. 1997).

Foxes experience population fluctuations regionally in response to local factors, although their range remains constant. They rely heavily on rabbits as a food source, and native wildlife generally comprises alternative, supplementary or opportunistic prey. Regions that lack rabbits or where rabbits are scarce have fewer foxes, and therefore threatened marsupials of medium size are at lower risk of predation: the endangered bilby (*Macrotis lagotis*) in the mid-Diamantina region is an example. Foxes are also a significant predator on marine turtle eggs on the central Queensland coast (Limpus and Reimer 1994).

Feral cats are found throughout Queensland. Their distribution appears to have remained constant for at least the past century. The nature and extent of the threat posed by feral cats are not well understood. On mainland Australia predation by feral cats is thought to threaten the survival of native species that currently persist in small numbers (Dickman 1996). Their largest impact is thought to be on ground-dwelling animals: reptiles, insects, small mammals and ground-nesting birds. Feral cats also carry diseases such as toxoplasmosis, which causes mortality in some marsupial species.

Rabbits (*Oryctolagus cuniculus*) consume much available vegetation and prevent regeneration of many plant species. In arid areas, they eat seedlings. This severely restricts vegetation distribution and lessens the availability of shade, shelter and food for native animals. The recently introduced rabbit calicivirus has reduced rabbit numbers and impacts.

Feral goats (*Capra hircus*) compete with native herbivores for food and have been implicated in the decline of several

Feral pig damage in Edmund Kennedy National Park, north Queensland

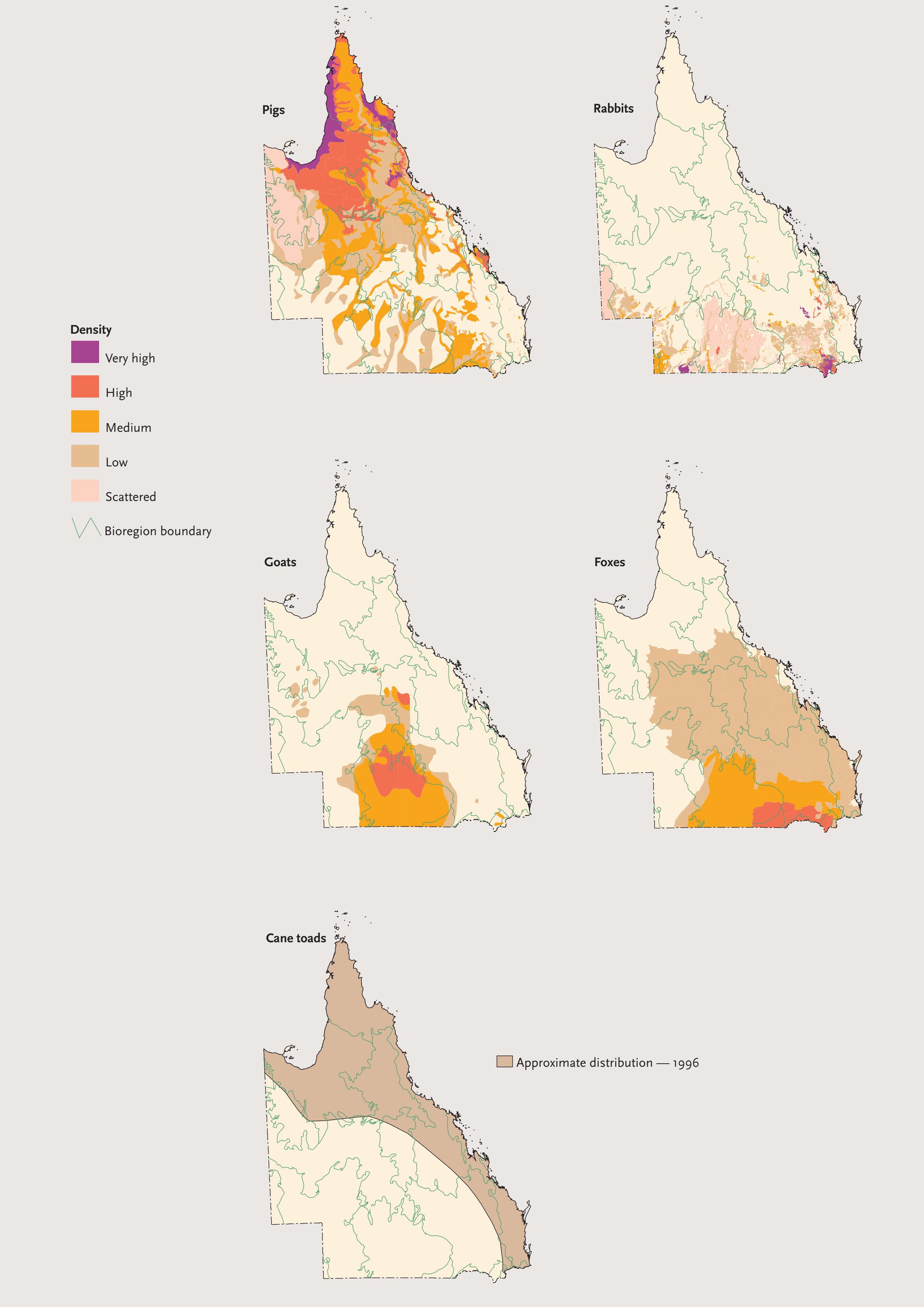


Figure 7-10 Distribution of five exotic vertebrate species in Queensland. The other significant exotic species, the feral cat, is found throughout all bioregions in the State.
(Sources: DNR and CSIRO)

species of rock-wallabies. They are found predominantly in the Mulga Lands. In particular, they are responsible for land degradation and changes in composition of vegetation in rangeland areas.

While little scientific work has been carried out to determine their impact on biodiversity, feral pigs (*Sus scrofa*) are believed to cause significant environmental damage through destruction of habitat, competition for food, disease transmission and land degradation, particularly along watercourses. Evidence also suggests that pigs play a significant role in the spread and propagation of environmental weeds such as pond apple (*Annona glabra*). Their preferred refuges are undisturbed areas where water and cover are available. They are a recognised major pest in rainforests in north Queensland.

Cane toads (*Bufo marinus*) have rapidly colonised Queensland since their introduction in 1935. During the 1980s they spread through the Gulf Country and moved north at about 30 km/year, reaching the tip of Cape York in 1993 (Alford, R., pers. comm.). As the cane toad is toxic at all stages of its life cycle, native predators are highly susceptible to poisoning. Cane toads have been implicated in the decline of native predators such as quolls and monitors (Burnett 1997). Studies also indicate that their eggs and larvae are toxic to many species of native freshwater animals, including the tadpoles of native frogs (Crossland 1996).

The number of non-native fishes that have entered Australia, legally or otherwise, is unknown. While 163 non-native fish species may be legally owned in Queensland under the *Fisheries Regulation 1995*, many more are brought in and traded illegally. At least 27 exotic fish species have been reported in Queensland's fresh waters (Arthington and McKenzie 1997; Zeller 1998; Webb, A., pers. comm.), and at least 11 of these have established self-maintaining populations (table 4-13, chapter 4).

North Queensland waters are particularly at risk as most aquarium fish are tropical and are unlikely to survive elsewhere. The number of exotic fish recorded is continuing to rise. In 1985, six species were found in north Queensland waters. By 1996 there were 13, of which at least nine had established breeding populations, and by 1997 there were 16 species (Webb, A., unpub. data).

Most non-native fishes have entered open waters as releases from home aquariums, both deliberate and accidental, or as escapees from outdoor ornamental ponds. Presently no specific requirements relate to the security of these ponds, probably the main source of introductions. Webb (1994) reported 12 cichlid species in ornamental ponds in the Townsville and Cairns regions.

Queensland Museum

The exotic mosquitofish threatens native biodiversity in Queensland freshwaters.

In most instances, the absence of detailed long-term research data into impacts associated with introduced fish makes assessment of impacts on native biodiversity extremely difficult. In general, introduced species have high invasive abilities, often have a high reproductive rate and have the potential to adversely affect native fish and their habitat through increased predation and competition. Four of the five native freshwater fish threatened in Queensland are adversely affected by exotic species (Wager and Jackson 1993). Mosquitofish (*Gambusia holbrooki*), widespread throughout Queensland, have been implicated in the decline of frogs because they prey on tadpoles, and in the decline of three threatened native fish species (QFMA 1996a). Species such as the carp contribute to habitat degradation by uprooting water plants, re-suspending sediments and destabilising river banks.

Large numbers of ornamental fish are imported into Australia, subject to only limited controls based on disease risks. As a result, there is a great potential to introduce exotic diseases into native fish populations (Arthington and McKenzie 1997). The trade in aquarium fish has been considered a likely source for the introduction of an exotic disease organism thought to be responsible for the decline and disappearance of frog species from rainforest stream habitats in Queensland (Laurance et al. 1996).

Invertebrates

It is estimated that more than 500 exotic species of insects, collembola (springtails) and arachnids (spiders, ticks) have become established in Australia since European settlement (Yen and Butcher 1997), but the number established in Queensland is unknown. While anecdotal evidence exists, there are few comprehensive data on the impact of these species on native biodiversity. The exotic earthworm *Pontoscolex corethrurus*, for example, is widespread in disturbed areas of the Wet Tropics but may also be spreading into native forest. It may pose a serious threat to native earthworm species and may threaten the integrity of the forest nutrient recycling systems (Dyne and Wallace 1994).

The introduced ant *Pheidole megacephala* is replacing the native ant *Philidris cordatus* in occupancy of the vulnerable ant plant (*Myrmecodia beccarii*). This displacement also threatens the endangered apollo jewel butterfly (*Hypochrysops apollo apollo*), as the introduced ant is indifferent to and does not tend the butterfly's larvae. The invasion of this ant species is likely to pose a serious threat to both the native ant and butterfly species.

Plants

Introduced plants that invade natural ecosystems and become naturalised can cause significant modification to ecosystem function. At least 1166 introduced plant species, representing 13 percent of all Queensland vascular plant taxa, have become naturalised in the State since European settlement. While not all have invaded native vegetation and become environmental weeds, possibly one-quarter of these naturalised species are, or have the potential to become, serious environmental weeds (Humphries et al. 1991).

Exotic plant species affect biodiversity by competing with and replacing native vegetation. This can lead to changes in native wildlife diversity in the invaded areas. Studies indicate a decline in species richness, canopy cover or frequency of native species as a result of weed invasion (Adair and Groves 1998). Weed

Table 7-7 Introduced plants posing significant threats to biodiversity in Queensland

Species	Key ecosystems affected/distribution	Nature of impact and threat to biodiversity
Prickly acacia (*Acacia nilotica*) — small tree or shrub	Has invaded more than 6.6 million ha of the Mitchell grasslands; has the potential to invade two-thirds of the State.	Replaces native grasses (*Astrebla* and *Iseilema* spp.); is a long-term threat to the Mitchell grasslands; converts grassland to shrubland.
Pond apple (*Annona glabra*) — tree	Is a significant weed of tropical lowlands, scattered throughout coastal north Queensland; wetlands prone to invasion.	Displaces native grasses, sedges, ferns and melaleuca species.
Groundsel (*Baccharis halimifolia*) — shrub	Grows in seasonally moist situations in south-east Queensland.	Forms pure stands in melaleuca woodland and open forest communities.
Para grass (*Brachiaria mutica*) — semi-aquatic grass	Is widely used in ponded pastures along the central Queensland coast; has invaded wetlands and streams in the wet-dry and wet tropics and subtropics.	Invades neighbouring wetlands, out-competing native species with far-reaching effects on waterfowl, fish and invertebrate communities.
Buffel grass (*Cenchrus ciliaris*) — groundcover	Grows in moist refuges and on river banks in the arid zone.	Threatens habitats by displacing native vegetation and altering fire regimes; is likely to reduce fauna resources.
Bitou bush (*Chrysanthemoides monilifera* ssp. *rotundata*) — shrub	Occurs mainly along sandy coastlines; is already a significant coastal weed in New South Wales; while still restricted in Queensland, is a threat to the Great Sandy Region.	Is an aggressive invader, out-competing and eliminating native plants; smothers coastal dune vegetation.
Rubber vine (*Cryptostegia grandiflora*) — vine/shrub	Threatens mainly riparian communities in the wet-dry tropics; more than 35 million ha affected, and 700 000 ha densely infested; most serious weed on Cape York Peninsula.	Smothers trees and shrubs and shades out ground layer; destroys riparian and remnant rainforest vegetation; most serious threat to riparian vegetation.
Water hyacinth (*Eichhornia crassipes*) — aquatic	Grows in standing surface waters, especially where nutrient levels are high.	Is still spreading despite biological control measures; is capable of rapid growth (doubling time of 5 days); impedes flow in waterways.
Hymenachne (*Hymenachne amplexicaulis*) — semi-aquatic grass	Was introduced in the 1980s for use in ponded pastures; has invaded up to 1000 ha of wet tropics including national parks.	Can grow in water up to 1 m deep; invades neighbouring wetlands; forms monospecific stands on riverbanks and seasonally flooded areas.
Lantana (*Lantana camara*) — shrub	Is widespread throughout subcoastal and coastal areas; 4 million ha invaded; is a serious weed in open forests in north Queensland; poses a threat to many conservation areas.	Is a serious invader of disturbed areas; dense stands shade out and dominate ground-storey native species, leading to loss of biodiversity.
Cat's claw creeper (*Macfadyena unguis-cati*) — vine	Riparian vegetation in central and south-east Queensland.	Climbs by adventitious roots and tendrils; smothers trees and shrubs.
Parkinsonia (*Parkinsonia aculeata*) — small tree/shrub	Grows in ephemeral wetlands and riparian communities in the wet-dry tropics; is present in the Fitzroy and Burdekin River systems, the Gulf region, the northern and central west and coastal districts, with small infestations in southern Queensland.	A woody, thorny shrub or small tree, it can form dense, impenetrable thickets in moist habitats such as river banks and ephemeral wetlands; threatens wetlands.
Parthenium (*Parthenium hysterophorus*) — shrub	Invades native grasslands; central blue grasslands extensively invaded; has spread to 10 percent of the State.	Is highly invasive; out-competes native grasses.
Mesquite (*Prosopis* spp.) — small tree/shrub	Colonises semi-arid and arid areas along watercourses, Mitchell grasslands; has affected more than 500 000 ha of north-west Queensland; has the potential to become established in 60 percent of the State.	Is similar to prickly acacia but has a wider range of soil tolerances.
Salvinia (*Salvinia molesta*) — aquatic fern	Grows in stationary and slow-moving water, especially where nutrient levels are high; is well established at various locations along the east coast and inland.	Is capable of very rapid growth (doubling time of 8–10 days); tolerates a wide range of conditions; can form extensive mats that affect water quality and other biota; is still spreading.
Blue thunbergia (*Thunbergia grandiflora*) — vine	Grows in lowland rainforests and remnant riparian vegetation in north Queensland.	Is a vigorous, rapidly spreading vine that smothers native vegetation to the canopy.

invasion is closely related to disturbance by human activity. Weeds can spread rapidly. Singapore daisy (*Wedelia trilobata*), for example, became established along 2500 kilometres of the Queensland coast within a 15-year period (Batianoff 1997).

Exotic species continue to spread throughout Queensland and more are being introduced. The trend is one of increasing pressure on biodiversity. The number of known naturalised species in Queensland increased by 5 percent in the period 1994–97. The number of environmental weeds identified in the Wet Tropics World Heritage Area rose from 48 in 1997 to 63 in 1998. Of the 1998 total, 38 have been identified as a threat to rainforest or rainforest edges (WTMA 1998).

Public demand for exotic ornamental plants and agricultural demand for new pasture and fodder species are the major reasons for the deliberate importation of exotic species. A high proportion, 45 percent, of all naturalised species in Queensland belong to the families Poaceae (grasses) and Fabaceae (legumes) and a further 27 percent belong to the ornamental Asteraceae (daisy) family. At least 73 percent of the 277 potential environmental weed taxa listed by Csurhes and

DNR

Rubber vine (*Cryptostegia grandiflora*), one of the most serious environmental weeds in Queensland, has densely infested 700 000 ha of mostly riparian vegetation. In total, 35 million ha of the State have some of these plants present.

Edwards (1998) are used as ornamentals, either in gardens or in home aquariums and ponds. The trade in ornamental plants appears to be the major source of new weed species in Australia.

Almost all Queensland ecosystems have been invaded by environmental weeds and are affected in different ways. While undisturbed rainforest is difficult to invade, rainforest margins are vulnerable to invasion by trees such as African tulip and privet, shrubs such as lantana and exotic vines such as cat's claw and Madeira. Sclerophyll forests are invaded by both native and exotic rainforest species when fire ceases to be used as a management tool. Lantana is a major invader of sclerophyll forest along the coastal strip. Introduced pasture grasses such as green panic and mission grass also readily invade sclerophyll forests.

Of the 35 most troublesome exotic weeds invading Queensland's sandy shore habitats, 30 were introduced intentionally (Batianoff 1997). Coastal dunes have been invaded by bitou bush and groundsel bush, which have an impact on local dune ecology. Pond apple is a highly aggressive tree that is very invasive of inundated coastal habitats in northern Queensland.

In the dry western areas, native rangeland grasses are being replaced by exotic shrubs such as prickly acacia, parkinsonia and mesquite. Invasion by these exotics may be accelerated by grazing where most of the groundcover has been removed. Prickly acacia has invaded close to 7 million ha of native Mitchell grassland, forming open woodlands. This serious woody weed has the potential to spread across most of Queensland under present climatic conditions (Kriticos 1997).

Queensland's aquatic ecosystems have been invaded by aquatic species such as salvinia and water hyacinth. They can form dense mats that cover the water surface of slow-moving rivers and waterholes. Introduced ponded pasture grasses such as para grass and hymenachne have spread throughout some shallow wetlands in coastal north Queensland, displacing some native plants (Lukas 1993).

Marine organisms

A review of the ballast content of ships arriving in Australia has shown that a large range of organisms including fish, crustaceans, molluscs, polychaetes, coelenterates, sea squirts and micro-organisms have been discharged into Australian waters (Thresher 1996). The spread of these introduced species has been exacerbated by localised currents and ships working from port to port within Australia. The impact of introduced species on native marine biodiversity is unknown. Twenty marine organisms (18 animal and two algal species) are known to have been introduced into Queensland waters (see table 5-12, chapter 5). These exotic organisms have been introduced via ballast water discharge, hull fouling and mariculture (oysters and mussels brought in for cultivation). Detailed surveys to detect introduced organisms in Queensland's waters have not been undertaken.

Translocated native species

Indicators

Number of translocated species and sites of translocation by bioregion

Translocation is the movement of native species or distinct genetic stocks of species to areas outside their natural distribution. Once outside their natural range, native species may pose as serious a threat as exotic ones. For example, the unauthorised release of the mouth almighty (*Glossamia aprion*), a native fish predator, was implicated in eliminating native rainbowfish (*Melanotaenia eachamensis*) from Lake Eacham in the late 1980s (Barlow et al. 1987). The absence of detailed research in Australia, however, makes assessment of the ecological impacts of translocation difficult.

The practice of translocating native fishes within Australia to enhance recreational fisheries poses a threat to aquatic systems (Arthington and McKenzie 1997). As part of the State Government's Fishing Enhancement Program, 34 translocations of seven native species into nine drainage basins have occurred in Queensland. Statewide, 96 publicly owned freshwater impoundments (and numerous smaller privately owned dams) have been stocked with native fishes (Zeller 1998). Webb (unpub. data) has identified 26 species in north Queensland translocated primarily for recreational fishing or as fodder fish for game species.

Accidental releases from aquaculture facilities have also occurred. These include releases from floating cages in the Hinchinbrook Channel of juvenile barramundi (*Lates calcarifer*) which included large numbers of Weipa stock, genetically different from the Hinchinbrook population (Webb, A., pers. comm.). The movement of native species beyond their historical gene pools increases the risk of hybridisation between closely related species or between native populations of the same species.

Non-indigenous native plant species are widely planted for horticultural purposes. Commercial native tree species and more specifically their productive provenances — for example, *Araucaria cunninghamii*, *Eucalyptus cloeziana*, *E. pilularis*, *Corymbia maculata/citriodora* complex — are also widely planted off-site, but are typically considered 'native'. Many of these are planted with little consideration of likely effects on surrounding native ecosystems.

Alteration and degradation of native habitat

Even where apparently intact habitat remains, biodiversity may be threatened by processes that can lead to ecological degradation. This occurs when changes in the physical/chemical environment or in the composition of species trigger a sequence of ecological changes that can lead to loss of species. Often the cumulative effects of several pressures acting together may be more damaging than the single impact of each pressure on its own.

For example, changing land use practices are invariably associated with changing fire regimes and it is difficult to separate them as issues when considering the end result. Grazed woodlands have undergone considerable structural changes since the arrival of domestic stock; there is evidence, supported by analyses of soil carbon, that many areas support increased woody plant density and biomass (Burrows et al. 1998). Woodland thickening and the widespread woody weed invasion of native grassland areas are attributed to a range of factors that shift the balance of competition between grass and woody plants to favour the latter. These factors vary between habitats but include (alone or in combination) excessive grazing pressure, lessened fire frequency, changing season of burning, long-term variations in the intensity of burning, fire exclusion, feral animal impacts and increased densities of native herbivores.

Grazing and associated land use changes, altered fire regimes and pollution of aquatic ecosystems are major pressures altering and degrading native ecosystems in Queensland.

Grazing

Of all the Australian States and Territories, Queensland has by far the greatest area of land under grazing by domestic stock. Approximately 87 percent of Queensland's area supports sheep and cattle to some extent. The Mulga Lands and Brigalow Belt bioregions, subject to high historical rates of land clearing for grazing lands, at present support the greatest cattle and sheep densities (see figures 3-6 and 3-7 in chapter 3, 'Land'). Most grazing land (>90 percent) is native pasture (grasses and forbs) that occurs in both grassland and woodland settings. Queensland also has six million hectares of introduced grass pastures and increasing areas of native pastures oversown with introduced legumes.

Introduced grazing animals eat and trample vegetation and degrade soil structure, leading to changes in vegetation cover. Native and feral herbivores add to grazing pressure; recent studies in south-west Queensland suggest they may contribute 30–40 percent of total grazing pressure (Pahl, L., pers. comm.). Grazing pressure is compounded by a range of factors including inappropriate property size, inappropriate pasture management, use of better-adapted stock, increased competitiveness of native and exotic trees and shrubs, extended drought, changes in fire frequency and provision of artificial water points.

The main effects of grazing on the grass layer are the decline of tall perennial grasses and their replacement with shorter grasses and some forb species. Many plant species are intolerant of grazing and are removed or diminished at even moderate grazing intensities (Fensham 1998a). The loss of plant community structure within the herbaceous layer has been reported in the extensive northern black speargrass (*Heteropogon contortus*) ecosystems (Brown, J., pers. comm.).

Through the removal and trampling of vegetation, grazing can lead to alteration and degradation of habitat for ground-dwelling animals. Grazing and associated habitat changes are known or suspected to be contributing factors in the decline of 11 threatened native reptile, 11 bird and 9 mammal species in Queensland (table 7-2). Holt et al. (1996) have demonstrated a link between overgrazing, loss of tussock grass species and changes in termite communities.

Domestic and feral herbivores also compete with native herbivores for food and water. The provision of extra water points has resulted in a greater abundance of native species in some areas, increasing grazing pressure. Competition from sheep has been implicated as a contributing factor in the decline of the endangered bridled nailtail wallaby (*Onychogalea fraenata*) (Maxwell et al. 1996).

Native pasture deterioration has been reported in Queensland, its causes usually being attributed to excessive grazing pressure from a combination of domestic stock, native marsupials and feral animals. Tothill and Gillies (1992) in a comprehensive assessment of native pasture condition concluded that there was widespread deterioration in most Queensland pasture communities, as indicated by undesirable changes in pasture composition and soil surface characteristics. Of the total pasture area, 58 percent was in a degraded or deteriorating condition at the time of assessment (figure 7-11).

More than 70 percent of Queensland's State forests are currently under grazing occupation. Grazing has been identified as a major disturbance type considered likely to have significant impacts on the ecological condition of eucalypt-dominated forests in the Southeast Queensland bioregion, although no quantitative information about its impact on native forests in Queensland is available (Kelly 1998).

Grazing is the most widespread pressure on Queensland's wetlands (Blackman et al. 1996) and has been identified as a significant factor contributing to the degradation of riparian vegetation (see box 'Riparian vegetation'). Grazing animals

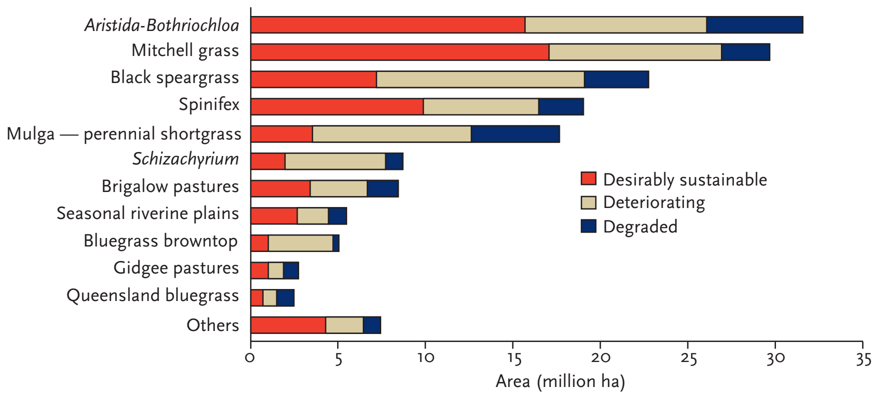


Figure 7-11 The condition of Queensland's 19 native pasture communities — 'others' include the eight communities with individual areas less than 2 million ha.
(Source: Tothill and Gillies 1992)

have direct impacts on wetland vegetation, soils and water quality that may have indirect impacts on fauna communities and the biogeochemistry of wetlands by altering habitat structure and patterns of primary and secondary production (Robertson 1998).

The introduction and spread of exotic pasture species (including ponded pasture species) have accompanied the development and intensification of grazing land management throughout much of Queensland. While the invasive potential of many of these species is unknown, many are now so well adapted that they have spread and become established naturally in native pasture areas. The major naturalised species were estimated to occupy 5 million ha in 1990 (Walker and Weston 1990). This area is now conservatively estimated at 10 million ha, of which 5 million ha is buffel grass (Weston, E.J., pers. comm.).

Indicators

Extent of native grasslands grazed by bioregion

Extent of naturalised, non-native grasses and legumes by bioregion

Because grazed native pastures occur across a wide variety of environments in Queensland and vary in degree of sensitivity to grazing pressures, it is difficult to quantify the impact of grazing pressures. Domestic stock densities (figures 3-6 and 3-7 in chapter 3, 'Land') may not provide any indication of the varying capacity of grazed areas to ecologically sustain grazing pressures. While long-term grazing experiments by CSIRO support the contention that moderate levels of grazing pressure and conservation of plant diversity are compatible, the research has indicated a need to develop criteria and indicators that can be used to define ecologically sustainable grazing management rather than ones that are mainly production-oriented (Brown, J., pers. comm.).

Altered fire regimes

The majority of Queensland's ecosystems evolved under the influence of fire occurring at varying frequencies and rely on particular fire regimes for continued survival. Since European settlement, fire regimes have changed dramatically in many habitats. Altered fire regimes impose disturbances that are not yet fully understood but have the potential to alter biodiversity.

Indicator

Extent of altered fire regimes by bioregion

Interpreting changes in fire regimes is difficult, because little is known about pre-European settlement fire regimes. For many ecosystems, little is known about the effects of fire intensity, frequency and timing on a wide range of ecosystem components. Research into the use and ecology of fire and the monitoring of its effects in natural systems have been limited in Queensland.

Reliable records and maps of fire occurrences are limited mainly to some public lands. A fire history coverage (prescribed burns and wildfire) of the eucalypt-dominated forests in the Southeast Queensland bioregion has been completed as part of the old-growth forest assessment for the region and represents the first complete inventory of forest-related fire disturbance over a region (Kelly 1998).

In a number of habitats the role of changing fire regimes in promoting long-term change and the interaction of fire regimes with other ecosystem processes is recognised from decades of observation and experiment with management practices (Stanton, P., pers. comm.). At least 24 threatened mammal, reptile or bird species owe part or all of their decline to the impact of inappropriate fire regimes (table 7-2).

Installation of artificial water points in semi-arid rangelands

Before the advent of pastoralism, there were very few permanent sources of drinking water in arid and semi-arid Australia. Artificial sources of drinking water have now been provided across nearly all the potentially productive rangelands and few of these areas are further than 10 km from sources of water (Landsberg et al. 1997). Livestock and native animals that require drinking water have benefited, but as a result grazing pressure has increased substantially across vast areas that were previously waterless.

Artificial water points have opened vast areas, previously waterless, for grazing.

In a recent study by CSIRO to determine the effects of these changes on biodiversity, Landsberg et al. (1997) conducted field surveys at locations in the chenopod and acacia rangelands of central and southern Australia, including two sites in south-west Queensland. Results showed major changes in the composition of biodiversity at different distances from water. While the number of species occurring close to the water was similar to the number occurring far from the water, there were significant and consistent changes in the composition of species with changing distance from water.

Some species in most groups of plants and animals increased in abundance at sites closer to water ('increasers') but some decreased at such sites ('decreasers'). Sites further from water had significant numbers of decreaser species that tended to show marked declines in abundance with proximity to water.

The highest proportions of decreaser species were found for plants growing in the understorey, and ants. At the mulga gradient in Queensland 54 percent of understorey species showed significant trends of decreasing abundance with proximity to water, while at the gidgee gradient 84 percent of understorey plants were decreasers. The relative proportions of decreaser species were slightly lower for animals (ants, birds and reptiles).

The results indicate that a significant proportion of native plant and animal species show a strong trend of decreasing abundance with proximity to water with associated grazing pressures. Coexistence of many of these species with the grazing levels that prevail near water points does not appear to be possible. Under present conditions, some of these species may be at risk of extinction, at least on a local scale. Given the widespread occurrence of artificial sources of water in arid areas, there may also be risks at broader scales (Landsberg et al. 1997).

Loss of wet sclerophyll forests in north Queensland

The wet sclerophyll forests are continuous-canopy forests dominated by tall eucalypts with a dense grass or shrub understorey. Currently, wet sclerophyll forests in north Queensland occupy a narrow band less than 4 km wide to the west of rainforest above an altitude of 600 m (figure 7-13). The total area is only 83 000 ha. These forests are particularly rich in species, at least 227 vertebrate species occurring within them (Williams et al. 1996). This high diversity is due to this habitat being an overlap zone between rainforest and dry sclerophyll forest.

The forests are being reduced by encroaching rainforest due to changes in fire regimes. Complete transition from wet sclerophyll forest to rainforest in as little as 30 years has been widely observed (Harrington, G., pers. comm.).

Fire is essential for the regeneration of wet sclerophyll forests. Fires also kill weeds and seedlings of rainforest species whose shade would prevent the germination of eucalypts. If the interval between fires is too long, rainforest development suppresses fire and wet sclerophyll species eventually die out. Since European settlement, fire regimes have been modified to prevent damage to settlements and to maximise the grazing potential of savanna country. Most fires move in an easterly direction from the lower, drier, pastoral country of the interior towards the rainforest margin near the ridge of the Great Dividing Range.

Aboriginal peoples' previous burning patterns in this region are not well known, but today pastoralists and foresters tend to burn early in the dry season before the fuel has dried out. This protects the forest from unplanned, high-intensity, late dry season burns but results in fires of much lower intensity. Graziers have restricted fires to times of low temperature and windspeed and burn frequently so that there is no large accumulation of fuel. For this reason, the hot wildfires that periodically burned up to the rainforest edge have largely been prevented. This has allowed encroachment of rainforest as far as firebreaks (roads etc.), soil types and rainfall permit.

Aerial photo analysis reveals that 48 percent of wet sclerophyll forest was invaded by rainforest between 1943 and 1992 (Harrington, G., pers. comm.). In some areas that were invaded before 1940, even the largest eucalypt trees have died out and the rainforest now abuts directly onto a drier type of sclerophyll forest. This process threatens all remaining wet sclerophyll forest, together with its endemic fauna, such as the endangered northern bettong (*Bettongia tropica*) and the vulnerable northern subspecies of the yellow-bellied glider (*Petaurus australis reginae*).

Most wet sclerophyll forest in the Wet Tropics bioregion occurs in the Wet Tropics World Heritage Area and is managed by the EPA; a small portion is under DNR jurisdiction. These agencies are burning prescribed areas to maintain the ecosystem in its present extent. The Cooperative Research Centre (CRC) for Tropical Rainforest Ecology and Management at Atherton has cooperated with the EPA and DNR to establish vegetation monitoring plots. CRC officers are monitoring fire behaviour under different fuel and climatic combinations with the aim of prescribing conditions for burning that will maintain wet sclerophyll forest. Vegetation, mammals, birds, reptiles and insects have been surveyed and mapped.

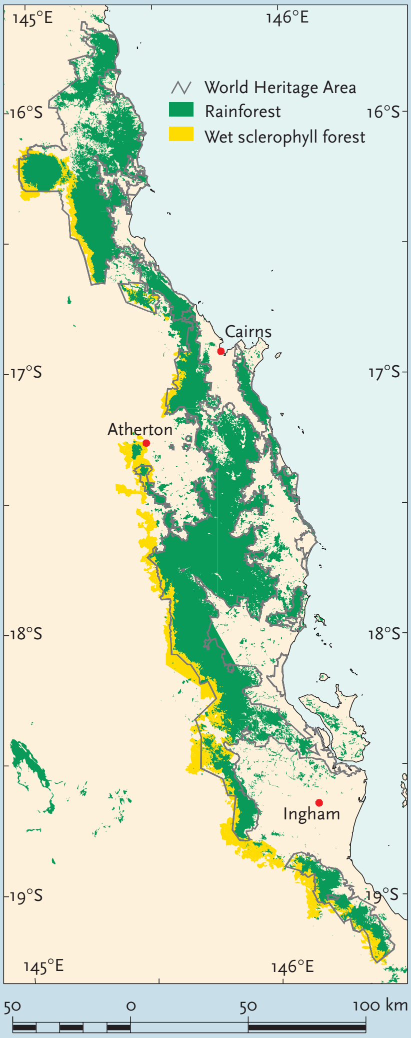


Figure 7-13 Location of wet sclerophyll forests in north Queensland

G. Harrington, CSIRO (both photos)

Changed fire regimes in wet sclerophyll forest (left) can lead to invasion by rainforest (right).

Rainforest communities will not burn under most circumstances, but they do have interfaces with habitats shaped by fire, and over thousands of years their boundaries have fluctuated widely. Today, where their boundaries are not strictly soil-determined, rainforests are capable of expanding and contracting in response to prevailing fire regimes in adjacent habitats. In coastal areas, the clearing of footslopes and replacement of rainforest with tall grasses have pushed the rainforest margin further uphill under the influence of repeated wildfire.

Fire regimes in most eucalypt-dominated forests and woodlands have changed significantly since European settlement. A loss of grassy groundcover in favour of shrub understoreys has been widely noted (Stanton, P., pers. comm.). This can be attributed to a combination of increased grazing pressure and decreased fire frequency. In the high-rainfall areas, a severe reduction of fire frequency or the complete removal of fire has been implicated in the conversion of tall wet sclerophyll forests to rainforest (see box 'Loss of wet sclerophyll forests in north Queensland').

Conversion of some grassland types to low open woodland on Cape York Peninsula in the last 30 years is probably due to altered fire regimes (Neldner et al. 1997). Some grassland areas are being replaced by *Melaleuca viridiflora* woodland at a rate of 5 percent per decade (Crowley and Garnett 1998). Studies of the endangered golden-shouldered parrot (*Psephotus chrysopterygius*) have implicated change in season of burning and decreased fire frequency as reasons for invasion of the parrot's grassland habitat by melaleuca trees (Garnett, S., pers. comm.) (figure 7-12).

The absence of fire has been suggested as the primary reason 25 percent of the area of the montane grasslands on the Bunya Mountains was invaded by forest between 1951 and 1991 (Fensham and Fairfax 1996). The role of fire, if any, in

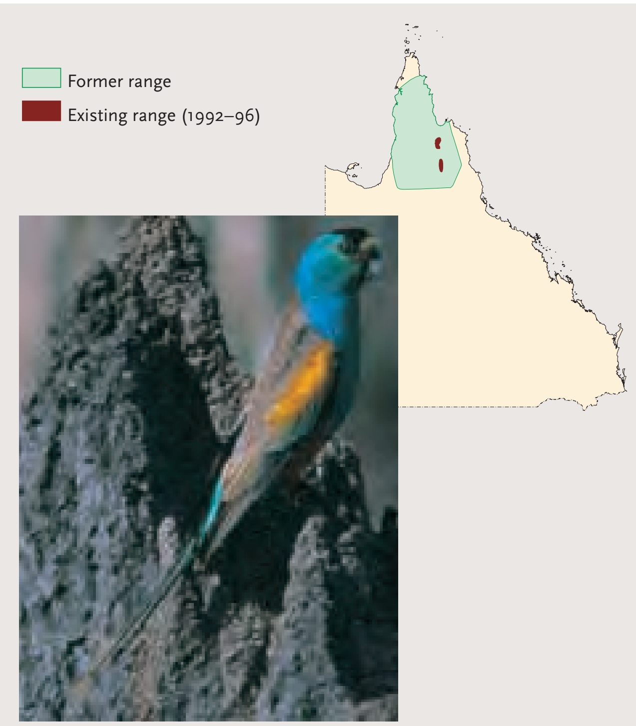


Figure 7-12 Changes in fire regimes are thought to be one of the major reasons for the contraction of the golden-shouldered parrot's original range by 90 percent. Approximately 250 pairs of birds are now located in two small populations.

the ecology of Queensland's most extensive grasslands, the Mitchell grass downs, is unclear.

The fire regime in spinifex shrubland has changed since European settlement from one of a mosaic of small-scale burns to infrequent fires that cover vast areas. While this has not affected the survival of spinifex shrublands and has probably promoted their extension, the severe fires have had an impact on components of the ecosystem such as scattered hollow trees, small pockets of fire-sensitive shrubs and small trees that might be critical as wildlife habitat. Neighbouring communities such as lancewood (*Acacia shirleyi*) have suffered severe loss of area because of the increased severity of the less frequent fires.

Pollution

Analysis of the impacts of pollutants on biodiversity is difficult. Pollutants are often dispersed widely from their sources and act synergistically with other contaminants so that effects on biodiversity are difficult to identify. Despite a widespread understanding that pollution can affect biodiversity, it is difficult to assess the extent of this pressure on biodiversity in Queensland. This stems primarily from a lack of data.

By world standards, air pollution in Queensland is limited because of the scattered distribution and generally limited size of human industrial and urban centres. Queensland biota on the whole is exposed to low or negligible levels of atmospheric pollutants. While air pollutants have been implicated in the reduction of lichen abundance close to industrial properties in Brisbane (Scarlett 1990), there is insufficient evidence to suggest significant impacts on biodiversity in Queensland.

Aquatic ecosystems in Queensland are subject to varying levels of potentially harmful inorganic sediments, organic matter, inorganic nutrients and toxicants, most of which arise from land-based activities.

Changing catchment land use and vegetation clearing in Queensland's east coast catchments have significantly increased the amount of suspended sediment and nutrients exported downstream to estuarine and inshore waters. While there is uncertainty about the size of the increase, the available information indicates that exports have increased by between two and five times over natural levels (see chapter 5, 'Coastal zone', for detailed discussion).

Increased sediment loads, while in suspension, can reduce available light to the benthos and eventually smother benthic communities during settlement. Significant seagrass loss in the western parts of Moreton Bay has been attributed to excessive sediment levels (Abal et al. 1998). Sedimentation and turbidity of streams resulting from catchment practices have been identified as major threats to fisheries habitat diversity in Queensland (Zeller 1998).

The marine environment and, in particular, estuaries act as sinks for nutrients. Increased nutrient inputs can foster increased aquatic plant growth. This can lead to the clogging of inland waterways, algal blooms in estuaries or the overgrowth of reefs and seagrass meadows. An abundance of nutrients can often promote or contribute towards toxic algal blooms. The Great Barrier Reef lagoon is particularly susceptible to nutrient enrichment due to its relatively enclosed and shallow nature. While most scientists now acknowledge that nutrient and sediment inputs to coastal waters have increased substantially as a result of human activity, clear long-term and regional-scale effects on the Great Barrier Reef ecosystems have proven difficult to detect (Wachenfeld et al. 1998).

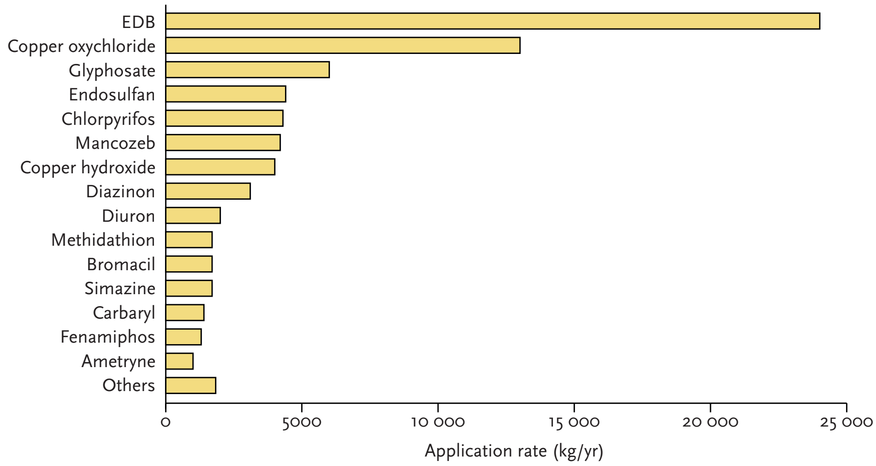


Figure 7-14 Pesticides used in the Pumicestone Passage catchment which, on the basis of use, movement pathways and persistence in the environment, warrant environmental monitoring
(Source: Simpson et al. 1993)

The potential for non-target species to be affected by biologically harmful chemicals, such as pesticides and heavy metals, is recognised. These chemicals entering waterways in Queensland give rise to sporadic kills of fish and other organisms. Even at low environmental concentrations, the persistent nature of many of these chemicals and their long-term cumulative effect on aquatic organisms and ecological processes are cause for concern.

Rates of pesticide application and the areas targeted are surrogate measures for total loads of biologically harmful ingredients in ecosystems. There are, however, few reports of investigations into either usage or residues of pesticides in aquatic ecosystems in Queensland.

Discharges of biologically harmful chemicals from land-based activites give rise to sporadic kills of fish and other organisms.

Pesticide audits of the Pumicestone Passage (Simpson et al. 1993) and Condamine–Balonne catchments (Rayment and Simpson 1993) identified a wide range of quantities and types used. Nineteen pesticides registered for use in the Pumicestone Passage catchment and 23 in the Condamine–Balonne catchment were identified as warranting environmental monitoring, based on the quantities used and their movement pathways and persistence in the environment (figure 7-14). An audit of pesticide use by the sugar industry in Queensland recommended monitoring of nine of the 30 pesticides in use (Hamilton and Haydon 1996). The estimated average annual use of these nine pesticides over all catchments is 948 tonnes of active ingredient.

While these audits list application rates, the quantities eventually discharging into aquatic systems and their ultimate impact on biodiversity are not known. Although these catchments are likely to be reasonably representative of other rural catchments in Queensland, they are less likely to reflect pesticide usage in urban catchments where garden and household pest control predominates. No audit of urban area pesticide use is available.

Acid drainage is a significant environmental problem associated with some mining operations. Major sources of acid release include waste rock dumps, overburden, stockpiles and abandoned mines. Once started, acid drainage is a persistent and potentially severe source of pollution. Contaminants from the large disused Mount Morgan goldmine continue to be released, uncontrolled, into surrounding river systems (see box 'Long-term effects of past mining practices' in chapter 4, 'Inland waters'). Acid releases from disturbed acid sulfate soils can be of much greater magnitude than those from mining dumps or industrial pollution and have led to fish and crustacea kills (see box 'Acid sulfate soils' in chapter 5, 'Coastal zone').

A range of indicators of pollution has been developed for chapters 3 ('Land'), 4 ('Inland waters') and 5 ('Coastal zone'). While many of these are being monitored throughout Queensland and are important in monitoring the health of ecosystems, there are limitations associated with their application to biological systems. There is a need to develop and introduce biological indicators in addition to the more traditional physico-chemical approaches (ANZECC 1992). Biological assessment protocols and indicators applicable to the protection of aquatic biodiversity are being jointly developed by the EPA, DNR and DPI Fisheries.

HARVESTING OF NATIVE SPECIES

Native plants and animals are harvested from the wild for commercial gain, recreation, subsistence and pest control. The most significant harvesting activities are commercial timber harvesting and fishing.

Wildlife and wildlife products are also illegally exported from Queensland. In the period 1990–97 the groups most commonly targeted were reptiles, butterflies and birds and their eggs. In this period 11 people in Queensland were prosecuted under the *Wildlife Protection (Regulation of Exports and Imports) Act 1982* (Cwlth). These prosecutions are unlikely to reflect the full extent of the trade, which is unknown. The impact on Queensland's wildlife is considered to be small in comparison with that of other harvesting pressures.

Indicators

Species and quantity of fish harvested commercially and recreationally

Ratios of bycatch to target species and amount of bycatch discarded

Tree species and quantity harvested commercially during forestry operations

Area of forest in which logging and thinning operations have occurred each year

Fishing

Pressure on some fish populations is reflected in the size of the commercial and recreational fish catch. While the commercial catch is regulated and quantified, the recreational catch generally is not. The commercial fishing industry in Queensland is based on 25 major species of fish, crustaceans and molluscs. Fishing is carried out along the entire Queensland coastline and in many inland rivers, fisheries on the southern and central coast having been heavily fished for many years.

The total commercial catch for Queensland's major fisheries in the period 1988–96 and the status of those fisheries are provided in chapter 5, 'Coastal zone'. A number of Queensland's major commercial fisheries appear to show signs of over-exploitation. The barramundi, coral trout and mud crab fisheries are listed as 'probably declining', and the king prawn, saucer scallop and Spanish mackerel fisheries are listed as 'declining'. However, clear trends are difficult to identify. In some cases, populations may be declining only locally.

Fishing continues to be one of the most popular recreational activities undertaken by Queenslanders, occurring in virtually all coastal areas and in many freshwater rivers. The Moreton Bay recreational fishery is used by some 300 000 fishers each year (QFMA 1997), who catch approximately 2000 tonnes of finfish a year. Despite its popularity, recreational fishing's contribution to total fish catch and overall impact on stocks are largely unquantified.

Some forms of commercial harvesting, such as trawling, are non-selective and take large numbers of non-target marine species. While some bycatch is retained and used, the majority dies and is discarded. The types and amounts of bycatch can vary between different fisheries and fishing gears. In the northern prawn fishery, the bycatch is predominantly small fish but also includes a mixture of cephalopods, crustaceans, sea snakes and turtles (Harris and Poiner 1990).

The ecological consequences of harvesting bycatch are largely unknown. By removing large quantities of bottom-dwelling organisms, trawling might significantly alter food webs: any discarded material eaten on or near the surface by scavengers is largely lost from the benthic system. The decline in the loggerhead turtle (*Caretta caretta*) population off the Queensland coast has been attributed primarily to bycatch mortality associated with trawling (Limpus and Reimer 1994).

Estimates of the proportion of bycatch in some fisheries suggest that the total annual bycatch could be very large and the ratio of bycatch to target species could be as high as 8:1 or 10:1 (QFMA 1996b). The bycatch from prawn trawling in Torres Strait was estimated at 6930 (±900) tonnes in 1985 and 4630 (±900) tonnes in 1986 (Harris and Poiner 1990). Prawn trawlers in Moreton Bay have been estimated to discard about 3000 tonnes a year (Wassenberg and Hill 1990). Of an estimated 5295 (±1231) turtles (predominantly loggerheads, greens and flatbacks) caught annually in the east coast trawl fishery, between 1 and 7 percent are thought to die (Robins 1995). Despite these estimates, the overall composition and quantity of the bycatch caught by the Queensland fishing industry are generally unknown.

Harvesting of forest products

Queensland forests cover approximately 49 million ha. Apart from their biodiversity values, forests are valued as sources of a variety of commercial products, ranging from soil and gravel, through seed and foliage, to sawlogs and other timber products. At December 1998, approximately 4.28 million ha (2.4 percent of Queensland) was under State Forest and Timber Reserve tenure, in which commercial forest operations are carried out and managed by the State. Forests also occur extensively on leasehold land (approximately half of the forest area), where commercial harvesting of forest products is regulated by the Crown. The area of forests under private ownership that are commercially harvested is unknown. In 1998, 61 percent of the area of State forest and timber reserves was considered available for harvesting, and 40 percent was considered suitable for productive sawlog harvest (figure 7-15).

Timber harvesting in areas managed by the State is by single tree selection in designated areas. Forest management activities on Crown lands are conducted according to strict environmental management guidelines including codes of practice, species management guidelines, multiple-use management planning, and other instruments. Management of harvesting of Crown forests aims to satisfy sustainable timber yield, biodiversity and other environmental values. At present no native forests on Crown land are cleared for plantations and areas in which timber harvesting occurs are regenerated. No timber harvesting is carried out in rainforests on public land.

Harvesting of forest products can affect forest biodiversity. Timber harvesting favours certain tree species and sizes, resulting in changes to the species, age, and size class distribution and, hence, habitat value of forests. Decades of logging and associated management in some forests have fragmented old-growth habitats, triggering a decline in the diversity and abundance of arboreal mammals and birds that use old-growth habitats and tree hollows.

Results from the South East Queensland Old Growth Forest Assessment Project indicate that timber harvesting (as historically practised in Queensland) has measurably affected the structural and ecological characteristics of dense eucalypt forests, the effects persisting for at least 50 years (Kelly 1998). To date, it has not been possible to demonstrate such an effect in the much more widespread open eucalypt forests. At present, 25 regional ecosystems known to contain commercially viable stands of native hardwood timber species are in areas available for logging on State lands in the Southeast Queensland bioregion. The status of three of these is listed as

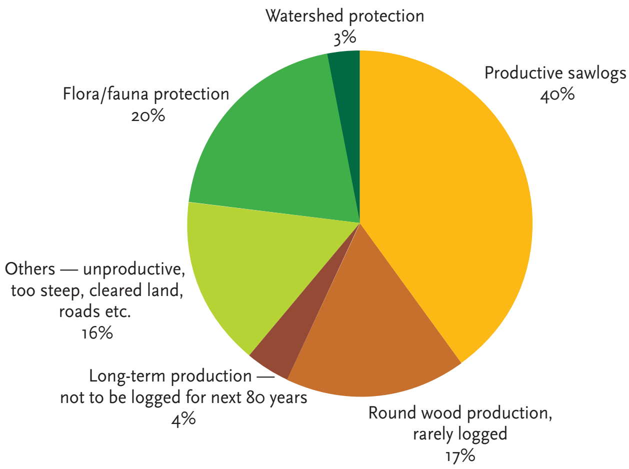


Figure 7-15 Breakdown of State forest and timber reserve areas in Queensland by forestry operations. The figures exclude plantations, which cover 185 742 ha.
(Source: DPI)

‘of concern’ as they have been cleared substantially.

The major native species harvested from State forests in Queensland in 1998 were cypress pine (*Callitris glaucophylla*), a softwood, and spotted gum (*Corymbia maculata*), a hardwood. In general, timber harvesting from native forests — of hardwoods in particular — has declined over the past 30 years (figure 7-16). Approximately 60 percent of the current hardwood harvest is from privately managed forests. On private lands there are limited harvesting controls and no summary information exists on the extent of areas harvested or the nature of harvesting operations. The quantities of forest products harvested vary by region, the Southeast Queensland bioregion accounting for the majority of all timber harvested.

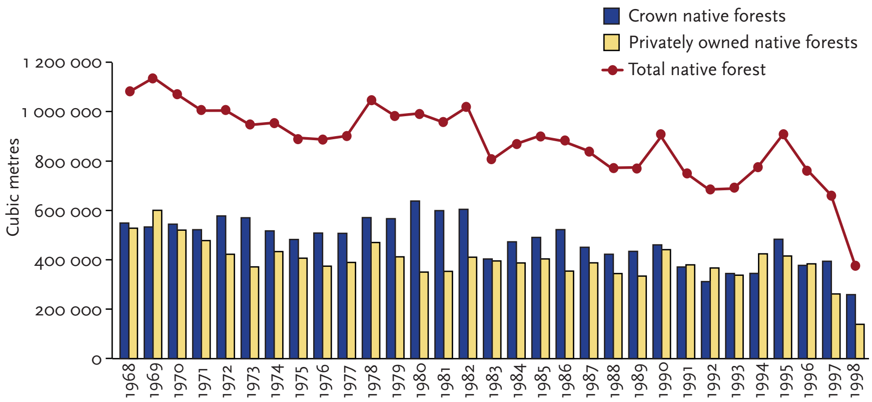


Figure 7-16 Queensland native forest timber removals, 1968–98, from State native forests and from privately owned native forests
(Source: DPI)

CLIMATE CHANGE

Most scientists agree that the climate is changing. However, any assessment of the likely impact of climate change on biodiversity is problematic. Many uncertainties surround the possible timing, magnitude and patterns of climate change. How species and ecosystems will respond to climatic changes is difficult to predict. Indicators on climate and climate change have been developed in chapter 2, ‘Atmosphere’.

Changes in atmospheric indicators of climate change, such as temperature, rainfall and carbon dioxide concentrations, may have a direct impact on some species (especially plants), but indirectly affect others through altered habitat conditions such as food availability, fire frequency and pathogen attack. Weed and feral animal distribution can be expected to change; the giant stinging tree (*Mimosa pigra*) and the cane toad are expected to have their ranges extended by climate change (Williams et al. 1995).

There might be a shift by individuals and populations towards higher latitudes and altitudes. Survival will depend largely on species’ dispersal ability and the availability of suitable habitat. Fragmented landscapes without habitat corridors will act as barriers to migration and severely restrict the ability of native animal species to disperse and move to new suitable habitats. Species vulnerable to climatic changes include those in small populations, those that have low genetic variability or a very specialised way of life, and those that are poor dispersers or are already isolated in conservation reserves. Climate change could then reduce the ability of small isolated reserves to protect the range of species within their boundaries. Models of climate change scenarios predict loss of core habitat for many of Queensland’s threatened species (table 7-8).

Researchers at the Cooperative Research Centre for Tropical Rainforest Ecology and Management at Atherton and CSIRO are currently investigating the possible effects of climate change on the diverse assemblage of leaf-eating marsupials (possums and tree-kangaroos) endemic to the Wet Tropics. Core habitat for these species is restricted to high elevation rainforests (>800 m) within the region, where populations occur on isolated mountain peaks. If, as it appears, this distribution is related to an intolerance of warm temperatures, any increase in temperature would force these species to higher altitudes, further fragmenting and greatly reducing the area of core habitat. A 1°C increase in temperature is likely to reduce the area of core habitat of these species by about two-thirds, and a 2°C increase by over 90 percent (Kanowski, J., pers. comm.).

Any long-term change to climate could substantially reduce core habitat of marsupials such as the rare Lumholtz’s tree kangaroo (*Dendrolagus lumholtzi*) in north Queensland.

Table 7-8 Even under a possible scenario of a small (0.3°–0.8°C) temperature increase, these rare and threatened species in Queensland might be further threatened with extinction due to contraction of core habitat.

Species	Status[1]	Vertebrate group	Predicted % loss of core climatic habitat
Kowari (*Dasyuroides byrnei*)	V	Mammal	99.6
Dusky hopping-mouse (*Notomys fuscus*)	E	Mammal	78.9
Northern hairy-nosed wombat (*Lasiorhinus krefftii*)	E	Mammal	59.4
Carpentarian grasswren (*Amytornis dorotheae*)	R	Bird	51.6
Southern gastric brooding frog (*Rheobatrachus silus*)	E	Amphibian	31.3
Bilby (*Macrotis lagotis*)	E	Mammal	24.5
Southern cassowary (*Casuarius casuarius*)	E/V[2]	Bird	23.5
Plains rat (*Pseudomys australis*)	E	Mammal	19.3
Sharp-snouted torrent frog (*Taudactylus acutirostris*)	E	Amphibian	15.1

[1]Status as listed in the *Nature Conservation (Wildlife) Regulation 1994*: V = vulnerable; E = endangered; R = rare.
[2]The southern population of *Casuarius casuarius* is listed as endangered while the northern population is listed as vulnerable.
(Source: Dexter et al. 1995)

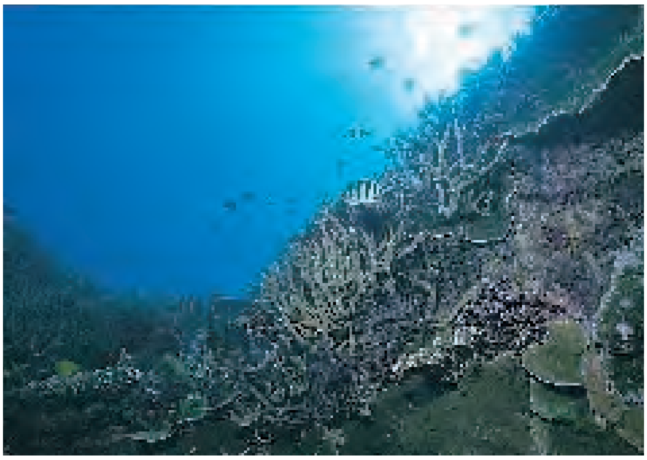
REGIONAL DIVERSITY

Queensland's 13 terrestrial bioregions vary greatly in size, from the large Brigalow Belt (35 158 000 ha) to the Queensland portion of the New England Tableland (341 000 ha). The smaller bioregions are on or near the coastline; most of the largest are in the arid or semi-arid areas, with broad climatic gradients and little topographic relief. The bioregions contain a number of subregions or provinces, each with a characteristic pattern of landforms and vegetation.

The seaward margin of the marine bioregions is the 200-metre depth contour. Generally, the marine bioregions form a continuous narrow segmented boundary around Australia. This pattern is varied in the shallow subtropical and tropical waters, where several parallel bands extend out from the coast. Eleven marine bioregions are totally within Queensland's waters. The Karumba–Nassau region, at approximately 5.6 million ha, is the largest and is a very significant saltwater crocodile, dugong, turtle and seabird habitat. The small and narrow Wet Tropic Coast, at 580 000 ha, is characterised by very complex and extensive mangrove forests and a very high littoral faunal diversity (IMCRA Technical Group 1998).

Indicators on ecosystem, species and genetic diversity and pressures at the bioregional scale collectively allow an assessment of the state of landscape diversity in Queensland. Our knowledge of the state of seascapes, on the other hand, is limited and difficult to assess as little information exists on marine habitat types and marine species diversity.


Regional diversity is the diversity of the landscape components of a region. (Lawn Hill National Park)


Ecosystem diversity encompasses the diversity of ecosystem types. (Great Barrier Reef Marine Park)

ECOSYSTEM DIVERSITY

Different vegetation types or marine habitat types reflect different environmental conditions and, therefore, different components of biodiversity. Across Australia, vegetation and habitat types recognised at the bioregional level are often used as surrogates for, or descriptors of, ecosystem diversity in state of the environment reporting. The examination of broad vegetation types, however, provides only a gross analysis of ecosystem diversity. A more detailed analysis of broad vegetation types may yield different mixes of species diversity (different ecosystems) nested within the similar vegetation types.

Regional ecosystems

As part of a nature conservation planning framework in Queensland, ecosystems have been identified and assigned a conservation status within individual bioregions (Sattler and Williams 1999). These regional ecosystems are defined as units of land that have distinct and characteristic combinations of geology, landforms, soils and vegetation. They reflect both abiotic and biological systems at the bioregional scale and are considered more useful indicators than broad vegetation types.

Their use, however, as surrogate indicators of biodiversity across bioregions is subject to continuing research and refinement. At present, there is a lack of comprehensive animal data to inform the description of most ecosystems to any extent. Information from comprehensive fauna surveys, such as those that have been undertaken in the Southeast Queensland bioregion as part of the comprehensive regional assessment, will enable fauna to be incorporated in far greater detail in the future. Detailed mapping of pre-clearing and remnant extent of ecosystems is continuing as a major project of the EPA. Further availability of mapped data will progressively refine the precise extent and status of regional ecosystems (Sattler and Williams 1999).

Queensland, with 1085 regional ecosystems, is highly diverse at the ecosystem level. This diversity varies considerably across bioregions. The Wet Tropics and Central Queensland Coast bioregions are particularly diverse relative to their areas (figure 7-17). Some regional ecosystems are naturally restricted and localised in extent while others occur over vast areas (figure 7-18). For example, one Brigalow Belt ecosystem — *Acacia harpophylla* and/or *Casuarina cristata* ± scattered eucalypts, currently 113 377 ha in extent — was estimated to have a pre-clearing extent of 2 141 699 ha.

A comparable level of analysis of marine ecosystem diversity has not been completed. While approximately 70 percent of mangroves, seagrass and other broad intertidal habitats have been mapped to some extent, knowledge of the types and extent of benthic habitats is very limited. Marine and coastal zone ecosystem diversity is discussed in chapter 5, 'Coastal zone'.

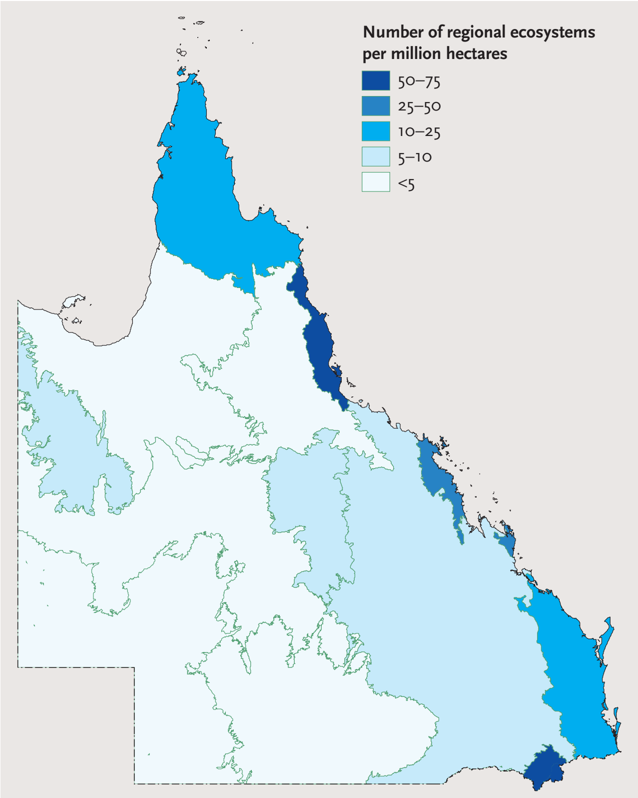


Figure 7-17 A measure of ecosystem richness provides an indication of those bioregions particularly diverse in ecosystems in relation to their area. For bioregions where most of the area lies outside Queensland (for example, the New England Tableland), high ecosystem/area indices would be expected to drop when data from the rest of the region outside Queensland are included in the analysis.

Conservation status

Indicators

Number and extent (current and pre-clearing) of regional ecosystems by bioregion

Number of threatened (endangered and of concern) regional ecosystems by bioregion

Sattler and Williams (1999) provide a detailed and comprehensive report on the conservation status of Queensland's regional ecosystems. Under definitions established by the IUCN and in JANIS (1996), individual regional ecosystems have been assigned conservation status of 'endangered', 'of concern' and 'no concern at present'. Status is assigned according to extent remaining in the landscape, condition and presence of threatening processes.

An ecosystem is classified as 'endangered' when less than 10 percent of pre-clearing extent remains in intact condition across the bioregion, or when distribution has contracted to less than 10 percent of its former range, or when severe degradation has occurred over an extensive area. An ecosystem is 'of concern' when 10–30 percent of pre-clearing extent remains in an intact condition in the bioregion, or when moderate degradation has occurred. An ecosystem is classified as of 'no concern at present' when more than 30 percent of pre-clearing extent remains in an intact condition, or when little to no degradation has occurred.

Of the 1085 regional ecosystems identified across Queensland's 13 bioregions, 107 are classified as 'endangered' and a further 243 as 'of concern' (table 7-9). In total, 32 percent of the State's regional ecosystems are threatened. The status of ecosystems varies considerably with each bioregion, indicating the varying level of threats, both past and present, operating within them.

Table 7-9 The state of regional ecosystem diversity in Queensland

Bioregion	Area ha	Regional ecosystems Number	Number endangered No.	Number endangered %	Number of concern No.	Number of concern %	Total threatened %	Protected area extent ha	Protected area extent %	Number of regional ecosystems in protected areas
Brigalow Belt	35 158 000	163	27	17	43	26	43	730 400	2	110
Cape York Peninsula	11 548 000	211	6	3	8	4	7	1 594 100	14	177
Central Queensland Coast	1 151 000	37	4	11	10	27	38	142 300	12	33
Channel Country	24 594 000	56	2	3	5	9	12	1 634 700	7	44
Desert Uplands	6 882 000	58	17	29	20	34	63	153 800	2	25
Einasleigh Uplands	12 808 000	46	1	2	21	46	48	226 900	2	26
Gulf Plains	21 377 000	83	3	4	26	31	35	525 300	2	25
Mitchell Grass Downs	22 787 000	53	2	4	10	19	23	238 900	1	21
Mulga Lands	19 097 000	66	5	8	22	33	41	464 900	2	47
New England Tableland	341 000	21	2	10	4	19	29	26 500	8	14
Northwest Highlands	6 950 000	41	3	7	13	32	39	369 100	5	27
Southeast Queensland	8 231 000	145	11	8	44	30	38	341 800	4	125
Wet Tropics	1 850 000	105	24	23	17	16	39	310 400	17	71
Total	**172 774 000**	**1085**	**107**	**10**	**243**	**22**	**32**	**6 759 100**	**4**	**745**

(Source: Sattler and Williams 1999)

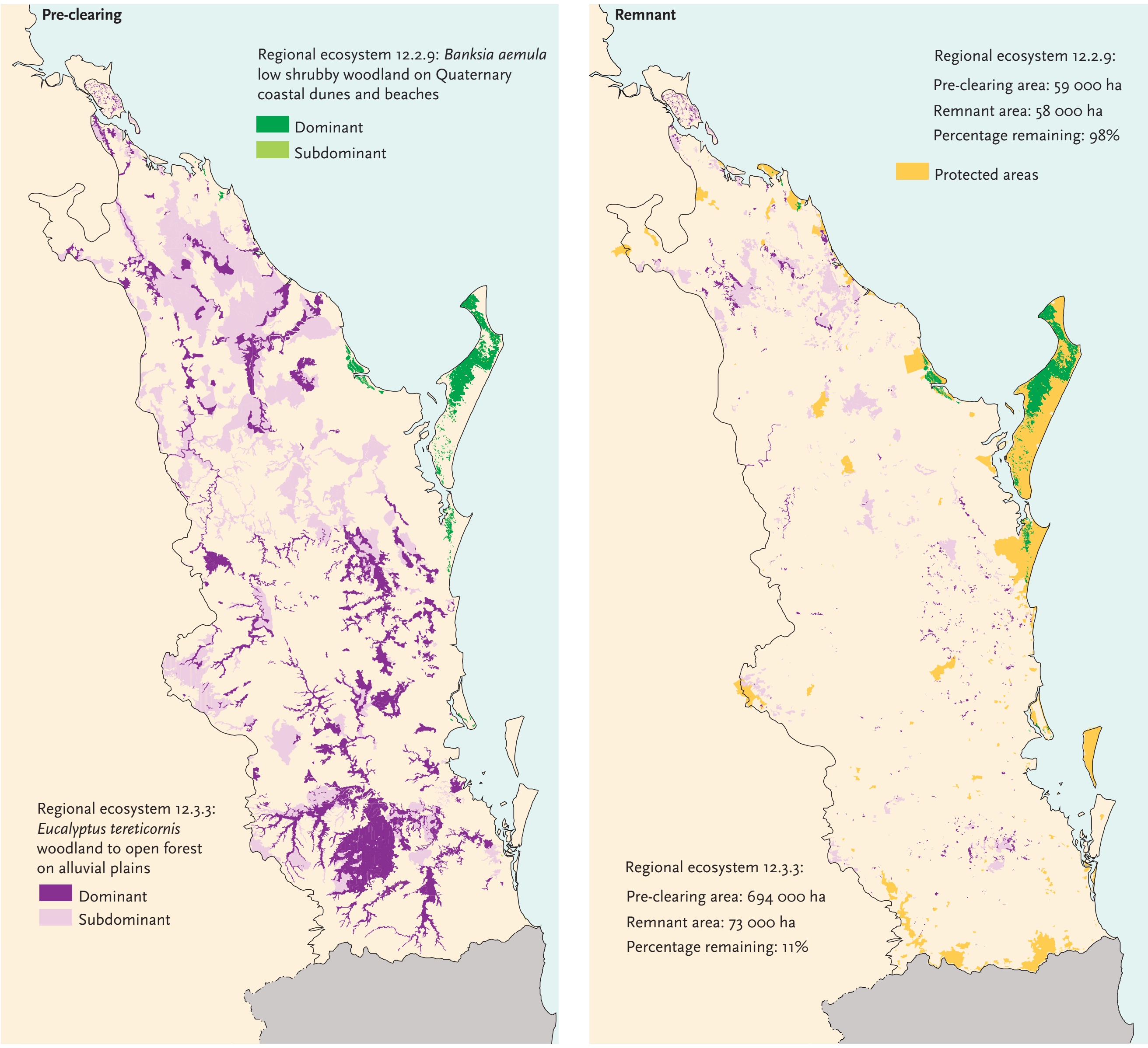


Figure 7-18 Two examples of the regional ecosystems mapped in the Southeast Queensland bioregion. The extent of each ecosystem is calculated on the basis of the proportion it occupies in each unique mapped area. 'Dominant' means that the ecosystem occupies the whole mapping area; 'subdominant' means that it occurs in association with others.

'Endangered' regional ecosystems are mostly in the fertile agricultural areas that have been extensively cleared — for example, acacia ecosystems of the Brigalow Belt clay plains, wetland and rainforest types on the Wet Tropics and Central Queensland Coast lowlands, and areas that have been extensively cleared for urbanisation. 'Of concern' regional ecosystems are widely distributed and include most of the more fertile alluvial land zones of arid and semi-arid parts. The once extensive eucalypt woodland systems are now 'of concern' or are rapidly contracting in a number of regions.

Protected area status of ecosystems

The extent of protected areas and the extent to which ecosystems are represented in these areas provide an indication of the state of landscape and ecosystem diversity. As the establishment and management of a protected area estate are also significant indications of response by governments to conserving biological diversity, these are discussed further in the 'Response' section.

Just over seven million hectares of Queensland's land area is within a protected area as defined in the *Nature Conservation Act 1992* (figure 7-19). Of the 459 individual protected areas, 66 percent are less than 1000 ha in size. Collectively, these smaller reserves account for 1 percent of the total protected area estate (figure 7-20). Eighteen protected areas are greater than 100 000 ha in size and collectively account for 75 percent of the total protected area.

While many small protected areas are critical for conserving specific elements of biodiversity, there is concern that many reserves may be too small and too isolated to protect biodiversity in the long term. There is, however, scientific debate regarding the appropriate sizes and shapes of reserves needed to adequately protect biodiversity. A model based on rainforest fragmentation data predicted that isolated reserves below 2000–4000 ha in area in north-east Queensland (depending on reserve shape) will be susceptible to increased disturbance and patterns of vegetation change that make them increasingly unlikely to preserve representative samples of primary rainforest (Laurance 1991).

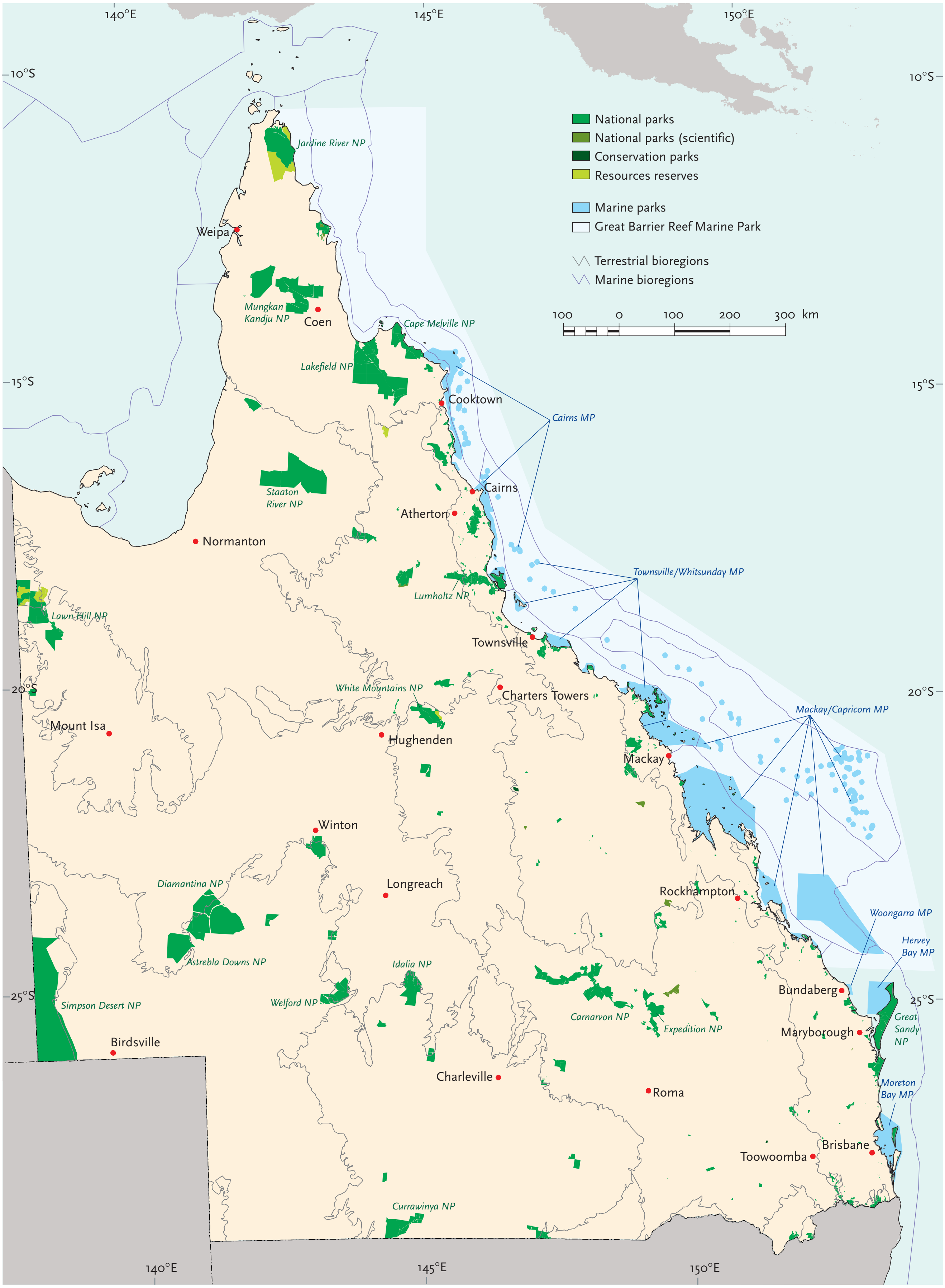


Figure 7-19 Terrestrial and marine protected areas in Queensland at January 1999

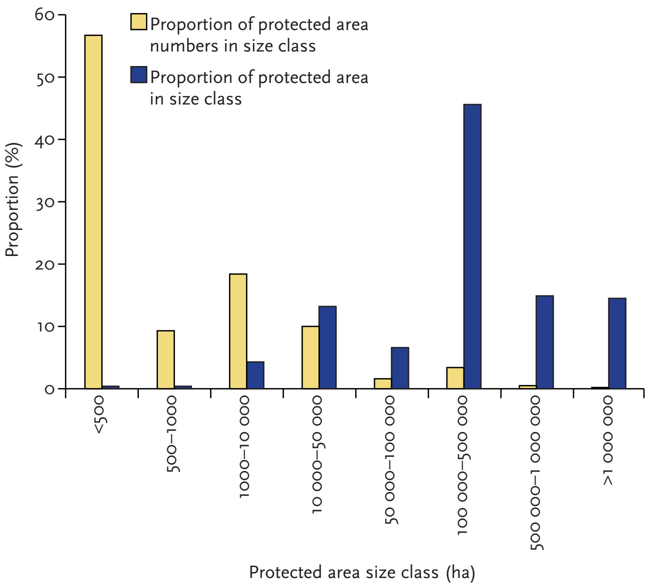


Figure 7-20 The majority of protected areas in Queensland are less than 1000 ha in size.

Indicators

Comprehensiveness, adequacy and representativeness of the protected area system

In nature conservation planning in Queensland, a 1000 ha threshold level has been selected for analysis of protected area coverage in recognition of the possible management problems associated with trying to ensure the viability of species and ecosystems in very small reserves (Sattler and Williams 1999).

While the extent of protected areas in a region provides a measure of a response to protecting biodiversity, a high percentage might mask the fact that much internal variation is unprotected. For example, in the ecosystem-diverse Wet Tropics bioregion, while 17 percent of the area is protected, 32 percent of all ecosystems remain outside protected areas. The need to sample the range of variation within ecosystems that extend across bioregions is inherent in the establishment of a comprehensive, adequate and representative reserve system, an objective of the National Strategy for the Conservation of Australia's Biological Diversity.

Comprehensiveness is the degree to which the reserve system includes the full range of biodiversity. As a measure of comprehensiveness, the representation of ecosystems within protected areas greater than 1000 hectares on a presence or absence basis is illustrated in figure 7-21.

Adequacy is the degree to which the reserve system contains samples of biodiversity that will maintain the ecological viability and integrity of species, populations and ecosystems. The extent to which regional ecosystems are represented in two or more protected areas greater than 1000 ha is a measure of adequacy of the reserve system (figure 7-21). Replication of ecosystems in reserves across their geographic range recognises possible genetic variations and impacts of disturbances (such as fires) that may reduce or remove key habitats.

Representativeness is the extent to which regional ecosystems selected for inclusion in reserves are capable of reflecting the known biodiversity and ecological processes of the ecosystems concerned. Where a regional ecosystem occurs in more than one province, there may be potential variation at a finer scale in the different provinces. The distribution of regional ecosystems across provinces and in protected areas gives a broad indication of the representativeness of the reserve system (Sattler and Williams 1999).

At March 1998, 69 percent of all regional ecosystems in Queensland were present in reserves. The Central Queensland Coast, Southeast Queensland and Cape York Peninsula bioregions had over 80 percent of their ecosystems represented; conversely, the ecosystems of the Gulf Plains, Mitchell Grass Downs and Desert Uplands bioregions had less than 50 percent represented. Statewide, the number of ecosystems represented in at least two protected areas was 39 percent.

Australia has a very high proportion of the world's marine protected areas and is acknowledged internationally for its efforts in marine conservation. However, current zoning of Queensland and Commonwealth marine parks provides for only a very small percentage (less than 5) of marine and estuarine waters along the Queensland coast to be fully protected. Most of the marine environment is available for commercial and private uses, which may or may not be governed by regulatory systems that prevent degradation and loss of biodiversity.

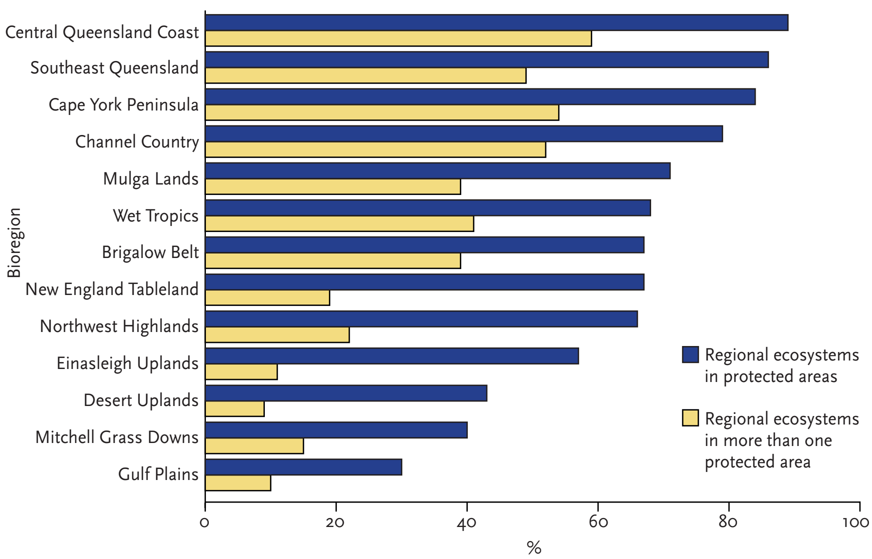


Figure 7-21 The number of Queensland's bioregional ecosystems and their degree of replication in protected areas greater than 1000 ha are measures of comprehensiveness and adequacy of the protected area system.
(Source: Sattler and Williams 1999)

In combination, Queensland and Commonwealth marine parks cover approximately 47 percent of Queensland's 14 marine bioregions. The six Queensland marine parks have a total area of approximately 5.2 million ha; the Great Barrier Reef Marine Park covers 34.1 million ha.

About 79 percent of the Great Barrier Reef Marine Park is zoned to allow a range of activities including trawling and line fishing. A further 16 percent of the area is zoned to prohibit trawling, while allowing other activities. Approximately 5 percent is protected and prohibits extractive uses and the siting of human structures. Within Queensland's State marine parks, a different zoning system is used. In Moreton Bay Marine Park, for example, 61 percent of the total park area is zoned general use, 27 percent habitat zone and 11 percent conservation zone; the protection zone is less than 0.01 percent.

Of the 14 marine bioregions, five in the Gulf of Carpentaria and Torres Strait are not represented in marine parks although approximately 39 000 ha of declared fish habitat areas occur in the Wellesley and Karumba–Nassau bioregions. All of the Wet Tropic Coast, Lucinda–Mackay Coast, Mackay–Capricorn, Shoalwater Coast, Central Reef and Pompey–Swains regions fall within the Great Barrier Reef Marine Park and are afforded some protection. In addition, the Shoalwater Coast has 59 percent of its total area, the Wet Tropic Coast 47 percent and the Lucinda–Mackay Coast 45 percent protected by Queensland marine parks (see table 5-44 in chapter 5, 'Coastal zone'). Data are not available to assess the comprehensiveness, adequacy and representativeness of marine protected areas.

Fish habitat areas declared under the *Fisheries Act 1994* provide protection to tidal wetland habitats. Under the Act, all marine plants (encompassing mangroves, seagrass, algae, saltwater couch, saltpan succulents, and melaleuca in adjacent swamps) are protected regardless of tenure of the land on which they are found. By 1998, 79 fish habitat areas had been declared, covering about 603 000 ha of tidal wetlands.

Mound springs — biological refuges

Many artesian springs result from natural leakage from the aquifer of the Great Artesian Basin (GAB). These are known as mound springs because of the distinctive mounds of vegetation, soil and rocks they usually form.

Considered to be one of the rarest landforms in Australia, they are of great significance as foci for plant and animal life and have been identified as refuges of biodiversity significance in arid and semi-arid Australia (Morton et al. 1995). Although these ecosystems are relatively poorly known, the available information has been reviewed by Wilson (1995).

Bruce Wilson

Queensland Museum

Elizabeth Springs (top) and the boggomosses near Taroom (bottom) support a rich and unique flora and fauna but are among the most threatened ecosystems in Queensland.

Many artesian springs are very degraded and many have become extinct in the last 100 years due to drawdown from the GAB.

In Queensland, artesian springs occur in an area bordering the GAB from north-east of Cloncurry almost to the Northern Territory border south-west of Boulia, and almost to the New South Wales border south-west of Eulo. They are located in several major groups, and are named according to location.

Drawdown resulting from general or local extraction of artesian water is the single greatest threat to the springs. Flows, especially in western springs, have diminished considerably following the massive extraction of artesian water since about 1880, and the flow has ceased entirely in 25 springs, rendering them extinct (Wilson 1995). Many of those still flowing have been reduced to seeps. The flow status of 35 percent of the 276 springs listed by Wilson (1995) is unknown.

While no Queensland artesian springs other than the boggomosses (mound springs found near Taroom) have been comprehensively surveyed for plants and animals (Ingram and Stanisic 1997), many endemic species have been recorded. Of the 12 species of snails, many are restricted to one spring group. Four species of endemic fish are found, each restricted to one spring. In the most comprehensive survey for inland insect fauna in Queensland, 1691 species, including 602 species of beetles, were identified from boggomosses (Monteith and Burwell 1997).

Although the vegetation of artesian springs is poorly known, Wilson (1995) lists vascular plants recorded from these habitats. Botanical surveys of the boggomosses reveal that some have extremely high conservation values: many support several rare and threatened species (Fensham 1998b). Little is known about the non-vascular plants associated with mound springs.

Several springs are protected in Carnarvon and Currawinya National Parks. All others are on pastoral leases. Among the most important springs are those at Edgbaston Station close to Aramac, where two species of endemic fish, six species of endemic snails, several other endemic invertebrates and three rare and threatened plant species are found. Some springs on pastoral properties suffer stock damage to varying degrees. Some boggomosses, however, have been fenced to exclude cattle.

The introduction of mosquitofish (*Gambusia holbrooki*) to some springs has probably had an impact on endemic fishes. Two endemic fish species and six species of plants are listed as threatened under the *Nature Conservation (Wildlife) Regulation 1994*. Recovery plans have been prepared for all the recorded threatened fish species (Wager 1995).

A bore-capping program has been undertaken in Queensland in an attempt to prevent further degradation of artesian springs. Between 1991 and 1996, more than 175 bores were rehabilitated. Some regions, notably Julia Creek and Aramac, have experienced an increase in water pressure since capping began.

Terrestrial vegetation types

The state of broad vegetation and habitat types is described for Queensland's terrestrial, wetland and subterranean (underground) environments to provide a general overview of ecosystem diversity. Coastal and marine habitat types are described in chapter 5, 'Coastal zone'.

Indicators

Extent of broad vegetation types by bioregion

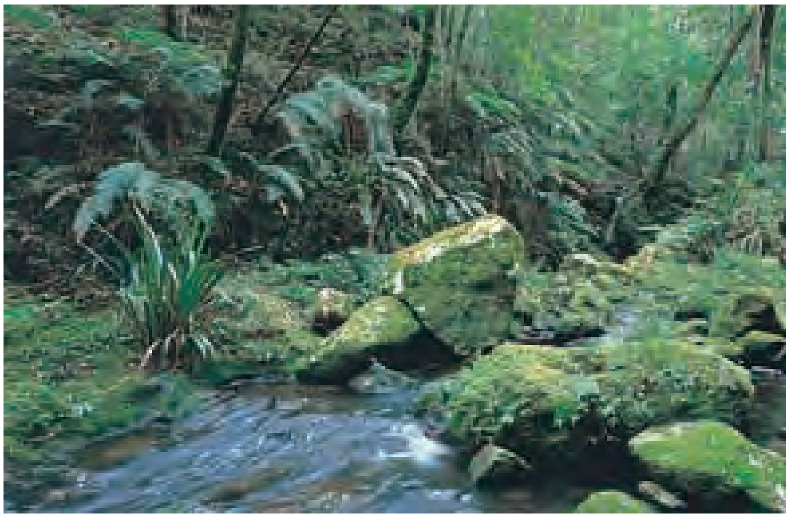
Extent of broad vegetation types within protected areas by bioregion

Forests

Queensland's forest ecosystems are among the most diverse and variable in Australia. They range from relatively restricted tall wet forests on and east of the coastal slopes to widespread open dry forests. Their distribution is strongly influenced by moisture availability and soil fertility. The height and productivity of the forests and their species richness and abundance broadly reflect this pattern.

The National Forest Inventory has grouped all native forests across Australia into eight broad native forest types, defined by structure and dominant species (table 7-10). At present forests cover approximately 28 percent of Queensland's land area, or about 47 percent of their pre-1750 distribution. The forest area represents 45 percent of the total Australian forest coverage. Forests can also be broadly grouped into three classes based on the density of their crown cover — 74 percent of the forest extent is woodland, 20 percent is open forest and 6 percent is closed forest (rainforest and mangrove).

Eucalypt open forests and woodlands are the most extensive forest group in Queensland. The tall eucalypt or wet sclerophyll forests, 2 percent of the forested area, are generally distributed as topographically isolated patches along the eastern ranges from the New South Wales border to the wet tropics. The medium-height eucalypt forests, the most extensive of Queensland's forest groups, are widespread on relatively infertile soils in low-rainfall areas in coastal and inland regions; the majority of these forests are classified as woodland. About 5 percent of total native forest cover is low eucalypt open forest and woodland less than 10 metres tall. Most of these forests occur in semi-arid regions in association with acacia species.



The rainforests of Lamington National Park in south-east Queensland fall within the World Heritage-listed Central Eastern Rainforest Reserves, recognised internationally for their outstanding biodiversity values.

Rainforests represent 5 percent of the forested area. They occur as remnants of subtropical and warm temperate rainforests in south-east Queensland, but more extensively as tropical rainforest in the north around Mackay, between Townsville and Cooktown, and in eastern Cape York. Rainforests are highly valued for the richness of their biodiversity. The rainforests of the Wet Tropics World Heritage Area, some 660 000 ha in area, are floristically and structurally the most diverse in Australia. They include 13 major structural types, further classified into 27 broad communities supporting more than 1000 species from 523 genera of 119 families. Approximately 31 percent of the national rainforest area occurs within this World Heritage Area.

Clearing and the resulting habitat fragmentation are significant threats to forest biodiversity. Woodland clearing, particularly, has been one of the most significant historical vegetation changes. Of the ten recognised woodland groups, nine are threatened by clearing. Those most affected include brigalow/belah woodland (less than 15 percent remaining), tropical savanna woodlands with poplar gum (25 percent remaining) and poplar box woodlands (less than 40 percent remaining). Other threats include timber harvesting, changed fire regimes and the invasion of exotic species.

The majority of woodlands have traditionally been used for grazing and agriculture. Because woodlands generally fail to elicit community interest in conservation to the same extent as other forests, this has resulted in a relatively low representation of woodland in nature conservation areas. Although woodlands comprise 74 percent of the total forest area, only approximately 4 percent of their area is within protected areas.

Table 7-10 Extent of broad forest types in Queensland, categorised by tenure

Forest types	Extent		Tenure categories (percentage of broad forest type area)				
	Area ('000 ha)	Percentage of total forest	Private	Leasehold	Conservation reserves	Other	Multiple use
Eucalyptus	31 984	65	32	55	4	2	6
Acacia	4 603	9	49	46	3	1	1
Melaleuca	2 643	5	18	72	8	<1	1
Rainforest	2 567	5	31	15	18	3	32
Mangrove	398	1	35	15	37	13	<1
Callitris	309	1	31	46	1	1	21
Casuarina	62	<1	90	<1	0	2	5
Other forests	6 490	13	46	28	8	4	15
Total	**49 056**	**100**	**35**	**49**	**6**	**2**	**8**

Private: forests owned privately, very limited clearing controls.
Leasehold: publicly owned forests on land leased from the Crown, subject to varying clearing controls.
Conservation reserves: publicly owned forests reserved for conservation, including national parks.
Other: forests on Crown (public) land not covered by the previous three categories.
Multiple use: publicly owned forests set aside for timber production, including State forest and timber reserves.
Note: These nationally derived data may differ from Queensland-derived data due to differences in the scale and methodologies used for data collection.
(Source: National Forest Inventory 1998)

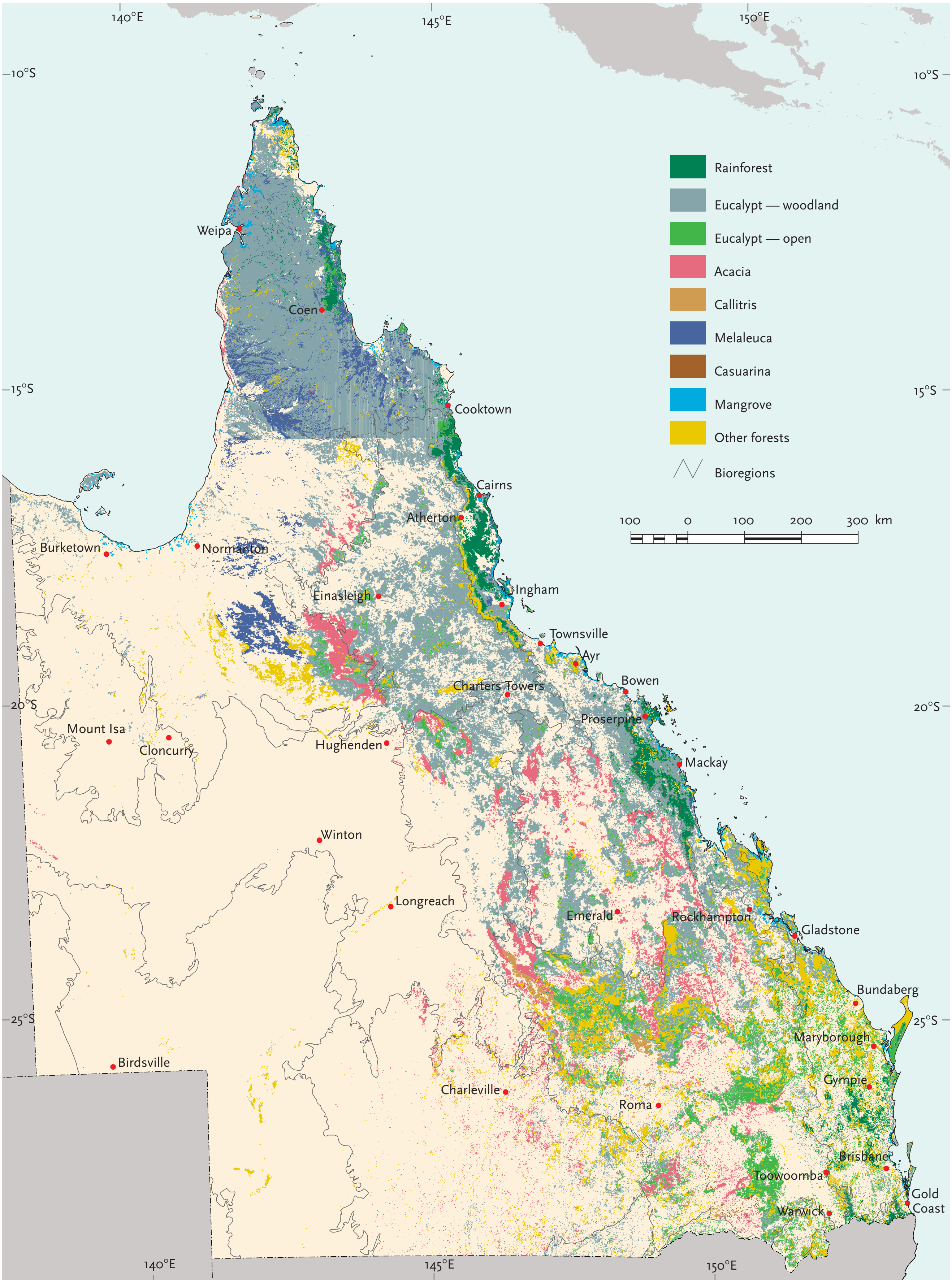


Figure 7-22 Distribution of broad forest types in Queensland. The sharp border across the south of Cape York is an artefact of mapping rather than of forest distribution.
(Source: National Forest Inventory 1998)

Table 7-11 Areas of old-growth forest by tenure in the Southeast Queensland bioregion

	State forest			National parks			Other tenures			Total	
	ha	% TF	% OG	ha	% TF	% OG	ha	% TF	% OG	ha	% TF
Yes OG	19 876	0.6	20.4	42 751	1.2	44.0	34 708	1.0	35.7	97 335	2.7
Likely yes OG	27 172	0.8	13.3	77 813	2.2	38.1	99 505	2.8	48.7	204 490	5.8
Total	**47 048**	**1.3**	**15.6**	**120 564**	**3.4**	**39.9**	**134 213**	**3.8**	**44.5**	**301 825**	**8.5**

TF = total forest, OG = old growth
(Source: Kelly 1998)

Old-growth forests

Available forest data are concerned mainly with the spatial distribution and extent of native forests; few data exist statewide on the composition, condition or quality of the forests. Knowledge of old-growth forest, defined as ecologically mature forest where the effects of disturbances are now negligible, is of conservation importance because many plants and animals are restricted to the old-growth stages or are dependent on old-growth forest for some of their habitat requirements. One of the most significant characteristics of the older stages of eucalypt forests is the development of tree hollows necessary for the survival of a range of fauna including many birds and arboreal and flying mammals.

Old-growth forests constitute a major determinant for identifying and developing a national forest reserve system (National Forest Inventory 1998). As part of the Comprehensive Regional Assessment for the Southeast Queensland bioregion, approximately 43 percent of the forested area has been assessed for old-growth values (Kelly 1998). Areas not assessed included non-eucalypt native forests and rainforest. Distribution of old-growth forest was found to be limited in extent and was largely patchy and fragmented. The total area of old-growth forest within the region is approximately 97 000 ha, or 2.7 percent of the total forest area, with a further 204 000 ha (5.8 percent) assessed as likely old-growth (table 7-11). Representative patches of old growth of all forest types may not remain. Of the total 106 forest ecosystems that occur in the region, 31 percent have no old growth identified within the region. A further 13 percent have less than 1 percent of their area old growth.

Table 7-12 Summary of the state of broad arid shrubland types in Queensland

Broad shrubland type	Estimated original area (million ha)	No. of regional ecosystems (percentage of total) with <30 percent extent remaining	Estimated percentage of area in protected areas	Threats
Mulga	19.1	54 (15%)	2.5	Grazing pressure (domestic stock and feral species) Feral predators (foxes, cats) Clearing and associated introduction of exotic pastures Changes in fire regimes
Gidgee	4.7	41 (39%)	0.8	Clearing and associated introduction of exotic pastures Exotic weeds in alluvial areas Feral predators (foxes, cats)
Spinifex	5.7	0	19.6	Changes in fire regimes Grazing pressure (rabbits, camels, pigs) Feral predators (foxes, cats)

Arid shrublands

In the arid and semi-arid parts of the State, low woodland ecosystems give way to shrublands. Shrublands consist of woody plants that are multi-stemmed at the base or within two metres of the ground or less than two metres tall. Queensland's arid shrublands are broadly grouped into three categories based on species composition (table 7-12).

Vegetation associated with these communities has been mapped and surveyed by regional studies (for example Neldner 1991). The associated fauna is generally poorly known, although some fauna surveys of the spinifex grasslands have been carried out in the Channel Country region (McFarland 1992). The widespread mulga shrublands are associated with many plant species, including many that are rare and threatened. The gidgee and spinifex shrublands, much less extensive than the mulga, are associated with relatively low species numbers. The gidgee, however, supports a relatively rich fauna compared with the surrounding grasslands (Wilson, B., pers. comm.), while the spinifex shrublands are habitat for rare and threatened species, particularly arid-zone mammals such as the kowari, mulgara and dusky hopping-mouse.

The mulga and related shrublands are in particularly poor condition. Pressures leading to degradation in the mulga shrublands are complex, but degradation is largely attributed to overgrazing by domestic stock in conjunction with grazing pressure by feral and native animals, particularly during drought periods.

Clearing and the introduction of domestic stock have contributed to biodiversity declines in mulga communities.

The gidgee shrublands have been most affected by clearing and the associated introduction of exotic pasture species, mainly buffel grass. Most clearing is in the eastern Mitchell Grass Downs, Mulga Lands, western Desert Uplands and Brigalow Belt bioregions. Virtually no clearing of the spinifex shrublands has occurred. In spinifex communities, however, changes in community structure and function have led to a reduction in diversity of microhabitat types. These changes have been associated mainly with changed fire regimes. These communities are not intensively grazed by domestic stock.

Gidgee shrublands have been invaded by the exotic weed species *Parkinsonia aculeata* and *Acacia nilotica*, particularly along alluvial areas, which are important wildlife habitat. Feral animals, widespread over all these communities, have had a particularly severe impact in the spinifex shrublands.

Table 7-13 Summary of the state of grasslands in Queensland

Broad grassland type	Estimated original area ('000 ha)	Percentage remaining uncultivated or unimproved	Estimated percentage of area in potected areas	Threats
Mitchell grasslands (including Channel Country herbfields)	25 000	98–99	0.5	Overgrazing Invasion by woody exotics
Gulf grasslands	4 779	99–100	<0.5	Overgrazing
Central blue grasslands	560	20–30	<0.5	Cultivation Overgrazing Invasion by parthenium
Cape York coastal plain grasslands	630	>95	8.2	Ponded pasture species such as para grass
Southern blue grasslands	400	1.3	0	Cultivation

Grasslands

Naturally treeless grasslands typically occur in Queensland on soils of generally high fertility. The five major grassland types are endemic to Australia (table 7-13). Other grasslands also occur, covering substantial areas on Cape York Peninsula and other coastal areas, but are relatively minor in area compared with those listed in table 7-13.

Of the 31 million ha of naturally treeless grasslands in Queensland, the Mitchell grasslands occupy 80 percent of the area. They are generally dominated by Mitchell grass (*Astrebla* spp.) and/or Flinders grass (*Iseilema* spp.) and occur in the semi-arid to arid interior of the State. Large areas of grassland also occur on the flat alluvial plains of the waterways leading into the Gulf of Carpentaria and are dominated by the bluegrass *Dichanthium fecundum*, browntop (*Eulalia aurea*) and Mitchell grass. The central blue grasslands of the Central Highlands are dominated by the bluegrass *Dichanthium sericeum*. Southern blue grasslands occur on the basaltic landscapes of the Darling Downs, but are distinct from those of central Queensland. Extensive grasslands occur on the saline and freshwater coastal plains of Cape York Peninsula; they are dominated by a variety of species, depending on salinity and the duration of inundation.

The vast treeless Mitchell grasslands occur in the semi-arid to arid interior of Queensland.

Legislation lists seven rare and threatened plant taxa from grasslands. One species, the daisy *Trioncinia retroflexa*, known from the Central Highlands, survives in a population of approximately 15 individuals and is one of Australia's rarest plants.

The coastal grasslands, other than those on Cape York Peninsula and the Gulf Plains, have never been the subject of a vegetation survey. No extensive native animal surveys have been carried out for any grassland type in Queensland, although some regional surveys and studies of rare species or species of restricted distribution have been done. These species include the golden-shouldered parrot, the bilby, the Julia Creek dunnart and a legless lizard (*Lerista allanae*) known only from the central blue grasslands, last collected in 1960 but not found by recent survey (Covacevich et al. 1996).

All broad grassland types in Queensland, except for those on Cape York Peninsula, have less than 1 percent of their area in protected areas. In terms of remaining area and protected area status, one of the most endangered ecosystems in Queensland is the blue grasslands of the Darling Downs (Fensham, R., pers. comm.).

Overgrazing, cultivation and weed invasion threaten grasslands. More than half of the total native pasture area has been assessed as being in a degraded state (Tothill and Gillies 1992). The vast Mitchell grasslands have scarcely been affected by cultivation, except in the south-eastern part of their range, where cropping is extensive. Some areas of wooded grassland, particularly in the Blackall district, have been converted to buffel grass pasture. Large areas of the Mitchell grasslands are converting to exotic shrubland with the advance of woody weeds. The use of ponded pasture species poses a threat to some freshwater grasslands on Cape York Peninsula (Neldner et al. 1997).

There has been a progressive shift to the cultivation of some grasslands for crops. Approximately 1 percent of the southern blue grasslands remains. Accurate figures for the central blue grasslands are not yet available, but the area has been reduced by approximately 30 percent. Large areas of the remaining uncultivated grassland in this area are overgrazed and heavily invaded by the exotic *Parthenium hysterophorus*.

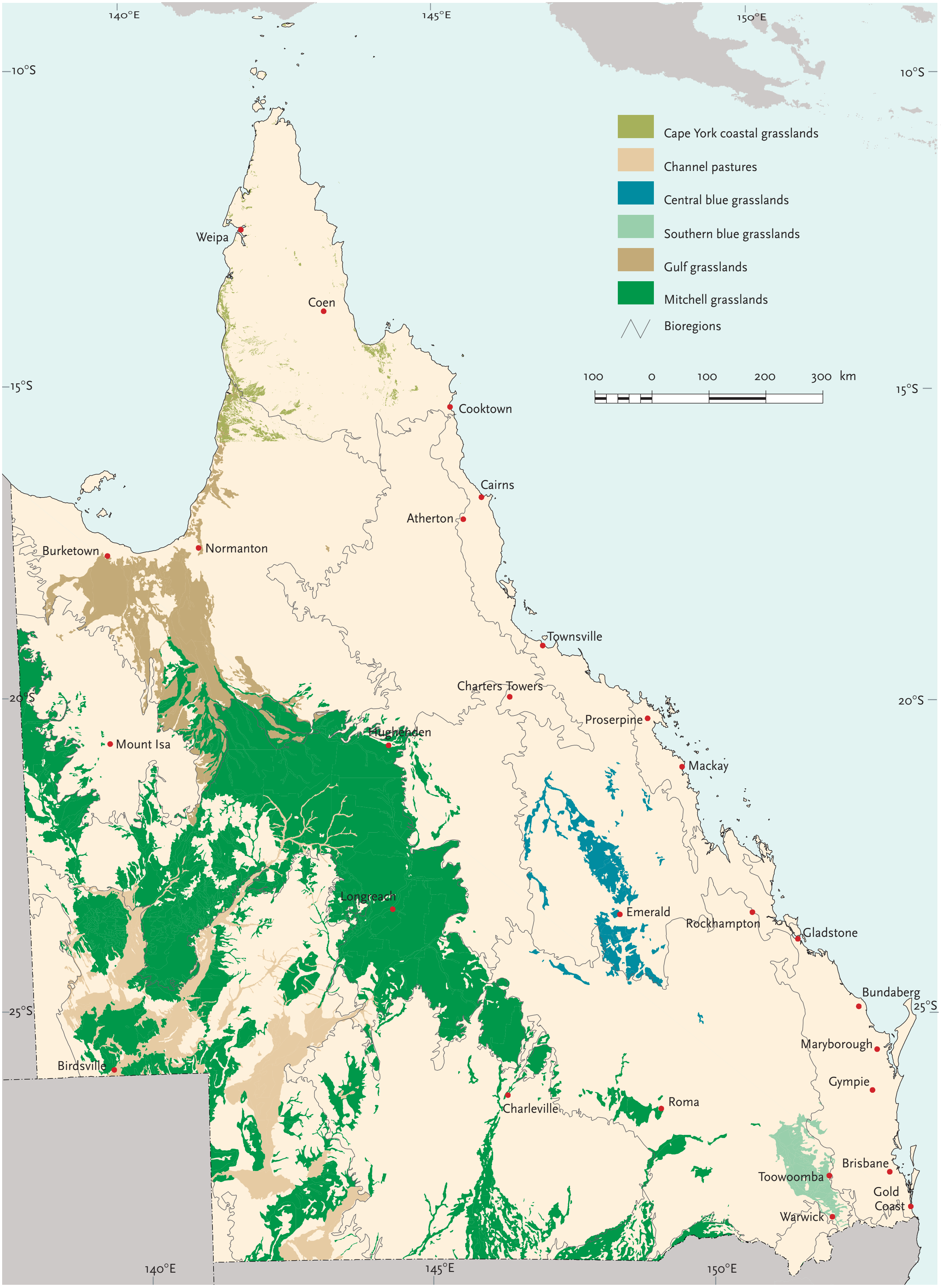


Figure 7-23 Extent of broad grassland types
(Source: DPI)

Wetlands

Queensland's wetlands are of outstanding diversity and vary greatly in type, extent and influence. They occur throughout the State and include estuaries, coral reef lagoons, lakes, rivers and adjacent floodplains, groundwater outflows such as springs and swamps, and built water storages.

The ephemeral nature of Queensland's freshwater wetlands is due mainly to climatic variability. The most extensive areas of freshwater wetlands are found in northern areas. However, some of the most biologically interesting wetlands are associated with terminal lakes and overflows and braided stream systems associated with the internal drainage patterns of the Channel Country and Desert Uplands bioregions, and the swale systems of coastal and inland dunefields.

Wetlands are complex and highly productive ecosystems. They provide essential habitat for a great variety of native plants and animals including more than 3000 species of plants and some 150 species of resident and migratory waterbirds. Many of Queensland's rare and threatened species are dependent on wetland habitat. The Carbrook Wetlands, on the outskirts of Brisbane, support at least 250 plant, 171 bird, 35 mammal, 18 frog and 42 reptile species (Greenway and Kordas 1994).

Indicators

Number and extent of wetlands by bioregion

Number and extent of wetlands represented in protected areas by bioregion

Wetlands are estimated to cover approximately 4.1 percent of Queensland's mainland area. Coral reefs and areas on or surrounding islands increase that figure. Seasonally and intermittently inundated wetlands account for about 69 percent of the total, while intertidal areas (mangroves and saline coastal flats) account for another 14 percent. Only 0.7 percent of the land area, or 1 200 000 ha, including more than 1 125 000 km of major rivers, is permanently inundated.

Nationally important wetlands

Of the 40 categories of wetlands recognised in Australia, only one — alpine/tundra wetlands — is absent from Queensland. There are 165 nationally important wetlands in Queensland, identified on the basis of applicability of any one of six broadly based criteria (ANCA 1996):

- all sites were considered to be good examples of the wetland types they represented within a bioregion (criterion 1);
- 103 sites played important ecological or hydrological roles (criterion 2);
- 123 sites were refugial (criterion 3);
- 46 sites supported 1 percent or more of the national populations of any native plant or animal taxon (criterion 4);
- 73 sites supported species or communities considered to be endangered or vulnerable at the national level (criterion 5); and
- 42 sites were considered to be of outstanding historical or cultural significance (criterion 6).

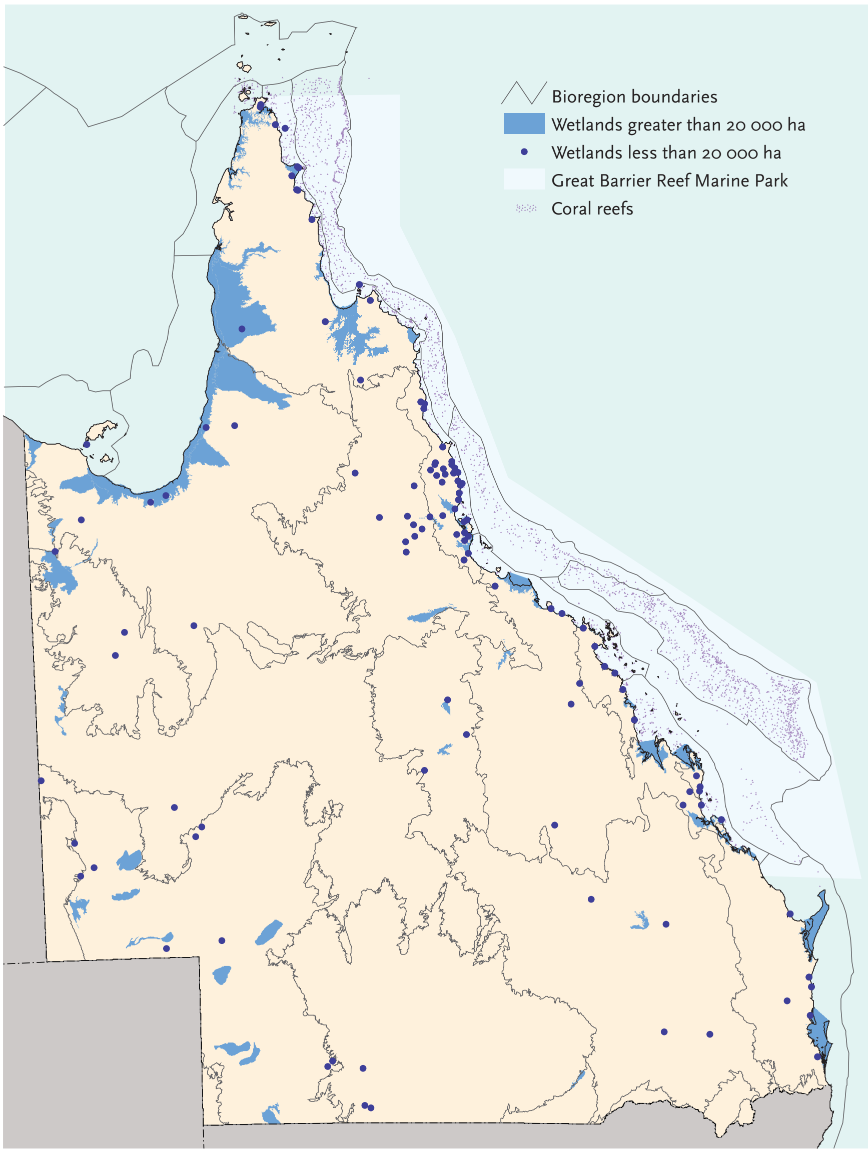


Figure 7-24 Location of the 165 nationally important wetlands in Queensland

Nineteen sites met all six criteria. These wetlands are amongst the most significant in Queensland and include the five internationally recognised Ramsar wetland sites.

Nationally important wetlands include 162 terrestrial wetlands totalling 7 929 343 ha in area (table 7-14) and three marine wetlands (including the Great Barrier Reef Marine Park) totalling 34 250 000 ha. The listed wetlands are considered to be a representative sample of important wetlands in Queensland but not an exhaustive statewide listing, which is yet to be achieved. For example, while there is a reasonable representation of about 57 percent of important inland wetland types, a suite of saline types, peatlands, karsts, shrub swamps and spring-oases are still poorly represented (Blackman et al. 1999).

The representation of wetland classes at the bioregional level is far from

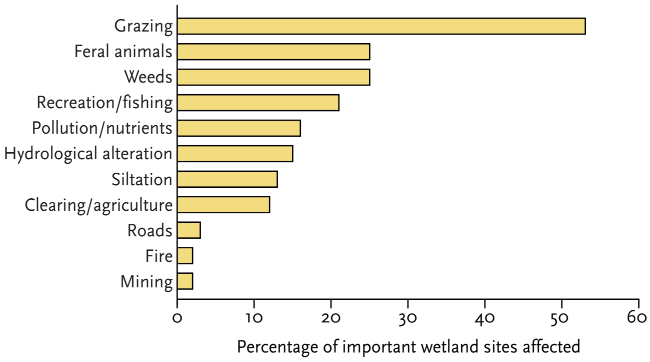


Figure 7-25 Pressures affecting the 165 identified nationally important wetlands in Queensland. Fire was considered a serious concern only in tropical areas.
(Source: Blackman et al. 1996)

complete. Significant areas have yet to be surveyed systematically for their wetland sites. Most wetlands that have been lost or modified (for example, drained and filled) have not been documented. However, some case study data can indicate trends in wetland area (see figure 7-6).

Significant wetland areas are found within the protected area estate, but in many cases it is questionable whether enough of the wetland system is included to ensure long-term survival. While 47 percent of important wetlands have at least partial protection within protected areas, very few have total protection, and even fewer have protection over the entire catchment. Protection of tidal wetlands also occurs under the *Fisheries Act 1994*. Freshwater areas can be gazetted under the Act as fish habitat areas, although at present none is declared in Queensland freshwaters.

Melaleuca wetlands, Woodgate National Park in south-east Queensland

Of nationally important wetlands surveyed, all but eight have suffered some form of disturbance. In a further 32 the disturbance is considered minor. The remainder have been modified and some have been destroyed through drainage and fill, water impounding and water harvesting, and introduction of exotic species. Grazing is the most widespread pressure on Queensland wetlands, affecting 53 percent of important wetlands to some extent (figure 7-25). With more than 85 percent of Queenslanders living within 50 km of the coast, development pressures on coastal wetlands in particular are great.

Table 7-14 Important terrestrial wetland sites in Queensland and their conservation status, by Interim Biogeographical Regionalisation of Australia (IBRA) bioregion, at June 1999

IBRA bioregion	Code	Number of nationally important wetland sites	Total area of important wetland sites (ha)	Percentage of bioregion area	Number of important wetland sites within or partially within protected areas	Percentage of total sites in bioregion	Area of important wetland sites protected (ha)	Percentage of total wetland area protected
Cape York Peninsula	CYP	23	2 448 662	21.0	8	35	461 526	19
Gulf Plains	GUP	15	2 211 090	10.5	2	13	46 387	2
Gulf Fall Uplands	GFU	1	1 408	0.2	1	100	942	83
Wet Tropics	WT	29	183 142	10.1	24	83	27 104	16
Einasleigh Uplands	EIU	13	125 966	1.0	3	23	54 902	42
Mount Isa Inlier	MII	4	320 844	4.8	2	50	134 602	41
Mitchell Grass Downs	MGD	2	69 734	0.3	0	0	0	0
Brigalow Belt North	BBN	9	480 821	4.3	5	56	33 351	8
Brigalow Belt South	BBS	13	238 009	1.0	9	69	1 823	1
Central Mackay Coast	CMC	13	221 634	15.2	7	54	5 194	2
Desert Uplands	DEU	5	50 583	0.7	0	0	0	0
Channel Country	CHC	20	893 561	4.2	2	10	2 236	<1
Southeast Queensland	SEQ	11	633 515	9.2	10	91	209 472	33
Mulga Lands	ML	3	27 290	0.1	3	100	21 422	81
Darling–Riverine Plain	DRP	1	23 089	1.8	0	0	0	0
Simpson–Strzelecki Dunefields	SSD	0	0	0	0	0	0	0
Nandewar	NAN	0	0	0	0	0	0	0
New England Tableland	NET	0	0	0	0	0	0	0
New South Wales North Coast	NNC	0	0	0	0	0	0	0
Gulf Coastal	GUC	0	0	0	0	0	0	0
Total		**162**	**7 929 343**	**4.6**	**76**	**47**	**998 960**	**13**

Riverine habitats

Indicator

Condition of riverine habitats by catchment

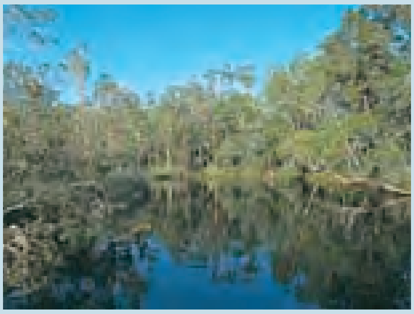
The Department of Natural Resources has undertaken a comprehensive survey of the ecological and physical conditions of rivers and streams in seven catchments. These surveys were based on a rapid assessment technique used at a particular time; they do not indicate a particular trend but provide a condition statement for the streams at the time of survey. Results from these State of the Rivers reports are the only available quantitative data on the broadscale condition of rivers in Queensland. (See chapter 4, 'Inland waters', for references.) On a variety of attributes assessed, the overall results show these rivers to be generally in poor condition. Riparian vegetation, in particular, was assessed as being in a poor to very poor condition throughout all catchments and was identified as the most significant management issue (see box 'Riparian ecosystems').

Aquatic vegetation was generally in very poor condition in all catchments. Low quantities recorded at most sites, dry conditions and reduced water levels influenced the results. Aquatic habitat diversity was also assessed to be in poor condition in all catchments. Only the Bremer River catchment had more than 40 percent of its stream length habitat diversity rated as 'good' to 'very good'. In some catchments restricted passage was recorded for fish and other aquatic organisms due to log jams and structures such as weirs and dams. In the Maroochy catchment 64 percent of surveyed sites had such restricted passage.

Riparian ecosystems

Riparian ecosystems fringing watercourses are important energy and nutrient sources for stream ecosystems. They provide food, habitat and shade for both terrestrial and aquatic organisms. They are important for streambank stability, guarding against excessive erosion and protecting water bodies from pollutants travelling overland in runoff. Riparian zones provide refuge for plants and animals in times of environmental stress. They are important wildlife corridors. Riparian forests fringing the major rivers on Cape York Peninsula act as dispersal corridors for many animals moving between the extensive rainforests on the east coast and the smaller sand ridge rainforests on the west coast (Winter and Lethbridge 1994).

Riparian ecosystems have been heavily cleared for flood mitigation, intensive cropping (notably sugarcane), grazing and irrigation. Grazing has been identified as the major pressure on riparian vegetation along all the rivers surveyed for the State of the Rivers reports. In the Dawson catchment, grazing was common at 90 percent of sites surveyed. Less than 10 percent of Queensland's 93 000 km of stream frontage is protected (for example by fencing) from grazing animals (McLennan 1996).



Riparian vegetation along the Noosa River, Cooloola National Park, in south-east Queensland

Degraded riparian zones have led to extensive weed invasions. Rubber vine, the most significant riparian weed species in Queensland, smothers riparian vegetation causing habitat loss. In the Herbert River catchment, the introduced para grass has spread from riparian zones to streams and has caused significant choking of watercourses. This has degraded natural stream processes and excluded native aquatic species.

In all catchments surveyed in the State of the Rivers surveys, the condition of the riparian vegetation was reported to be generally poor: riparian vegetation was heavily cleared, trampled and degraded by stock and/or invaded by weed species (table 7-15).

Several legislative mechanisms provide varying levels of protection for riparian zones. Under the Queensland Government's Broadscale Tree Clearing Policy, buffer zones are required to protect riparian lands on both sides of a watercourse; the dimensions vary according to stream order, size and location. The *Water Resources Amendment Act 1993* provides protection to vegetation within the top bank of streams but not to the principal part of the riparian zone beyond that. *The Fisheries Act 1994* protects all marine plants including those in riparian zones on or adjacent to tidal land.

All sectors of the community are engaging in a high and increasing level of activity in riparian restoration. Catchment management groups in Queensland have identified riverine degradation as a key issue requiring urgent attention through coordinated action at State, regional and local levels. Riparian restoration features in many current Natural Heritage Trust projects.

Table 7-15 Riparian values for surveyed river catchments in Queensland. Surveys were conducted between September 1992 and June 1995.

	Mary River catchment	Maroochy River catchment	Upper Condamine River catchment	Dawson River catchment	Herbert River catchment	Lockyer Creek catchment	Bremer River catchment
Percentage of stream length in poor to very poor condition	63	83	88	83	76	75	83
Mean width (m) (min.–max.)	17 (0.5–365)	14 (0.5–400)	18 (0.1–250)	14 (0.5–150)	19 (0.1–155)	7 (1–50)	8 (0.1–50)
Percentage of surveyed sites with exotic species	63	82	96	88	65	89	86

(Source: DNR)

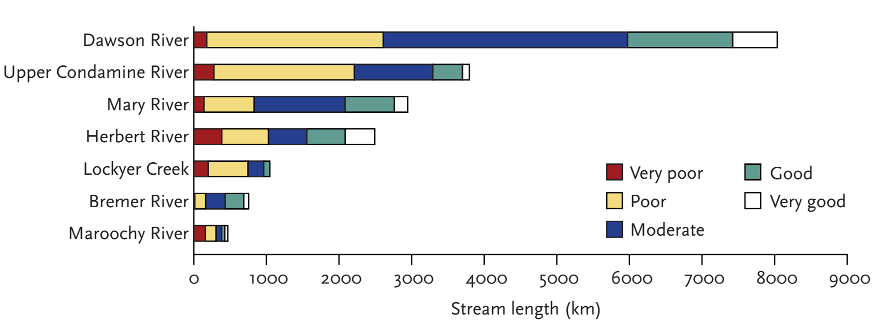


Figure 7-26 Conservation values for selected catchments in Queensland
(Source: DNR)

Conservation values assigned to a survey site were based on the site's value as a habitat for aquatic plant and animal species, its value as a habitat for riparian species and its value as a wildlife corridor. It was considered that sites that received an assessment in the 'good' and 'very good' categories should receive some form of protective management that will maintain those conservation values (figure 7-26).

Subterranean environments

Indicators

Number and extent of cave and lava tube systems of biodiversity significance by bioregion

Extent of cave and lava tube systems in protected areas by bioregion

Caves in limestone areas (karst) and lava tubes are used by and are home to a unique fauna in Queensland (table 7-16). These ecosystems contribute significantly to the State's biological diversity. Caves found in other rock types, while important sites for a variety of fauna, are not as extensive or as well documented as the limestone caves and lava tubes in Queensland. Abandoned mines that have been adopted by cave-dwelling bats as cave substitutes also constitute significant sites (Hall et al. 1997).

Queensland caves are generally dry caves. Very few have permanent streams or even standing water. The towering nature of many of the limestone outcrops tends to support fire-sensitive vegetation — evidence of the fire-protective nature of the steep, bare rocky slopes. The same characteristics protect these areas from the influence of agricultural and pastoral practices. The 'island' nature of these outcrops is also reflected in the degree of endemicity and diversity recorded in the land snail populations (Stanisic 1997).

The invertebrate fauna of tropical Australian caves has been poorly studied. Those Queensland caves surveyed for invertebrates usually contain very localised endemic species restricted to isolated cave habitats (Howarth 1988; Weinstein and Slaney 1995). Chillagoe-Mungana, Mitchell-Palmer and the Undara Lava Tunnels, all of which have highly significant invertebrate faunas, are examples (Howarth and Stone 1990). The cave fauna found in the Undara Lava Tunnels near Chillagoe is the most diverse recorded for any lava tube in the world (Howarth 1988).

Caves are particularly important as nursery sites for bats. Female bats return to the same caves each year to give birth and raise their young. Sometimes this can involve several hundred thousand bats, as at Mount Etna. Many bats are highly selective in their choice of cave roost sites, and these vary significantly during the year. Troughton's sheathtail-bat (*Taphozous troughtoni*) is listed as endangered, while four other species of cave-dwelling bats are listed as vulnerable. Listing is helpful as a guide for management and research involving these species. For example, at Barker's Lava Tube (Undara), which is used by bent-wing bats (*Miniopterus* spp.) as a maternity site, underground visits by people are replaced during the maternity season by surface-based watching of the bats emerging from the cave in the evenings.

About 60 percent of Queensland's bat species, including the vulnerable ghost bat (*Macroderma gigas*), roost in caves.

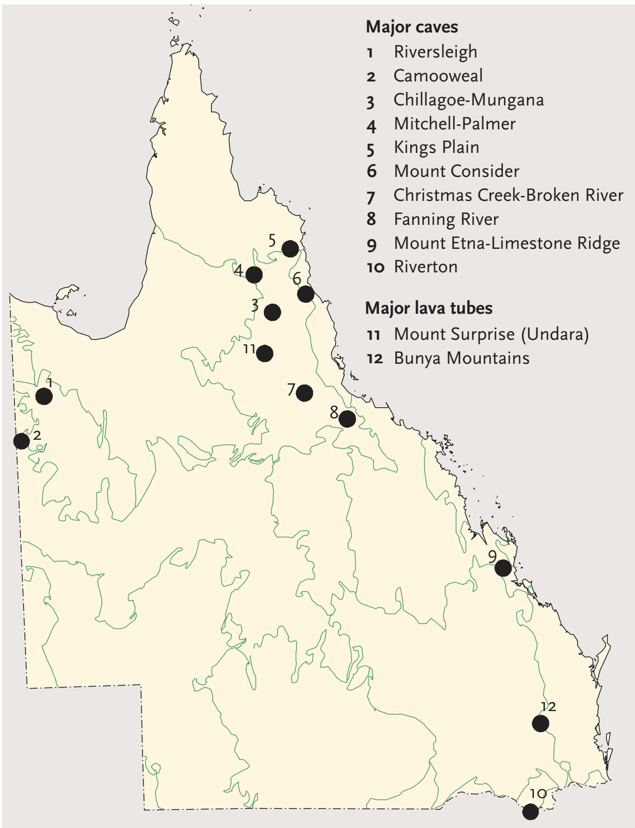


Figure 7-27 Location of major cave and lava tube systems in Queensland

Table 7-16 State of Queensland's major limestone caves and lava tubes

	Features	State of biodiversity	Threats/pressures
Limestone areas			
Barkly Tableland	Spectacular karst landscapes prominent; extensive fossil deposits at Riversleigh		Mine dewatering Fossil collecting Visitor impacts
Chillagoe-Mungana and Mitchell-Palmer	Striking landscape with towers; karst belts of these localities total about 60 km in length, with maximum width of 8 km; 517 caves in Chillagoe-Mungana area and 261 caves in Mitchell-Palmer area; area subject to broadscale grazing	Caves support significant bat, swiftlet and invertebrate communities; diversity of land snails (27 species) higher than surrounding woodlands	Mining activities Altered fire regimes Groundwater pollution Groundwater abstraction Visitor impacts
Kings Plain-Wallace Creek	Small outcrop of limestone; large number of caves; outcrop covered with tropical vine scrub	Roost sites for a large colony of the vulnerable ghost bat and a small colony of the vulnerable Semon's leaf-nosed bat	
Mount Consider	Small isolated limestone tower covered by mosses and epiphytes in many places; four caves described; surrounding country open woodland	A significant biogeographical site; large bat populations, including (most likely) rare large-eared horseshoe-bat and vulnerable ghost bat	Quarry on southern end of outcrop
Broken River-Christmas Creek	Six prominent outcrops with a sizeable number of caves known; one highly geologically significant; extensive reef fossil beds; sites of significance to Aborigines	Large maternity roost for common sheathtail bat; swiftlet colonies	Mining activities and, to a lesser extent, grazing and altered fire regimes
Fanning River	Small low outcrop containing a number of large caves; numerous fossils in Ladder Cave; outcrop covered by dense vine thicket	Nursery for little bent-wing bats; survey in Ladder Cave yielded 14 species of invertebrates from 14 families and 10 orders, including new species of pseudoscorpion endemic to cave	Some mining interest in limestone
Mount Etna-Limestone Ridge	The limestone stands above the surrounding plain, usually covered with vine scrub; probably significant Tertiary–Quaternary fossil deposits	Important bat colonies — nursery site for approx. 100 000 female little bent-wing bats, most southerly population of ghost bat breeds in caves; rock-wallabies live on outcrops and use cave entrances; outcrop important refuge for rainforest flora	Limestone quarrying Grazing impacts Fire Possible groundwater contamination Visitor impacts
Riverton-Texas	Some caves are extensive and contain large fossil deposits; type locality for a rare troglobitic silverfish	Nursery site for both little and common bent-wing bats	Riverton deposit quarried for limestone
Lava tubes			
McBride Plateau, Undara, Bunya Mountains, Barambah	Lava tubes of varying length and size; most on private land; small, low lava cave in Bunya Mountains National Park	Highly significant invertebrate fauna at Undara; all lava tubes important for bats — maternity site for bent-wings at McBride Plateau, nursery site for eastern horseshoe-bats at Barambah	Grazing and agriculture Visitor impacts

The Chillagoe-Mungana caves in north Queensland support a highly significant invertebrate fauna.

Important karst areas are located substantially in national parks, for example Limestone Ridge National Park. Some entire outcrops (towers) such as Donna, Royal Arch and Queenslander Towers at Chillagoe are within a protected area. Many protected areas do not give sufficient catchment protection, often encompassing only the cave entrance rather than the whole cave or karst system. Substantial portions of some reserved cave systems extend beneath private land, State forest or land under other tenure, thus compounding the difficulties of management and conservation.

Species diversity

Indicators

Number of known species by taxon by bioregion

Number of species by taxon presumed extinct, endangered, vulnerable or rare by bioregion

A juvenile green tree python (*Morelia viridis*), one of 112 species of land and sea snakes found in Queensland, is representative of the great diversity of species occurring in the State.

Queensland supports a diverse range of native species (table 7-17). Approximately 89 percent of Australia's known fresh-water fish species and 58 percent of its frog, 55 percent of its reptile, 79 percent of its bird, 65 percent of its mammal and 47 percent of its vascular plant species are found in Queensland. Many of these are endemic to the State: approximately 253 species of frogs, reptiles, birds and mammals occur nowhere else.

However, knowledge of Queensland's invertebrate, non-vascular plant, fungi and micro-organism diversity is very poor compared with that of vertebrate and vascular plant diversity. The less-known groups are generally smaller, less conspicuous and less charismatic than the larger plants and animals. They are, however, often the most important in sustaining ecological processes and systems. The identification and study of these groups is often made difficult by their small size and the vast numbers of taxa represented. Lack of taxonomic expertise is also a problem in describing new species as they are found.

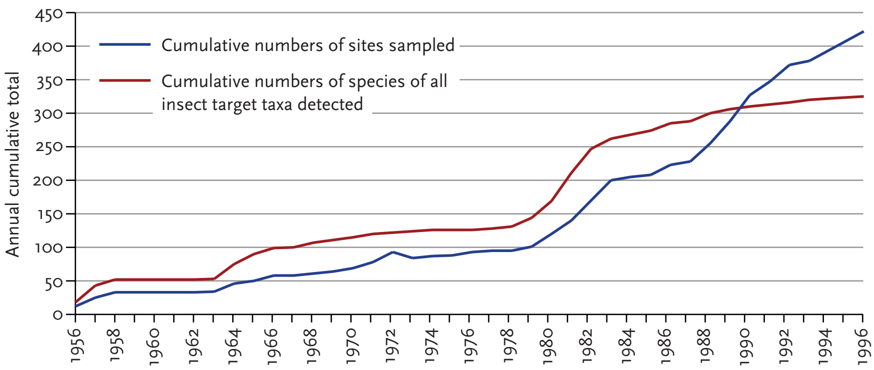


Figure 7-28 Collection curve showing the rate of accumulation of selected insect taxa in the Wet Tropics bioregion in far north Queensland. The year 1980 marked the beginning of intensive surveying of the mountainous areas by the Queensland Museum. After 40 years of intensive collection, the number of new species being discovered has begun to plateau.
(Source: G. Monteith, Queensland Museum)

There are difficulties in estimating total numbers of species and confidence in doing so generally decreases with the less studied but more diverse groups. Estimates of total numbers for these groups are based on the rate at which new species are collected and described. While intensive surveys can still yield small numbers of new vertebrate and vascular plant species, intensive collecting of some invertebrate groups can yield new species at a very rapid rate (figure 7-28). Micro-organisms, fungi, non-vascular plants and invertebrates, so poorly known, might collectively account for well over 90 percent of all Queensland's species. The total number of these species occurring in Queensland cannot be stated with any certainty.

Micro-organisms and fungi

Bacteria are responsible for much of the recycling of elements in nature. Knowledge of their diversity is poor, however, and they seldom receive attention in discussions on biodiversity. There are no inventories of bacterial diversity of Queensland. Traditionally, most taxonomic research in Queensland has centred on the surveillance of bacteria for the purposes of health, quarantine and pathology.

There is no comprehensive listing of protozoa (single-celled organisms) recorded from Queensland. Current knowledge of their diversity is sparse, fragmentary and confined to miscellaneous reports in the scientific literature (O'Donoghue, P., pers. comm.). While the parasites of human and domestic

Queensland Museum

Fungi are significant decomposers in ecosystems but knowledge of their diversity is limited.

Table 7-17 Queensland's known species diversity. For some groups, the level of knowledge is so poor that even estimates cannot be given and are indicated by ?.

Major taxonomic group	Number of native species in Queensland	Percentage endemic to Queensland	Number of known naturalised species
Micro-organisms			
Bacteria	?	?	?
Protozoa	?	?	?
Fungi	2000	?	?
Non-vascular plants			
Bryophytes	1000	?	?
Algae	1500	?	?
Lichens	1370	?	?
Vascular plants			
Flowering plants	7668	31	1153
Gymnosperms	61	20	3
Ferns	376	25	10
Invertebrates			
Sponges	428	?	?
Cnidarians	?	?	?
Echinoderms	350	?	?
Worms	350	?	?
Annelids	600	?	?
Platyhelminths	800	?	?
Nematodes	800	?	?
Molluscs			
Marine spp.	4000	?	?
Land snails	246	?	16
Crustaceans			
Decapods	1030	6	?
Arachnids	1200	43	?
Insects	?	?	?
Vertebrates			
Fish			
Freshwater	173	15	11
Marine	2000	?	?
Amphibians	120	32	1
Reptiles	442	32	2
Birds	615	6	12
Mammals	226	15	19

(Sources: Queensland Museum; The University of Queensland; EPA databases)

Lichens are a complex and diverse group of plants found growing on rocks, wood, bark and soil.

animal populations have been well researched, comparatively little is known about free-living species or those infecting native animals. Preliminary surveys have been conducted on freshwater free-living protozoa.

The fungi are enormously diverse, ranging from microscopic forms such as yeasts and moulds to larger macrofungi such as mushrooms and toadstools. Like bacteria, fungi are significant decomposers and nutrient recyclers. Queensland is believed to have a particularly diverse macrofungal flora, but its precise composition is unknown and its importance to biological diversity has not been assessed. There is no catalogue of Queensland fungi. The Queensland Herbarium houses a fungi collection of about 24 000 specimens, of which about 18 000 are microfungi. Currently only about 2000 macrofungi species are known for Queensland (Young, A., pers. comm.).

Non-vascular plants

Information about the diversity, distribution and ecological roles of the algae of Queensland is limited, yet algal species are the basis of food chains in freshwater and marine aquatic ecosystems. Over 1000 freshwater species are known. The Great Barrier Reef region supports a diverse marine macro-algal (seaweed) flora. Of the estimated 400–500 species, the majority are the red algae (McCook and Price 1997). Forty-six taxa of red, green and brown algae have been recorded in Moreton Bay (Abal et al. 1998).

Lichens have a clear economic and soil conservation role in semi-arid lands, where they often form a perennial and more or less continuous and species-rich carpet over the soil surface. These lichen species are capable of nitrogen fixation and provide a habitat for a well-developed microfauna and for a range of fungi and algae. Lichens are found throughout Queensland habitats including intertidal areas on coral reefs. While it comprises more than 1300 species, Queensland's diverse lichen flora is not well known.

Bryophytes, comprising mosses, liverworts and hornworts, occur to some degree in all terrestrial environments and are particularly significant components of rainforest and semi-arid/arid vegetation. Almost 1000 species (including 595 moss species) have been collected and recorded from Queensland, yet taxonomy, biogeography and population studies have been limited.

Vascular plants

Queensland's wide range of climatic and edaphic environments is reflected in the diversity of its vascular plants. The native flora comprises 8105 known species in 245 families (Henderson 1997). The knowledge base is continually increasing as a result of botanical exploration. Taxonomic research has also resulted in redefinition of many taxa. In the last five years, more than 300 species have been added to the Queensland floral database. In 1997–98, one genus and 14 species of plants from Queensland new to science were formally named and described. Thirty-one percent of flowering plant taxa are endemic to Queensland. Of plant families with more than 100 taxa, those with a major endemic element include Sapindaceae (54 percent), Lauraceae (51 percent), Orchidaceae (47 percent), Myrtaceae (44 percent) and Proteaceae (43 percent).

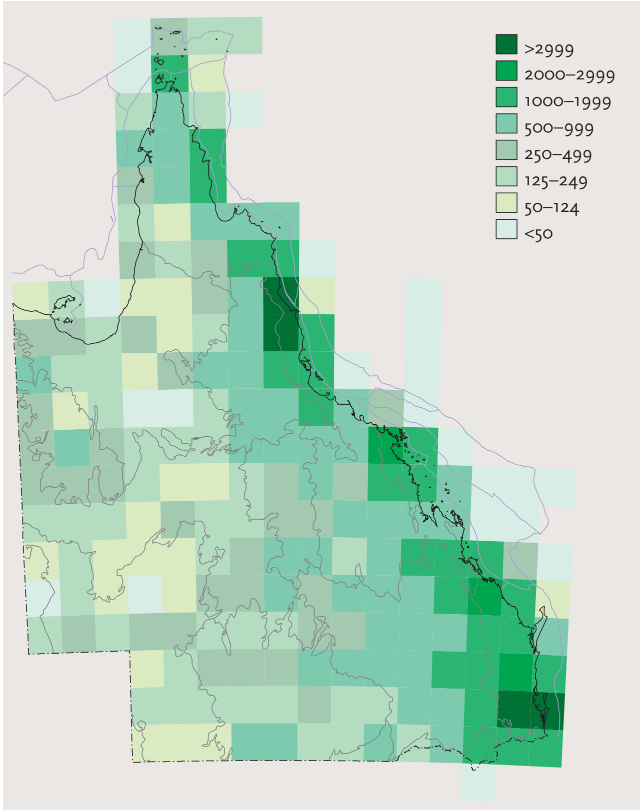


Figure 7-29 Numbers of plant taxa (including naturalised taxa) recorded by grid, based on Queensland Herbarium records at December 1998. Southeast Queensland and the Wet Tropics are the most botanically rich bioregions.

Approximately 60 percent of Queensland's vegetation has been surveyed and mapped. The major centres of botanical diversity are the Wet Tropics and Southeast Queensland bioregions (figure 7-29). Other botanically rich areas include the Mackay–Whitsunday and Rockhampton districts and the Iron Range–McIlwraith Range and Bamaga areas of Cape York Peninsula. Totals recorded for these areas partly reflect the intensity of botanical exploration.

Invertebrates

Invertebrates (animals without backbones) include groups as taxonomically diverse as worms, spiders, crustaceans, insects and molluscs. They occur in almost every habitat and collectively they are the predominant fauna both in number of species and in total biomass. Australia has approximately 100 000 described invertebrate species (Yen and Butcher 1997). In general, knowledge of invertebrate diversity is very poor and only a fraction of that diversity has been catalogued.

Insects may account for up to 75 percent of all animal species. Queensland has the most diverse recorded fauna for some insect groups in Australia including 335 (85 percent) of Australia's butterfly species, 261 (77 percent) of Australia's dung beetle species and 179 (66 percent) of Australia's dragonfly species. The combination of high species diversity and pronounced local endemism is a feature of the invertebrate fauna in the Wet Tropics. The richest overall insect fauna studied to date in Australia is found in the Bellenden Ker Range, where an intensive survey yielded 4029 species of insects including 1514 species of beetles. Sampling of insects via high-altitude surveys revealed a high degree of site endemicity and low faunal similarity between sites (Monteith and Davies 1991). The most comprehensive survey for inland insect fauna ever completed, for the boggomosses (mound springs), yielded 1691 species; of these, 36 percent were beetle species (Monteith and Burwell 1997).

Over 1200 species of spiders (51 percent of Australia's total) from 63 families have been recorded in Queensland. Areas of high diversity include the rainforests of the Wet Tropics and Southeast Queensland bioregions. More than 60 000 species of spiders may exist in Queensland (Raven, R., pers. comm.).

The Great Barrier Reef supports some 4000 marine mollusc species, while 21 species of cephalopods (octopus and squid) have been recorded in the Gulf of Carpentaria (Dunning et al. 1994). Land snails and slugs of Queensland comprise one-third of the total species found in Australia. Of 246 species recorded, 222 are from the Wet Tropics region alone, 185 of them local endemic species (Stanisic et al. 1994). Although there are no clear figures on the total number of land snail species in Queensland, a total of 500–600 might be expected (Stanisic, J., pers. comm.).

While 428 species of marine sponges have been described from Queensland waters, the number may be in excess of 1500, based on Queensland Museum collections (Hooper et al.1999). Analysis of sponge diversity by Hooper et al. (1999) has revealed 17 regional sponge faunas off the Queensland coast. The highest diversities are found at Swains Reef (208 species), the Capricorn–Bunker Group (187 species), Lizard Island region (176 species) and Moreton Bay (166 species).

Queensland has the highest diversity of crustaceans of any Australian state. Reef environments generally are the most diverse, followed by seagrass, mangrove and then soft-sediment communities. However, only a few crustacean groups have been studied in any detail. The decapod crustaceans, including crabs (550 species) and prawns (22 species), are one of the better-known groups. The known decapods total 1030 species, of which 62 are endemic to Queensland. This fauna is estimated at about 75 percent known (Davie, P., pers. comm.).

Collectively, there are about 20 major worm groups. Worms are found free-living in all major habitats and as parasites in humans, plants and other animals. They are of considerable economic concern as pests and pathogens. Earthworms are important in the recycling of nutrients in soils. While over 2000 species of worms have been recorded from Queensland, probably only 10 percent of the worm fauna is known (Cannon, L., pers. comm.). The three major groups are the platy-

All photos: Queensland Museum

Based on comprehensive insect surveys undertaken in Queensland, beetle species comprise about 36 percent of the State's insect fauna.

helminths (flatworms, more than 800 species), nematodes (roundworms, nearly 800 species) and annelids (earthworms, marine worms and leeches, nearly 600 species). More than 80 percent of the platyhelminths and nearly all of the nematodes are parasitic.

Vertebrates

Nearly 70 percent of all known Australian freshwater fish species occur in Queensland, 37 of the 39 fish families in Australia being represented. Fifteen percent of the recorded 173 native species are endemic. Some species, such as the endangered Elizabeth Springs goby (*Chlamydogobius micropterus*), are restricted to one location. The Wenlock River on Cape York, with 48 recorded species, contains the richest known freshwater fish fauna of any river in Australia. No two river basins are alike in terms of their fish biodiversity.


Queensland Museum

Snakehead gudgeon (*Ophieleotris aporos*), one of Queensland's 173 freshwater fish species


Queensland Museum

The skink *Nangura spinosa*, discovered and described in 1993, is known only from one population in a 300 m dry watercourse in Nangur State Forest, south-east Queensland, the smallest distribution of any known Australian reptile (Covacevich et al. 1993).


Redland Shire Council

The native jute (*Corchorus cunninghamii*), one of the State's 81 endangered plant species, has a very restricted distribution in south-east Queensland.

About 2000 marine fish species have been identified in Queensland's coastal waters. Diversity tends to be highest in association with reef systems and tends to decline in pelagic (mid-water column) environments. A total of 750 fish, of which 355 are considered uncommon or rare, have been recorded in Moreton Bay (Johnson 1999).

Of the 120 frog species found in Queensland, 51 belong to the tree frog family Hylidae. Most frog species are found in the coastal moist forests, frog diversity being particularly high in the Southeast Queensland and Wet Tropics bioregions. Thirty-two species are endemic to Queensland; 23 species are found only in the Wet Tropics. Bioregions such as the Desert Uplands, Channel Country and Mitchell Grass Downs are poorly surveyed, however, and known frog species numbers in these areas are expected to increase significantly after more intensive survey work (McDonald, K., pers. comm.). Within most bioregions, assessment of distribution patterns is difficult because detailed information at this scale does not exist. Even knowledge of species within protected areas is limited.

Queensland's reptile fauna comprises 442 species from 16 families. Of this total, 43 percent belong to the skink family, Scincidae. Thirty-two per cent of Queensland's reptiles are confined to the State (apparent endemics). Between December 1993 and December 1998, 23 species of reptiles new to Queensland were described. Two were discovered in south-east Queensland, the most densely settled and (herpetologically) one of the better-known areas. Six of the world's seven species of marine turtle breed in Queensland's coastal zone, along with 22 species of sea snakes and the only two species of crocodiles found in Australia. For most species, 'best data' are still inadequate data. For some bioregions, reptile diversity is well documented; for others, there is almost no information.

Queensland has the richest bird fauna of any Australian state. In total, 615 native species from 82 families have been recorded; these include more than 160 international migratory species and many altitudinal migratory or nomadic species. The highest bird diversity in Australia occurs in Queensland rainforests. The extensive coastal sand and mudflats are important habitats for 46 resident, regular migrant and occasionally recorded species of shorebirds. A total Queensland summer population of approximately 399 000 waders has been estimated (Driscoll 1996). About 90 percent of Australian seabirds have been recorded in Queensland, the islands off the coast being home to more than 1.2 million breeding pairs.

The Wet Tropics is a very rich area for mammal species. The area provides habitat for 36 percent of all Australian mammals, including 30 percent of the country's marsupials, 58 percent of its bats and 25 percent of its rodents. It is an area of great importance to the conservation of many relict and endemic species. In all, 226 mammal species from 31 families — 65 percent of Australia's total — occur in Queensland. The bat fauna, comprising 66 species, is particularly rich. None of the 28 species of whales and dolphins that have been recorded in Queensland waters is endemic to Australia. The vulnerable dugong (*Dugong dugon*) has high biodiversity value as the only species in the family Dugongidiae and one of only four species worldwide in the order Sirenia.

Rare and threatened species

Major pressures on biodiversity in Queensland have caused many species to decline in abundance and range and be reduced to small populations in extremely restricted areas. As pressures continue to operate, populations may experience further loss of numbers and loss of genetic diversity, to a point where the population may no longer be viable. Even after a small population is afforded protection, it may be too late to stop eventual extinction.

Twenty-one plant and six animal species are listed under the *Nature Conservation (Wildlife) Regulation 1994* as presumed extinct in Queensland. Populations of other species have been reduced to a level at which concern for their survival is warranted, and these species are now threatened — they are listed as endangered or vulnerable (table 7-18). Some species are naturally rare and have a geographically restricted range and mostly restricted habitat preferences. Their rarity might not be linked to human pressures, but they are listed because these pressures could place them at risk.

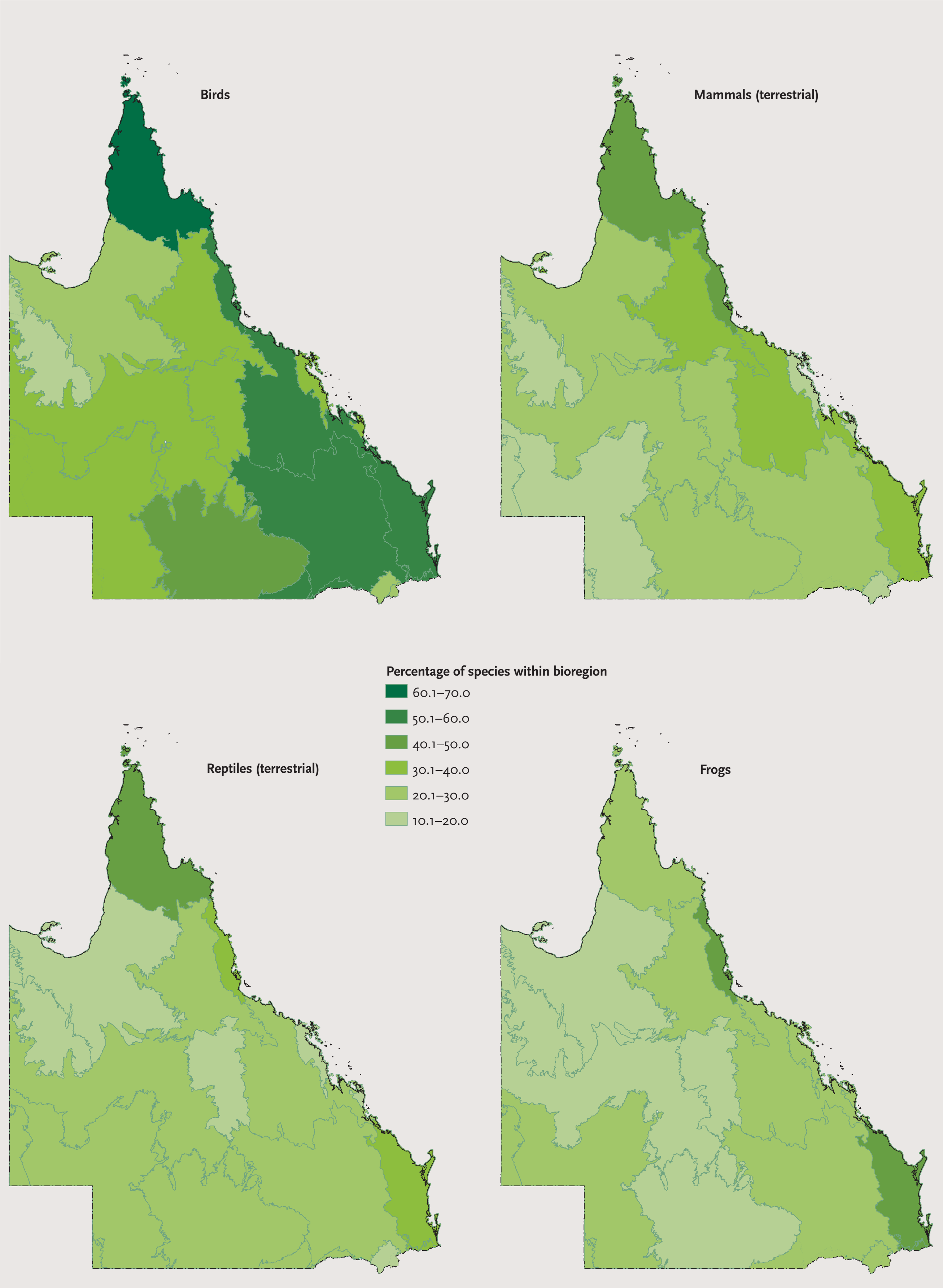


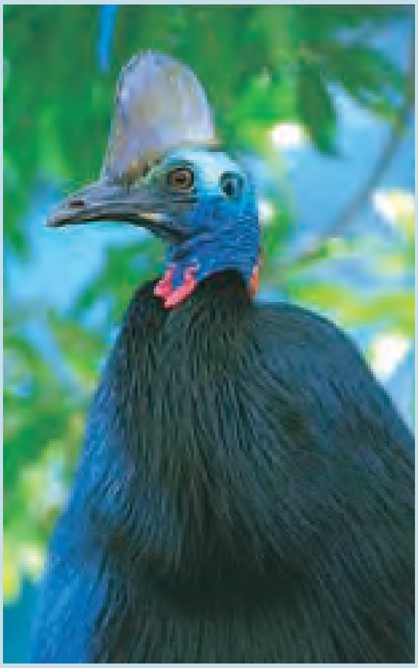
Figure 7-30 Diversity of birds, mammals, reptiles and frogs by bioregion

The southern cassowary — a keystone species

The southern cassowary is an important public symbol of the health and status of Queensland's landscape. A major disperser of seeds from over 100 species of rainforest trees and vines, the cassowary plays an intrinsic part in the ecology of the forests throughout its range in north Queensland. It is possibly the only long-distance disperser of some tree species with large fleshy fruits.

The cassowary's conservation is important for maintaining forest dynamics and the persistence of entire systems that provide habitat for a great range of organisms. On this basis, the bird can be considered a 'keystone' species. Keystone species are those that play critical ecological roles and whose loss from a particular system could result, directly or indirectly, in the disappearance of several other species. While it is impossible to monitor all species in all ecosystems, the monitoring of keystone and other selected indicator species is crucial for assessing the state of ecosystem health and biodiversity in Queensland.

The cassowary is one of the most threatened vertebrate species in Australia's northern rainforests. Records indicate that the cassowary was once more widespread than the present range of two isolated populations. The southern population occurs in the rainforest areas between Cooktown and Townsville and is listed as endangered. The northern population extends from the tip of Cape York Peninsula to the McIlwraith Range and is listed as vulnerable. The birds are thought to be extinct in many areas. The population is still declining, mostly due to habitat destruction. Approximately 1500 adults are thought to exist in the Wet Tropics. There is currently no reliable information on cassowary numbers in the Cape York region as this area has not been surveyed. Long-term trends in the bird's numbers are also unquantified.



The southern cassowary is one of the largest and most spectacular vertebrate species in Australian rainforests.

Loss of cassowary habitat is a major problem in lowland areas where cassowary densities are often highest and the clearance of natural vegetation is greatest — for example in the Mission Beach area and north of the Daintree River. Land clearing disrupts individual cassowaries' movement paths, can segregate feeding and breeding sections of an individual's range, and might predispose the species to genetic isolation and local extinctions. It also increases the birds' vulnerability to other random events and threatening processes such as disturbance, predation by dogs and vehicle accidents.

A large proportion of the cassowary's range is included, and thus protected, within the Wet Tropics World Heritage Area. While not specifically directed towards cassowaries, the Daintree River Rescue Package and the Sugar Coast Environmental Rescue Package could contribute to habitat protection for the species. Both packages include funds for buying land and for negotiating voluntary conservation agreements over freehold land, some of which supports cassowaries. The draft strategic plan prepared by Johnstone Shire Council makes considerable provision for habitat retention.

A cassowary recovery program coordinated and funded by the Wet Tropics Management Authority and the Queensland Parks and Wildlife Service relies on a strong foundation of community involvement and support. A Cassowary Advisory Group made up of local community representatives, scientists, local government delegates and conservation agencies runs the program. The support for cassowary conservation is considerable; active community groups at Mission Beach, Kuranda and the Daintree are achieving significant conservation gains in their local areas.

Despite the listing of many taxa (species and subspecies), the number threatened may be much higher. The list is biased towards vertebrates and vascular plants, reflecting in part the poor state of knowledge of many of the less well known taxonomic groups.

While numbers of listed threatened species provide a statewide overview, the list masks the extent of regional extinctions and continuing regional decline for many species. In the Brigalow Belt, for example, four species of mammals (long-nosed bandicoot, bilby, northern bettong and plains rat) that at present occur outside the region are now presumed extinct within it. The long-nosed bandicoot is not listed as threatened statewide. A total of 19 bird species (5 percent of species recorded from the region) may already be lost from the region (Smyth 1997). Of these, 10 are not threatened outside the region. Seven of the 13 species of reptiles confined or virtually confined to the region are currently threatened and another four are listed as rare (Covacevich et al. 1998).

Regional extinctions and continuing regional declines are significant biodiversity issues in Queensland. However, our knowledge base for most rare and threatened species is currently incomplete: we cannot provide a region-by-region picture of their historical distributions and, therefore, of the extent of their regional decline.

The high proportion of threatened frogs is due to the sharp but as yet unexplained decline in 14 stream-dwelling species from upland rainforest stream habitats. Of these, six have not been seen for some time and could be extinct (see box 'Declines in Queensland's frog species'). Knowledge of rare and threatened frogs is limited to a few rainforest species, and information on their ecology is limited. Ninety-two percent of all Queensland endemic frogs are rare and threatened.

The high proportion of threatened mammals has been attributed, in part, to the severe impact of introduced feral predators on small to medium-sized mammals. This has resulted in the presumed extinction of five species. Forty-two percent of the mammal family Dasyuridae (quolls, dunnarts, antechinuses and planigales) are rare and threatened, as are 32 percent of bats. Two marine mammals, the dugong and the humpback whale, are listed as vulnerable.

Table 7-18 Conservation status of native plants and animals listed under the *Nature Conservation (Wildlife) Regulation 1994*

Taxonomic group	Number of known species	Number of taxa: Presumed extinct (PE)	Endangered (E)	Vulnerable (V)	Rare (R)	Percentage of taxonomic group: PE, E and V	R
Mammals	226	5	12	20	31	16.4	13.7
Birds	615	1	11	22	31	5.5	5.0
Reptiles	442	0	4	15	64	4.3	14.5
Amphibians	120	0	14	6	25	16.7	20.8
Fish (freshwater)	173	0	3	2	0	2.9	0.0
Butterflies	320	0	7	10	0	5.3	0.0
Total animals	**1896**	**6**	**51**	**75**	**151**	**7.0**	**8.0**
Total vascular plants	**8105**	**21**	**81**	**243**	**693**	**4.3**	**8.6**

The endangered loggerhead turtle (*Caretta caretta*) breeds almost totally in the southern Great Barrier Reef region. The nesting population in eastern Australia has declined by 50–80 percent since the early 1970s, from about 3000+ to 1000+.

Twenty-one percent of all skinks are listed as rare, indicating the restricted nature of their populations and/or lack of knowledge. *Lerista allanae*, a skink listed as endangered, is probably extinct, the first reptile thought to have become so since European settlement (Covacevich et al. 1996). All marine turtles are threatened and three are endangered. The only known Australian mainland extinction of a bird species since European settlement occurred in Queensland: the paradise parrot was last recorded in 1927.

The conservation status of species varies considerably with bioregions, indicating the varying level of threats, both past and present, operating within the bioregions (figure 7-31 and table 7-19). Thirty-six percent of the State's threatened fauna species occur in the Southeast Queensland bioregion. Of the Wet Tropics bioregion number of threatened fauna, 64 percent are endemic to Queensland, indicative of the high rates of species endemicity in this bioregion. Half of the 14 endangered endemic frog species and 54 percent of rare frogs occur in this bioregion.

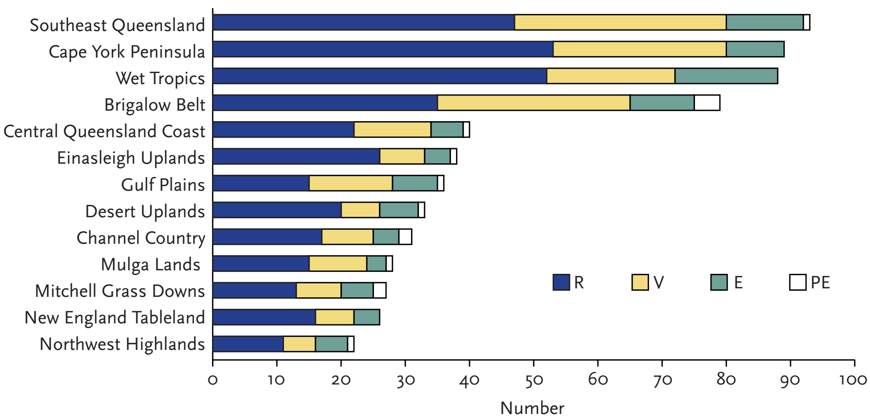


Figure 7-31 Number of rare (R), vulnerable (V), endangered (E) and presumed extinct (PE) animal taxa in each bioregion

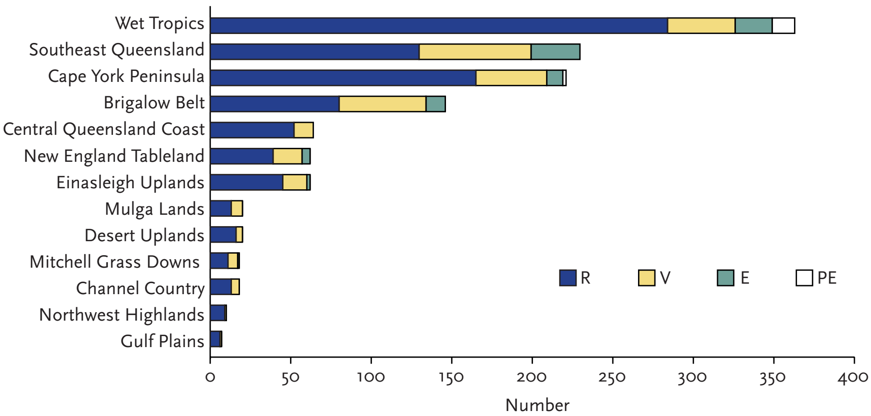


Figure 7-32 Number of rare (R), vulnerable (V), endangered (E) and presumed extinct (PE) plant taxa in each bioregion

While five freshwater fish are listed as threatened under the *Nature Conservation Act 1992*, the Threatened Fishes List published by the Australian Society for Fish Biology lists 14 species (four endangered, three vulnerable, one potentially threatened and six restricted). No marine fish species are listed under the Act, but this absence might reflect the lack of scientific knowledge.

Approximately 13 percent of vascular plants in Queensland (1038 taxa) are recognised as rare or threatened, endemic taxa comprising almost three-quarters of the total. Numbers of rare or threatened taxa are highest in the Wet Tropics, Cape York Peninsula and Southeast Queensland bioregions (figure 7-32). This is partly a reflection of the large number of locally restricted endemic species (for example in montane habitats) as well as of the degree of habitat loss, particularly in lowland areas.

Table 7-19 Total number of rare and threatened taxa, by taxonomic group, in each bioregion. Percentage figures represent the percentage of total listed as rare or threatened for that taxonomic group.

Bioregion	Birds		Mammals		Reptiles		Butterflies		Amphibians		Fish		Plants	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Brigalow Belt	33	51	12	18	28	34	4	24	2	4	0	0	144	14
Cape York Peninsula	29	45	20	29	27	33	8	47	5	11	0	0	219	21
Central Queensland Coast	18	28	4	6	12	14	2	12	4	9	0	0	64	6
Channel Country	15	23	11	16	4	5	0	0	1	2	0	0	18	2
Desert Uplands	21	32	2	3	8	10	0	0	0	0	2	40	21	2
Einasleigh Uplands	19	29	5	7	14	17	0	0	0	0	0	0	62	6
Gulf Plains	22	34	5	7	8	10	0	0	1	2	0	0	7	1
Mitchell Grass Downs	14	22	7	10	5	6	0	0	0	0	1	20	16	2
Mulga Lands	16	25	6	9	5	6	0	0	1	2	0	0	19	2
New England Tableland	15	23	3	4	5	6	0	0	3	7	0	0	62	6
Northwest Highlands	14	22	7	10	1	1	0	0	0	0	0	0	10	1
Southeast Queensland	38	58	8	12	26	31	4	24	16	36	2	40	230	22
Wet Tropics	24	37	20	29	21	25	5	29	17	38	0	0	363	35

GENETIC DIVERSITY

Some species look the same and it is difficult to distinguish them. The endangered mahogany glider, top, was for many years thought to be a northern subspecies of the squirrel glider (*Petaurus norfolcensis*), bottom, until taxonomic studies confirmed it as a separate species, *Petaurus gracilis* (Van Dyck 1993). Genetic analyses are increasingly being used to identify not only the existence of separate species, but also the existence of genetically distinct subpopulations within the same species.

Genetic diversity is the variety of genetic information contained in all individual organisms. The amount of genetic variation determines the capacity of a species to respond to environmental changes. Genetic diversity is of crucial concern in the maintenance of biodiversity: it ensures the short-term viability of individuals and populations, maintains the evolutionary potential of populations and species, and has value as a potential source of genetic resources for humans (Brown et al. 1997). Genetic diversity, unlike species or ecosystem diversity, is often cryptic: that is, species that look the same may be a complex of cryptic, or hidden, species distinguishable only by genetic analysis.

Many populations are distributed as distinct groups of subpopulations, often geographically isolated. If current patterns of genetic diversity are to be conserved, then diversity within and among populations should be considered. Some species might have high levels of dispersal among their subpopulations, while other species might occur naturally as a series of isolated subpopulations. For species in which the bulk of the genetic diversity is distributed among populations, conservation strategies need to address the viability of multiple local populations distributed across the species' range. Recognising this, and the fact that molecular surveys often reveal cryptic species, it may sometimes be necessary to preserve 'evolutionarily significant units' (Moritz 1994) — that is, historically isolated sets of populations. Other populations, although isolated, may not be sufficiently different genetically to be classed as evolutionarily significant units.

The endangered fish Oxleyan pygmy perch (*Nannoperca oxleyana*) has been recorded from 18 discrete localities in coastal wallum swamps and streams in south-east Queensland and northern New South Wales. Each of the nine subpopulations examined has been found to be genetically distinct (Hughes, J., pers. comm.). Data suggest that the subpopulations do not exchange individuals and that they are likely to have been separated since the last major changes in sea level. Any local extinctions would not be recolonised naturally and any mixing of populations via deliberate translocation would significantly reduce diversity between subpopulations.

Systematic genetic studies in Queensland using molecular analysis have provided an insight into amounts and distribution of genetic diversity and current and historical population processes. Most research has focused on rainforest-dwelling animals and has been conducted as part of the research program of the Cooperative Research Centre for Tropical Rainforest Ecology and Management at Atherton. These studies have several implications for the management of genetic diversity. For example, widely distributed animal species restricted to rainforest, even relatively mobile species such as birds, typically comprise multiple, evolutionarily distinct units. Therefore assessments of biodiversity based solely on species richness might not adequately reflect genetic diversity. Also, geographically disjunct rainforest areas, particularly those at high altitude, have high conservation significance from a genetic perspective, regardless of their richness and endemicity for species (Moritz, C., pers. comm.).

Many species, such as the northern hairy-nosed wombat, through the combined effects of habitat loss, fragmentation and introduced species, have been reduced to small remnant populations with a consequent loss of genetic diversity (see box 'The northern hairy-nosed wombat'). In other species confined to small remnants, such as the bridled nailtail wallaby, bilby, yellow-footed rock-wallaby and the rainforest tree *Austromyrtus gonoclada*, substantial genetic variation remains (Moritz, C., pers. comm.). This genetic variation may reflect the remnants' recent contraction from large populations, so occasional monitoring of high levels of genetic diversity may still be warranted.

Despite the results from genetic studies in Queensland, no coordinated and systematic statewide monitoring of genetic diversity of targeted species or populations is undertaken currently. Since it is impractical to monitor populations of all species for genetic diversity, it is important to select a small suite of taxa that may be indicative of general trends. This is a difficult task.

Indicator

Numbers of discrete populations, location of populations and population numbers for selected species

Population changes are the best measure currently available for trends in genetic diversity (Brown et al. 1997). Indicators for these include local population size, number of separate populations and connectivity between geographically separated populations. For plants, extent of remnant patches will provide a reasonable basis on which to estimate population size. While moderate declines may not be significant, major declines in population probably indicate a decrease in genetic diversity. Major declines should be triggers to investigate changes in genetic diversity using more sensitive techniques. The monitoring of appropriate indicator taxa for genetic diversity is required to enable assessment of this level of biodiversity in Queensland.

Significant genetic differences exist between the Queensland population of the yellow-footed rock-wallaby (*Petrogale xanthopus celeris*), above, and New South Wales populations, so that they represent evolutionarily significant units (Pope et al. 1998).

The northern hairy-nosed wombat — loss of genetic diversity

One of Australia's most endangered mammals, the northern hairy-nosed wombat, is represented by one small population on Epping Forest National Park in central Queensland (figure 7-33). As a result of small size, isolation and subsequent inbreeding, the population contains only 41 percent of the genetic diversity of similar-sized but non-isolated populations of the closely related southern hairy-nosed wombat (Taylor et al. 1994). Loss of genetic diversity is a major concern and is likely to reduce the wombat's capacity to resist pressures such as drought, disease and climatic change.

Further pressures are predation by and competition from other native animals. The dingo is the wombat's major predator. Since the removal of cattle from Epping Forest National Park, the wombat's major competitor for food has been the eastern grey kangaroo. The diets of both species overlap closely, especially during dry periods.

The establishment of the exotic buffel grass, favoured by pastoralists in central Queensland, poses another threat. Left ungrazed, this grass becomes rank and impenetrable, rendering large areas of the wombat's habitat unusable.

The Queensland Parks and Wildlife Service is currently implementing a major recovery program to save the northern hairy-nosed wombat. The program includes a range of research and management actions.

Figure 7-33 Distribution of the northern hairy-nosed wombat

Researchers are examining the species' population structure and dynamics, behaviour and ecology. Semen has been collected from northern hairy-nosed wombats to preserve genetic diversity. The development of a 'DNA fingerprinting' technique that uses wombat hairs collected at burrow entrances allows accurate and remote censusing of the population. Trials are under way to improve the quality and quantity of pasture plants available to the wombats, and supplementary feeding trials continue.

Epping Forest National Park was gazetted in 1971 to protect the last known population, and fenced in 1981 to exclude cattle. Management strategies include regular firebreak maintenance; patch burning to reduce fuel loads; and burning and slashing of buffel grass in an attempt to thin it and improve its quality, and increase the occurrence of native species such as black speargrass.

There are encouraging signs for the northern hairy-nosed wombat's recovery. A 1993 estimate put the population at 65 animals. By 1998, the population was estimated at 75–80 animals, possibly including 20 young wombats. The search for suitable habitat in which to establish new populations has been successful. Forty-four sites have been surveyed in central and southern Queensland, and nine sites appear to be suitable: of these, five supported northern hairy-nosed wombat populations in the past.

RESPONSE

Responses are those actions taken by society directed at the conservation of biodiversity. Many statutes, policies, international agreements and community initiatives influence biodiversity management. Responses cover different spatial scales, ranging from the global to the local. Responses are also hierarchical, local actions often complementing and implementing national and international initiatives. While not all responses target biodiversity specifically, they all affect it.

GOVERNMENT ACTIONS

Biodiversity planning and management involve all tiers of government and many agencies and organisations. Given the often competing management aims of such agencies, integrating decision-making processes and identifying common management goals are difficult. The complexity of institutional arrangements for administering biodiversity has long been recognised and has resulted in several major legislative and policy initiatives directed at facilitating a broader strategic approach to planning and management. Increasingly, governments at all levels are establishing strategic links and co-operative partnerships with non-government organisations, industry and community groups to conserve biodiversity.

National initiatives

While responsibility for land use and nature conservation rests primarily with the States and Territories, the Commonwealth has obligations and responsibilities arising from international conventions and treaties. Australia is committed to the protection of biodiversity and the sustainable use of biological resources through the goals and principles of ecologically sustainable development. This commitment is evident through Australia's international ratification of the Convention on Biological Diversity and other major international agreements and conventions (see box 'International conventions and agreements'). It is met at a national level by the States and Territories under the Intergovernmental Agreement on the Environment and implemented through actions of national strategies such as the National Strategy for the Conservation of Australia's Biological Diversity and the National Strategy for Ecologically Sustainable Development.

One of the three core objectives of the National Strategy for Ecologically Sustainable Development is to protect biodiversity and maintain essential ecological processes and life-support systems. The National Strategy for the Conservation of Australia's Biological Diversity outlines a range of objectives to achieve its stated goal of protecting biodiversity and maintaining ecological processes and systems. The establishment of the National Reserve System and the National Representative System of Marine Protected Areas also supports the program of the World Conservation Union (IUCN) World Commission on Protected Areas to promote the establishment of a global representative system of terrestrial and marine protected areas.

Other major national policies influence the management of biodiversity in Queensland:

- The National Forest Policy Statement provides broad conservation and industry goals for the ecologically sustainable management of Australia's forest estate.
- The Commonwealth Wetlands Policy comprises a series of objectives, principles and strategies to guide the Government's actions relating to the 'wise use' of wetlands in Australia.
- Australia's Oceans Policy provides a framework for integrated and ecosystem-based planning and management for all of Australia's marine jurisdictions.

In 1996 the Commonwealth Government established the Natural Heritage Trust (NHT) to fund projects in five major environmental areas — vegetation, rivers, biodiversity, land, and coasts and marine. The NHT is the most important mechanism by which the Commonwealth will contribute to implementing the National Strategy for the Conservation of Australia's Biological Diversity. Queensland has entered into a partnership agreement with the Commonwealth to deliver the NHT programs. This agreement outlines the objectives of the eleven programs and monitoring, evaluating and reporting requirements.

NHT funding to Queensland for 1997–98 totalled $25.3 million. Most of the funding went to National Landcare projects

INTERNATIONAL CONVENTIONS AND AGREEMENTS

Although the Commonwealth Government is the legal signatory to international conventions, the Queensland Government, by virtue of its land management roles, is primarily responsible for the day-to-day implementation of these agreements in the State. This means that provisions of international agreements can directly influence the management of biodiversity in Queensland. Such international agreements include:

- Convention on Biological Diversity
- Convention on Wetlands of International Importance especially as Waterfowl Habitat (the Ramsar Convention)
- Convention Concerning the Protection of the World Cultural and Natural Heritage
- Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds in Danger of Extinction and Their Environment (CAMBA)
- Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds and Birds in Danger of Extinction and Their Environment (JAMBA)
- Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)
- Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)
- Convention on the Regulation of Whaling
- Convention on Conservation of Nature in the South Pacific (Apia Convention)

(53 percent of funding) and Bushcare projects (19 percent of funding). Bushcare (the National Vegetation Initiative) seeks to reverse the long-term decline in the quality and extent of Australia's native vegetation communities. While it is the most significant component of NHT funding for biodiversity conservation, all other programs support projects with biodiversity conservation and/or sustainable resource use outcomes.

State initiatives

A range of legislative and non-legislative means to conserve biodiversity on various land tenures are used in Queensland. More than 40 Queensland statutes influence, to varying degrees, the way biodiversity is managed. While most do not deal specifically with biodiversity, they do deal in some way with the range of threatening processes operating on it. The introduction over the last ten years of major legislation such as the *Nature Conservation Act 1992*, the *Environmental Protection Act 1994*, the *Coastal Protection and Management Act 1995* and the *Integrated Planning Act 1997* is indicative of a move to a more integrated and holistic approach to the sustainable management of biodiversity.

The Nature Conservation Act is Queensland's primary statute directed at the conservation of biodiversity. The Act is based on principles to conserve biological diversity, ecologically sustainable use of wildlife, ecologically sustainable development and international criteria developed by the World Conservation Union for establishing and managing protected areas. Three regulations operate under the Act — the *Nature Conservation Regulation 1994*, the *Nature Conservation (Wildlife) Regulation 1994* and the *Nature Conservation (Protected Areas) Regulation 1994*.

While the legislative framework provides for biodiversity conservation, there is at present no Queensland biodiversity strategy providing an overall framework for integrating and coordinating government and community efforts. The development of such strategies by State and Territory governments is one of the actions called for in the National Strategy for the Conservation of Australia's Biological Diversity.

The Strategy for the Conservation and Management of Queensland's Wetlands provides a framework to guide State agencies responsible for wetlands management, and sets out initiatives to encourage and help landholders sustainably manage wetlands under their control. The strategy does not have legislative force, but provides a framework for applying other legislation and collecting the necessary information about wetlands to ensure informed decision making.

The Queensland Government is committed to the development of a comprehensive system of vegetation management across all tenures that provides for the ecologically sustainable development of land while protecting biodiversity and other environmental and social values. A Vegetation Management Advisory Committee has been established to advise on the development and implementation of new legislation and associated policies, guidelines and incentives for the comprehensive system.

Major initiatives in regional planning have occurred in Queensland through integrated catchment management plans, coastal zone management and regional natural resources management strategies. These initiatives incorporate biodiversity conservation within a broad regional framework for ecologically sustainable development.

Natural resources management strategies are currently under development for thirteen regions across Queensland. These strategies provide a long-term framework for communities to work together on regionally significant natural resource issues, including the conservation of biodiversity. By October 1998, two strategies (the Natural Resource Management Strategy for the Queensland Murray–Darling Basin and the Cape York Peninsula Land Use Strategy) had been endorsed.

Other regional strategic plans of importance for biodiversity management include:

- the Moreton Bay Strategic Plan, which provides for the ecologically sustainable use of Moreton Bay and for protection of its natural, recreational, cultural and amenity values;
- the Great Sandy Region Management Plan, the purpose of which is to protect natural, cultural and economic values; and
- the Wet Tropics Management Plan, subordinate legislation that provides regulatory powers to the Wet Tropics Management Authority to assist in conserving and presenting World Heritage values.

Local government initiatives

In regions undergoing significant land use changes, local government responsibility for land use planning and development appraisals is the most significant mechanism through which councils contribute to the conservation of biodiversity. Mechanisms in place include strategic plans, development control plans, land use zoning, local planning policies, by-laws and vegetation protection ordinances. Increasingly, local governments are supporting community-based programs to protect and manage biodiversity.

The significance of local government involvement in biodiversity conservation was affirmed in late 1998 with the adoption by the National Assembly of Local Government of a National Local Government Biodiversity Strategy, developed jointly by the Australian Local Government Association and the Biological Diversity Advisory Council. The strategy sets out a national plan to enable biodiversity conservation to become a mainstream function of local government.

COMMUNITY ACTIONS

Community groups and networks play a vital role in motivating, organising and linking individuals in community conservation activities. The success of Bushcare and other NHT programs, organisations such as Greening Australia, and community conservation networks such as the Marine and Coastal Community Network and the Threatened Species Network are testimony to the positive role of these groups. Peak conservation organisations are also active in stimulating public debate on conservation issues and are involved in public policy formulation, direct action campaigns, and public media and education campaigns.

Many community groups and organisations in Queensland regularly monitor aspects of biodiversity and take part in projects to protect, rehabilitate or restore biological diversity:

- NatureSearch, a community wildlife and habitat monitoring program coordinated by the Queensland Parks and Wildlife Service, involves volunteers across Queensland undertaking flora and fauna surveys in their local areas. The information gathered is used in conservation planning.

- Greening Australia Queensland Inc. is a non-profit organisation working with community groups to achieve sustainable land and water resources, primarily through improving vegetation management practices. It is involved in a wide range of practical biodiversity projects as well as providing technical advice, education and training services.
- The Threatened Species Network (TSN) is an Australia-wide community-based program of Environment Australia and World Wide Fund for Nature Australia. It aims to increase public awareness of, and involvement in, the protection and recovery of threatened species and their habitat.

Redland Shire Council

Redland Shire Council conservation staff member conducting a fauna awareness field day with local community members

Many community group projects are coordinated through State Government agencies and through conservation organisations and community conservation networks. Many local governments support community efforts through their conservation and environmental programs and employ local government conservation, bushland, wildlife and extension officers.

The NHT is a major funding source for many community group projects. Of the 399 projects funded in 1997–98, 58 percent were conducted by community groups. The investment in community projects represented 38 percent ($9.7 million) of the total funding. State Government agencies attracted 48 percent of funding.

The development of Bushcare, particularly as a significant funding source for community group projects, has presented new opportunities in Queensland because of the previously low levels of resources available to community groups for biodiversity conservation projects. However, a significant remaining challenge in Queensland is to ensure that Bushcare funding targets the strategically important issues. Analysis of existing funding allocations across the State indicates that funding is not targeting some of the regions (particularly the rangelands) where biodiversity faces some of the greatest threats. Reasons for this include the lack of strategic information on biodiversity issues, the absence of community groups with a capacity to manage larger projects over wide areas, and the bias of the Bushcare guidelines towards tree-related projects rather than conservation of scheduled threatened species and ecosystems.

The extent and effectiveness of community involvement across the State, while substantial, are difficult to assess as the number of groups and the number of people within those groups fluctuate considerably and depend on the groups' current activities and funding arrangements. Under new NHT reporting requirements, data on the extent of community group involvement are beginning to be collated in Queensland to enable reporting against national NHT indicators.

In situ conservation

The establishment of a representative system of protected areas is widely regarded, both nationally and internationally, as one of the most effective mechanisms for protecting biodiversity in situ while permitting the sustainable use of natural resources.

Much biodiversity in Queensland, however, is outside a formally protected area system under tenure with varying controls on its protection and sustainable use. While 67 percent is under leasehold with some regulatory controls in place, 26 percent is managed by private landholders under freehold tenure with little control in place. Much of this freehold area is distributed along the biologically diverse and heavily populated coastal zone.

More than 89 percent of the State is managed for production-oriented outcomes. While much biodiversity exists on this land, the amount managed for conservation purposes or used in an ecologically sustainable manner is not known.

While strategies are in place to increase the protected area network, opportunities for acquisition of large tracts of land for conservation are diminishing, due in part to the small size of many remnants and to acquisition costs. These costs are very high in some regions, particularly in the more fertile parts. An example is the scale of investment required to protect remaining habitat of the mahogany glider (*Petaurus gracilis*) and other threatened coastal lowland species and ecosystems at risk from sugarcane expansion. Through the Sugar Coast Environmental Rescue Package, $15 million of the total $16 million funding package was allocated for land acquisition.

Increased attention is being given to further protection and sustainable use of biodiversity outside protected areas. This 'off-reserve conservation' involves a range of strategies to involve landholders in the management of biodiversity on their land. Integration of nature conservation strategies with ecologically sustainable land and sea use is increasingly taking place within a regional framework.

Collectively, off-reserve conservation strategies, protected areas, threatened species and ecosystems management, restoration of degraded ecosystems and management of threatening processes are important if biodiversity is to be conserved and used sustainably. Planning for these at the bioregional level is a key objective of the National Strategy for the Conservation of Biological Diversity and other major policies.

Bioregional planning is a social and ecological framework in which conservation priorities are dealt with, together with socioeconomic development considerations. It is yet to be fully developed and implemented in Queensland and is dependent on a statewide review of bioregional issues. Categorisation of endangered and of-concern ecosystems by the EPA is one means of integrating ecological assessment and determining relative conservation priorities across bioregions (Sattler and Williams 1999).

Information compiled on the conservation status of regional ecosystems and rare and threatened species in the Mulga Lands has provided a model framework for biodiversity

Bioregional planning is a framework for integrating conservation and socioeconomic priorities at the landscape level.

Table 7-20 Number and extent of classes of protected areas in Queensland at June 1999

Protected area category	No.	Area (ha)	Percentage of Queensland
National park (scientific)	7	52 181	<0.1
National park	215	6 612 542	3.8
Conservation park	160	29 222	<0.1
Resources reserve	39	351 206	0.2
Nature refuge	37	12 099	<0.1
Coordinated conservation area	1	1 170*	<0.1
Total (all protected areas)	**459**	**7 058 005**	**4.1**

*Includes Venman Bushland National Park (415 ha), also included in national park total.

management of the region (Wilson and Egan 1996). The information is being used in various extension activities and regional land management programs such as tenure conversions, land clearing applications, nature refuge proposals and evolving regional conservation strategies.

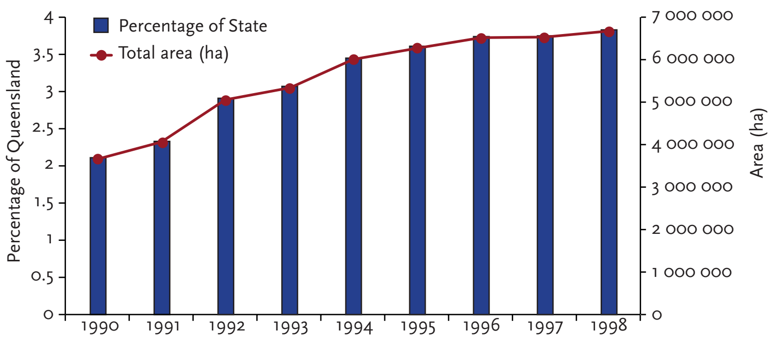


Figure 7-34 Queensland's expansion of the national park estate from 1991 was based on increasing the representation of regional ecosystem diversity across all bioregions.

Protected areas

Goals of the National Reserve System (NRS) Program are the establishment and management of a comprehensive, adequate and representative system of protected areas. Under the NRS Program, a number of projects are funded through the NHT with the aim of extending the national reserve system and developing best practice management.

The Interim Biogeographical Regionalisation of Australia (IBRA) provides an appropriate national framework to focus on reservation needs in the least conserved and most threatened terrestrial bioregions in Australia. The Interim Marine and Coastal Regionalisation of Australia (IMCRA) is being developed for use in marine environments. Eleven of the 20 IBRA regions in Queensland remain under-represented in the NRS and have been rated as a high priority for the protection of biodiversity in Australia (Thackway and Cresswell 1995).

In Queensland, many categories of reserves provide different levels of protection. While all categories of reserves, including multiple-use categories, are significant for biodiversity conservation, those that have nature conservation as their primary role are particularly important.

Terrestrial protected areas

The Nature Conservation Act provides for the declaration of protected areas that are representative of Queensland's biological diversity, natural features and wilderness. Eleven classes of protected areas provide for varying levels of protection. National parks (scientific), national parks, conservation parks and resources reserves are declared over Crown land only. National parks (Aboriginal land) and national parks (Torres Strait Islander land) can be declared over Crown land and various land tenures described in the Aboriginal Land Act and the Torres Strait Islander Land Act. Nature refuges, coordinated conservation areas, wilderness areas, World Heritage management areas and international agreement areas can be declared over other forms of tenure, including private land.

Each protected area is managed in accordance with the management principles outlined in the Act and the purpose for which the protected area was created. However, the Act does not provide criteria for conservation values for each class of protected area.

Originally, national parks in Queensland were seen as protecting areas of scenic interest, rainforest and waterfalls being the two most common features found in early national parks. From 1960, national parks began to be gazetted in order to protect representative vegetation types or land systems, and this idea evolved into the rationale for protected area acquisitions today. Biogeographic surveys are undertaken to identify the components of a reserve system that maximise the representation of regional ecosystems (figure 7-34). Other factors, such as the location of rare and threatened species and the need for practical management boundaries, are then taken into account in the preparation of an acquisition strategy for each bioregion. Further acquisitions will be required to capture regional ecosystems not currently contained in protected areas; it is estimated that a statewide representation of 80 percent is achievable using this approach.

The Nature Conservation Act requires protected areas to be managed according to specified management principles and management plans. Management plans guide managers, who are required to protect the outstanding scenic, biological and cultural values of national parks and other protected areas while providing opportunities for nature-based recreation

Table 7-21 World Heritage areas in Queensland

World Heritage area	Area (ha)	Criteria under which site is listed*
Fraser Island	184 000	2, 3
Wet Tropics	894 000	1, 2, 3, 4
Central Eastern Rainforest Reserves (Queensland extent)	59 223	1, 2, 4
Great Barrier Reef	34.87 million	1, 2, 3, 4
Australian Fossil Mammal Sites (Queensland extent)	10 000	1, 2

*Criteria:
1 As an outstanding example representing the major stages in the Earth's evolutionary history
2 As an outstanding example representing significant ongoing ecological and biological processes
3 As an example of superlative natural phenomena
4 Containing the most important and significant habitats for in situ conservation of biological diversity

and tourism. By January 1999, management plans had been approved for 57 protected areas. Development of a national park master plan has started; this plan is intended to provide a strategic and comprehensive framework for protected area management over a 10-year period.

Fifteen parks have been declared available for claim under the *Aboriginal Land Act 1991*, most protected areas being subject to native title claims. The development of policy for the indigenous joint management of national parks commenced in 1999.

Marine protected areas

Declarations of marine reserves in Queensland are made under three Acts. The *Great Barrier Reef Marine Park Act 1975* (Cwlth) provides for the protection and conservation of the Great Barrier Reef Marine Park, and the *Marine Parks Act 1982* provides for the declaration of marine parks over Queensland tidal waters or tidal land and development of zoning plans to regulate use. Fish habitat areas declared under the *Fisheries Act 1994* also provide some measure of protection to tidal wetland habitats.

The early focus of the marine reserve system was on protection of commercial resources rather than representative habitat types. Currently, depending on the provisions of management plans or zoning plans, different areas receive protection to different degrees, ranging from negligible to total.

A National Representative System of Marine Protected Areas (NRSMPA) is being developed, its primary goal being to establish and manage substantial, representative examples of marine and estuarine ecosystems as protected areas. Guidelines for establishing the NRSMPA were released in December 1998 (ANZECC TFMPA 1998). A Queensland Marine Protected Areas Strategy is being developed to include detailed proposals for a comprehensive system of marine protected areas for the whole of the State. This process will link with Commonwealth Government initiatives for a national system of marine protected areas by the year 2000.

The five internationally significant Ramsar wetland sites in Queensland are Moreton Bay (113 314 ha), Shoalwater and Corio Bays Area (239 100 ha), Bowling Green Bay (35 500 ha), Currawinya Lakes (151 300 ha) and Great Sandy Strait (93 000 ha). While listing does not provide any additional legal protection to a site, it does facilitate protection by highlighting the site's international significance to decision makers. All Queensland Ramsar sites have some form of management regime partly or wholly in place. The Moreton Bay Ramsar site has also been included in the East Asian-Australasian Shorebird Reserve Network, recognising its significance for migratory shorebirds.

World Heritage areas

World Heritage areas are outstanding examples of the world's natural or cultural heritage. The World Heritage List is administered under the World Heritage Convention by the World Heritage Committee on behalf of the United Nations Educational, Scientific and Cultural Organization (UNESCO). Five of Australia's 11 listed sites are in Queensland (table 7-21). Each site was listed for its outstanding natural universal values under one or more criteria. Complementary Commonwealth and State legislation creates a comprehensive scheme of environmental protection and management for World Heritage areas.

Other areas protected

Of Queensland's 4.3 million ha of State forest and timber reserves, approximately 20 percent is dedicated to flora and fauna conservation. This includes areas gazetted as scientific areas and feature protection areas with specialised management objectives to protect biodiversity.

Local government plays an important role in acquiring and protecting areas of significant conservation value through enforcement of development controls, regulation of clearing and purchase of land. Vegetation protection orders (VPOs) have proven effective in protecting vegetation in the non-urban zone in Brisbane City. The area of land protected by VPOs increased from 12 910 ha in 1991 to 18 250 ha in 1998 (BCC 1998). Conservation/bushland levies operated by several local authorities have targeted key conservation areas for acquisition. Maroochy Shire Council, through its Vegetation Conservation Levy, is adding to its 4400 ha of bushland (MSC 1998). Brisbane City Council has purchased 1499 ha through its Bushland Levy, with the focus on consolidating many core areas, particularly koala habitat (BCC 1998).

Daintree National Park, one of over 20 national parks comprising 30 percent of the Wet Tropics World Heritage Area

The endangered bilby (*Macrotis lagotis*) is subject to a comprehensive recovery program. A significant population has been conserved in Astrebla Downs National Park.

Management of threatened species and ecosystems

All Australian governments have obligations under international and national agreements and strategies for the conservation and recovery of threatened species and prevention of further extinctions. The *Endangered Species Protection Act 1992* (Cwlth) lists nationally threatened species and ecological communities and provides for the development and implementation of recovery plans for them. The Endangered Species Program, funded through the NHT, is implemented through parallel programs run by State and Territory conservation agencies, community groups and other organisations.

Rare and threatened species are afforded protection under the Nature Conservation Act. There are no provisions for the listing of threatened ecosystems under the Act. The Queensland Parks and Wildlife Service coordinates statewide programs for the protection and recovery of threatened species, including programs to protect their habitats. Its role is to develop policies, promote community ownership of conservation programs, facilitate preparation and implementation of conservation or recovery plans, and establish priorities for research into threatened species and ecosystems and their management. It is also involved in captive breeding and translocation programs for threatened species.

Action plans and recovery plans are strategies to identify threatened species and instigate steps for their recovery. National action plans are used to guide preparation of the more detailed and comprehensive recovery plans and have been published for freshwater fishes, reptiles, rodents, frogs, cetaceans (whales and dolphins), birds, bats, marsupials and monotremes. Conservation overviews on Australian non-marine invertebrates and non-vascular plants have also been completed. Individual species recovery outlines are available for 31 mammals, 17 birds, 16 reptiles, 15 frogs and four of the freshwater fish that are scheduled as threatened under Queensland legislation (table 7-22). No action plans have been prepared for plant species; these have generally been treated on an individual or plant community basis.

The recovery plan process aims to establish a community-based approach to conserving threatened species and ecosystems. A recovery plan is a comprehensive plan that describes, schedules and costs all actions assessed as necessary to support the recovery of a species or ecological community.

Recovery programs such as those under way for the Julia Creek dunnart, threatened frogs, the northern hairy-nosed wombat and the bridled nailtail wallaby attempt to secure habitat protection, identify and manage potential threatening processes, or extend the range and population size of the threatened species. Land management objectives are incorporated into recovery planning work, particularly for those species with ranges outside the protected area estate. The golden-shouldered parrot program on Cape York Peninsula has involved local landholders in surveying and monitoring and advising on fire management practices that achieve production as well as conservation outcomes.

The development of recovery programs is constrained by the absence of a detailed understanding of habitat and other requirements of many threatened species. Resource constraints further limit both the development and the implementation of such programs. These restraints are reflected in the relatively low numbers of recovery programs currently being implemented in Queensland — 23 percent of all threatened animal and 5 percent of threatened plant taxa are covered. All recovery plans are reviewed regularly.

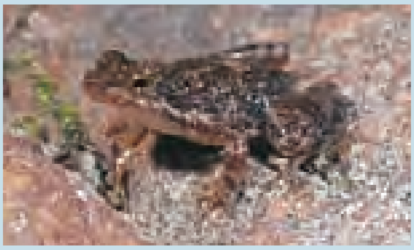
Individual species protection and management also occur through conservation plans developed in accordance with the Nature Conservation Act. Five of the current conservation plans allow for the ecologically sustainable taking and use of protected wildlife from the wild for commercial or non-commercial purposes. One provides for the conservation and management of whales and dolphins, while draft plans cover the mahogany glider and the dugong.

The Great Barrier Reef Marine Park Authority also manages a dugong conservation program. Sixteen dugong protection areas comprising 600 000 ha in total have been established. Restrictions on fish netting and boating have been imposed and there is greater management focus on protecting seagrass habitat.

Table 7-22 Number and proportion of threatened fauna scheduled under the *Nature Conservation Act 1992* with action plans and recovery plans prepared or implemented at October 1998

Taxonomic group	Number of threatened taxa	Threatened taxa with a national action plan		Threatened taxa with a recovery plan		Threatened taxa with recovery plans implemented	
		No.	%	No.	%	No.	%
Mammals	37	31	84	10	27	7	19
Birds	34	17	50	7	21	3	9
Reptiles	19	16	84	1	5	0	0
Frogs	20	15	75	16	80	16	80
Freshwater fishes	5	4	80	4	80	3	60
Butterflies*	17	–	–	2	12	2	12
Total	**132**	**83**	**63**	**40**	**30**	**31**	**23**

*A national action plan for butterflies is in preparation.



Eungella torrent frog (*Taudactylus eungellensis*)

Common mist frog (*Litoria rheocola*)

Northern gastric brooding frog (*Rheobatrachus vitellinus*)

Australian lacelid (*Nyctimystes dayi*)

Four of Queensland's endangered frog species. The northern gastric brooding frog has not been recorded since 1985 and could well be extinct.

There is widespread evidence for and concern over a global and dramatic decline of amphibian species. Fourteen frog species are known to have disappeared or declined sharply in Queensland in recent years. Six species have not been sighted for many years and could be extinct. All species are locally endemic, from upland rainforest stream habitats. Declines have occurred across a variety of land tenures, including habitats remote from human interference.

Frogs are important indicator species as they react swiftly to environmental changes. Declines in their numbers may indicate widespread changes or disturbances in the environment of which we are currently unaware.

The first declines were recorded in 1979 in the Conondale Range in south-east Queensland. Five species declined in the area. Since then a north–south pattern of declines has emerged. At Eungella, west of Mackay, two species disappeared in the mid-1980s. In the tropical rainforests of north Queensland, seven species declined or disappeared in the late 1980s and 1990s. Declines moved northwards at an average rate of 100 km a year (Laurance et al. 1996).

For most species, there is no clearly identifiable cause of decline. Possible causes include introduction and spread of disease, loss and degradation of habitat, predation by introduced fish, pollution and other environmental changes. Investigations into these declines have provided support for a rapidly spreading epidemic disease as the responsible agent (Laurance et al. 1996; Berger et al. 1998).

An exotic chytrid fungus, known to be fatal to amphibians, has been detected in the skin of sick and dead frogs in Queensland (Berger et al. 1998). Laurance et al. (1996) contend that the thriving international trade in aquarium fish is especially likely to promote transmission of pathogens to aquatic organisms such as frogs.

Fourteen species of Queensland frogs are listed as endangered, six as vulnerable and 25 as rare under the Nature Conservation Act. Ten species are also listed under Commonwealth legislation as endangered. The action plan for Australian frogs describes and costs research and management actions considered necessary to counter the current declines. The plan, while describing recovery outlines for 27 Australian species, suffers from a fundamental deficiency of biological information when compared with action plans for marsupials and birds (Tyler 1997). Fifteen species threatened in Queensland are listed in the plan.

Two recovery teams are implementing four recovery plans covering 15 species (table 7-23). The Queensland Parks and Wildlife Service is the lead agency in these recovery processes. Efforts to improve the conservation status of these species are dependent on location of an extant population. Environment Australia, the Queensland Parks and Wildlife Service and the Department of Natural Resources, the Queensland Museum and universities have continued to fund surveys of sites where these frogs were found in the past.

Table 7-23 Conservation status of Queensland threatened frogs for which recovery plans have been prepared

Species		Status		
		ESPA[1]	Action plan[2]	NCR[3]
Wet Tropics recovery plan				
Litoria lorica	Armoured waterfall frog	E	E	E*
Litoria nannotis	Torrent tree frog	E	E	E
Litoria nyakalensis	Mountain mist frog	E	E	E*
Litoria rheocola	Common mist frog	E	E	
Nyctimystes dayi	Australian lacelid	E	E	E
Taudactylus acutirostris	Sharp-snouted torrent frog	E	E	E*
Taudactylus rheophilus	Northern tinker frog	E	E	E
Eungella recovery plan				
Rheobatrachus vitellinus	Northern gastric brooding frog	E	E	E*
Taudactylus eungellensis	Eungella torrent frog	E	E	E
Southern day and gastric brooding frog recovery plan				
Rheobatrachus silus	Southern gastric brooding frog	E	E	E*
Taudactylus diurnus	Mount Glorious torrent frog	E	E	E*
Barred frogs recovery plan				
Mixophyes fleayi	Fleays barred frog		E	E
Mixophyes iteratus	Giant barred frog		E	E
Mixophyes balbus	Stuttering barred frog		V	
Litoria pearsoniana	Cascade tree frog		K	E

[1] *Endangered Species Protection Act 1992* (Cwlth); E = endangered.
[2] Action Plan for Australian Frogs; E = endangered; V = vulnerable; K = insufficiently known species that may be of concern.
[3] *Nature Conservation (Wildlife) Regulation 1994*; E = endangered.
*These species could be extinct as they have not been located despite searches over the last 8–19 years.

Off-reserve conservation

Off-reserve conservation entails a number of programs and strategies including a range of incentive mechanisms aimed at involving landholders in the management of biodiversity on their land. Effective incentive schemes to foster off-reserve conservation have yet to be comprehensively applied in Queensland. The development of appropriate economic and other incentives to encourage conservation is being pursued by local government and through Bushcare-funded projects. Mechanisms in place include rate rebates, grants and conservation agreements:

- Johnstone Shire Council provides rate relief for landholders who have entered into voluntary conservation agreements to retain and protect habitat values on their properties. These rate deferrals are based on the type of habitat classification, the highest being for areas with critical habitat values.
- Through Brisbane City Council's Voluntary Conservation Agreements (VCA) Program, landholders and the Council form a partnership through a legally binding contract to conserve environmental values. At August 1998, 18 agreements were in place, with a total of 102 ha conserved.
- Land for Wildlife (LFW) is a voluntary program that encourages improved habitat management through the formation of agreements with owners of land containing remnant habitat, and through the provision of information on ways to enhance native habitat. In south-east Queensland 11 local governments are paticipating in the LFW program. At June 1999, 425 properties totalling 3106 ha were fully registered or working towards LFW agreements. Approximately 323 ha of habitat type was classified as of concern or endangered.

Provision exists under the Nature Conservation Act for voluntary conservation agreements over private land. The Queensland Parks and Wildlife Service is promoting the establishment of nature refuges, with a particular emphasis on priority bioregions. Nature refuges generally allow for the protection of specific conservation values while the land is managed for a variety of compatible land uses. In the period 1995–99, nature refuges declared increased from one (42 ha) to 37 (12 099 ha total area) (table 7-20).

Support for off-reserve conservation activities is being coordinated through State agencies, local government and non-government organisations. The Queensland Parks and Wildlife Service's Community Nature Conservation Program aims to encourage the development of a land ethic in Queensland that promotes the integration of nature conservation considerations into the management of land across all tenures in the State. Extension officers work with local communities to promote nature conservation on private land.

An 18-month project, an initiative of the QPWS and funded through the 1995–96 National Landcare Program, used case studies to demonstrate the integration of nature conservation, commercial and practical uses of native vegetation and agricultural production (Dorricott et al. 1997). Each of the eight case studies undertaken on properties within the southern Brigalow Belt included a fauna survey and the preparation of a property plan that made provision for wildlife, for example through retention of important habitat areas linked by corridors. The range of fauna species recorded, including rare ones, coexisting with production systems was seen as encouraging, as was the willingness of landholders to retain remnant habitat for nature conservation purposes. *Balancing Production with Nature Conservation*, a handbook aimed at landholders in the study area and featuring examples generated from the project, was published in 1998. A second case studies project, funded for three years by the NHT, began in early 1997 in south-west Queensland.

Restoration of biodiversity

Restoration of degraded biodiversity is an important response to biodiversity decline. It occurs primarily through revegetation programs undertaken by community groups. Revegetation is a major objective of the Bushcare program, which seeks to reverse the long-term decline in the quality and extent of Australia's native vegetation cover by the year 2001. While some individual project data are available, there are no available data to assess the extent or effectiveness of revegetation across the State.

Riverbank restoration features in many Bushcare projects. The Barung Revegetation/Remnant Protection project in the Upper Mary River catchment has generated strong community involvement in the establishment of corridor linkages at seven sites for the purposes of habitat, bank stabilisation and water quality, among others. Three and a half hectares of land has been revegetated.

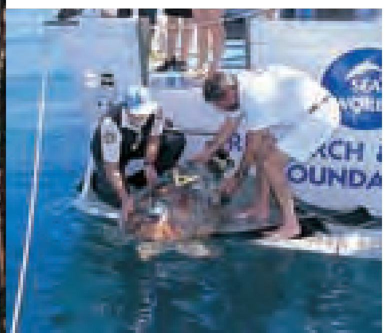
A number of projects have emphasised the revegetation of degraded land for wildlife:

- Stanley River Park Richmond Birdwing Project, which to date has planted 200 *Aristolochia praevenosa* vines, host vines for the larvae of the threatened Richmond birdwing butterfly;
- Noosa Coastal Dune Foreshore and Creek Revegetation Project, which has undertaken plantings to stabilise Noosa Spit and provide enhanced fauna habitat;
- Massey Creek Corridor Rehabilitation, which aims to establish a critical wildlife corridor through degraded riparian land in liaison with the Tree Kangaroo Mammal Group; and
- Walter Hill Ranges Corridor Rehabilitation, which has completed site preparation and to date has planted 2.2 ha of land to enhance the mobility of the southern cassowary.

Most revegetation projects established within planning frameworks rely on catchment management plans or local government conservation strategies. The Wet Tropics Vegetation Management Program has developed a series of action plans in consultation with the local Aboriginal community, Landcare, Integrated Catchment Management, CSIRO, local government and State Government staff. Rehabilitation criteria from the Far North Queensland 2010 Regional Environment Strategy have been used to assign priorities for these action plans.

Queensland Museum

Insect research, Wet Tropics



Turtle research, Moreton Bay

Comprehensive monitoring and research programs in biodiversity are undertaken in Queensland.

RESEARCH AND MONITORING

The Commonwealth funds biodiversity research and monitoring programs through the Environment portfolio, the NHT and major institutions such as CSIRO. Cooperative research centres (CRCs) are collaborative research ventures bringing together researchers from universities, CSIRO, the public sector and business. Two CRCs located in Queensland — the CRC for Ecologically Sustainable Development of the Great Barrier Reef, in Townsville, and the CRC for Tropical Rainforest Ecology and Management, in Atherton — have particular relevance for the management of biodiversity within the World Heritage-listed Great Barrier Reef and Wet Tropics.

In addition to their role in CRCs, the major tertiary institutions in Queensland carry out a wide range of research programs in biodiversity. The Centre for Conservation Biology at The University of Queensland is one of Australia's major collaborative conservation research centres. The work of the Australian Institute of Marine Science in Townsville is particularly relevant to the Queensland coastal and marine environments.

The Queensland Parks and Wildlife Service (QPWS) and the Environmental Protection Agency (EPA) conduct monitoring of and research on threatened ecosystems, rare and threatened species and protected area management issues. One of the EPA's major initiatives is the identification of regional ecosystems and the continuing mapping of their remnant and pre-clearing extent. Both pre-clearing and remnant vegetation have been surveyed and mapped in about 60 percent of the State (figure 7-35).

Continuing statewide assessment of wetlands is being undertaken through the Queensland Wetland Inventory Program. Regional-scale identification, classification and delineation of all wetland aggregations, including the characterising of wetlands relevant to criteria of importance, are major priorities.

The Queensland Herbarium, part of the EPA, documents Queensland's plants and plant communities; carries out identification of plants, vegetation surveys and mapping; and undertakes taxonomic and ecological research. In 1998 the Herbarium housed 600 000 plant specimens; approximately 15 000 new specimens are added to the collection each year.

As Queensland's lead land management agency, the Department of Natural Resources is involved in researching and monitoring land management issues that directly and indirectly affect biodiversity. It has completed assessment of old-growth forests in the Southeast Queensland bioregion (Kelly 1998) and begun a similar assessment of forests in the southern Brigalow Belt bioregion.

The Statewide Landcover and Trees Study (SLATS) is directed at monitoring land clearing, tree growth and regrowth. Data are used for policy decisions regarding sustainable land management and the National Greenhouse Response Strategy. Vegetation cover, documented for 1988, 1991, 1995 and 1997, is being compared.

The Department of Primary Industries monitors the condition and trend in Queensland fisheries habitats and produces reports on the status of and trends in Queensland's fisheries resources.

The Queensland Museum is a major public research institution involved in identifying the State's biodiversity. Museum staff undertake taxonomic and ecological research on Queensland's fauna. The Museum is active in public education programs, is a reference centre and houses more than three million specimens of micro-organisms and animals. The Museum's Queensland Centre for Biodiversity is Australia's authority on the taxonomy of tropical and subtropical aquatic and terrestrial animals.

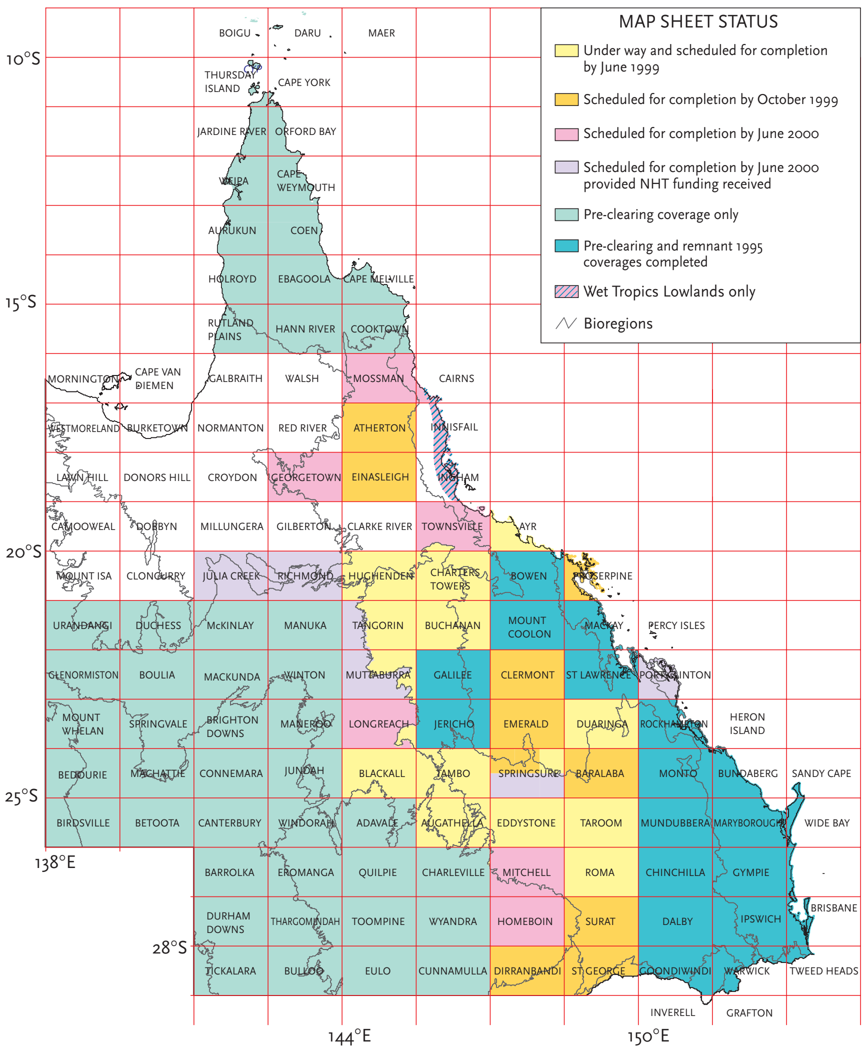


Figure 7-35 Status of Queensland Herbarium vegetation survey and mapping program at April 1999

RESPONSES TO PRESSURES AND KEY ISSUES

In addition to actions necessary to conserve biodiversity, a range of actions are in place to minimise threatening pressures.

Management of underlying pressures

While Queensland's growing population brings economic growth and opportunity, ensuring that biodiversity values are protected is a major challenge for all levels of government. Recent planning and legislative initiatives are an attempt to deal with some of these issues (see chapter 8, 'Human settlements', for detail).

The Department of Communication, Information and Local Government and Planning is working with local government, other Queensland and Commonwealth agencies, sector groups and the community to coordinate regional planning in several regions most affected by population increase. A number of regional growth management strategies have been prepared or are in preparation. These include SEQ 2001 (for south-east Queensland), FNQ 2010 (for far north Queensland), Wide Bay 2020 and recently begun projects based in Rockhampton and Mackay. These strategies establish a framework for decision making, including appropriate policies and actions for guiding the use and development of natural resources.

The regulatory framework of planning in Queensland was changed fundamentally by the enactment of the *Integrated Planning Act 1997*. This Act is based on the principle of ecologically sustainable development and places a statutory obligation on all planning authorities to apply the 'precautionary principle' in decision making.

Very few cost–benefit analyses of biodiversity-related decisions have been undertaken. Some economic evaluations provide an indication of what is invested in biodiversity and what some of the returns are.

The Australian Bureau of Statistics is undertaking statistical analyses in environment protection expenditure accounting across Australia. Estimates of total and per capita expenditure on the protection of biodiversity and landscape include amounts from the public and private sectors and households (table 7-24).

Table 7-24 Expenditure on protection of biodiversity and landscape, 1994–95 and 1995–96

Area	1994–95		1995–96	
	Total ($ million)	Per capita ($)	Total ($ million)	Per capita ($)
Queensland	153.3	47	153.4	46
Australia	679.3	38	695.2	38

(Source: ABS 1998)

While the direct benefits of activities such as tourism, fishing and forestry can be quantified, assigning values to less tangible benefits of biodiversity is a greater challenge, as is incorporating the costs associated with biodiversity depletion. Full environmental accounting is yet to be adopted into mainstream decision making in Australia.

A range of legislative and policy measures regulate to some extent the clearing of vital habitat corridors, essential for the protection of biodiversity.

Controls on clearing of native vegetation

In Queensland, legislative and policy measures regulate clearing of native vegetation. Under the *Land Act 1994*, a Broadscale Tree Clearing Policy and associated Local Tree Clearing Guidelines came into effect in late 1997. The policy and guidelines apply to 67 percent of Queensland's area, leasehold land on which the State owns the trees and where grazing or agriculture is the primary land use.

Clearing on leasehold requires a permit; the permit is valid for five years. The tree management provisions under the Land Act stipulate 23 criteria that must be considered in the assessment of a tree clearing permit. These include the protection of restricted vegetation types and areas of high nature conservation value, particularly riparian lands and areas of heritage values. Endangered ecosystems may not be cleared. The tree clearing guidelines also prohibit clearing of other ecosystems that would result in the downgrading of their conservation status. All tree clearing applications are evaluated against local tree clearing guidelines.

Tree clearing permit data (see chapter 3, 'Land') allow analysis only at a very broad scale. The figures do not specify which ecosystem types were covered by clearing permits, nor is the extent of ecosystem types actually cleared under permits available.

The EPA is undertaking a vegetation mapping program in those parts of the State subject to greatest clearing pressures (figure 7-35). This will provide baseline data that can be used to monitor change in the extent of individual regional ecosystems. Analysis of the pre-clearing and 1995 remnant extent of regional ecosystems threatened by tree clearing in the Mulga Lands, Brigalow Belt, Mitchell Grass Downs and Southeast Queensland bioregions has been completed (Wilson 1998).

Other legislation partly regulates the removal of native habitat. Under the Nature Conservation Act, an interim conservation order can be issued over any area of land to prohibit or control land clearing if it is likely to have a detrimental effect on rare or threatened wildlife, critical habitat, an area of major interest or a protected area. In addition, conservation plans can deal with threatening processes, such as land clearing, which affect the survival of wildlife habitat or its capacity to sustain natural processes. Some orders have been issued to protect mahogany glider habitat.

The *Water Resources Act 1989* controls the removal of native vegetation in creeks and rivers (non-tidal watercourses) across all tenures, through a permit system administered by DNR. Provisions under the Fisheries Act, administered by DPI, protect marine plants and allow for the management of fish habitats. A permit is required to disturb marine plants (including seagrass, mangroves, saltmarsh and other littoral vegetation) or to undertake work in a declared fish habitat area.

Special leases for broadscale tree clearing in forest reserves are administered by DNR under the Forestry Act.

The primary regulatory control over activities on private lands is through local authority planning schemes and regulations. Some local governments have vegetation protection ordinances or tree protection local laws applicable to freehold land. The Queensland Government, in consultation with stakeholders, is developing a tree clearing and native vegetation management framework to apply across leasehold and freehold land.

Managing introduced species

The traditional pest animal and weed management goal of eradication has not worked in Australia despite campaigns that have been expensive and of varying intensity over many years. Current feral animal and weed control strategies and management programs are coordinated at all levels of government and focus on those species known to be causing significant problems or posing significant threats.

Feral animals

National threat abatement plans have been prepared for foxes, cats, rabbits and goats in accordance with the *Endangered Species Protection Act 1992* (Cwlth). Foxes, rabbits, goats and pigs are declared as pests under the *Rural Lands Protection Act 1985* in Queensland. Control is the responsibility of every landholder. Feral animal control programs have been implemented for protected areas across the State. Control of feral animals is also part of many recovery programs for threatened species. There is, however, no comprehensive statewide strategy for controlling feral animals to protect rare or threatened species or ecosystems.

Control techniques for feral species in Queensland vary and include conventional methods (such as fencing, trapping, poisoning and shooting) and biological control. Overall, control tends to be for agricultural rather than conservation purposes and, for some species, is opportunistic and haphazard:

- Rabbits are controlled through a combination of myxoma virus release, poisoning, warren fumigation, shooting, trapping, fencing and, most recently, the release of rabbit calicivirus (RCV). Monitoring the consequence of RCV on rabbit populations and the flow-on effects that might eventuate in native ecosystems is part of the Queensland RCV action plan.
- Management of feral goats is usually performed opportunistically — that is, feral goats are mustered, trapped or shot when seen or when large numbers seem to be present. Numbers have been reduced to about 120 000.
- There are no successful techniques to control feral cats except in small areas. No known pathogens are suitable as biological control agents for feral cats, but some success is being achieved in developing toxic baits.
- Control techniques for foxes include use of poison baits, shooting, trapping, fumigation and adjustments to farming practices. However, the use of these techniques is haphazard and their effectiveness is unknown.
- In far north Queensland, feral pigs are controlled by poisoning, trapping and shooting. Trapping in the Wet Tropics has recorded a cumulative total of 6500 pigs since early 1994. The costs of effective feral pig management prohibit sustained control programs being implemented.
- Research into biological control of the cane toad is continuing. South American viruses imported into high-security facilities are being characterised and evaluated for their potential as biological control agents.
- Sixteen fish species are declared noxious in Queensland. The Fisheries Act has regulations and penalties regarding noxious fish and their release into open waters. However, there are no clear, uniform regulations relating to keeping non-native species in outdoor ornamental ponds.

A National Translocation Policy has been prepared for endorsement by the Standing Committee on Fisheries and Agriculture. A draft procedural policy to manage the translocation of native species in Queensland freshwater systems has also been developed.

Environmental weeds

The National Weed Strategy provides guidelines under which weed management measures can be used more strategically and effectively, integrating the efforts of all stakeholders. The strategy deals with weeds of national significance, in particular those that constitute major threats to Australia's biodiversity. A methodology is being developed to identify and rank weeds of national importance. The current national focus is on preventing importation of plant species that are potential weeds.

In a report for the National Weeds Program, Csurhes and Edwards (1998) identified 277 non-indigenous taxa that are potential weed species in Australia. Of these, 30 species for which eradication may be feasible were identified. Eleven are already established naturally in Queensland, and a further eight are found in gardens or are available in nurseries. However, no national controls over the sale of ornamental plants exist, and species prohibited in one State may be sold legally in another.

The Rural Lands Protection Act lists, or 'declares', plants that have or could have serious economic, environmental or social impacts in Queensland. All landholders, including local government and government agencies, are required to control declared plants on land under their control.

Biological controls have had some success in the control of water hyacinth, salvinia and rubber vine. Research into effective biological control options for prickly acacia, parkinsonia, parthenium, lantana and mesquite is also occurring.

Many community groups are involved in eradication projects. Strategies have focused on priority weeds within regions. DNR's Weedbuster Project focuses on delivering weed information to the community and supports the work of local government, Bushcare and other community groups involved in the protection and restoration of native bushland.

Marine pests

Management of marine pests currently focuses on preventing entry rather than relying on post-entry eradication or control. Environment Australia, the CSIRO Centre for Research on Introduced Marine Pests (CRIMP), the Australian Ballast

Water Management Advisory Council and the Australian Quarantine Inspection Service are involved in a pilot community monitoring program aimed at the early detection and eradication of marine pests. CRIMP has conducted a number of surveys of Queensland ports, including Hay Point, Mackay and Abbot Point.

Grazing management

DPI and DNR are monitoring the condition of native grasslands used for pasture throughout Queensland's grazing lands. Satellite overviews used in combination with ground truthing are improving quantitative knowledge of the State's grazing lands. Through the TRAPS monitoring system, woodlands are monitored at more than 100 sites by following the changes in woody plant populations along permanent vegetation transects. These transects are also incorporated into QGRAZE, an extensive pasture monitoring network. QGRAZE monitors the impact of grazing animals on herbaceous vegetation composition and stability, and regularly determines trends in the condition and health of the State's grazing lands. More than 400 monitoring sites have been established to provide quantitative information on the state of native pastures.

CSIRO is researching grazing impacts on biodiversity in Queensland's chenopod (saltbush) shrublands and acacia woodlands. Through CSIRO's long-term grazing experiments in the northern speargrass region, the effect of livestock grazing on tussock grass persistence has been documented (Brown, J., pers. comm.).

Reducing impacts of altered fire regimes

There is no coordinated monitoring of changed fire regimes statewide for major vegetation types or ecosystem types. The CRC for Tropical Rainforest Ecology and Management at Atherton has cooperated with the QPWS to establish vegetation monitoring plots throughout the wet sclerophyll forests in north Queensland.

The Queensland Forest Research Institute maintains a series of long-term fire experiments in forests in south-east Queensland. These have provided important information in the development of fire management strategies in use in State forests and timber reserves.

The QPWS devotes considerable resources to fire planning and management on protected areas. On national parks, fire management plans are prepared and fire is managed to ensure that fire regimes do not threaten the parks' conservation values. A fire management plan for the Central Eastern Rainforest Reserves World Heritage Area is being developed to ensure protection of the World Heritage values.

Pollution management

Chapters 2, 'Atmosphere', 4, 'Inland waters', and 5, 'Coastal zone' describe the management of pollution. The National Rivercare Initiative, administered under the NHT, received $3.7 million in 1997–98 to monitor and assess the health of Australia's rivers through the use of biological indicators and conduct research into the environmental flow requirements of rivers and streams. The National River Health Program is developing a biological monitoring tool as a national protocol to monitor the in-stream health of rivers.

While there is no statewide strategy dealing with the management of land-sourced pollutants discharging into aquatic environments, the Integrated Catchment Management program is the major mechanism for reduction of such pollutants. Landcare and other community-based projects are working with landholders to instigate better land management practices through education and on-ground projects.

Managing harvesting

The Nature Conservation Act allows for the preparation of conservation plans that permit the ecologically sustainable taking and use of wildlife from the wild for commercial or non-commercial purposes. Each conservation plan is administered in conjunction with a corresponding management program. Five conservation plans have been prepared to date and cover macropod harvesting, duck and quail, Eulo lizard races, protected plants in trade and problem crocodiles.

Forestry management

The Commonwealth and State and Territory Governments are addressing issues of forest sustainability through several international and national processes. The National Forest Policy Statement calls for the development of a comprehensive, adequate and representative (CAR) reserve system. The joint Ministerial Council subcommittee (JANIS) entrusted to implement the National Forest Policy Statement has recommended nationally agreed criteria for the development of such a reserve system for Australia's forests (JANIS 1996).

Internationally agreed criteria and indicators for sustainable forest management have been developed through the Montreal Process Working Group countries, of which Australia is a member. The Montreal Process Implementation Group for

Regional Forest Agreements

Australia's National Forest Policy of 1992 sets out broad conservation and industry goals for the management of Australia's forests agreed between Commonwealth, State and Territory Governments. To implement this national policy, governments have opted for an approach that involves:

- providing interim protection to forest areas that may be required for a comprehensive, adequate and representative (CAR) forest reserve system;
- undertaking comprehensive regional assessments of environmental, heritage, economic and social values of forests; and
- negotiating Regional Forest Agreements (RFAs) between the Commonwealth and State Governments regarding the long-term management and use of forests in a particular region.

Governments have agreed to establish a national reserve system that will safeguard biodiversity, old growth, wilderness and other natural and cultural values of forests. Forests outside the reserves will be available for wood production, subject to codes of practice that will ensure long-term sustainability and contribute to the conservation of these natural and cultural values.

A comprehensive regional assessment of the forests of the Southeast Queensland bioregion has been completed. The process included a systematic native animal survey of more than 250 sites on State lands, establishment of a native animal database containing 200 000 records, and ecosystem mapping. Surveys have added records for four native animal species and 15 native plant species new to the region.

Australia is developing a framework of regional indicators for use in Australia. Each indicator is being assessed through a nationwide research program to test its applicability in different ecosystems and to develop quantitative performance measures.

Just over 8 percent of Queensland's forests are within State forest and timber reserves (4.3 million ha) and are managed for a variety of uses including timber production, grazing, conservation, protection of water quality and recreation. DNR independently sets and monitors environmental resource management standards for DPI's forestry production activities. DNR has established a framework for implementing sustainable forest management on State forests and timber reserves and for Crown-managed operations on forests of other tenures. This framework includes:

- research and monitoring programs;
- policies, codes of practice and harvesting guidelines to direct operations;
- species management profiles to guide forest managers in managing plants and animals that are rare or threatened or require special management; and
- a multiple-use planning procedure to guide the allocation of forests to appropriate combinations of uses within a landscape context.

DNR is developing interim management arrangements for forest areas of high conservation value. As a result, timber harvesting has been excluded from certain key conservation areas, including areas of old growth. A management priority zoning system means that approximately half of the State forest area is excluded from timber production; of this, 20 percent is specifically for biodiversity protection. Draft management plans have been developed for 465 000 ha of State forest, 11 percent of Queensland's State forest and timber reserve area.

Fishing management

One of the objectives of the *Fisheries Act 1994*, the legislative basis for the management and protection of Queensland's fisheries, is to ensure that fisheries resources are used in an ecologically sustainable way. The Queensland Fisheries Management Authority (QFMA), established under the Act, is developing fisheries management plans. Fourteen management plans are in force or under development. Some are for a specific location (for example, the Moreton Bay Fisheries Management Plan), while others are specific to a fishery. QFMA, through these plans, has implemented closures for different areas, times, seasons and apparatus.

The National Fisheries Action Program aims to protect and restore fisheries habitats such as mangroves, estuaries and seagrass beds. The program also deals with issues such as aquatic pest control and developing sustainable fishing practices and management plans.

Considerable progress is being made towards developing modifications to trawl gear to reduce bycatch. The Queensland fishing industry is increasingly using bycatch reduction devices and turtle excluder devices. Methods to evaluate the effectiveness of bycatch reduction gear are presently under development.

The Effects of Fishing Program is a multi-project collaborative research program focusing on the effects of fishing in the Great Barrier Reef Marine Park. The primary objective is to gain a greater understanding of the impacts of fishing to ensure ecologically sustainable fishing, the protection of critical habitats and the protection of rare and endangered species.

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CHAPTER 8

QUEENSLAND'S HUMAN SETTLEMENTS

Human settlements

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Contents

KEY ISSUES AND FINDINGS

In 1996, 80.7 percent of Queenslanders lived in cities or urban areas. This pattern of distribution concentrates human impacts and waste production into relatively small areas. The quality of the urban environment, in terms of its health, aesthetic, recreational and cultural attributes, is important to urban residents.

- In 1996, south-east Queensland accommodated 2.2 million people, or 66.7 percent of the State's 3.4 million population. Nevertheless, Queensland is the most decentralised of all the States: only 45.5 percent of the population live in the Brisbane Statistical Division. Queensland's coastal areas including Brisbane contain 85.2 percent of the population.
- Between 1986 and 1996, Queensland's population increased by 27.2 percent at an average annual rate of 2.4 percent, the highest rate experienced by any Australian State or Territory. The highest growth rates were all in coastal areas in the south-east of the State. The population in far northern coastal Queensland around Cairns also grew rapidly.
- Population growth in recent years has been caused largely by migration from other States rather than natural increase. Some migration appears to be due to lifestyle factors rather than growth in employment opportunities. This has implications for the economic health of communities.
- Rural population decline is a nationwide problem and has been a persistent feature since the 1930s. The population of Queensland's inland shires grew at a net average annual rate of only 0.9 percent between 1986 and 1996.
- Queensland's population is ageing: between 1991 and 1996, median age increased from 32 to 33 years. This has significant implications for infrastructure and service planning.
- Queensland's average population density of 1.97 people/km^2 conceals the large variations in regional densities. The average population density in inland Queensland is 0.4 people/km^2, while in Brisbane City it is 715.4 people/km^2. Urban population densities are, however, far lower than is typical in the developed world. The dominant trend is for dispersed, low-density suburbs along the coast north and south of the major cities.
- State, Commonwealth and local government and community bodies are working together in several regions most affected by population increase to coordinate regional planning for facilities, tourism, transport and land use planning. Major programs in place are the South East Queensland 2001, Wide Bay 2020 and Far North Queensland 2010 growth management projects.
- Planning frameworks in Queensland were changed fundamentally by the *Integrated Planning Act 1997*, which is based on the principles of ecologically sustainable development. The local planning system, which tended to encourage property speculation while inhibiting integrated planning, was replaced with a system of performance-based planning criteria and integrated development approvals.
- Tourism contributes strongly to the Queensland economy but puts pressure on urban facilities and natural environments, particularly on the Gold Coast, the Sunshine Coast and in centres such as Port Douglas. Between 1995 and 1997, visitor numbers increased by 12 percent. A significant proportion of visitors identify nature-based features as attracting them to Queensland.
- *Queensland Tourism: A Framework for the Future*, the Government's tourism strategy, recognises the need for a whole-of-government approach and a sustainability focus for tourism development. In recognition of ecotourism's growing role, the Queensland Government launched the Queensland Ecotourism Plan in 1997. Queensland operators have embraced the National Ecotourism Accreditation Program, recording the highest percentage of accreditations of any State.
- Loss or deterioration of green space and other public areas, loss of pedestrian access, social isolation and increased noise and air pollution have all been observed as direct consequences of increasing private vehicle use in cities. In 1995, Queensland road vehicles travelled an estimated 34 417 million kilometres, a 38 percent increase on the total distance travelled in 1988.
- Queenslanders are highly dependent on private vehicles. The percentage of people travelling to work as car drivers in 1996 was 79.2 percent; of these, 81.8 percent were sole occupants. Non-availability was the reason most often cited for not using public transport.
- The Integrated Regional Transport Plan for South-East Queensland aims to develop a more sustainable transport system by better integrating the transport system with urban development, moderating traffic growth and encouraging the use of public transport, ride-sharing, walking and cycling. Integrated regional transport plans are being developed for other regions across Queensland including Mackay, Townsville–Thuringowa, Toowoomba, Far North Queensland and Wide Bay. Brisbane City Council's travel management strategy, TravelSmart, also aims to reduce private vehicle trips.
- Queensland's energy consumption is high by Australian and international standards. This is due to the State's energy-intensive industries and long-distance transport needs. Per capita consumption of energy in Queensland rose steadily from 239 GJ/person in 1986–87 to an estimated 286 GJ/person in 1995–96. Although Queensland's climate favours the use of solar energy, only 4.8 percent of households use solar hot water systems. In 1994, more than 71.5 percent of Queensland homes had no insulation. In 1998, the Queensland Government launched the Office of Sustainable Energy to encourage energy-efficiency and use of renewable sources.
- Most households in Queensland rely on mains/town water as their principal water supply (89.4 percent in 1998). In 1998, 64.2 percent of Queensland households reported being satisfied with their drinking water supply. The Brisbane region appears to be using less water, despite an

increasing population. Government responses to demands on water resources include providing suitable catchments for domestic water supply, conducting education campaigns and introducing pricing reforms.

- Per capita waste generation in 1994–95 was estimated at 806 kg. Across the State, local councils are involved in planning for waste management on a regional basis and are improving waste management processes. Many are encouraging waste reduction through provision of recycling services, pricing structures, education, rates rebates as incentives, collection facilities for green waste and compost bins.
- The community continues to support recycling. The percentage of households reporting that they did not recycle fell from 18.1 to 7.9 between 1992 and 1996. The Queensland Recycling Advisory Council conducts a range of public education programs and provides grants to local government.
- 'Cleaner production', a holistic approach to reduce resource inputs and waste outputs, is being promoted to Queensland industry by a range of government, research and private bodies. Case studies demonstrate significant savings as well as environmental benefits.
- The concept of the 'ecological footprint' is used to quantify the direct local effects and the indirect regional and global effects of the resources cities use and the wastes they produce. The ecological footprint for Queenslanders has been calculated at 5.98 ha per person, compared with a global 'fair share' of 1.3 ha.
- Most Queenslanders report concern about environmental problems, although between 1992 and 1998 the percentage reporting concern fell from 74.0 to 67.5. Thirty-nine percent felt that not enough information was available on the environment. Environmental information is provided by a wide range of government, community and private organisations, with an increasing focus on individual participation.
- Queensland as a whole is well placed in terms of economic advantages to allow strong commitment to ensuring sustainable development. The State is expected to achieve economic growth from 1997 to 2002 of 4.1 percent a year. Median income and education levels are increasing. Some poorer communities, however, may need support to afford environment protection technologies and to give priority to long-term sustainability objectives rather than short-term economic goals.
- Indoor air quality is an emerging environmental health issue in human settlements. Most people spend about 80 percent of their time indoors and the quality of indoor air may be much lower than that of air outdoors. Inadequate ventilation is a major factor. The Department of Public Works is responsible for indoor air in government buildings and is working with Education Queensland in schools.
- Noise, especially transport noise, is a significant form of pollution in human settlements. The *Environmental Protection (Noise) Policy 1997* aims to achieve an acoustical quality objective for most Queenslanders of less than 55 decibels. It provides a framework for decision making and dispute resolution, accurate assessments and noise management programs. Government bodies that manage transport are implementing noise reduction strategies. Local councils are increasingly including noise considerations in land use planning.
- Data on green space are not consistently available for urban settlements throughout the State. In Brisbane City the Council manages about 9 per cent of the city's land as park or natural-area reserve. Native vegetation in Brisbane covers approximately 24 percent of the city.
- Overall population health in Queensland is good. Between 1976 and 1997, life expectancy at birth increased by 6.4 years for males and by 5.2 years for females. However, there are significant health variations between urban and rural populations, and between indigenous and non-indigenous populations. Of the Australian States, Queensland has the highest mortality rates for melanoma.
- Queensland Health has a public health program which aims to improve health and reduce disease for the whole community using preventive strategies, with particular attention given to priority issues such as immunisation, preventing communicable disease and diabetes in indigenous communities, breast cancer and cervical cancer screening, control of key infectious diseases such as tuberculosis and hepatitis, quality assurance in the food industry, and preventing smoking uptake by children.

INDICATORS

Pressure

Population patterns

Total population

Population distribution

Percentage population change

Net natural increase

Net migration

Coastal population change

Rural population change

Median age

Dependency ratio

Population density

Tourism

Visitor numbers and nights

Visitor beds and occupancy rates

Proportion of visitors undertaking nature-based activities

Transport

Number of motor vehicles by population

Distance travelled

Distance travelled by type of vehicle

Average trip length

Distance travelled to work or study

Average age of vehicle fleet

Fuel consumption

Road vehicle stock by fuel type

Mode of transport to work or study

Public transport patronage by mode

Use of resources

Per capita energy use

Household energy use

Sources of hot water

Use of dwelling insulation

Urban water use

Daily water use by population

Household water conservation practices

Ecological footprint of Queenslanders

Waste

Volume of liquid waste

Amount of solid waste

Amount of solid waste by source (municipal, commercial and industrial, building and demolition)

Amount and type of hazardous waste (household and industrial)

Socioeconomic pressures

Percentage of population concerned about the environment

Environmental concerns by issue

Educational attainment

Income

Median rent as a proportion of median income

Median housing loan repayment as a proportion of median income

Proportion of owner-occupied private dwellings

Forecast economic growth

State

The urban environment

Reported illness, irritation and allergic reactions relating to indoor air quality

Number of noise complaints and the related sources of noise

Proportion of urban land conserved as green space

Proportion of remnant vegetation conserved in settled areas

Access to environmental services

Proportion of population with access to mains water

Satisfaction with quality of mains water

Length of roads, railways and bikeways

Proportion of people reporting lack of public transport options

Proportion of households with access to public transport within 800 metres of home

Average speed of travel on roads

Housing stock

Occupancy rates

Number of retirement dwellings and proportion of total dwellings

Percentage of households with access to recycling services

Percentage of households with access to hazardous waste disposal services

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Life expectancy

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Urban, rural and remote variations in life expectancy and causes of death

Indigenous and non-indigenous variations in health status

Notifications of high blood lead levels in children

Mortality from and incidence rates for melanoma

INTRODUCTION

INTRODUCTION

This chapter is concerned with the environmental aspects of Queensland's human settlements. Human settlements are an important part of a 'state of the environment' report because they both influence and are influenced by the environment within which they are located.

Human settlements clearly have an impact on the environment. How we live, our work and recreation, and our patterns of habitation, travel and consumption can impose demands on our water, land and energy resources and have impacts on air, land, water and biodiversity. When people live together in human settlements, these negative impacts are concentrated in small areas and can have significant downstream effects. On the positive side, the concentration of people and economic activity provides opportunities for economies of scale in resource use, environment protection programs and waste management. Managing the impacts of population growth, urban development, tourism, transport and waste associated with human settlements is important to the ecological sustainability of Queensland and to the sustainability of our quality of life. The impacts of human settlements are discussed in the 'Pressure' section of this chapter.

Society is influenced by the environment. Our health is affected by the quality of the air we breathe, the water we drink and the land we work and live on. In our cities and towns we look for clean air, clean water, efficient waste disposal systems, green space for recreation and so on; to find these we need access to services such as transport and waste disposal systems that minimise our impact on our environment. We value aspects of the environment for aesthetic and recreational reasons: blue skies, green forests, sparkling water, colourful reefs, unique plants and animals. Our culture, both indigenous and non-indigenous, is built around identification with many environmental elements. The 'liveability' aspect of human settlements is discussed in the 'State' section of this chapter.

The interdependence of social, economic and environmental factors is reflected in the broad definition of 'environment' in the *Environmental Protection Act 1994*, which states that the environment comprises 'ecosystems and their constituent parts, including people and communities' and 'the social, economic, aesthetic and cultural conditions' affecting or affected by the environment. While this chapter cannot explore all socioeconomic and health issues in detail, it attempts to provide an overview of the major pressures that human settlements exert on the environment, discuss some aspects of the state of the environment and human health in human settlements, and describe major responses to these issues.

SCOPE

The main spatial units for socioeconomic data in Queensland in decreasing order of size are Australian Bureau of Statistics statistical divisions (SDs), statistical local areas (SLAs) and census collection districts (CDs), as defined in the Australian Standard Geographical Classification (ASGC). Local government areas (LGAs) are also used. These vary in size, and the number of SLAs that make up an LGA varies from 163 for Brisbane to only one for most rural Queensland LGAs.

Boundaries of all these units change from time to time to reflect demographic and political changes. In this chapter Queensland population and settlement data are analysed and presented using the 1995 ASGC boundaries that resulted from post-1994 local government amalgamations.

In some cases, figures are presented for the State and for regions (e.g. south-east Queensland) as well as for ASGC units. The coastal strip (SLAs with a coastal boundary or the centroid within 50 km of the coast) is also treated as a distinct unit in some analyses.

DME

More than 80 percent of Queenslanders live in urban areas. Many of these areas are characterised by sprawling low-density suburbs.

PRESSURE

The nature of human settlements — their form, environmental impacts and resource consumption rates — depends on the attitudes and behaviours, individually and collectively, of the people who inhabit them. These, in turn, depend on socioeconomic factors and our level of knowledge about the environment.

This section first discusses the broad population patterns placing pressure on the environment, and associated patterns of urbanisation and tourism. It then examines some specific environmental impacts of human settlements: the impacts of transport, the use of resources such as energy and water and the generation of waste. It concludes by looking at two socioeconomic pressures that underlie these impacts: community attitudes and the community's socioeconomic resilience, that is, the educational and economic strength to protect the environment in the long term in the face of economic downturns. The section focuses largely on the pressures human settlements place on their environment but also discusses pressures on the settlements themselves.

Issues of particular pertinence to Queensland settlements include:
- the effects of positive and negative population change due to migration;
- the effects of drought, deteriorating terms of trade and the pursuit of economic rationalism on the viability of country towns;
- the effects of changing age structure and family and household size on dwelling densities;
- counter-urbanisation and the apparent reversal of population decline in inner city areas (a national phenomenon); and
- the impact of global and national tourism on Queensland coastal resorts.

POPULATION PATTERNS

Indicators

Total population

Population distribution

Population distribution

At 30 June 1998 Queensland's estimated population was 3.45 million.

Queensland's population is highly urbanised and becoming more so, reflecting a nationwide trend. In 1947, 59.8 percent of the population lived in urban areas, that is, centres with over 1000 residents. This had grown to 79.2 percent by the 1991 census and to 80.7 percent by 1996 (table 8-1). At 30 June 1996, 64.0 percent of the population resided in the Brisbane and Moreton Statistical Divisions in south-east Queensland. Nevertheless, Queensland has the least centralised population of all the mainland States. Only 45.5 percent of the population live in the Brisbane Statistical Division (ABS 1999). This compares with 73 percent living in the State capitals in Western Australia and South Australia. The majority — 70 percent — of Queensland urban residents live within 50 km of one of the State's four largest east coast centres: Brisbane, Gold Coast City, Townsville and Cairns (figure 8-1).

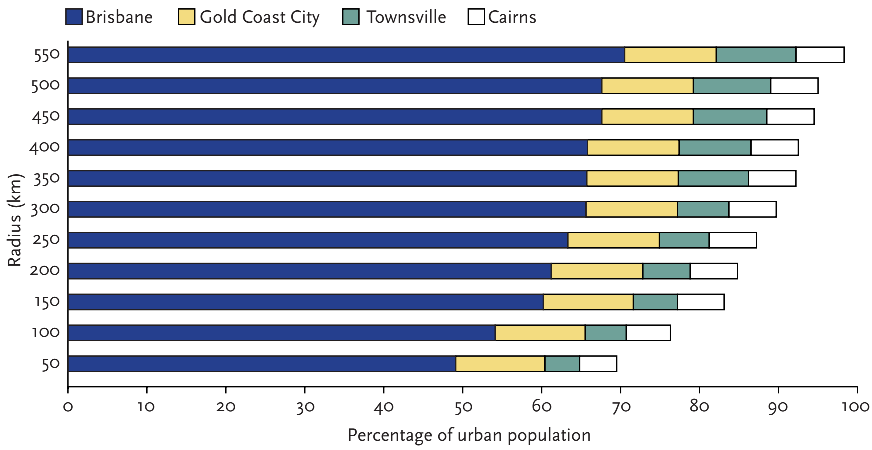
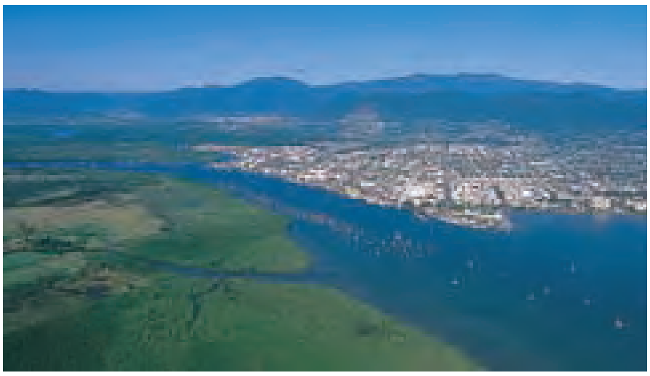


Figure 8-1 Percentage of Queensland's urban population living within various distances from the four largest east coast urban centres
(Source: Derived from ABS data)

The percentage of the population living in small localities of between 200 and 999 people declined from 3.7 in 1986 to 3.1 in 1996, and the percentage of the population living outside population centres declined from 17.1 to 16.3 (ABS 1998a).

Figure 8-2 shows the distribution of population centres in Queensland. It illustrates the high proportion of larger centres along the coast and their relationship with the road network.



Seventy percent of Queensland urban residents live within 50 km of Brisbane, Gold Coast City, Townsville or Cairns (pictured).

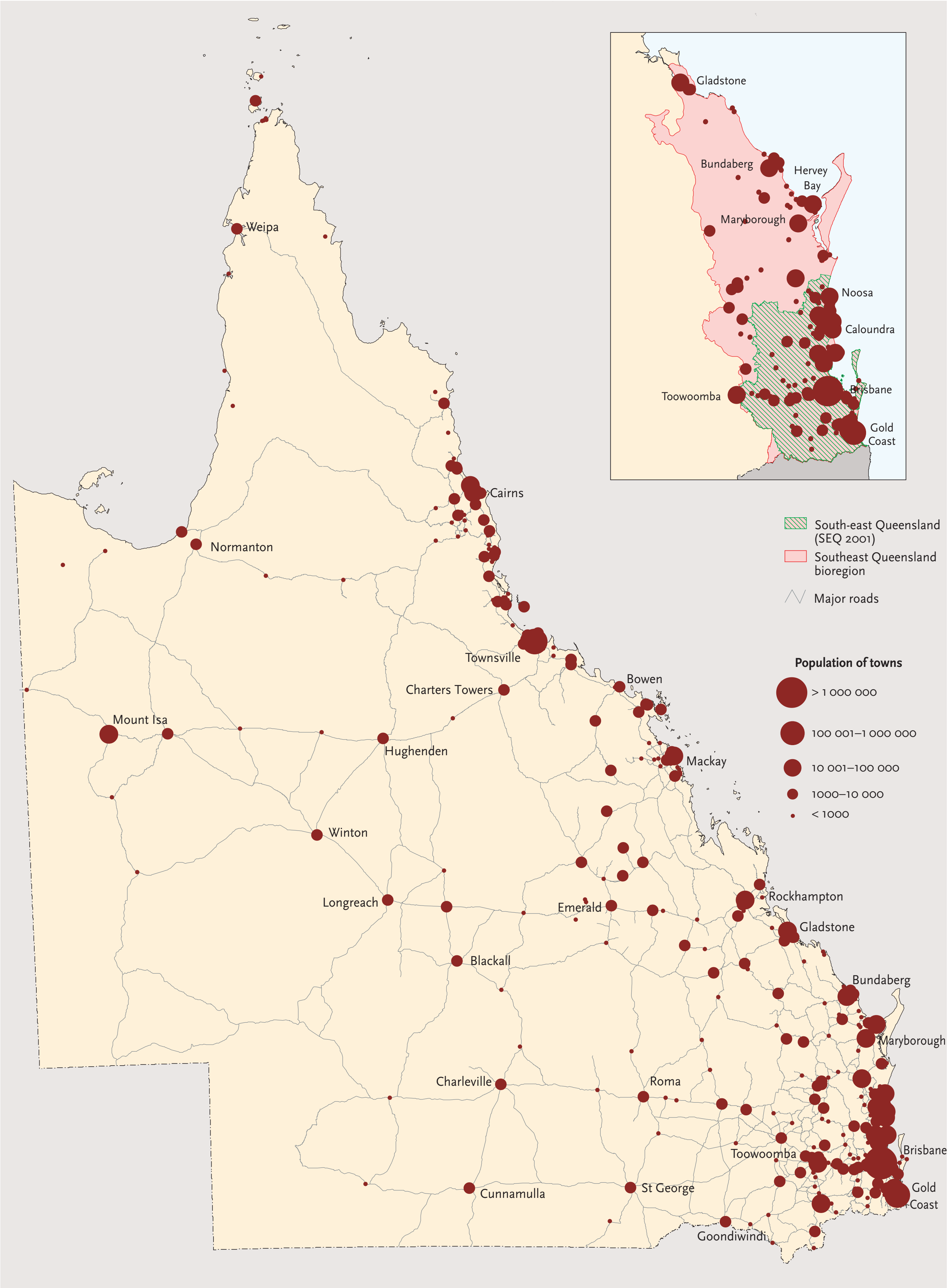


Figure 8-2 Size and distribution of population centres in Queensland
(Source: ABS)

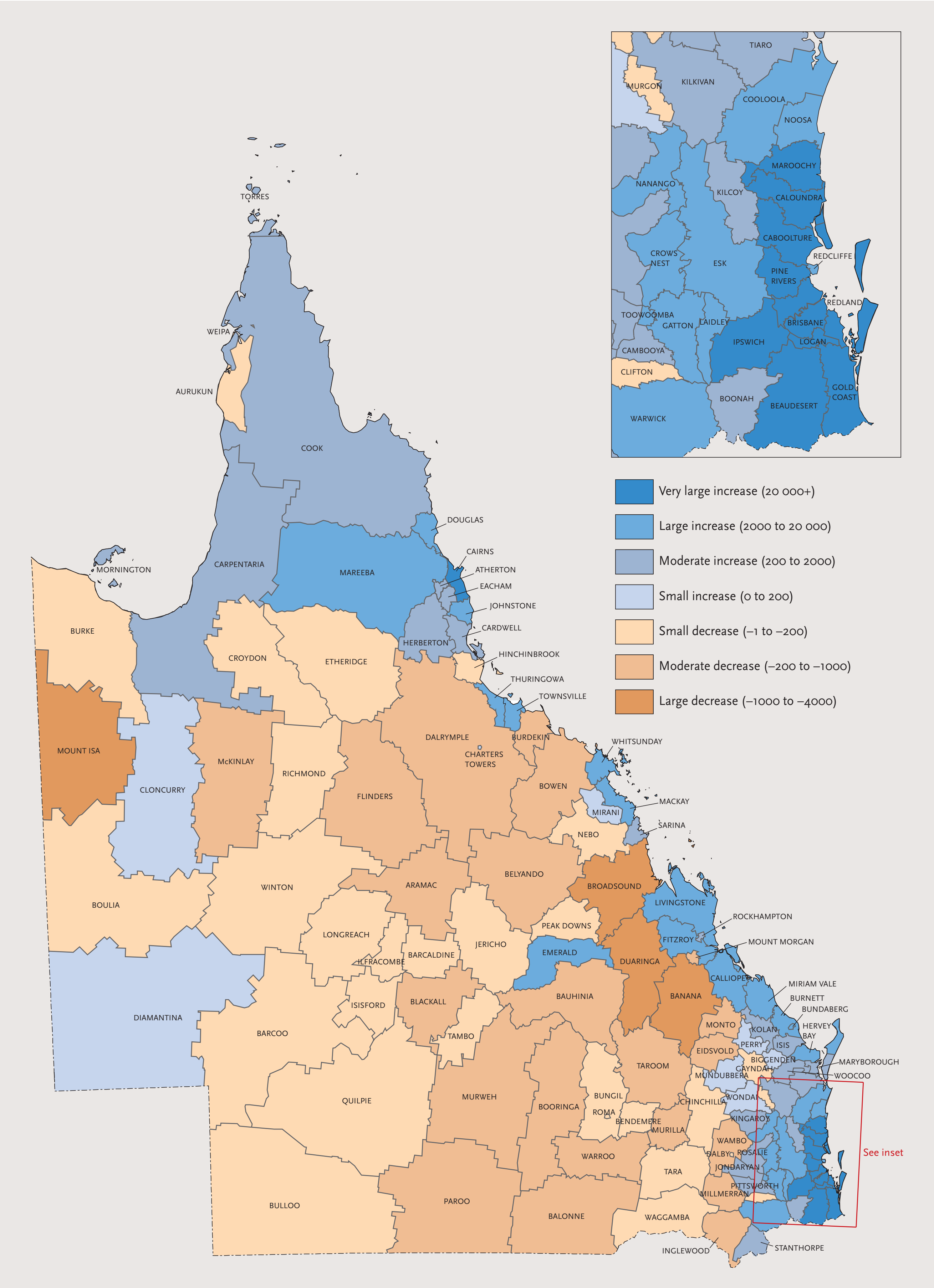


Figure 8-3 Absolute population growth, Queensland, 1986–96, by local government area
(Source: ABS)

Table 8-1 Distribution of Queensland's urban population (centres with >200 people), 1986 and 1996

	Number of population centres		Qld population count		Share of Qld population count (%)	
	1986	1996	1986	1996	1986	1996
500 000 and over	1	1	1 037 820	1 291 117	40.1	38.3
100 000–499 999	1	2	163 330	384 071	6.3	11.4
75 000–99 999	1	2	96 230	175 623	3.7	5.2
50 000–74 999	3	1	180 590	57 770	7.0	1.7
25 000–49 999	2	7	71 970	235 162	2.8	7.0
20 000–24 999	4	2	86 190	43 037	3.3	1.3
15 000–19 999	1	2	16 210	33 835	0.6	1.0
10 000–14 999	4	9	46 820	113 810	1.8	3.4
5 000–9 999	22	20	158 080	148 425	6.1	4.4
2 500–4 999	19	32	82 360	108 758	3.2	3.2
2 000–2 499	17	21	38 000	47 759	1.5	1.4
1 000–1 999	50	56	71 570	78 749	2.8	2.3
200–999	187	192	95 340	103 711	3.7	3.1
Total	**312**	**347**	**2 144 510**	**2 821 827**	**82.9**	**83.7**

(Sources: ABS 1988, ABS 1997a)

Population change

Indicators

Percentage population change
Net natural increase
Net migration
Coastal population change
Rural population change
Median age
Dependency ratio

The consequences of population growth are greater demand for resources and increased pressures on services such as hospitals and health care, transport infrastructure, reticulated water supplies and domestic waste disposal. These demands can increase impacts on the environment: for example, loss of biodiversity through habitat destruction for new housing and industry; more air pollution from energy generation, transport and industry; and greater noise pollution from industrial and transport activity.

Urbanisation and development associated with population growth require land or increased population densities. As low-density housing continues to be the favoured option, growth applies pressure to develop land which is often (although not always) natural habitat or being used for agriculture or forestry. Urban encroachment on rural areas or on semi-industrial areas can also mean that some activities are unsuitably close to one another. This issue is discussed in detail in chapter 3, 'Land'.

Population decline causes different pressures. For example, it is more difficult to justify providing services and to finance environmental protection initiatives.

It is not clearly understood how much growth is sustainable but there is an increasing recognition that the causes of population growth and decline need to be understood and strategic planning must be undertaken to manage population change in an equitable and sustainable way. Initiatives in integrated planning are discussed in the 'Response' section of this chapter.

Growth rates

Between 1986 and 1996, Queensland's population increased by 27.2 percent, a growth rate almost twice Australia's at 14.3 percent (figure 8-3). Queensland's average annual population growth rate, the highest experienced by any Australian State or Territory in the period, was 2.4 percent, an average increase of 71 465 people a year.

Queensland's population is projected to increase to between 4.7 million and 5.0 million by the year 2021 and to between

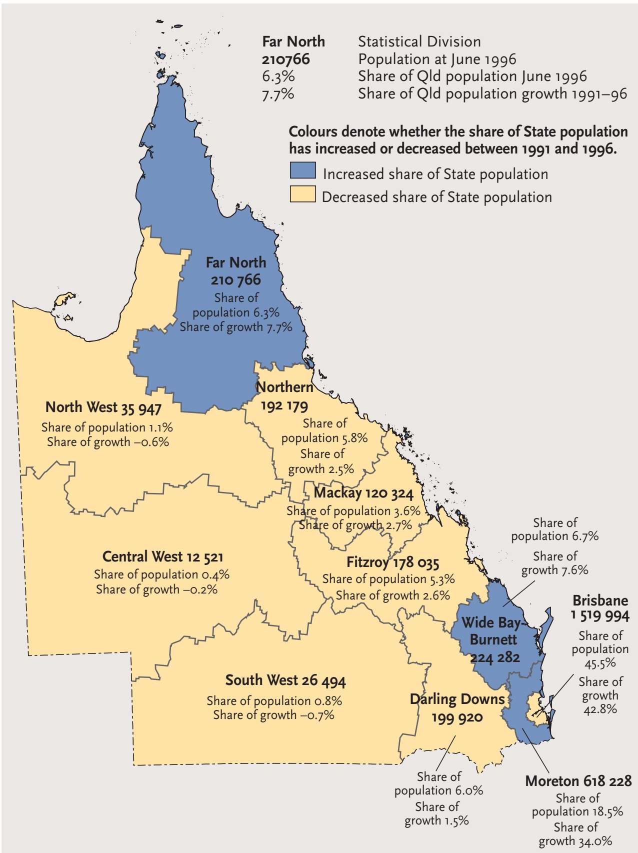


Figure 8-4 Estimated resident population, proportion of Queensland population and share of growth, 1991–96, by statistical division
(Sources: After QDLGP 1997; ABS data)

Table 8-2 Estimated resident population and population change, Queensland statistical divisions, 1986–96

Statistical division	1986	1996	Absolute change 1986–96	Percentage change 1986–96	Average annual growth rate 1986–96
Brisbane	1 217 348	1 519 994	302 646	24.9	2.2
Moreton	375 549	618 228	242 679	64.6	5.1
Wide Bay–Burnett	170 832	224 282	53 450	31.3	2.8
Darling Downs	183 112	199 920	16 808	9.2	0.9
South West	28 843	26 494	–2 349	–8.1	–0.8
Fitzroy	160 127	178 035	17 908	11.2	1.1
Central West	13 563	12 521	–1 042	–7.7	–0.8
Mackay	103 499	120 324	16 825	16.3	1.5
Northern	171 744	192 179	20 435	11.9	1.1
Far North	161 042	210 766	49 724	30.9	2.7
North West	38 377	35 947	–2 430	–6.3	–0.7
Queensland*	2 624 036	3 338 690	714 654	27.2	2.4

*Excluding offshore areas and migratory statistics
(Sources: QDCILGP, ABS)

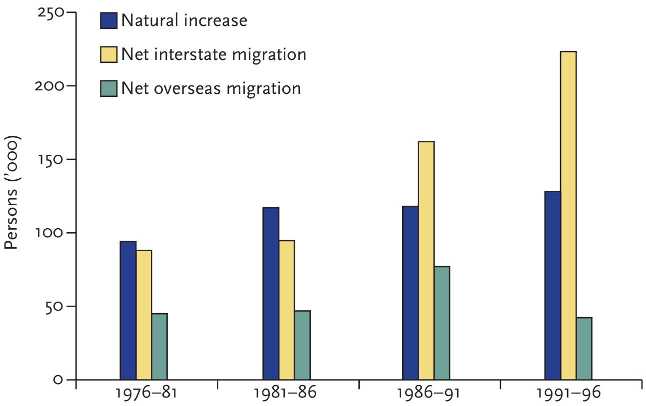


Figure 8-5 Components of estimated residential population change, Queensland, 1976–81 to 1991–96
(Sources: after QDLGP 1997; ABS data)

6.0 million and 6.5 million by 2051. Annual population growth rates are expected to decline from the 1.9 percent measured between 1996 and 1997 to an average of 1.1–2.0 percent between 1997 and 2021 and 0.6–1.3 percent between 2021 and 2051 (ABS 1999).

At the time of the 1996 census, south-east Queensland accommodated 2.2 million of the State's 3.4 million population, representing 66.7 percent of the total (figure 8-4). Most of the population increase between 1986 and 1996 occurred in south-east Queensland, where the population increased by 34.2 percent. Populations of the Gold Coast and the Sunshine Coast increased by 65.1 percent and 78.6 percent respectively. Under a medium-growth prediction, south-east Queensland's share of the State's population will increase to 69.3 percent by 2011, accounting for 77 percent of the State's forecast population growth (QDCILGP 1998).

Table 8-2 provides summary regional data for population change in Queensland statistical divisions. Absolute population growth by LGA is shown in figure 8-3.

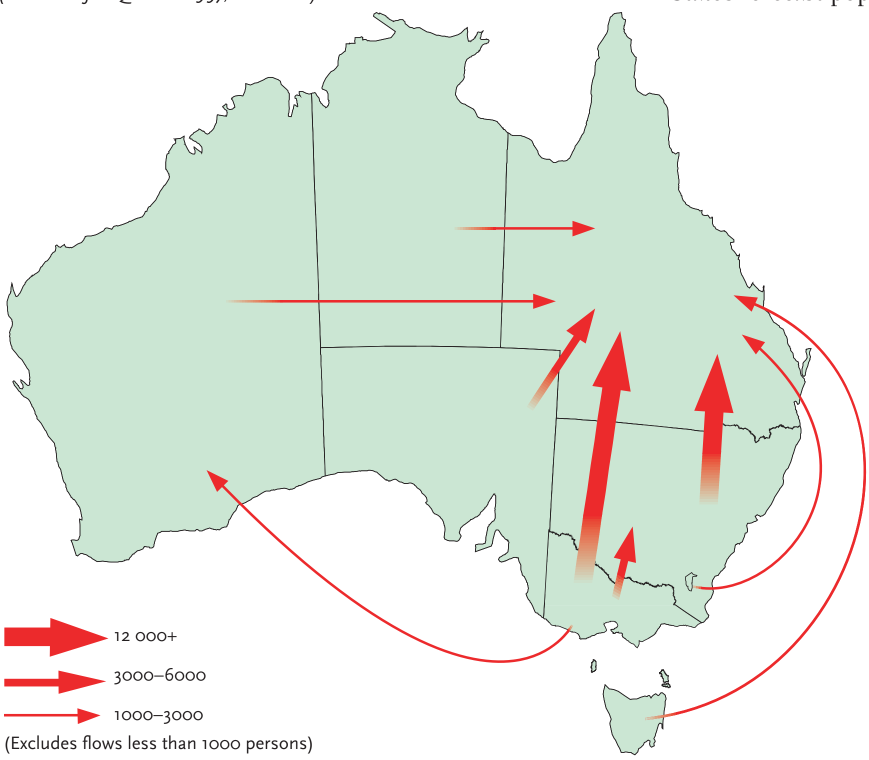


Figure 8-6 Average annual net interstate migration flows, Australia, 1991–96
(Sources: After QDLGP 1997; ABS data)

Natural increase

While the major contributors to population growth between 1976 and 1996 were natural increase and interstate migration, interstate migration has progressively become more important (figure 8-5). By 1996, natural increase accounted for only 34.2 percent of Queensland's population change.

Queensland's overall fertility rate — the number of children 1000 women would be expected to bear in their lifetimes — has been decreasing for the past 25 years. Since 1978 the rate has been consistently below the long-term replacement level of 2100. This has not, however, resulted in population decline, due to the high fertility of previous generations and net migration gain.

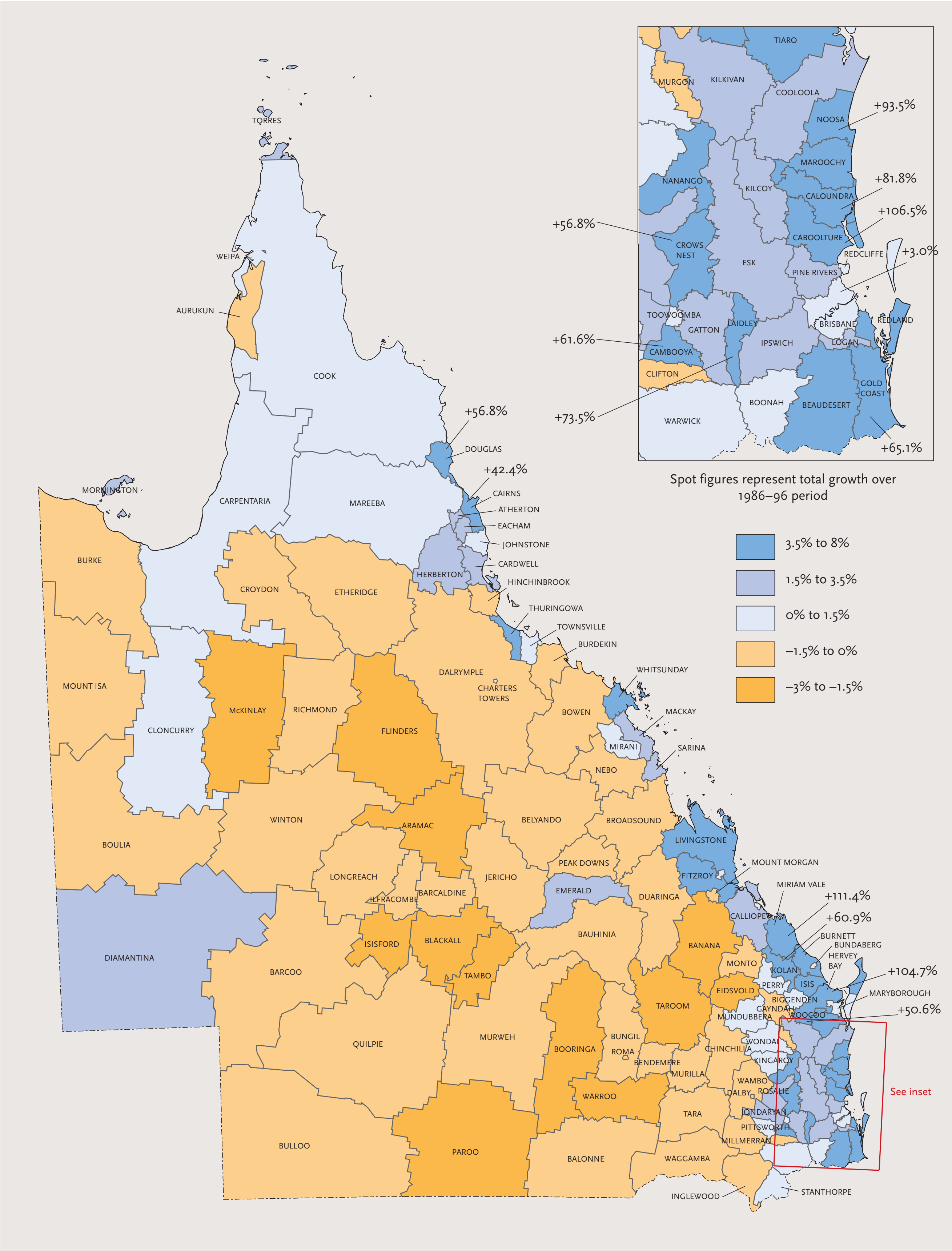


Figure 8-7 Average annual population growth, Queensland, 1986–96, by local government area
(Source: ABS)

Net migration

The dominant pattern of interstate migration in Australia since the mid-1980s has been a northerly drift of population up the east coast towards Queensland, as shown in figure 8-6 (Newton and Bell 1996). Interstate migration was responsible for 56.7 percent of the population growth in Queensland between 1991 and 1996. Net overseas migration accounted for 10.7 percent. Overall, two-thirds of Queensland's annual population growth is attributable to net migration gains.

The great majority of interstate and overseas migration to Queensland has been to south-east and coastal Queensland. Nearly all of the 60 fastest-growing local government areas are on the coast or in south-east Queensland and the bulk of their growth is due to migration.

Of significance is the change in the motivation behind migration. In 1970 about 43 percent of all moves were work-related. This had decreased to 26 percent by 1987. Increasingly, interregional migration in Australia is due to consumption-related rather than production-related motives (Flood et al. 1991). Much of Queensland's net migration gain during the 1980s comprised the aged and the unemployed — those outside the labour force (Bell 1996). Migrants are likely to have been attracted to the high-growth south-east and coastal areas of Queensland by the lifestyle and relatively low cost of living, rather than by employment opportunities. Industry growth in these areas is often confined primarily to 'city building' and 'people serving' activities (construction, public services, personal services etc.) rather than export-oriented manufacturing and producer-service industries (Newton and Bell 1996). This has implications for the longer-term overall economic health of the regions (see 'Socioeconomic pressures' below).

Economic factors continue to motivate some migrants. Employment opportunities arising from the growth of service industries draw migrants to Queensland. Labour displaced by the restructuring of extractive and traditional manufacturing industry, particularly in Sydney, Melbourne and Adelaide, has been partly absorbed by this rise.

Other events and cycles, such as changes in terms of trade, occurrence of drought and periodic pursuit of economic efficiency by government as well as the private sector, affect population movement and cause large annual fluctuations in the net gains and losses in individual States (Newton and Bell 1996).

Coastal population change

In 1996 Queensland's coastal areas, including Brisbane, contained 82.5 percent of the population (2.87 million people). These areas comprise 26 percent of the State's total land area. Growth has also been concentrated in coastal regions. Local government areas with the highest population growth in the period 1986–96 were all on the coast: Miriam Vale (111.4 percent), Caboolture (106.5 percent), Hervey Bay (104.7 percent), Noosa (93.5 percent) and Caloundra (81.8 percent) (figures 8-4 and 8-7).

While the population of Brisbane City LGA increased by 11.2 percent between 1986 and 1996, much less than the State average of 27.2 percent, more dramatic population increases occurred along the coast within commuting distance to the north and south and in coastal urban centres. In south-east Queensland shires such as Caboolture, Noosa, Beaudesert, Maroochy and Redland, and in Gold Coast and Caloundra cities, there have been increases of more than 50 percent. This is consistent with a trend towards a dispersed, multinodal super-city comprising the Gold Coast, Brisbane and the Sunshine Coast.

The population also grew rapidly in far northern coastal Queensland between 1986 and 1996. The population of Cairns grew by 42.4 percent and that of Douglas Shire by 56.8 percent. These increases can be explained partly by socioeconomic benefits flowing from the opening of the Cairns International Airport and increased tourism.

Central Queensland coastal economies were not stimulated to the same degree by the late 1980s boom in Queensland tourism. Nonetheless, the populations of regional coastal areas such as Calliope, Mackay, Bundaberg and Gladstone grew steadily.

With most population growth since 1986 occurring on the coast, there is a clear trend to increasing urbanisation and hence increasing pressure on the social services and environmental values of this ecologically sensitive zone.

Rural population change

Rural population decline is a nationwide issue and has been a persistent feature since the 1930s. Much of Australia's interior, especially pastoral and dryland farming regions and inland towns, has experienced net losses in population in favour of larger regional centres and major cities. Overall, the population of Queensland's inland shires grew at a net average annual rate of only 0.9 percent between 1986 and 1996. The population of some remote rural shires declined by as much as 22.4 percent during that period, at average annual rates of about 2.5 percent. Shires with the highest annual rates of population decline were Isisford, Flinders and Eidsvold (all 2.5 percent), and Aramac and Warroo (both 2.3 percent).

Many Queenslanders have a preference for coastal living. Waterside land is valued but is in limited supply, leading to the development of canal estates.

Rural population decline is due largely to the migration of younger people from rural to urban areas in search of employment, educational and lifestyle opportunities. Factors such as deteriorating terms of trade for agricultural commodities, drought, farm amalgamation, closure of rail lines and the withdrawal of private and public services such as banks and employment offices can also play a part. Some of these factors can be both causes and effects of rural decline.

An opposite effect, commonly called counter-urbanisation, became apparent in the 1970s. The term refers to movement away from the major cities to nearby towns, rural areas and the coast. People are drawn by cheaper land prices outside major urban centres while retaining proximity to those centres, as well as by the lifestyle and employment factors discussed in 'Net migration' above. Counter-urbanisation has resulted in some inland shires close to Brisbane and other coastal centres experiencing high population growth. Examples include Laidley (73.5 percent growth from 1986 to 1996), Cambooya (61.6 percent) and Crows Nest (56.8 percent) near Brisbane and Toowoomba; and Kolan (60.9 percent) and Woocoo (50.6 percent) near Hervey Bay.

Median age and dependency ratio

In 1996 just over one-fifth (21.9 percent) of Queensland's population (excluding overseas visitors) were aged 0–14 years, 14.8 percent were aged 15–24, 30.2 percent were aged 25–44, 21.1 percent were aged 45–64, and 12.0 percent were aged 65 years and over. The LGAs with the highest proportions of their populations aged 65 years and over were Mount Morgan Shire (19.7 percent) and Redcliffe City (18.8 percent). High proportions of people aged 65 years and over were generally found in popular coastal resorts and some regional centres and rural communities. The proportion in Brisbane City LGA (12.8 percent) was close to the State average. The LGAs with the highest proportions of their populations aged less than 15 years were Torres Shire (37.3 percent) and Aurukun Shire (33.1). Mining towns and LGAs accommodating urban overspill from adjoining cities also had high proportions of persons aged under 15. Brisbane City was the LGA with the lowest proportion of its population aged less than 15 years.

Median age in Queensland in 1996 was 33 years. Median ages ranged from 30 years in the North West SD to 37 years in the Moreton SD. Queensland's population is ageing: median age in 1991 was 32 years. In the south-east, the median age of the population also increased by one year between 1991 and 1996. More pronounced increases were recorded in the Central West SD (from 30 to 34 years), South West SD (from 30 to 33 years) and North West SD (from 27 to 30 years).

The age distribution of the population is expected to change substantially in the future. The dependency ratio, which measures the number of children (0 to 14 years) and elderly (65 years and over) per 100 people of working age (15 to 64 years) declined from 59.7 in 1976 to 49.7 in 1996. It is expected to rise slightly to 51.0 by 2016. After 2011 the dependency ratio is expected to increase as the baby boom generation reaches 65 years of age and the proportion of over-65s outweighs the proportion of children (QDLGP 1997).

The changing population age structure has significant implications for housing trends and densities and demands on infrastructure and services. It is expected that there will be increased demands for health care for the aged and for certain types of housing. Expenditure on age-related services is expected to shift from the young to the old (QDLGP 1997).

Population density

Indicator

Population density

As well as the direct impacts of habitat clearance, human settlements generate impacts beyond their geographic limits due to the resources they use or the wastes they produce. While these impacts are complex (see box 'High-density or low-density settlement: which is the more sustainable?'), population density can be a valuable indicator of the local intensity and manageability of the environmental impacts associated with human settlements. This indicator can show where human impacts are likely to be concentrated and whether the pattern of settlement has the potential to be environmentally efficient.

Regional and local population densities vary widely, so average population density at the State level reveals little about individual settlements. Queensland's average population density is 1.97 people/km^2. Although Queensland has the largest habitable area of the Australian States, much of western Queensland is semi-arid with poor soils and is not suitable for sustaining a dense population. In fact, the average population density in inland Queensland is 0.4 people/km^2. Figure 8-8 shows population density in Queensland.

Dudley Nott

Residential townhouse and unit development, as in this area in Kangaroo Point in Brisbane shown in 1968 and 1998, increases the population density of city settlements.

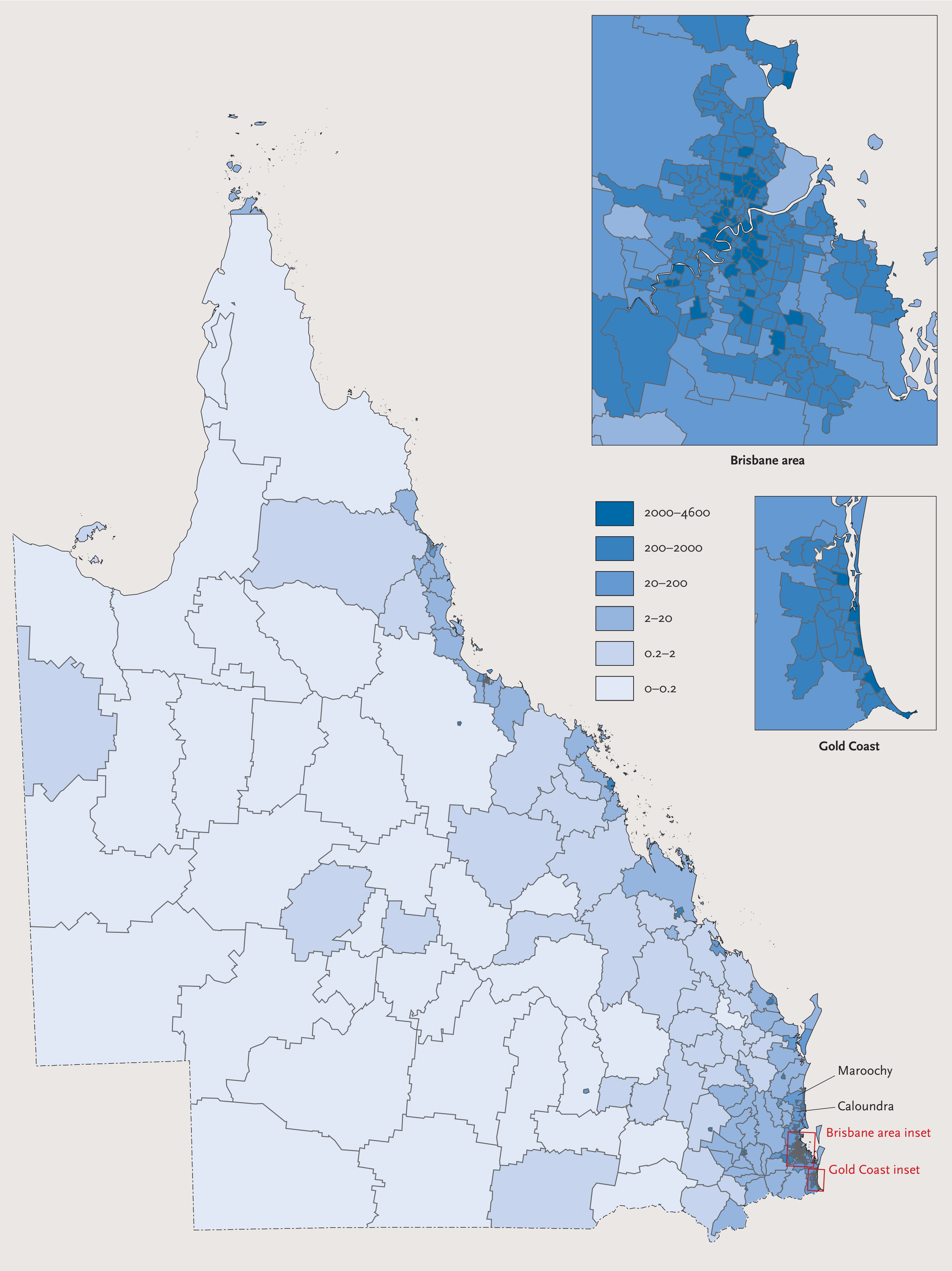


Figure 8-8 Population density (people/km²) in Queensland, 1996, by statistical local area
(Source: ABS)

High-density or low-density settlement: which is the more sustainable?

Two radically opposed schools of thought exist in town planning: one believes that high-density settlement is preferable, while the other supports low-density patterns of settlement.

High-density settlement

The first school argues that it is much cheaper for the community and better for the environment to concentrate population around transport and employment nodes and in areas where high-quality water, energy, waste disposal facilities and other amenities can be provided in a cost-effective manner.

Consider, for example, the costs of providing liquid waste disposal facilities as a function of the density of population. Providing reticulated sewerage is less likely to be economically feasible where urban population is of low density, as tends to occur in regions where minimum subdivisions apply, or where there is a preference for large house blocks. The further apart households are, the more kilometres of sewerage are required to connect them to a reticulated sewage disposal and treatment system. Average per capita treatment costs are reduced as dwelling density increases because, all other things being equal, less energy is used to pump sewage to the treatment facility. The economy of scale required to justify a sophisticated tertiary sewage treatment facility is also easier to achieve if the population is concentrated.

Some also argue that high-density housing has social amenity advantages. Access to services is generally agreed to be better than in low-density suburbs, particularly in low-income areas (SEAC 1996). In recent years there has been a trend to urban consolidation in cities such as Brisbane, where an increase in the number of inner-city dwellings has attracted more people back into the city centre. This has increased the number and viability of recreational amenities and generally raised property values, creating a challenge for providers of affordable housing.

Low-density settlement

The second school believes that high-density settlement serves to concentrate and amplify environmental impacts, encouraging lifestyles with a heavy use of resources. Reticulated sewerage systems are part of the problem. If houses were built with efficient greywater and sewage composting systems, and if industry recycled and treated all its own waste, there would be less need for expensive sewerage systems or ocean outfalls, and there would be far less waste and pollution. While the costs of providing amenities such as public transport and health services are likely to be greater for a low-density settlement, these can be outweighed by savings in other areas.

In terms of social amenities, Australians have shown a continuing strong preference for low-density living (NHS 1992), although this may be partly due to lack of attractive high-density choices in the past (SEAC 1996). Outer suburban householders often have resources such as private vehicles which enable them to overcome difficulties caused by distance from services (Maher 1995), although this itself has negative environmental and social impacts and is not true for low-income suburbs.

More than 80 percent of Queenslanders live in cities or agglomerations of urban areas which concentrate human resource consumption and waste production into relatively small areas. In 1996, the most densely populated part of Queensland, Brisbane City, had an average density of 715.4 people/km^2 and contained 24.5 percent of the State's population. While the average density for coastal Queensland is 7.2 people/km^2, average densities in Caloundra and Maroochy Shires have climbed in recent years to 59.4 and 92.8 people/km^2 respectively.

Although population densities are higher in coastal south-east Queensland than elsewhere in the State, they are still far lower than is typical of urban and suburban regions in the developed world. Indeed, low density of living is part of the lifestyle appeal of Queensland. While there is debate on the comparative environmental, social and economic impacts of high and low density (see box 'High-density or low-density settlement: which is the more sustainable?'), the dominant trend of low-density suburbs along the coast north and south of major cities may have significant environmental, economic and lifestyle costs if planning and management are inadequate.

Tourism

Queensland is a popular tourist destination because of its climate and abundance of natural attractions.

In 1996–97, tourism accounted for almost $6 billion in expenditure, or 7.3 percent of the Gross State Product. Expenditure has been growing at an average annual rate of 10.4 percent since 1982 (ABS 1999). Perhaps more than any other industry, tourism benefits regional Queensland, complementing 'traditional' industries and diversifying the economic base (QTTC 1998a).

In environmental terms, tourism can be both a benefit and a pressure. The economic value of tourism can provide an incentive for conservation and environment protection, increased understanding of other cultures and preservation of cultural and natural heritage.

On the other hand, tourists exert significant direct pressure on natural environments, urban facilities and resources. An indirect pressure of tourism is the encouragement of development in sensitive areas. For example, in recent years several controversial developments have been undertaken in or adjacent to the ecologically sensitive Great Barrier Reef Marine Park. Tourism development has gone hand in hand with urbanisation, as can be seen on the Gold Coast and the Sunshine Coast and in developing tourism centres such as

Coastal development as a consequence of tourism (as here on the Gold Coast) places increasing pressures on sensitive inshore environments.

Table 8-3 Queensland tourism visitors and visitor nights by origin, 1995–96 and 1996–97

Origin	Visitors ('000)			Visitor nights ('000)		
	1995–96	1996–97	Change (%)	1995–96	1996–97	Change (%)
Queensland	3 363	3 771	12	12 876	12 395	–4
Interstate	2 188	2 556	17	16 115	17 606	9
International	1 430	1 483	4	9 313	9 560	3
Total	**6 981**	**7 810**	**12**	**38 303**	**39 561**	**3**

(Source: QTTC 1998b)

Table 8-4 Queensland tourism regional destinations, visitors and visitor nights, 1995–96 and 1996–97

Destination	Visitors ('000)			Visitor nights ('000)		
	1995–96	1996–97	Change (%)	1995–96	1996–97	Change (%)
Gold Coast	2 122	2 321	9	10 656	11 286	6
Brisbane	1 511	1 592	5	4 746	4 586	–3
Sunshine Coast	1 412	1 302	–8	6 147	6 173	0
Wide Bay–Burnett	776	829	7	2 503	2 634	5
Fitzroy	603	769	28	1 782	1 997	12
Mackay	382	387	1	1 006	1 034	3
Whitsundays	323	342	6	1 541	1 563	1
Northern	544	593	9	1 767	1 742	–1
Far North	1 278	1 408	10	6 491	6 693	3
Darling Downs	377	488	29	839	940	12
Western Queensland	196	323	65	826	914	11
Total	**6 981**	**7 810**	**12**	**38 303**	**39 561**	**3**

(Source: QTTC 1998b)

Port Douglas. Like urbanisation, tourism places pressure on prime agricultural land. For example, pressure to rezone canegrowing land in Douglas Shire to supply Port Douglas' residential and tourism market could threaten the viability of the local sugar industry.

The following indicators show the increasing size of the tourism sector, and its base in the natural environment.

Growth in tourism

Indicators

Visitor numbers and nights

Visitor beds and occupancy rates

Short-term movement statistics over recent years reveal a boom in Queensland tourism. Table 8-3 shows data for visitors and visitor nights for the years 1995–96 and 1996–97. Visitor numbers increased by about 12 percent and visitor nights in commercial accommodation increased by 3 percent. The strongest growth was in visitors from interstate, with increases of 17 percent in visitors and 9 percent in visitor nights. The number of overseas visitors increased from about 400 000 in 1984 to about 1.5 million in 1996–97. The Asian economic downturn may have some impact on these figures in the late 1990s. There was a 21 percent drop in short-term airport arrivals into Australia from Asia in the ten months to October 1998 compared with the same period in 1997, contributing to a decline of 3.9 percent in figures for arrivals from all countries (QTTC, unpub. 1999).

Table 8-4 gives a regional breakdown of number of visitors and visitor nights. It shows that increasing numbers of visitors are being attracted to outback Queensland and to heritage sites in urban areas as well as to the traditional coastal holiday destinations.

The growth in facilities for tourists and the implication for demand for land and other resources can also be seen in trends in visitor beds (table 8-5). From 1996 to 1997, the stock of hotel/motel beds grew by 7 percent, unit beds by 4 percent and hostel beds by 6 percent. This growth is slightly offset by decreased overall occupancy rates in the same period (ABS 1999).

Nature-based tourism

Indicator

Proportion of visitors undertaking nature-based activities

As well as placing increased pressure on urban facilities, tourists place pressure on the State's natural resources, particularly national parks and marine parks. Understandably, tourists flock to visit natural attractions such as the Daintree rainforest, the Great Barrier Reef, and the islands and beaches.

A significant number of visitors, particularly international visitors, identify natural features as attracting them to Queensland and undertake nature-based activities during their visit. In 1994,

Table 8-5 Visitor beds and occupancy rates, Queensland, 1996 and 1997

Year	Licensed hotels with facilities	Motels and guesthouses with facilities	Caravan parks	Holiday flats, units and houses	Visitor hostels
			No. of beds		
1996	64 096	73 082	55 360	82 271	9 681
1997	67 635	79 136	54 524	85 523	10 294
		Room occupancy rate (%) — bed occupancy rate (%)			
1996	62 — 38	60 — 35	46 — na	60 — na	na — 52
1997	61 — 37	59 — 34	46 — na	58 — na	na — 53

(Source: ABS 1999)

Springbrook National Park. The number of visitors to natural attractions is increasing, especially in areas close to major urban centres.

13 percent of visitors to Australia aged 15 and over reported having undertaken a bushwalk, 12 percent went coral viewing, 11 percent undertook rainforest walks, 2 percent undertook outback safari tours, 50 percent reported having visited national or State parks, reserves or caves, and 8 percent visited Aboriginal sites (DTSBI 1997a). Queensland's terrestrial and island national parks attract 12.5 million visitor days per year.

In 1999 about 176 tour operators and 40 resorts depend on national parks for much of their business. These businesses directly support about 6000 jobs. The terrestrial parks currently attracting the most visitors on commercial tours are in the Wet Tropics World Heritage Area, the Great Sandy region and south-east Queensland. Significant potential exists for expansion of the industry outside these areas as the current distribution pattern reflects the availability of tours.

Cruises to the Great Barrier Reef for snorkelling, diving, sailing and fishing are a significant component of Queensland's nature-based tourism industry. Approximately 1.6 million person days per year of trips on commercial vessels are made. A large number of operators have permits to undertake tourism activities within the Great Barrier Reef Marine Park; more than 750 operators were active in 1996 (QTTC).

These uses of Queensland's natural attractions contribute strongly to the State's economy. A recent study on economic values of tourism and recreation visits to national parks found that visitors spend more than $600 million in association with their visits. This has a total direct and indirect output effect in the Queensland economy of about $1.2 billion (Kinhill Economics 1998). Overseas visitors undertaking nature-based activities tend to spend more on their trips to Australia than visitors undertaking other activities (Blamey 1995).

The recent growth in 'ecotourism' operations reflects the increased demand for nature-based activities as well as the desire to minimise the environmental pressures of tourism (see 'Response', this chapter).

TRANSPORT

While essential to Queensland's economy, transport in human settlements places a major pressure on the environment. The impacts of the transport system are wide-ranging and result from building and maintaining transport facilities as well as from transport operations themselves. While most forms of motorised transport have environmental impacts, the increasing distances travelled by private vehicles are the major concern. In Queensland cities, motor vehicles are the main source of noise and air pollution, affecting human health and wellbeing (see chapter 2, 'Atmosphere'). Transport is responsible for a significant proportion of total energy use (see chapter 6, 'Energy resources'). Loss or deterioration of green space and other public areas, loss of pedestrian access and social isolation have also been observed as consequences of the increasing use of private vehicles in cities. The major impacts of transport are summarised in table 8-6.

Table 8-6 Major impacts of transport on the environment

Transport mode	Air quality impacts	Waste impacts	Social impacts	Other environmental impacts
Road	CO_2, CO, NO_x, non-methane VOC, lead and particulate emissions	Waste oils, vehicle bodies and parts, tyres and batteries	Death and injury from accidents, traffic noise, traffic congestion, urban sprawl, loss of community	Wildlife habitat loss and fragmentation, depletion of land resources, risk associated with transport of hazardous materials, urban stormwater pollution, impacts of off-road vehicles
Rail	CO_2, CO and NO_x emissions	Abandoned infrastructure and rolling stock	Death and injury from accidents, noise and vibration from terminals and along lines	Wildlife habitat loss and fragmentation, depletion of land resources, risk associated with transport of hazardous materials
Shipping	CO_2, CO and NO_x emissions	Scrapped vessels and craft	Death and injury from accidents	Risk associated with transport of hazardous materials, oil spills, ballast water discharges, dredging and dredge-spoil, destruction of marine life, marine debris
Air	CO_2, CO and NO_x emissions	Scrapped aircraft, dumped fuel	Death and injury from accidents, aircraft noise pollution, congestion on routes to airports	Depletion of land resources used for infrastructure, modification of watertables and river courses in airport construction

(Sources: ABS 1997b; OECD 1988)

Road transport

Indicators

Number of motor vehicles by population

Distance travelled

Distance travelled by type of vehicle

Average trip length

Distance travelled to work or study

Average age of vehicle fleet

Fuel consumption

Road vehicle stock by fuel type

Indicators of road vehicle pressures on human settlements include distance travelled. The level of impacts of transport use is determined also by the type of fuel used and the age and condition of vehicles. The pattern of driving is significant: short trips are less fuel-economical and have proportionally higher emissions. Use of motor vehicles for travel to work or study exacerbates impacts during peak hours.

Vehicle ownership

At April 1996, 88 percent of Queensland households had some kind of motor vehicle; 42 percent had one, 34 percent had two and 12 percent had three or more (ABS 1996a). At 30 October 1997, 2 065 517 motor vehicles were registered in Queensland. This represented 627 vehicles for every 1000 people, a significant increase from 485 in 1976 (ABS 1998b).

Distance travelled

In 1995, Queensland road vehicles travelled an estimated 34 417 million kilometres, a 38 percent increase on the total distance travelled in 1988 (ABS 1997b). Passenger vehicles accounted for the vast majority of kilometres travelled (72 percent in 1995). Light commercial vehicles accounted for 19 percent (figure 8-9). The total distance travelled by these vehicle types increased by 38 percent and 44 percent respectively between 1988 and 1995.

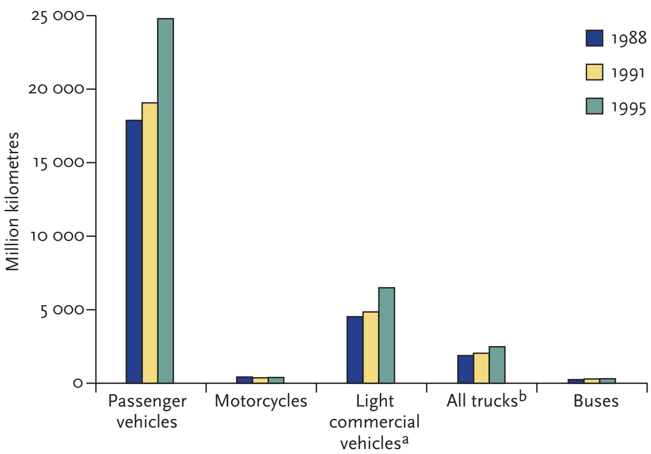


Figure 8-9 Total distance travelled (million kilometres) by type of vehicle in Queensland, 1988–95

[a]In 1991, this category was broadened from utilities and panel vans only (the 1988 definition) to include light commercial vehicles (previously classified under rigid trucks). [b]'All trucks' includes rigid trucks, articulated trucks and other truck types.

(Source: ABS 1997b)

Table 8-7 Average annual distance ('000 kilometres) travelled by type of vehicle in Queensland and Australia

Type of vehicle	Queensland Year to 30 Sept. 1988	Queensland Year to 30 Sept. 1991	Queensland Year to 30 Sept. 1995	Australia Year to 30 Sept. 1995
Passenger vehicles	15.4	15.0	16.3	14.4
Motorcycles	7.1	6.7	5.9	5.2
Light commercial vehicles*	17.5	16.9	19.2	17.7
Rigid trucks	18.6	20.3	21.9	20.0
Articulated trucks	75.6	79.7	92.5	87.9
Other truck types	12.3	19.8	19.4	15.9
Buses	34.0	34.7	34.0	32.5
All vehicles	**16.0**	**15.7**	**17.1**	**15.2**

*In 1991, this category was broadened from utilities and panel vans only (the 1988 definition) to include light commercial vehicles (previously classified under 'Rigid trucks').

(Source: ABS 1997b)

The increase in number of vehicles on the road accounts for some of the increase in total distance travelled, but average distance per vehicle has also increased for all vehicle types except buses and motor cycles. The average distance travelled by private vehicles increased by 5.8 percent between 1988 and 1995. The average annual distance travelled by both private and commercial vehicle types was higher in Queensland than nationally in 1995 (table 8-7) (ABS 1997b).

The reasons for increasing private vehicle use are complex: they include the preference for the privacy, convenience and personal safety of private vehicles and the prevalence of low-density housing. Sprawling, low-density cities increase the need for mobility and make it difficult to provide efficient, effective and affordable public transport services (see box 'Why urban sprawl can create transport problems'). In the past, governments tended to invest in roads rather than in public transport systems, resulting in a patchy public transport network with variable access and availability. New suburbs have been planned on the assumption that private vehicles will continue to be the dominant mode of transport into the foreseeable future.

Freeways can reduce commuting times for some road users but can encourage private vehicle use, leading to increases in congestion, travel time, and noise and air pollution impacts for inner urban residents.

Most cities experience travel peaks twice daily, at start and close of business. The difference between transporting 50 people between points A and B by a train or bus and transporting 50 people between the same points by 50 private vehicles is significant in terms of environmental and social impacts. The private transport method typically causes the volume of traffic to rise as much as 80 percent above average for relatively short periods at the beginning and end of the working day, costing more money, using more energy, causing more air and noise pollution and more road congestion, and requiring up to 30 times more space in road use and parking to achieve the same result. Part of the problem is that each individual wishing to travel has a different set of points A and B. Connecting all sets of points cost-effectively and time-effectively is very difficult.

To be viable, a public transport service must carry consistent numbers of passengers at a convenient frequency and not take significantly longer than alternative means of undertaking the same journey. Meeting these criteria is difficult in a sprawling city. Passengers must travel by some private means to a small number of transit stations and make many connections, or the transit service must have a large number of stops and follow a circuitous route. Either option results in longer travel times and inconvenience.

Transport problems can be examined by comparing a 'transit city' and an 'automobile city'. These cities may have the same number of people travelling to work each day, the same average population density and the same amount of money available to spend on public transport services. The pattern of land use, however, is very different. Zurich, in Europe, typifies the transit city, where mass public transit is a way of life and many people do not own cars. Most Australian cities, including Brisbane, are automobile cities in which owning a car is the norm.

The transit city has been planned so that its homes (points A) and its workplaces (points B) are clustered tightly around train stations and other transit stops. While housing is medium to high density, the city has a large area of public green space and productive farmland. Most people live within an easy walk of a transit stop. In this type of city, the money available for public transport buys a comprehensive system.

In contrast, the automobile city has been allowed to sprawl. Numerous housing estates with large individual blocks of land have been established in areas remote from existing rail services. There is little public green space, and farmland has been subdivided for low-density housing development. Only a few people are within an easy walk of a transit stop. In this city, the amount of money which would provide an excellent public transport system in a transit city can buy only the most basic service. The system runs at a loss and requires heavy subsidies because the expensive facility is chronically under-used. The system runs to capacity only at peak hours because people who use it to commute between home and work still find a car essential for activities such as visiting, recreation and shopping.

If widely adopted, changes to working practices such as telecommuting (e.g. working from a base other than the office, using phones, faxes, computers and the Internet) or more flexible working hours could greatly reduce peak-hour traffic congestion.

If vehicle use continues to increase, congestion, pollution and noise problems will increase unless there are major technological advances. While wishing to continue using their private vehicles as their main form of transport, few Queenslanders want to live on a busy road, contend with heavy traffic, or spend more than 30 minutes travelling to work. Building freeways might reduce the commuting times of some road users (in the short term) but is likely to create congestion and increase travel time and noise and air pollution impacts for inner urban residents.

Average trip length

Data on the length and frequency of trips for the whole of the State are not available. However, data are available on travel to home and workplace or place of study, including travel by public and private transport. These trips account for about 25 percent of travel (table 8-8). In 1996, 55.2 percent of Queensland commuters travelled less than 13 km from their homes to their workplaces or educational institutions. About one-third travelled between 18 km and 50 km to get to their work or study destinations (ABS 1996b).

Table 8-8 Average distance ('000 km) travelled by purpose, year ending 30 September 1995

Purpose	Queensland	Australia
Business	16.9	15.5
To and from work	8.2	6.6
Private	8.3	8.0

(Source: ABS 1995a)

Vehicle trips on Brisbane's road system are increasing at about 1.8 percent annually. The number of commuters from surrounding cities and shires is estimated at 90 000 currently and is predicted to rise to about 200 000 by 2011.

Information available for south-east Queensland indicates that most private vehicle trips are short ones. In 1992, an average household generated about 10 trips each day and almost 95 percent of these were local trips, under 20 km. Average trip length was 12.5 km. This is predicted to increase to 15 km due to the expansion of urban areas and the dominant pattern of detached housing with little mixing of non-residential land uses (QT 1997). Annual traffic count surveys carried out by Brisbane City Council show that vehicle trips on Brisbane's road system are increasing at about 1.8 percent annually. Not all of these vehicles belong to Brisbane residents; many — 90 000 currently, predicted to increase to approximately 200 000 by 2011 — commute from surrounding cities and shires (BCC 1998). South-east Queensland's dispersed settlement pattern exacerbates local traffic impacts in Brisbane.

Vehicle age

The estimated average age of Queensland vehicles is 10.5 years, compared with an Australian average of 10.7 years (table 8-9) (ABS 1998b). An older vehicle fleet is associated with higher levels of emissions. (See chapter 2, 'Atmosphere'.)

Fuel type and use

Pressures associated with fuel use relate to both type and volume of fuels consumed. Modern vehicles are significantly more fuel-efficient than their earlier counterparts so their impact per kilometre travelled is lower, but there are more vehicles on the roads. Impacts associated with various fuels are identified in chapter 2, 'Atmosphere'.

Between 1985 and 1996, consumption of petrol in Queensland increased by 24 percent (see chapter 6, 'Energy resources'). Diesel fuel consumption (for mining, electricity, construction and road transport) rose by almost 39 percent over the same period (ABARE 1997). The percentage of petrol-fuelled vehicles in Queensland decreased from 91 in 1986 to 87 in 1997. There was a corresponding increase in the percentage of diesel-fuelled vehicles, from 8 in 1986 to 10 in 1991 and 12 in 1997. Dual-fuel (petrol and LPG) vehicles were introduced in Queensland in the period and numbered 18 290 in 1997.

Despite changes in vehicle technology, and requirements that post-1986 petrol-fuelled vehicles use unleaded petrol, nearly one-third of Queensland drivers, slightly fewer than the national average, were still driving vehicles fuelled by leaded petrol in the year to April 1996. The volume of leaded petrol sold fell 47 percent between 1985 and 1996 (QT, unpub. 1999).

Tighter controls on diesel-fuelled vehicles, introduced in 1996, are intended to limit particle, hydrocarbon and nitrogen oxide emissions (see chapter 2, 'Atmosphere', for more detail).

Other modes of transport

Indicators

Mode of transport to work or study

Public transport patronage by mode

In Queensland, the percentage of people driving themselves to work is far greater than the percentage commuting by any other mode of transport and increased in the decade 1986–96 from 66.4 percent to 79.2 percent of commuters (see table 8-10). In 1996, of these, 81.8 percent were the sole occupants of the car. The next most frequently used mode, at 8.2 percent of travellers, was as a passenger in a car, truck or van (ABS 1996a). These figures show a higher motor vehicle dependency for Queenslanders than for Australians generally. In the period 1986–91, the proportion of people travelling to work by public transport remained well below 10 percent.

In south-east Queensland, however, the proportion of people travelling to work by public transport increased from 7.7 percent in 1991 to 8.2 percent in 1996. The average number of public transport trips made per person per year in Brisbane rose from 60 in 1993–94 to 62 in 1994–95 (QT 1998):

- About 43 million trips were made on Brisbane's bus system in 1993. The total rose to 48 million in 1995 then declined to 45 million in 1997. In 1995, Queensland buses travelled a total of 299 million kilometres and carried 163 million passengers. Route services accounted for 104 million passengers, travelling 101 million kilometres.
- Citytrain patronage in Brisbane decreased from 39 million trips in 1993 to 37 million in 1995 but grew to 39.2 million in 1996 and 41 million in 1997. In 1994–95, Queensland passenger trains travelled 8 842 153 kilometres and accounted for 37 921 000 passenger trips.

People give many reasons for not using public transport, but non-availability of service is the reason most often cited (table 8-11). Access to public transport is discussed in the 'State' section of this chapter.

In the decade 1986–96, the number of Queenslanders using options such as

Table 8-9 Average age in years of motor vehicle fleet, Australia, 1993 and 1997

State/Territory	Qld	NSW	Vic.	WA	SA	Tas.	Australia
1993	10.2	9.5	11.0	10.8	11.4	11.8	10.4
1997	10.5	9.7	11.4	11.0	12.2	12.4	10.7

(Source: ABS 1993, 1998b)

Table 8-10 Percentage of the population using various modes of transport, 1996

Main form of transport	To work or study*		To shop#
	Queensland	Australia	Australia
Car/truck/van as driver	79.2	77.6	86.4
Car/truck/van as passenger	8.2	7.2	included in above
Train	4.8	8.5	0.4
Bus	5.5	7.1	3.2
Motorcycle or motor scooter	2.0	1.3	0.2
Bicycle	3.6	2.8	0.3
Walking	6.4	6.3	8.3
Taxi	nr	nr	0.8
Tram	nr	nr	0.2
Other	1.2	2.0	0.2

*More than one transport mode can be specified. #Queensland data not reported. nr = not reported/relevant for this category
(Source: ABS 1996a)

Only 5.5 percent of Queenslanders use a bus to travel to work or study: most (79.2 percent) drive themselves.

Table 8-11 Reasons (by percentage) for not taking public transport to work/study and shopping, April 1996

Reason*	To work/study		To shop	
	Queensland	Australia	Queensland	Australia
No service available at all	48.7	36.3	46.9	37.1
Takes too long	14.8	26.2	9.7	14.1
Infrequency of service	13.0	13.8	12.9	11.5
Reliability of service	3.7	5.4	nr	nr
Carry tools/equipment	6.7	7.8	nr	nr
Vehicle needed during work hours	13.0	15.3	nr	nr
Vehicle needed before/after work/study	6.8	8.1	nr	nr
Use company/employer's car	4.8	5.9	nr	nr
Comfort/privacy	6.6	10.1	nr	nr
Concerned about own personal safety	3.7	3.9	nr	nr
Fares cost too much	3.2	3.7	2.6	2.2
Unable to carry shopping	nr	nr	33.8	44.1
Transport not within walking distance	nr	nr	5.9	7.1
Drove straight from work/university	nr	nr	5.4	5.2
Other	4.3	5.9	14.3	15.6

*More than one reason can be given. nr = not reported/relevant for this category
(Source: ABS 1996a)

cycling or walking to get to and from their work or places of study increased. The proportion, however, remained steady at about 10 percent. In 1996, 3.6 percent used a bicycle and 6.4 percent walked. Most said they walked or cycled because of proximity and nearly one-third reported walking or cycling for health/fitness reasons (ABS 1996a).

USE OF RESOURCES

Energy use

Indicators

Per capita energy use

Household energy use

Sources of hot water

Use of dwelling insulation

Energy use by population

Queensland's energy consumption is high by Australian and international standards. Per capita consumption of energy in Queensland showed a steady rise from 239 GJ/person in 1986–87 to 286.1 GJ/person in 1995–96. Comparative figures for 1995–96 show that Queensland has the third highest energy consumption per capita of the Australian States (figure 8-10) (ABARE 1997). This is due to the presence of energy-intensive industries and the transport costs incurred by a population dispersed across a large State. More details are available in chapter 6, 'Energy resources'.

Household energy use

Since 1984 household energy consumption has accounted for approximately 5 percent of energy used in Queensland (see chapter 6, 'Energy resources'). A major component of household energy use is for water heating. Although Queensland's climate is highly favourable for use of solar hot water, only 4.8 percent of households use such systems; 82 percent

Figure 8-10 Energy consumption, Australian States, 1995–96 (GJ/person)
(Source: ABARE 1997)

use mains-electric systems, which are among the least environmentally sustainable systems.

Housing design and insulation can reduce the amount of energy required to heat or cool a building. In 1994, more than 71.5 percent of Queensland homes had no insulation. Only 7.3 percent of homes had insulated walls and 26.1 percent had insulated roofs or ceilings (ABS 1996b). In 1999, increased air conditioning loads shifted peak electricity demand, previously associated with the use of heaters on winter evenings, to hot summer days for the first time in Queensland.

Water use

Indicators

Urban water use

Daily water use by population

Household water conservation practices

In 1993 Queensland's urban water use (not including industrial use) was estimated at 560 000 ML/year, about 17 percent of the State's total water use (see chapter 4, 'Inland waters').

Table 8-12 Water use for selected months in the Brisbane region (ML)

Local government	September 1995	September 1996	September 1997	February 1998
Brisbane City	16 533	16 731	14 344	12 670
Ipswich City	2 153	2 353	2 271	2 243
Logan City	2 574	2 197	2 051	1 899
Redcliffe City	420	107	155	214
Pine Rivers Shire	788	972	798	613
Caboolture Shire	790	747	838	522

This is equivalent to 177 000 litres per person per year, or nearly 500 litres per person per day (DNR 1997).

Table 8-12 compares water use in the Brisbane region for September from 1995 to 1997, and for February 1998 (a hot, relatively dry summer). An estimated 30 percent of this water was used for industry and 70 percent for domestic purposes. A trend towards less overall use of water is evident, despite increasing population. Water meters have been used in Brisbane City since July 1997 and have been associated with the decline in consumption, although a declining water use trend is also evident in Pine Rivers Shire, which does not have meters.

On a less positive note, ABS surveys of households indicate that the number of Queensland households which did not take any steps to conserve water increased from 47.2 percent in 1994 to 52.5 percent in 1998 (ABS 1998c).

Total resource use

Indicator

Ecological footprint of Queenslanders

Various models are being developed to help estimate the extended environmental impacts of settlements. In natural ecosystems the population of a particular species that can be sustained without damaging ecosystem functions is termed the 'carrying capacity'. Applying this concept to human settlements is more difficult because their consumption requirements (including oil, minerals, timber and food) and the effects of their wastes (including greenhouse gases, ozone-depleting substances and hazardous materials) can reach well beyond the settlement boundaries.

A more promising indicator is the concept of the ecological footprint, defined as 'the ecological impact of cities, including the direct local effects and the indirect regional and global effects due to resources they use and wastes they produce' (SEAC 1996). The ecological footprint for Queenslanders has been calculated at 5.98 ha, compared with a global 'fair share' of 1.3 ha (see box 'The ecological footprint').

Another model being developed around the world for examining the sustainability of cities is the concept of 'urban metabolism'. This is an input–output model, which describes cities as a metabolic process in which there are inputs of people, services, resources and energy. These inputs are transformed into a distinctive quality of life; and people, activities, products and services generate wastes as outputs. Cities vary in the efficiency of this process, and improving efficiency will lead to more sustainable cities (Kuroda et al. 1993). The model has the advantage of emphasising the importance of behavioural and cultural aspects as well as physical solutions such as urban planning. The approach is being used in research for the development of regional planning strategies building on the Regional Framework for Growth Management for South East Queensland (QDHLGP 1995), discussed in the 'Response' section (Stimson 1998).

Waste

Indicators

Volume of liquid waste

Amount of solid waste

Amount of solid waste by source (municipal, commercial and industrial, building and demolition)

Amount and type of hazardous waste (household and industrial)

Waste is defined in the *Environmental Protection Act 1994* as 'any gas, liquid, solid or energy (or a combination of these) that is surplus to, or an unwanted by-product from, any industrial, commercial, domestic or other activity, whether or not it is of value'. Types of waste differ in the level of hazard they present. Hazard is assessed in terms of quantity and potential impact on human health and the environment. Small quantities of highly toxic waste can have a contaminating impact equivalent to that of large quantities of low-toxicity waste.

The volume of waste generated in Queensland constitutes a major pressure on the environment, particularly in and adjacent to major population centres. Disposal to landfill, the main domestic and commercial waste disposal method in Queensland, can result in the leaching of contaminants into soil and groundwater if the landfill is not properly designed and managed. Unwelcome concentrations of odours and gases, including methane from the decomposition of organic waste, can be emitted. Landfill sites occupy considerable, sometimes valuable, space and have significant impacts on land use and landscape. Landfill impacts are discussed in chapter 3, 'Land'.

Waste management hierarchy

The key to dealing with Queensland's waste problem is waste minimisation — avoiding or reducing waste at the beginning of the production cycle (QDEH 1994). In the hierarchy of waste management options the disposal of waste is the least preferred option:

- Avoid the production of waste.
- Reduce the volume of waste produced.
- Reuse as much waste as possible.
- Reprocess the waste as a raw material for another product.
- Reclaim the waste as a source of energy or other raw materials.
- Treat the waste to reduce the hazard from the waste.
- Dispose of the waste in the most environmentally appropriate manner.

The ecological footprint is the area of ecologically productive land needed to produce the natural resources that the population consumes and to assimilate the waste that the population generates (Wackernagel et al. 1993). The ecological footprint includes not only the land area consumed directly by the population in question, but also land appropriated from other regions and countries through the consumption of imported goods. By comparing the ecological footprint of a population with the land area available, the extent to which the population is living 'beyond its ecological means' for achieving long-term sustainability can be measured. For example, recent research shows that globally about 1.3 ha of land per capita are available, yet the world average ecological footprint is currently 1.8 ha per capita (not including sea area) (Wackernagel et al. 1997). This difference is referred to as an 'ecological deficit'. We are consuming resources at rates faster than they can regenerate — that is, the present global pattern of consumption is unsustainable.

Western countries, including Australia, contribute significantly to the ecological deficit through their energy-intensive, high-consumption lifestyles. The average Australian appropriates nearly 6 ha per capita in consumption of food, energy, goods and services (Simpson et al. 1998). This is many times more than the global 'fair share' of 1.3 ha per person and well above the world average.

The ecological footprint for Brisbane's total population is shown in figure 8-11. The ecological footprint for the typical Queenslander is shown in table 8-13, which lists consumption categories and land use categories.

The first of the land use categories, 'energy', is measured as the area of forest required to assimilate the carbon dioxide produced during the combustion of fossil fuel. The average Queenslander requires about 2.2 ha for this purpose. 'Degraded land' refers to land occupied by the built environment (roads, buildings etc.). Each Queensland resident appropriated, on average, 0.14 ha in 1991. The 'garden' land use category includes land used for growing fruits and vegetables and also land occupied by residential backyards, which together accounted for 0.03 ha of the average Queensland ecological footprint. The area required for crops for food, cotton, tobacco and alcohol was 0.42 ha per capita in 1991, while the area of pasture appropriated by the consumption of meat products and wool amounted to 2.61 ha per capita. The area of forest appropriated by the average Queenslander's consumption of paper (in the form of packaging, books, magazines etc.) and timber products in 1991 was 0.6 ha.

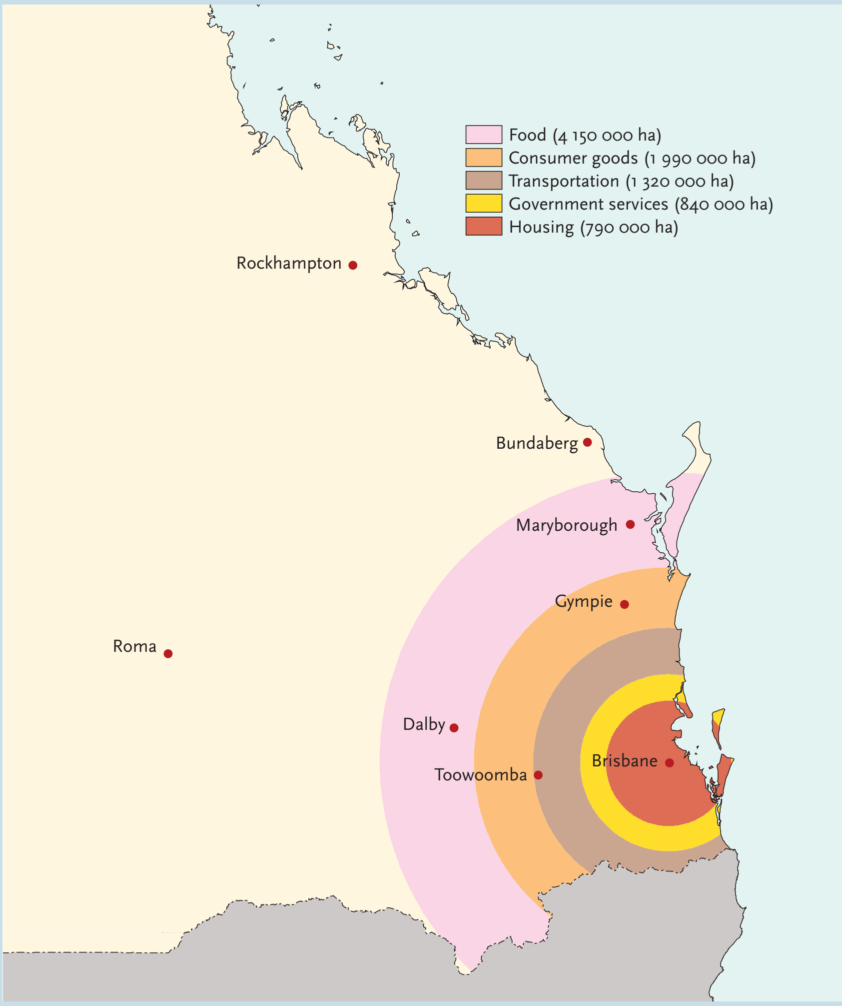


Figure 8-11 Estimated ecological footprint of Brisbane, 1992
(Source: Adapted from Simpson et al. 1998)

Table 8-13 The consumption–land use matrix for an average consumer in Queensland (ha/capita), 1991–92[a]

Consumption category	Energy	Degraded land	Garden	Crop	Pasture	Forest	Total
	Land use category						
Food	0.45		0.03	0.41	1.76	0.08	**2.73**
Housing	0.20	0.05	0.002	–	–	0.27	**0.52**
Transport	0.82	0.05	–	–	–	–	**0.87**
Consumer goods	0.18[b]	0.02	–	0.01	0.85	0.25	**1.31**
Government services	0.53	0.02	–	–	–	–	**0.55**
Total	**2.18**	**0.14**	**0.03**	**0.42**	**2.61**	**0.60**	**5.98**

[a]Estimates based on world productivity
[b]Excludes 0.3 ha for transport of consumer goods (already included in transport category)
(Source: Adapted from Simpson et al. 1998)

Table 8-14 Waste* disposal to landfill by local authorities, 1994–95

Local government area	Waste disposed to landfill (t)
Brisbane	650 000
Atherton	10 000
Belyando	2 500
Burdekin	33 000
Burke	850
Caboolture	77 400
Cardwell	9 000
Croydon	150
Gladstone	4 800
Hervey Bay	30 000
Jericho	300
Mareeba	2 400
Nanango	2 750
Pine Rivers	95 000
Redcliffe	32 000
Redlands	82 600
Taroom	400
Thuringowa	28 000
Tiaro	125
Total	**1 061 275**

*Includes municipal, commercial and industrial, and building and demolition waste

(Source: CRCWMPC 1997)

Other waste disposal options are not trouble-free. Incineration of waste, regulated in Queensland, can lead to emissions of toxic substances into the atmosphere and contaminated ashes which require appropriate management. Recycling produces the lowest load of emissions and conservation of resources, but can involve considerable sorting and treating so that pollutants are not transferred to the environment.

Liquid waste

Liquid waste volume data are not available for the whole of the State. In 1995, Brisbane generated 124 529 ML at a rate of 340 ML/day. Of this, 85.3 percent was domestic waste and 10.3 percent was trade wastes; both were discharged directly to sewers. About 4.4 percent was nonsewered waste discharged directly to waterways, while less than 0.03 percent comprised non-sewered recyclable liquids or hazardous

It is estimated that, on average, each Queenslander contributed 806 kg of waste to landfills in 1994–95.
(Source: CRCWMPC)

Table 8-15 Waste to landfill per capita, 1994–95

State/Territory	Kg per person per day
Queensland	2.21
New South Wales	2.31
Victoria	2.80
South Australia	2.41
Western Australia	3.45
Australian Capital Territory	2.41

(Source: CRCWMPC 1997)

Table 8-16 Solid waste by source for Brisbane, 1997–98

Source		’000 tonnes (est.)
Domestic	kerbside collection	225
	self-delivered to landfill/transfer station	88
	special kerbside clean-ups	2
Commercial and industrial		103
Council-generated waste		6
Disposal by charitable organisations		4
Special receivals (e.g. contaminated soil, odorous wastes, bonded asbestos)		7
Total waste to landfill		**436**
Recycled	kerbside collection	44
	self-delivered to landfill/transfer station	5
	green waste	38
Total recycled		**86**
Clean fill		**1000**
Construction and demolition		**200**

(Source: BCC, unpub. 1999)

industrial liquids. Total per capita liquid waste production rates equate to 230 L/person/day, or 83 760 L/person/year (BCC 1996).

For more details on industrial liquid wastes see chapter 4, ‘Inland waters’.

Solid waste

Comprehensive figures on waste generation are not available on a statewide basis. Table 8-14 gives information provided by 19 Queensland local authorities about waste disposal to landfill. These local government areas held a population of 1 317 110 in 1994–95, so average waste generation per capita was 806 kg in that year. Table 8-15 shows comparative figures for other States.

A Beverage Industry Environment Council audit in 1997 of households in eight LGAs in the Brisbane region found an average of 12.0 kg of waste per household per week compared with a national average of 15.7 kg. Householders diverted 17.8 percent of the waste to recycling, compared with a national average of 19.8 percent. The potential diversion rate, including green waste, is 64.8 percent (BIEC 1997).

Gold Coast City Council estimated that in 1997 it generated about 343 000 tonnes of waste to landfill, or about 1000 kg per resident. The higher figures compared with other parts of Queensland may be due to the high number of visitors to the area, who are not counted in the population calculation. Of the waste generated, nearly 70 percent is compostible and only 7 percent is recycled (GCCC 1998). Maroochy Shire sent about 75 000 tonnes (household and industrial waste) to disposal in 1997; this equates to about 670 kg per person (MSC 1998).

The waste stream is made up of wastes from domestic, commercial, industrial, building and demolition sources. Allocation of total waste to each of these sources is available for Brisbane for the 1997–98 year (table 8-16), but not for the whole of Queensland. Gold Coast City Council estimates that half its putrescible waste is commercial and half is household, and that non-putrescible waste is about 10–30 percent demolition materials, 40–60 percent dry industrial and 10–40 percent household waste (GCCC 1998). Maroochy Shire Council estimates that 47 percent of its waste to landfill is commercial or industrial in origin and 53 percent originates from householders (MSC 1998).

Hazardous waste

Hazardous wastes from industry are listed and regulated in the *Environmental Protection Regulation 1998* as 'regulated wastes'. Regulated wastes include a wide range of wastes, from acids to tyres. These wastes are regulated because they possess characteristics such as toxicity or flammability which can affect human health or the environment. Hazardous household waste materials include garden chemicals, paint products, metal and oven cleaners, fluorescent light tubes, car and other batteries, motor oil and pharmaceutical products.

Little information is available on the type and volume of household hazardous wastes in Queensland, and before 1997 this was also the case for hazardous/regulated industry wastes. In 1997 the Department of Environment and Heritage undertook a voluntary statewide survey and developed a predictive waste generation model to complete the picture for non-respondents and those not surveyed. The categories of waste are too numerous to reproduce here, but items of higher volume or of particular interest are shown in table 8-17 (EPA, in press).

Availability and awareness of services for disposal of household hazardous waste are discussed in the 'State' section of this chapter.

Litter

Long-term trends show an overall decrease in the amount of litter collected (DEH 1998). Nevertheless, the Keep Australia Beautiful Council reports a 20 percent increase in items of litter collected from 1997 to 1998 (KABCQ). Cigarette butts were the single most common litter item, accounting for close to half the litter stream (KAB 1996).

Litter continues to be a cost to the community, particularly in tourist areas. A 1998 survey of Queensland local councils found that 41 percent of councils each spent more than $25,000 annually on litter collection, and nine percent spent more than $80,000 (KABCQ 1998). Beach cleaning by Gold Coast City Council collects approximately 1500 tonnes of rubbish each year, mainly cigarette butts, paper, food wrappings, bottles and cans (GCCC 1998). More than 4000 cubic metres of litter were collected in a 1996–97 Brisbane roadside litter clean-up by Department of Main Roads contractors (on State and national roads only).

Table 8-17 Reported and predicted waste quantities for selected generic and regulated wastes, 1996–97

Waste	Units	Recorded quantities[a]	Predicted quantities[b]
Asbestos	tonnes	2 300	5 000
Alkalis and alkaline solutions	megalitres	1 100	4 800
Car batteries	number	5 400	370 000
Detergents	kilolitres	270	49 000
Dyes	litres	730	18 000
Lubricant grease wastes	tonnes	66	4 300
Paint wastes: solvent-based	tonnes	54	280
Paint wastes: water-based	tonnes	35	600
Pesticide wastes	kilolitres	100	670
Resins	kilolitres	670	1 000
Tyres	number	20 000	1 800 000

[a]Recorded quantities were obtained directly through survey. [b]Predicted quantities were calculated for the whole of the State using modelling.
(Source: EPA, in press)

SOCIOECONOMIC PRESSURES

Attitudes are an underlying factor in determining active responses to environmental issues. Not only do they underlie individual behaviours, but community consensus can also influence government priorities. Support for environmental goals also relies on sound economies which, in turn, rely on well-educated communities. Measures to protect the environment can cost substantial amounts to implement and maintain. Poorer communities may not be able to afford upgraded technology to manage the impacts of waste or transport, for example. Similarly, in poorer communities short-term economic goals can carry higher priority than long-term sustainability objectives in making environmental decisions such as whether to conserve ecosystems or harvest a resource.

Economic growth can be an environmental pressure, if it comes at the expense of ecologically sustainable activities. Queensland as a whole is well placed economically to allow strong commitment to sustainable development. Some local governments and communities, however, may need support to achieve that objective.

Attitudes to environmental issues

Indicators

Percentage of population concerned about the environment

Environmental concerns by issue

Most Queenslanders report concern about environmental problems. However, between 1992 and 1998 the number who reported that they were concerned about the environment decreased from 74.0 percent to 67.5 percent. This is a much steeper drop than that of Australia as a whole, where reported concern dropped from 74.8 percent to 71.1 percent (ABS 1998c).

Air pollution, ocean/sea pollution, freshwater pollution and destruction of trees/ecosystems were the environmental problems that most concerned Queensland residents in 1998 (see table 8-18). There has been some shift in the issues of concern: in 1992, garbage disposal, the ozone layer, toxic/chemical waste and destruction of animals/wildlife/extinction were raised as concerns by significantly more people than in 1998 (ABS 1998c).

Differences between responses of metropolitan residents and those of non-metropolitan residents are outlined in the 'State' section of this chapter.

Educational attainment

Indicator

Educational attainment

The proportion of Queenslanders aged 15 and over with basic vocational or higher-level qualifications increased from 24.1 percent in 1991 to 27.6 percent in 1996. The 1996 census revealed that 8.6 percent of Queenslanders aged 18 and over had a bachelor degree or higher (6 percent in 1991) compared with an Australian average of 10.4 percent (ABS 1998d). In 1996, 5.4 percent of the State's population had an undergraduate or associate diploma (4.9 percent in 1991), 11.3 percent had skilled vocational education qualifications (10.6 percent in 1991) and 2.3 percent had basic vocational education qualifications (2.6 percent in 1991) (ABS 1998e).

The proportion of Brisbane City residents with tertiary qualifications almost doubled between 1986 and 1996, increasing from 8 percent of those aged 15 and over to 15.1 percent, or 104 211 people. In 1996, 175 460 people — 5.2 percent of Queensland's population — were reported to be attending a technical and further education (TAFE) institution, or a university or other tertiary institution (ABS 1998e).

The retention rate for later years in schooling also gives an indication of rising education levels. In Queensland, the retention rate for Year 12 increased from 57.6 percent in 1986 to a peak of 85.0 percent in 1992, dropped to 76.3 percent in 1995, then increased to 77.9 percent in 1997 (ABS 1999).

Economic capacity

Indicators

Income

Median rent as a proportion of median income

Median housing loan repayment as a proportion of median income

Proportion of owner-occupied private dwellings

Income can be a useful indicator of a community's capacity to protect the environment. The weekly median income for a person aged 15 years or over in Queensland was assessed in the 1996 census at $293, compared with $251 in 1991. The average figure for Australia in 1996 was $310 (ABS 1998d).

Low income earners were found in all areas (figure 8-12). Relatively high proportions of low income earners were found in the Wide Bay–Burnett SD. Ten of 21 local government areas there recorded more than half the population receiving a low income.

In 1996, 1.5 percent of Queenslanders recorded incomes of more than $1,500 a week. High income earners were found in two of the State's mineral-rich regions. These are the area between Mount Isa and Richmond and Etheridge, and the area containing Belyando, Broadsound, Peak Downs, Nebo, Duaringa and Emerald Shires.

The median total household income in the 1996 census was found to be $618, compared with $527 in 1991 (ABS 1998e). In Brisbane, 19.6 percent of households reported a weekly income of more than $1,200, with 19.3 percent less than $300 (ABS 1997c).

The median rent payment for Queensland rose from $106 a week in 1991 to $125 in 1996, an increase of 17.6 percent. In the same period, median weekly personal income rose from $251 to $286, an increase of 14 percent. In 1996, median rent as a proportion of median income was 44 percent, an increase of 2 percent since 1991.

Between 1991 and 1996, the median monthly housing loan repayment for Queensland increased from $543 to $800 (a 47.3 percent increase). Median repayments ranged from $557 in Central West SD to $867 in Far North SD. Highest housing loan repayments were recorded in the Brisbane SLAs of Pullenvale ($1,421), Brookfield and Mount Coot-tha ($1,310), and Inner City, Mount Ommaney and Chandler ($1,300).

The proportion of owner-occupied private dwellings decreased from 40.5 percent in 1991 to 38.2 percent in 1996.

Table 8-18 Environmental concerns, Queensland, 1992 to 1998

Environmental concern	Percentage of respondents			
	1992	1994	1996	1998
Air pollution	36.9	29.2	25.9	24.8
Ocean/sea pollution	36.4	25.7	24.8	22.8
Freshwater pollution	31.2	22.5	23.0	22.1
Destruction of trees/ ecosystems	37.1	29.3	25.2	21.8
Garbage/rubbish disposal	21.7	14.7	10.6	11.7
Toxic/chemical waste	21.4	13.3	8.0	10.2
Ozone layer	26.2	15.6	9.4	10.1
Greenhouse effect	15.2	6.9	4.6	8.0
Destruction of animals/ wildlife/extinction	21.3	14.9	9.8	7.4
Soil erosion/salinity/land degradation	16.3	9.9	6.1	6.4
Conservation of resources	15.5	9.4	5.7	6.0
Use of pesticides	15.6	7.9	4.0	5.7
Urban development/ overpopulation*	15.0	8.7	7.0	5.5/2.8
Nuclear testing/weapons	14.5	6.4	6.3	5.3
Other pollution	15.1	9.7	7.9	4.3
Uranium mining/use/ radioactive materials	8.3	3.8	3.9	3.3
Other	6.5	7.0	5.6	3.8
No concerns	24.0	29.1	32.0	31.2
Don't know	1.9	2.4	1.3	2.1

Note: More than one concern can be specified. *In 1998 responses were reported in two categories: 'Irresponsible urban development' (5.5%) and 'Overpopulation' (2.8%).
(Source: ABS 1998c)

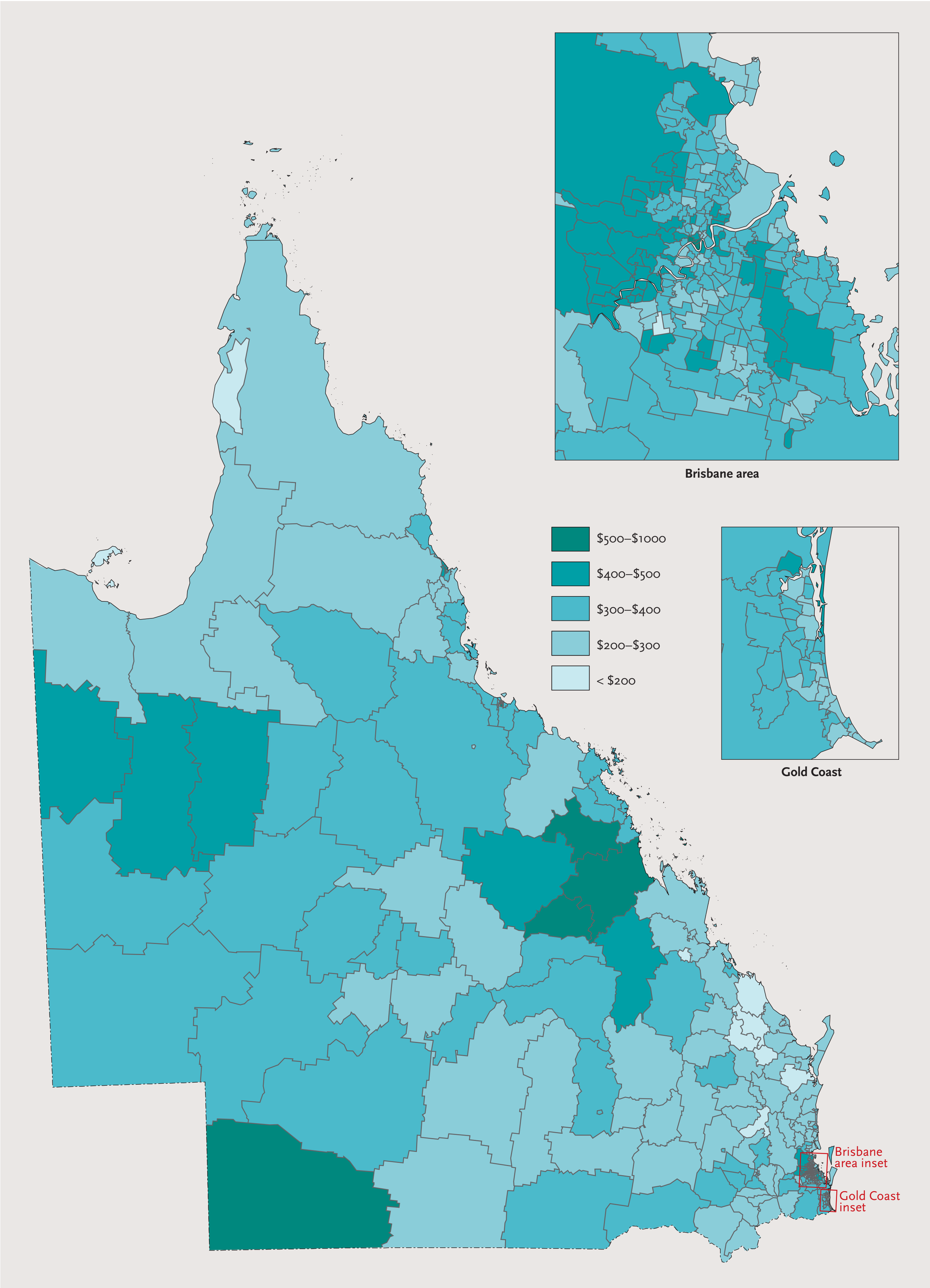
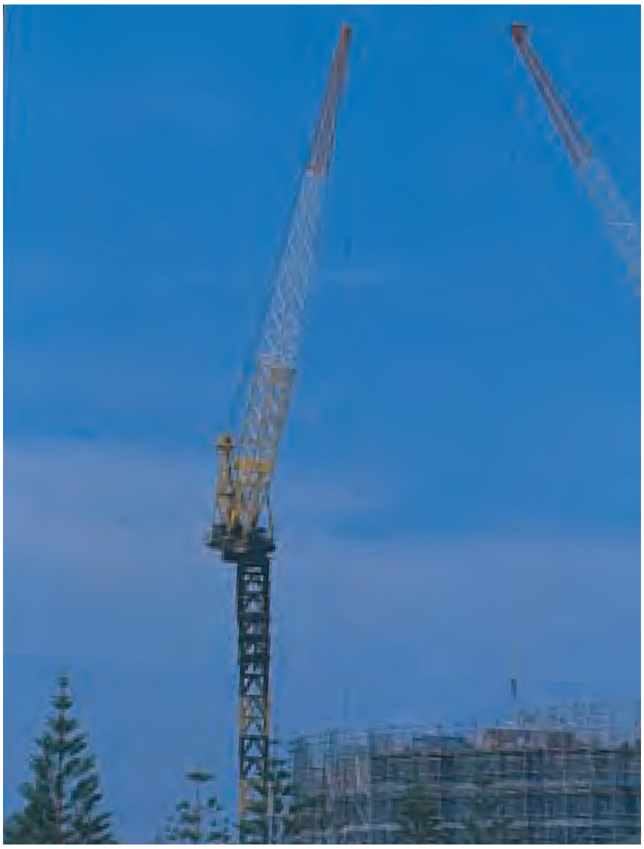


Figure 8-12 Median personal weekly income, Queensland, 1996, by statistical local area
(Source: ABS)



Economic growth places more demands on environmental resources, but can also provide increased capacity for environmental protection.

This was offset by marginal increases in the proportion of dwellings being purchased (up from 24.5 percent to 25.6 percent). Rentals accounted for 28.4 percent in 1991 and 32.1 percent in 1996 (ABS 1999).

In 1996, levels of home ownership varied widely across Queensland, ranging from 30.5 percent in North West SD to 47.6 percent in Wide Bay–Burnett SD. The highest proportions of owner-occupied dwellings were recorded in the SLAs of Perry (67.3 percent), Rochedale (63.6 percent), Bendemere (62.7 percent) and Chandler (61.6 percent).

High proportions of rented dwellings were recorded in the SDs of North West (42.9 percent), Far North (39.2 percent) and Mackay (37 percent). At the SLA level, Weipa (94.9 percent), Aurukun (81.5 percent) and Mornington (80.8 percent) recorded the highest proportions of rented dwellings (ABS).

Economic growth

Indicator

Forecast economic growth

Queensland continues to have a sound economy which supports community wealth and Australia's economic worth in the world sphere. Economic forecaster BIS Shrapnel estimates that Queensland will achieve 4.1 percent growth a year from 1997 to 2002, stronger than the forecast Australian average of 3.1 percent. The State's strong economic growth is attributed to expansion of the mining and services sectors, the export orientation of its industry and a strong phase of private business investment.

BIS Shrapnel forecasts that growth in Queensland will substantially outperform the national average in all 17 industry sectors over 1997–2002. The total value of manufacturing turnover for Queensland in 1995–96 was $28,976 million, an increase of 3.6 percent on the previous year, compared with the national average increase of just 2.1 percent. For the period 1990–91 to 1995–96, Queensland's production of manufactured goods grew by almost 22 percent, the highest growth rate of any State. In 1994–95, Queensland had a total farm turnover of almost $6,005 million, an increase of 19 percent over 1993–94. In the same year, Queensland farm businesses averaged a turnover of $265,800, significantly higher than the Australian average of $201,700 (DEDT 1997).

STATE

This section focuses on the condition of Queensland's settlements from an environmental rather than a socioeconomic perspective. People choose to live in urban environments because they value security, access to employment, shelter, health, safety and wellbeing. The reasons they choose to live in particular human settlements are more complex and harder to characterise, and can change over time. They include employment and family factors, climate, environment, lifestyle, community spirit and availability and quality of resources.

Environment aspects include:

- environmental health in terms of air, water and acoustic quality;
- the amount and accessibility of open space and other recreational resources;
- the nature and quality of the built environment;
- the quality and accessibility of environmental services such as transport, energy, water and waste disposal;
- levels of community health; and
- the nature and accessibility of socioeconomic facilities and human services.

Social and economic aspects are also strongly linked to environmental factors with respect to the 'livability' of the urban environment. Equity is important in large cities with areas of poor and disparate services. Some of these factors have been discussed above in 'Socioeconomic pressures'.

THE URBAN ENVIRONMENT

The concentration of people and their activities — transport, commerce and industry — within urban settlements means that these are generally the areas where the environment is most degraded and where media and public attention is focused. A national ABS survey in 1998 indicated that Australians in non-metropolitan areas were less likely to have concerns about the environment than people living in metropolitan areas (ABS 1998c). Table 8-19 lists environmental concerns of metropolitan and non-metropolitan residents and indicates higher levels of concern, in particular, about air and water pollution among urban residents and about land degradation among rural residents.

Table 8-19 Selected environmental concerns, metropolitan and non-metropolitan residents, Australia, 1998

Environmental concern	Percentage of respondents		
	Metropolitan areas	Non-metropolitan areas	Australia
Air pollution	36.9	23.9	32.2
Freshwater pollution	28.7	24.8	27.3
Ocean pollution	24.6	22.5	23.8
Destruction of trees/ ecosystems	21.9	21.7	21.8
Garbage/rubbish disposal	15.1	13.5	14.6
Ozone layer	13.4	13.2	13.4
Toxic/chemical waste	10.9	12.2	11.3
Greenhouse effect	11.4	10.1	10.9
Soil erosion/salinity/land degradation	8.5	12.2	9.8
Destruction of animals/ wildlife extinction	9.5	9.9	9.6
Use of pesticides	5.0	7.8	6.0
Irresponsible urban development	5.5	5.8	5.6
No concerns	25.8	29.0	26.9

Note: More than one concern can be specified.
(Source: Modified from ABS 1998c)

Dudley Nott

The Brisbane CBD in 1968 (left) and 1998 (right). Recreational facilities have replaced the commercial wharves.

Outdoor air, water and land quality

Outdoor air quality is an issue for human settlements because of the concentration of polluting activities: motor vehicles, household activities such as lawn mowing, and commercial and industrial activities. Potential air pollution problems in Queensland are limited, by world standards, by the dispersed population and the low number of industrial centres. Sites of major industrial activity are usually separated from the largest population centres, reducing the exposure of human populations to atmospheric pollutants. The most problematic areas are Queensland's major urban and industrial airsheds — south-east Queensland and Gladstone. Air quality issues in human settlements are discussed in detail in chapter 2, 'Atmosphere'.

Urban waterways are susceptible to degradation because of the high level of urban inputs, particularly stormwater and sewage. Most cities in Queensland are in coastal regions and thus suffer the accumulated impact of upstream inputs. In the south-east, where the State's human population is greatest, more than 40 sewage treatment plants discharge either directly or indirectly into Moreton Bay, and in an average year more than 650 000 tonnes of sediments are washed into the Brisbane River. This may be adversely affecting activities worth approximately $255 million in the catchment (commercial and recreational fishing, aquaculture and tourism) and the region's livability in terms of swimming, boating, fishing and waterside activities (BRMG 1998). Water quality issues for the State's human settlements are discussed in detail in chapter 4, 'Inland waters', and chapter 5, 'Coastal zone'.

There are some land contamination issues of significance to human settlements, the most prominent being contaminated sites. These are discussed in detail in chapter 3, 'Land'.

Three aspects of the physical environment of importance to urban residents not discussed elsewhere in this report are indoor air quality, noise and the provision of urban green space.

Indoor air quality

Indicator

Reported illness, irritation and allergic reactions relating to indoor air quality

Indoor air quality is an emerging environmental health issue in human settlements. The National Health and Medical Research Council defines indoor air as 'air within a building occupied for at least one hour by people of varying states of health'. The term is generally used to refer to air within homes, schools, restaurants and public places, but not to workplaces, where workers are covered by workplace health and safety legislation.

Although most people spend about 80 percent of their time indoors, and the quality of indoor air may be much lower than that of air outdoors, to date there have been few recorded data and little recognition by the community of health risks (SEAC 1996). While aggregated, quantitative data on reported illnesses, irritation and allergic reactions relating to indoor air quality are not available, commonly reported problems have been:

- fumes, offensive odours and irritation from volatile organic chemicals (VOCs) emitted by paints and formaldehyde, some building materials, floor coverings and furniture;
- illness, irritation and allergic reactions from microbial contamination in air-conditioning ducts and plant;
- illness, irritation and allergic reactions caused by environmental tobacco smoke, dust, and particles entering through air conditioning;
- health effects of carbon monoxide, carbon dioxide, nitrogen dioxide and polycyclic aromatic hydrocarbons from fuel combustion and motor vehicle exhausts;
- health effects of lead from deteriorating paints manufactured before 1970 and from motor vehicle exhausts; and
- long-term health effects of asbestos used as an insulation material.

Building methods, materials and design, ventilation, interior decoration, and household appliances and equipment are some of the factors affecting indoor air quality. Some emerging changes in lifestyle are likely to increase the incidence of reported indoor air pollution problems in Queensland. These include living in home units, closing of doors and windows to increase security, more filtered air ducting and air conditioning of enclosed areas, and use of electronic devices including laser printers, copiers and fax machines.

Noise pollution

Indicator

Number of noise complaints and the related sources of noise

Noise can be defined as unwanted sound. Unreasonable or excessive noise can have detrimental effects on health and amenity.

Transport and industry are sources of many community noise problems. However, noise associated with recreation (such as sporting events and concerts with amplified music), various residential pursuits (including keeping noisy pets, and operating swimming pool pumps and motor mowers) and domestic construction can also result in complaints.

A national study found that 22 percent of Queensland participants reported disturbance by noise at some time. The survey indicated that residents regarded noise pollution as one of the most serious forms of environmental pollution within their homes: traffic noise, barking dogs and motor mowers cause the most irritation (AEC 1988). A study in Brisbane from 1986 to 1988 indicated that residents were more concerned about noise pollution than any other form of urban pollution. Transport noise was most significant to 62 percent of respondents, followed by pet noise (15.3 percent) and garbage trucks (13.9 percent) (Duhs et al. 1989). A 1995 telephone survey by AGB McNair for Brisbane City Council indicated that noise was the environmental health issue of greatest concern to Brisbane residents (18 percent of unprompted responses, followed by 'barking dogs' at 9 percent) (BCC 1996).

Noise complaints give some indication of community concerns about noise, although not all those affected make a complaint (Duhs et al. 1989). Industrial and commercial noise is responsible for most environmental complaints to the Environmental Protection Agency across Queensland. In 1996–97, 809 (37 percent) of 2170 complaints received related to noise. In 1997–98, noise complaints accounted for

1399 (40 percent) of the total 3468 complaints. In the same year, 31 percent (2511) of the total 8047 complaints to local governments concerned noise, mostly non-industrial/commercial noise (up from 27 percent in 1996–97). Most noise complaints came from the densely populated areas of Gold Coast City (629), Brisbane City (1024), Cooloola Shire (162) and Logan City (164) (DoE 1997; DEH 1998).

In the past little consistent or broadscale noise monitoring has been undertaken in the State. Monitoring is generally limited to problem areas: for example, Gold Coast City Council reports that noise impacts associated with the Pacific Highway are above the Department of Main Roads guideline at some sites. The Department of Main Roads estimates that approximately 4000 residences are affected by excessive noise (GCCC 1998; Huson and Assoc. 1997; Rust PPK 1996).

Provision of urban green space

Indicators

Proportion of urban land conserved as green space

Proportion of remnant vegetation conserved in settled areas

Data on green space are not consistently available for urban settlements throughout the State. In Brisbane City the Council manages 10 166 ha of land, or about 9 per cent of the city's 114 500 ha (excluding Moreton Island), as park or natural-area reserve. This includes 2589 ha as open parkland, 87 ha as ornamental parkland, 1119 ha as sporting parkland and 6371 ha as urban nature parkland (BCC 1998).

Green space in human settlements is highly valued for social, recreational and health reasons.

Native vegetation in Brisbane covers approximately 29 750 ha, or 24 percent of the city. This includes bushland, wetland and riparian vegetation. The Commonwealth and State Governments own approximately 7000 ha, or 23 percent of this cover (BCC 1998).

Brisbane City Council can prevent clearing through Vegetation Protection Orders (VPOs), as part of a comprehensive bushland protection strategy. The program has proved effective in protecting large areas of significant vegetation in the city's outer fringes. Table 8-20 shows the area covered by VPOs. Note, however, that some VPOs protect vegetation only until a building or development application has been assessed.

Table 8-20 Area of significant vegetation protected by Vegetation Protection Orders, Brisbane

Year ending	Total area added each year (approx. ha)	Total area (approx. ha)
1990	0	0
1991	12 910	12 910
1992	190	13 100
1993	1 530	14 630
1994	1 030	15 660
1995	860	16 520
1996	580	17 100
1997	450	17 550
1998	700	18 250

(Source: BCC 1998)

ACCESS TO ENVIRONMENTAL SERVICES

Mains water

Indicators

Proportion of population with access to mains water

Satisfaction with quality of mains water

Most households throughout Queensland rely on mains/town water as their principal water supply (89.4 percent in 1998, below the national average of 92.8 percent). Rainwater tanks, the next most heavily used source of water, are found in 18.0 percent of households (ABS 1998c) (table 8-21). Although rainwater is usually of good quality, small-scale studies have found that problems can arise from contaminants such as pesticides on roofs and from the lack of regular cleaning or first-flush systems (NSW EPA and NSW Health 1996; Gee 1993). Of all Australian States, Queensland has the highest level of use of recycled water and greywater for use in gardens, although use is still very low compared with use of other water sources surveyed (ABS 1998c).

In March 1998, 64.2 percent of Queensland households reported being satisfied with their drinking water supply, slightly less than those satisfied Australia-wide (64.6 percent). The main problems reported by those who were dissatisfied were 'taste' (63.3 percent) and 'too much chlorine' (31.2 percent). Water filters for drinking water were used by 20.1 percent of households; the national average is 18.3 percent (ABS 1998c).

Access to transport

Indicators

Length of roads, railways and bikeways

Proportion of people reporting lack of public transport options

Proportion of households with access to public transport within 800 metres of home

Average speed of travel on roads

Access to economical, efficient and, increasingly, environmentally friendly transport is a major urban issue. Available

Table 8-21 Sources of water for various uses, Queensland and Australia, 1998

Water source	Source for all uses*		Main source for use in/for: Garden		Bathing/showering		Drinking	
	Qld	Aust.	Qld	Aust.	Qld	Aust.	Qld	Aust.
Mains/town	89.4	92.8	85.2	88.4	86.8	91.2	79.8	80.9
Rainwater tank	18.0	16.9	3.3	2.9	7.9	6.2	15.9	13.4
Bottled	9.5	11.5	nr	nr	nr	nr	3.6	5.1
Spring	0.1†	0.4	0.1†	0.1†	–	0.1†	0.1†	0.2†
Bore/well	8.3	5.3	6.4	4.9	4.5	1.6	nr	nr
River/creek/dam	4.4	3.6	3.2	2.9	0.6†	0.7	nr	nr
Recycled water/greywater	nr	nr	1.0†	0.4	nr	nr	nr	nr
Other	1.2	1.0	0.7†	0.5	0.2†	0.2†	0.6†	0.4

*More than one source can be specified. nr = not reported/relevant for this category. †Subject to sampling variability too high for most practical purposes (i.e. relative standard error greater than 25 percent). – = nil or rounded to zero.
(Source: ABS 1998c)

data are dispersed, but there are indications that access to public transport in Queensland is limited.

Between 1986 and 1996, the total length of usable railway track in Queensland decreased from 10 225 km to 9458 km due to the closure of some country lines. The total length of bikeways in Brisbane rose from 310 km in 1993 to 380 km in 1997. The length of roads open to the public in Queensland was 175 020 km in 1993 (35.2 percent sealed) and 177 017 km in 1997 (37.4 percent sealed) (ABS 1995b, 1999).

In April 1996, 28.3 percent of all Queenslanders reported that they had no public transport options available to them. This is the lowest rate of reported public transport availability in Australia. Of those who did not take public transport to work or study, nearly half (48.7 percent) said the reason was that no service was available (table 8-11) (ABS 1996a).

The Government's 'Shaping Up' Planning Guidelines (see 'State Government initiatives' below) state that, ideally, 90 percent of potential passengers should live within 400 metres of their nearest bus stop for peak period services or within 800 metres of rail services. Modelling shows that wide variations exist within the south-east Queensland region. Brisbane City Council nearly reaches the 90 percent service provision goal, with 88 percent total coverage meeting the 400 metre standard. For the region as a whole, however, the model shows that 90 percent of potential passengers are not covered until a threshold distance of approximately 7 km is reached — far from the stated ideal targets (Stimson 1998).

The level of service provided by roads and by public transport is also an issue. Average speed of travel at morning peak hours on Brisbane's major arterial roads increased from about 32 km/h in 1993 to more than 35 km/h in 1995, an indicator of improved road services and decreased congestion. However, it fell sharply to 29.9 km/h in 1996 and then to 29.7 km/h in 1997 (QT, unpub. 1999). Preliminary data show that peak hour travel times increased by 5.5 percent between 1995 and 1997 and general travel time increased by 3.5 percent (Abacus Surveys 1997). Citytrain, the passenger rail travel service in Queensland's south-east, has improved its on-time running services dramatically, from 58 percent within three minutes of scheduled time over a 24-hour period in 1995–96 to 95 percent in 1999 after the introduction of new timetables (ABS 1999).

Access to housing

Indicators

Housing stock

Occupancy rates

Number of retirement dwellings and proportion of total dwellings

Housing stock

The stock of private dwellings in Queensland grew by 208 784 between 1991 and 1996, an average annual increase of 3.5 percent. The number of detached houses grew at an average annual rate of 2.9 percent and other dwellings at 4.0 percent (QDLGP 1997). This rate exceeded the population growth rate (2.4 percent a year). This may indicate lower densities and/or occupancy rates: more dwellings (9.2 percent) were vacant on census night in 1996 than in 1991 (8.9 percent) (QDLGP 1997).

The number of houses counted in the 1996 census was 135 688 more than in the 1991 census, an average annual growth rate of 2.9 percent. Although growth in houses was lower than growth in other types of dwellings (mainly units, flats and caravans), houses continued to account for more than three-quarters of the dwelling stock (76.3 percent in 1996, down from 78.4 percent in 1991) (QDLGP 1997).

Occupancy rates

On average, occupancy rates in Queensland, as in Australia as a whole, continue to decline. Between 1986 and 1996, occupancy rates for detached houses fell from an average of 3.1 people/dwelling to 2.9 people/dwelling. For all other dwellings, occupancy rates fell from an average of 2.1 people/dwelling to 1.8. The highest occupancy rates are recorded in the remote north and north-west regions, the northern coastal regions, much of the central Queensland coalmining region and selected LGAs in the south-east of the State (Logan, Pine Rivers, Murgon, Cambooya and Jondaryan) (QDLGP 1997).

Retirement dwellings

In 1996, 9524 occupied dwellings were devoted to self-care of the retired or aged. This is just 0.8 percent of total occupied dwellings in Queensland. The aged (who represent 11.2

percent of the population) are housed mainly in other types of accommodation. The available self-care units are concentrated in the south-east — in Brisbane City (25.2 percent), Gold Coast City (15.5 percent) and Maroochy Shire (10.6 percent) (QDLGP 1997).

Household access to recycling and disposal services

Indicators

Percentage of households with access to recycling services

Percentage of households with access to hazardous waste disposal services

In Queensland, local governments provide regular collection services for household waste. However, two particular household waste collection services are less widely available: recycling and hazardous waste disposal services.

Recycling facilities

Householders in Queensland reported in 1996 that they recycle through kerbside collection (57.7 percent of households), depositing recyclable materials at central collection points (77.1 percent), or mulching with or composting organic materials (57.9 percent). Recyclable materials are also taken to designated areas at waste transfer stations or landfills (9.3 percent) (ABS 1996a).

In 1997, an estimated 87.3 percent of Queensland households had access to recycling facilities of some sort. Almost 75 percent of households had access to a regular kerbside collection (QRAC 1997), a significant increase from the 31.1 percent estimated in 1993 (CEPA 1994). However, there appears to be some lack of awareness of these services. In the 1996 survey, the main reason cited for not recycling was 'not enough recyclable materials' (42.4 percent of respondents); other reasons included lack of, inadequacy of and uncertainty about facilities (32.8, 7.3 and 4.2 percent respectively) (ABS 1996a).

Rates of recycling are affected by service frequency and bin size. A national audit found that the highest diversion rates are achieved where councils provide two 55-litre bins per household and the lowest where councils provide 240-litre bins. The most common bin size in the LGAs audited in Queensland (those in the south-east of the State) is 240 litres.

A high percentage of Queensland households recycle waste material.

Councils that conduct weekly recycling services achieve a rate of diversion to recycling of 28.2 percent and an average weight of 3.8 kg of recyclables collected. Councils that conduct fortnightly services achieve a diversion rate of 17.8 percent and an average weight of 2.9 kg (BIEC 1997).

Hazardous waste disposal services

In March 1996 only 29.6 percent of Queensland households surveyed by the ABS reported knowing of available facilities for disposing of hazardous waste materials (garden chemicals, paint products, metal and oven cleaners, fluorescent light tubes, car and other batteries, motor oil and pharmaceutical products) (ABS 1996a). This lack of awareness precludes environmentally responsible hazardous waste disposal.

Queensland-specific figures are not available, but Australia-wide figures indicate that in 1996 most householders disposed of hazardous waste with the usual domestic waste collection (61.9 percent of respondents), an inappropriate disposal method. A quarter of households disposed of, and in some cases recycled, hazardous waste products by taking them to a shop or business outlet. Table 8-22 shows other disposal methods and indicates that most householders lack awareness of the appropriate ways to dispose of hazardous wastes (ABS 1996a).

Table 8-22 Disposal methods for hazardous waste, Australia, March 1996

Disposal method	Percentage of households
With usual domestic waste collection	61.9
Special service from house	6.2
Landfill — general area	11.0
Landfill — special area	12.0
Collection point other than landfill	6.6
Poured down the drain	11.0
Taken to a business/shop	24.9
Buried	2.3
Other	6.6

(Source: ABS 1996a)

POPULATION HEALTH

Social, economic, genetic, lifestyle and environmental factors influence population health. It is not always possible to demonstrate cause-and-effect relationships, and available data on health indicators rarely differentiate between environmental, social or economic backgrounds. Nevertheless, indicators of population health can point to significant environmental factors.

Life expectancy and mortality

Indicators

Life expectancy

Mortality rates

Life expectancy, or the number of years that a person can expect to live (based on death rates of the population), is often used to indicate the health status of communities (table 8-23). Life expectancy in Queensland has risen significantly

Table 8-23 Mortality and life expectancy, Queensland, 1976, 1986, 1996 and 1997

Indicator	1976		1986		1996		1997	
	Males	Females	Males	Females	Males	Females	Males	Females
Expected years of life at birth	69.0	76.1	72.7	79.3	75.1	80.9	75.4	81.3
Standardised death rate	12.8	7.5	9.6	5.7	8.3	5.0	7.8	4.8
Median age at death	68.4	75.2	70.6	76.9	73.2	80.1	73.3	80.4

(Sources: ABS 1996c, 1997d, 1998a, 1999)

Table 8-24 Principal causes of death, Queensland, 1995 and 1996

Underlying cause	Percentage of total deaths			
	1995		1996	
	Males	Females	Males	Females
Heart disease	28.9	30.8	28.4	29.8
Cancer	29.0	23.8	29.1	24.7
Cerebrovascular disease	7.3	13.2	7.5	12.5
Respiratory system disease	8.0	6.4	8.2	7.4
External causes	10.2	5.1	9.6	4.5

(Sources: ABS 1998a, 1999)

in the past twenty years. Between 1976 and 1997, life expectancy at birth increased by 6.4 years for males and by 5.2 years for females.

Standardised death rates for all persons have fallen from 9.6 in 1976 to 6.2 in 1997. (Standardised rates are the overall death rate that would have prevailed in a standard population if it had experienced at each age the death rates of the population being studied. The standard population is all persons in the 1991 Australian population.) The greatest reductions in death rates have been at the very youngest ages: in 1997 the infant mortality rate (that is, deaths of children under one year per 1000 live births) was 5.8; in 1976 it was 15.0 (ABS 1996c, 1997d).

Approximately one-third of all deaths in 1995 and 1996 were caused by heart disease and one-quarter by cancer (table 8-24). Lifestyle, genetic and dietary factors contribute significantly to these deaths. The causes of death vary with sex and age: for example, death by external causes is much more prevalent for males than for females, and the highest rate is for males aged 25–44 years.

Urban, rural and remote variations

Indicator

Urban, rural and remote variations in life expectancy and causes of death

Australians generally consider life in the country healthier than life in the city, but in many respects Australia's rural and remote populations have poorer health than their metropolitan counterparts. They have higher mortality rates and lower life expectancy, and experience higher hospitalisation rates for some causes of ill health, particularly injury, falls (in the aged) and burns (AIHW 1998).

As noted above, social, genetic and economic factors as well as environment have an influence on population health. High rates of ill health for indigenous people appear to contribute strongly to poorer population health statistics in remote areas in Queensland (Kennedy, B., Qld Health, pers. comm.). Generally speaking, people living in rural and remote areas have less access to health care than those living in metropolitan areas. Indexes of socioeconomic wellbeing all show increasing socioeconomic disadvantage with increasing distance from a major urban centre. Remote areas also involve a higher exposure to risk of occupational and vehicle injury (AIHW 1998). Some key indicators for Australia (not Queensland-specific) are shown in table 8-25.

The health of indigenous populations

Indicator

Indigenous and non-indigenous variations in health status

Australia-wide, Aboriginal people suffer disproportionately more disease than other Australians, as shown in table 8-26. Similar data for Queensland are unavailable. Life expectancy is 16 to 18 years less than the Australian average and mortality rates for infants and young and middle-aged adults are comparatively high (ATSIC 1994).

In Queensland specifically, the hospital separation rate for pneumonia and influenza is 7.4 times higher for indigenous and Torres Strait Islander communities than for 'all of Queensland', and for diabetes it is 11.2 times higher (Qld Health 1998).

While contributing factors are complex, environmental factors play a role in indigenous health status; for example, many Aboriginal or Torres Strait Islander communities do not have adequate sewerage and/or water supplies, which may increase rates of communicable disease (ATSIC 1993).

Lead

Indicator

Notifications of high blood lead levels in children

In recent years there has been increasing concern about the effects of lead on human health. Lead from past industrial activities and consumer products such as paint and petrol can persist in the environment as it does not decay or biodegrade. Lead is toxic because it can harm virtually every human system, especially the brain, kidneys and reproductive systems.

Recent Australian and international research has shown an association between elevated blood lead levels in children aged up to five years and impaired intellectual development. While uncertainties exist in the available data, the research indicates that adverse effects begin to become apparent at blood lead levels greater than 0.48–0.72 µmol/L (10–15 µg/100 mL) (Qld Health, unpub. 1998).

Table 8-25 Selected health indicators for metropolitan, rural and remote populations, Australia

	Metropolitan		Rural			Remote	
	Capital cities	Other	Large centres	Small centres	Other	Centres	Other
Socioeconomic indexes for areas, 1990–92[a]							
Disadvantage	1 018	986	981	968	999	975	949
Economic resources	1 041	996	970	956	947	983	905
Education and occupation	1 032	977	979	954	950	958	929
Health indicators							
Life expectancy at birth (years), 1994–96:							
Males	75.6	75.2	74.5	74.7	74.7	72.3	71.5
Females	81.2	80.8	80.6	80.8	80.8	78.3	77.4
Percentage of infants weighing less than 2500 grams at birth, 1991–95	6.3	6.1	6.3	6.3	6.1	6.8	8.8[b]
Total death rate, 1992–96 (per 100 000 population):							
Males	828	843	836	883	877	1 037	1 003
Females	509	522	534	529	527	651	636
Cancer incidence, 1986–94 (new cases per 100 000 population):							
Males	436.2	409.2	383.2	426.7	387.1*	319.0*	324.6*
Females	308.6	287.6	282.9	301.8	284.6	258.4	255.4*
Hospital separation rates, 1995–96 (per 1000 population):							
for all causes of injury:							
Males	21.8	23.6*	30.2*	29.4*	31.8*	48.5*	53.2*
Females	14.5	14.1	17.5*	17.5*	19.3*	31.5*	37.1*
for stroke:							
Males	3.0	2.9	3.4*	3.4*	3.7*	3.3	4.3*
Females	2.1	2.0	2.3*	2.4*	2.8*	3.0*	3.7*
for coronary heart disease:							
Males	11.7	11.7	11.9*	12.1*	11.3	10.7	10.8
Females	4.8	5.5*	5.5*	5.8*	5.6*	6.7*	6.3*
for asthma, people aged 5–64 years:							
Males	1.0	0.4*	0.9	0.7*	0.8*	0.9	1.2
Females	0.9	0.5*	0.9	0.7*	0.7*	1.1	1.2*
Health service supply indicators							
Primary care medical practitioners, 1996 (per 100 000 population)	122.9	110.8	107.0	94.8	80.0	90.2	66.0
No. of hospital beds, 1995–96 (per 100 000 population)	457	423	735	439	411	incl. in 'other rural'	incl. in 'other rural'

[a]These indexes are based on 1991 census results and the Australian average is 1000. These are average scores which hide the wide variations within and between centres in each category. Note that higher scores for 'disadvantage' indicate more advantaged populations. [b]The relatively high proportion of indigenous babies in remote areas may contribute to this rate as indigenous Australians have a rate of low-birthweight infants twice that of non-indigenous Australians. Also, females may not have the same access to prenatal care as in metropolitan and rural zones. *Significantly different from 'capital cities' at the 5 percent level.
(Source: AIHW 1998)

Table 8-26 Diseases disproportionately affecting Aboriginal Australians

Disease/disorder	Description
Diabetes mellitus	The incidence of diabetes mellitus peaks at about 40 years for Aborigines, which is about 30 years earlier than for non-Aborigines. In the 20–50 year age group, the prevalence is over 10 times higher in Aborigines than in non-Aborigines.
Circulatory system disorders	For young and middle-aged adults, such disorders are 10–20 times higher.
Respiratory disorders	The most marked differences occur with infective respiratory diseases.
Eye disorders	Studies have shown that in those over 60, 20 percent of Aborigines were blind compared with 5 percent of non-Aborigines. Signs of trachoma were present in 38 percent of Aborigines, compared with 1.7 percent of non-Aborigines.
Invasive diseases caused by haemophilus influenza	There were 990 cases per 100 000 in Aboriginal children in central Australia compared with 350 cases per 100 000 in non-Aboriginal children in the same area.
Tuberculosis	Incidence is 15–20 times higher among Aborigines.
Leprosy	Aborigines accounted for more than 25 percent of all new cases reported in 1984–86.
Sexually transmitted disease	Syphilis notification rate is 60 times higher for Aborigines than for non-Aborigines in the Northern Territory.
Hepatitis B	The prevalence of chronic carriers of hepatitis B virus ranges from 3 to 26 percent in Aborigines. These levels are far above the rate of 0.07 percent documented for blood donors in Sydney.
Diarrhoeal diseases	Hospital separations for these conditions were 16–20 times more frequent for Aboriginal infants than for non-Aboriginal infants in 1981–86.
Skin diseases/infestations	Separation rates are twice as high for Aborigines as for non-Aborigines.
Cancer	Overall mortality rates are slightly higher than for non-Aborigines, the most significant differentials being for cancer of the liver (males) and lung cancer and cancer of the cervix uteri (females).
Urinary tract diseases	Prevalence is 10 times that of the general population.
Injuries	Mortality rate is at least three times that of the general population.

(Source: ABS 1996b, from National Health Strategy 1992)

In Queensland, blood lead levels greater than 0.72 µmol/L (15 µg/100 mL) are notifiable to the Chief Executive, Queensland Health, if the person is not occupationally exposed to lead. In people occupationally exposed to lead, the notifiable level is a blood lead level greater than 2.4 µmol/L (50 µg/100 mL).

In 1997, there were 20 notifications relating to children aged under 10 years. Places of residence of these children were scattered around Queensland, with no geographic clustering. The probable causes for 17 of the cases were identified:

- ten cases were associated with removal of lead-based paint at the child's residence;
- five of the children had swallowed a solid lead object, typically a fishing sinker; and
- two cases were the result of the ingestion of lead-based paint chips or the ingestion of contaminants associated with the making of lead sinkers at home.

These data suggest that excessive exposure of children to lead is typically the result of local personal factors rather than broadly based environmental factors. Exposure during the removal of lead-based paint at a child's residence remains the most common cause of notifications for children in Queensland. Information is readily available for householders who are considering renovating homes which might have been painted with lead-based paint at some time in the past.

Table 8-27 Mortality rates from melanoma, Queensland and Australia

		Deaths per 100 000 population, mid-year estimate				
		1970–74	1975–79	1980–84	1985–89	1990–94
Queensland	Male	3.8	5.7	4.9	7.1	7.1
	Female	2.6	3.1	2.5	3.8	3.2
	Total population	**3.2**	**4.4**	**3.7**	**5.5**	**5.2**
Australia	Male	3.1	4.3	5.0	6.2	6.0
	Female	2.3	2.8	2.8	3.5	3.9
	Total population	**2.7**	**3.5**	**3.9**	**4.8**	**5.0**

(Source: ABS 1996b)

Prolonged exposure to the sun contributes to the high incidence of melanoma in Queensland.

Melanoma

Indicator

Mortality from and incidence rates for melanoma

The reported incidence of skin cancers in Queensland and Australia increased significantly in the 1980s and 1990s, possibly due to increased awareness and detection over the past 20 years. Preliminary estimates of incidence rates for males in Queensland in 1991–94 were 54.9 per 100 000 population; for females, they were 40.3 per 100 000 population (CDHFS and AIHW 1997).

In the face of rising reported incidence, the mortality rates in the last decade for melanomas are reasonably steady (table 8–27). Mortality rates for melanoma are higher in Queensland than in other States (ABS 1996b). Without behavioural change, it is estimated that there may be a 0.5 to 2.0 percent increase in cancers for every 1 percent increase in ultraviolet radiation exposure over a lifetime (Marks and Fraser 1995).

Response

RESPONSE

Most environmental impacts associated with human settlements result from the resource consumption and waste production patterns of the human population and the provision of services such as water, waste disposal, transport and energy. Increasing population and urban, industrial and agricultural expansion are straining the capacity of human settlements to supply these needs in an environmentally sustainable manner.

Minimising the environmental impacts of large, extended settlements requires a range of strategies which are most effective when carefully integrated and planned with the objective of sustainability held firmly in view. While progress is slow, Commonwealth, State and local governments are increasingly accepting the goal of sustainability and are working cooperatively with industry and the community to develop integrated policies and programs.

Protecting the environment in urban settlements

Water and air quality

Responses aimed at maintaining water quality, including the development of a Waterways Management Plan for the Brisbane River and Moreton Bay, are discussed in chapter 4, 'Inland waters', and chapter 5, 'Coastal zone'. Responses to protect air quality in human settlements are discussed in chapter 2, 'Atmosphere'.

Indoor air quality

The Built Environment Research Unit (BERU) of the Queensland Department of Public Works has developed strategic auditing initiatives on a whole-of-government basis. These include a program introduced in 1993 which audits all government buildings to identify the existence and condition of asbestos products.

BERU and Queensland Health have developed an Environmental Health Auditing Guideline. It will help identify environmental health hazards so that remedial action can be taken before the hazards translate into illness or injury.

In 1997, BERU helped initiate a national Built Environment Protocol to give direction to organisations working towards a healthier built environment. It aims to introduce ecologically sustainable development to the purchasing and service provision functions for public buildings.

Education Queensland and BERU have recently undertaken a joint research project investigating dust, noise and chemical use in selected secondary schools.

Controlling noise

Responsibility for noise control in Queensland is shared: the most common noise problems are managed by local government (domestic noise and domestic construction), the Environmental Protection Agency (waterways, large construction activities, commercial and industrial premises) and the Queensland Police Service (amplified noise, alarm systems, rowdy crowd behaviour).

Noise in Queensland is controlled under the *Environmental Protection Act 1994*, the *Environmental Protection Regulation 1998* and the *Environmental Protection (Noise) Policy 1997* (EPP Noise). The EPP Noise, which took effect on 1 December 1997, aims to achieve an acoustical quality objective of less than 55 decibels for most Queenslanders (DoE 1998). Schedules to the EPP Noise include planning sound levels for airports, public roads and railways, reasonable noise levels for certain areas and activities, information for product labelling, noise models and definitions.

Other State and local authorities are working to manage noise in their own jurisdictions. Queensland Rail is erecting noise barriers and greasing tracks, initially in south-east Queensland. It is also purchasing quieter rolling-stock and locomotives. The Department of Main Roads is developing a program for noise-barrier erection.

Brisbane City Council has developed Operators' Environment Guidelines for various industry sectors. These provide practical advice on how to meet noise control standards, and offer best practice environmental management suggestions. The Council recognises the need to include noise considerations in land use planning and incorporates noise management strategies into its Local Area Plans and planning policies in the Town Plan (BCC 1998). Some councils, for example Maroochy Shire, include noise considerations in local area traffic management planning (MSC 1998).

Managing impacts of population growth

While an expanding population brings economic growth and opportunity, ensuring that environmental values are protected and adequate transport and waste disposal services are provided is a major challenge.

Managing the potential problems related to growth is a high priority for the Queensland Government, the Commonwealth Government and local governments and has required a major cultural shift in local government management. The major legislative initiative in this area is the *Integrated Planning Act 1997*, discussed under 'Planning legislation'.

Coordinated regional planning for sustainable development

A key strategy in managing growth is ensuring that planning takes a broad and long-term view. The Department of Communication and Information, Local Government and Planning is working with local government, other State agencies, Commonwealth agencies and the community to coordinate regional planning in several regions most affected by population increase. The objective of these frameworks is to enable land use planning and decisions on facilities, tourism, transport and other services to be based on reliable information about socio-demographic patterns and change. Frameworks integrate national, State, regional and local environmental, social and economic priorities. Major programs in place are the South East Queensland (SEQ) 2001, Wide Bay 2020 and Far North Queensland (FNQ) 2010 growth management projects:

- The SEQ 2001 cooperative regional planning project, established in 1991, developed a Regional Framework for Growth Management (RFGM) to provide a policy and planning framework to guide growth management in south-east Queensland for the next 20 years (QDHLGP 1995). The project aims to improve relationships between employment location, transport and homes, helping ensure that environmental assets are protected, people's social and economic needs are met and the region continues to prosper. Key sector strategies being implemented include an Integrated Regional Transport Plan, a regional approach to water resources, provision of regional facilities and services, and coordination of State works and strategies. An RFGM update in 1996 included an element focusing on sustainable economic development and creation of high-quality employment (QDLGP 1996).
- The Wide Bay 2020 Growth Management Project is developing an RFGM that will include a set of integrated policy principles and actions to guide the balanced development of the Wide Bay region.
- The FNQ 2010 Regional Planning Project is developing strategies to manage growth and development in and around Cairns over the next 20 years. Key aspects are an RFGM, nine regional strategies and the associated Wet Tropics Management Plan, an Integrated Catchment Management Program and an ATSIC Cairns and District Regional Strategic Plan.

Planning legislation

Historically, Queensland, like the rest of Australia, has employed a land use planning system which divides land into zones and dictates which activities are permissible or not permissible in those zones. However, the regulatory framework of planning in Queensland was changed fundamentally by the *Integrated Planning Act 1997* (IP Act). This Act, which took effect in March 1998, is based on the principle of ecologically sustainable development and places a statutory obligation on all planning authorities to apply 'the precautionary principle' in decision making. The IP Act is an extension of planning reforms initiated through the *Local Government Act 1993* and replaces the *Local Government (Planning and Environment) Act 1990*.

The IP Act aims to bring about efficient integrated planning by replacing the local planning system with a system using performance-based planning criteria. Specifically, the Act:

- abolishes any concept of prohibition of use, replacing this with performance-based planning criteria and an integrated development approval system;
- gives the Minister for Local Government and Planning powers to intervene in any development involving State interest;
- enables a formal but voluntary approach to integrated regional land use planning; and
- establishes a more accountable system of charging for facilities and services.

When reviewing existing planning schemes under the IP Act, local governments must have regard to State planning policies, the regional policy context of the RFGMs (see above) and related planning guidelines, subregional structure planning reports, and the various Acts, codes of practice and standards administered by State Government agencies.

TRANSPORT

Successful transport planning is one of the most critical factors determining the environmental outcome of population expansion and urbanisation. When developing a new area, planners need to consider where its inhabitants will work and enjoy their recreation, how they will travel and the environmental and social effects of that travel. Failure to provide adequate facilities for alternative transport such as safe, convenient public transport services and cycling or walking tracks is a planning oversight that could prove costly to the environment and to the wellbeing of the population.

State Government initiatives

The Integrated Regional Transport Plan (IRTP) for South-East Queensland, launched in May 1997, is a key component of SEQ 2001 (QT 1997). Its objectives include developing a more sustainable transport system by:

- better integrating the transport system with urban development by supporting more compact, better-designed settlements which support public transport and allow people to walk and cycle more;
- ensuring the efficient movement of freight by high-quality rail, road, air and sea links and providing intermodal

The SEQ 2001 regional planning project aims to balance socioeconomic development and environmental protection.

freight and passenger facilities in major industry and employment areas; and providing a continuous system of designated high-capacity, safe and secure freight roads which maximise separation of heavy freight traffic from urban settlement areas and give priority to freight movements; and
- moderating traffic growth and encouraging the use of public transport, ride-sharing, walking and cycling. Targets have been set to increase the proportion of trips made by public transport (from 7 percent of all trips to 10.5 percent by 2011), walking (from 13 to 15 percent) and cycling (from 2 to 8 percent). Strategies include providing a 'seamless' public transport system which links all public transport operations, improving cross-city public transport services and introducing more flexible public transport. Improved facilities for pedestrians and cyclists are planned.

The IRTP has a number of key projects:
- The South East Transit Project, launched in December 1996, includes a dedicated busway on the South East Freeway corridor between the Brisbane City area and the Gateway Motorway and high-occupancy vehicle lanes south to the Logan Motorway connection.
- The 'Shaping Up' Planning Guidelines provide ideas and opportunities for local government and land developers to provide better-designed communities which support public transport, cycling and walking.
- Queensland Transport's AirCare program includes a trial of on-road vehicle emissions testing (see also chapter 2, 'Atmosphere').
- Car Pool Connection is a car pool pilot program operating in the Brisbane–Gold Coast corridor.
- Cycle South East, an integrated cycle strategy for south-east Queensland, was released in draft form for consultation in October 1998.

Encouraging the use of public transport is a key component of the Integrated Regional Transport Plan for South-East Queensland.

Implementation of the IRTP for south-east Queensland is being undertaken through State Government agencies including Queensland Transport, the Department of Main Roads, the Department of Communication and Information, Local Government and Planning and local governments.

Integrated regional transport plans are also being developed and implemented for other regions across Queensland including Mackay, Townsville–Thuringowa, Toowoomba and Far North Queensland and as part of Wide Bay 2020. More than half the local government areas in regional Queensland are now covered by a regional plan with a transport component (QT 1998).

The State Government is developing a Transport Portfolio Environmental Framework to set the broad policy direction for Queensland's transport system. The Framework aims to provide guidance to, and improve awareness in, all agencies within the transport portfolio.

Queensland's transport agencies are developing environmental management systems (EMSs) to improve their environmental performance and to assist in meeting their obligations under environmental legislation:
- The Department of Main Roads' EMS commits the Department to cost-effective best practice and continuous improvement in environmental management in all facets of road design, construction, maintenance and operations.
- Queensland Rail's EMS, now being developed, will cover all its planning, development and operational activities. Among other things, Queensland Rail aims to promote rail as the environmentally superior transport option.
- Queensland Transport started developing its EMS during 1998. The EMS will deal with the policy and planning processes of the transport system as well as the Department's own energy use and waste management.

Public education about the environmental impacts of vehicles and the benefits of public transport is an important strategy. Queensland Transport provides a range of promotional and educational activities and is working collaboratively with the Queensland School Curriculum Council to identify and develop public transport teaching resources in support of the new Study of Society and Environment Syllabus document.

Local government initiatives

Brisbane City Council is responsible for most of the city's road network, a total of 5650 km of roads and streets, and is the only local authority in Australia to own and operate its own bus and ferry service. In 1995 the Council released TravelSmart, a travel management strategy. (This should not be confused with the Department of Transport's public transport promotion initiative of the same name.) The strategy aims, by 2011, to reduce the overall proportion of trips by private vehicle by 15 percent from 1992 rates and to double the proportion of trips by public transport and increase the number of trips by bicycle nearly sixfold (BCC 1995).

Recent and current Council initiatives include:
- applying traffic management strategies in residential areas and improving coordination between traffic signals, giving buses priority through lights and lanes and upgrading arterial routes;
- improving public transport by developing a $600 million busway network, introducing electronic ticketing, ensuring that new buses have low-emission and fuel-efficient engines, and introducing 'hail and ride' services;

- introducing in 1996 six high-speed, low-wash catamarans and four new terminals to provide an expanded ferry service on the Brisbane River. Patronage is 40 000 passengers per week, double the original estimate;
- approval of the Brisbane Bicycle Plan, which identifies possible routes for some 900 km of bikeways and lanes over the next 10 years; and
- introducing, with the State Government, a reduced speed limit of 50 km/h across Brisbane. This will be implemented in conjunction with the development of a road hierarchy which identifies the use of all roads and establishes appropriate speed limits (BCC 1996, BCC 1998).

TOURISM

The emphasis of the Government's current programs and strategies is not merely on maintaining the current viability of the lucrative tourism industry but on ensuring that it is sustainable. *Queensland Tourism: A Framework for the Future* sets out the vision for tourism in Queensland. The Framework outlines the priority areas within the industry and provides clear direction on the objectives of these areas (DTSBI 1997b).

Commonwealth and Queensland laws provide for the orderly assessment of social and environmental impacts of proposed tourism development. The *Integrated Resorts Development Act 1987* requires that, when resorts are developed, measures be taken to minimise the risk of damage to the environment. The *Recreational Areas Management Act 1988* provides for the creation and maintenance of recreational areas, taking into account matters affecting the environment.

Plans of management and zoning plans are in place for the Great Barrier Reef Marine Park and Queensland marine parks. These plans intend to balance the conservation and protection of the resource with tourism and other industry uses and may limit the types or extent of certain activities and visitor numbers. Management plans are in place or are being developed for protected areas including national parks under the *Nature Conservation Act 1992*.

Ecotourism

Ecotourism is nature-based tourism that involves education about and interpretation of the natural environment and is managed to be ecologically sustainable (DTSBI 1997a). Ecotourism integrates tourism and conservation and provides an economic and educational incentive for environment protection.

Ecotourism is a growing industry in Queensland. In 1995 an estimated 105 ecotourism operators worked in Queensland (ABS 1996b) and by 1999 the number had increased to 158 (preliminary estimate, QTTC, unpub. 1999). A number of these operations have been accredited under the National Ecotourism Accreditation Program (NEAP) administered nationally by the Ecotourism Association of Australia. NEAP has been developed by the tourism industry to identify genuine ecotourism products and services. Ecotourism accreditation assures consumers of a service backed by a commitment to best practice environmental management and the provision of a quality ecotourism experience. Queensland operators have embraced the program, recording the highest percentage of accreditations of any State. The accreditation program is the only scheme of this type in the world. The accreditation manual can also be used by non-ecotourism operators to help make their operations more sustainable.

In recognition of ecotourism's growing role within Queensland tourism, the Queensland Government launched the Queensland Ecotourism Plan in 1997. The plan provides a framework for the planning, development, management and marketing of Queensland's ecotourism industry into the twenty-first century. The plan's vision is to develop ecotourism as an ecologically, commercially, culturally and socially sustainable industry, providing best practice leadership for other sectors of the industry (DTSBI 1997a).

The Environmental Tourism Department of the Queensland Tourist and Travel Corporation was established in October 1997 to coordinate implementation of the Queensland Ecotourism Plan. The department is the only dedicated environmental tourism unit within a State tourism agency in Australia.

RESOURCE USE

Developing resource use strategies is about reducing resource requirements without reducing the livability of urban environments. Efforts to reduce resource consumption to date across Australia have focused largely on energy (electricity rather than petroleum-based fuel) and water, with some focus recently on conserving packaging material. Little information about conservation of resources other than water and energy is available. Table 8-28 provides some indications of householders' conservation practices.

Energy resources

In 1998 the Queensland Government launched the Office of Sustainable Energy. The programs of this office and other bodies to encourage energy efficiency and use of renewable sources are discussed in 'Energy efficiency' in chapter 6, 'Energy resources'.

Water resources

Government responses to demands on water resources are varied. They include providing suitable catchments for domestic water supply and minimising urban water use through education campaigns. In line with ecologically sustainable development principles, governments have begun to introduce pricing reforms that take into account social and environmental costs (ICESD 1996). For details of these responses, see chapter 4, 'Inland waters'.

Selected water conservation measures used by householders are shown in table 8-29.

REDUCING WASTE

All sectors of the community can help reduce waste through avoidance of waste production, choice of product, reuse and recycling. The Environmental Protection Agency has a regulatory and advisory role and is the lead agency for waste management in Queensland. Local government plays the key role in managing domestic waste in particular, but also in managing some commercial and industrial wastes. Local governments provide services such as waste collection, recycling and disposal. Legislation provides for prosecution of individuals and companies who choose not to use available waste disposal services if their actions are illegal and create environmental harm. Generators of waste, including industrial

Table 8-28 Selected resource conservation practices of householders, Queensland and Australia

Conservation practices	Percentage of respondents			
	May 1992		March 1998	
	Qld	Aust.	Qld	Aust.
Using recycled paper? 'Yes'	68.6	67.9	46.8	47.6
Using recycled paper? 'Sometimes'/'Depends'	nr	nr	23.9	23.5
Using refillable containers? 'Yes'	67.0	63.3	64.4	61.0
Using refillable containers? 'Sometimes'/'Depends'	nr	nr	10.7	11.4
Prepared to accept less product packaging? 'Yes'	85.0	84.5	86.2	87.0
Prepared to accept less product packaging? 'Depends'	5.0	4.4	2.3	3.3

nr = not reported/relevant for this category
(Source: ABS 1998c)

Table 8-29 Selected water conservation measures used by householders, Queensland and Australia

Water conservation measures	Percentage of respondents			
	June 1994		March 1998	
	Qld	Aust.	Qld	Aust.
Dual flush toilet	31.5	39.0	53.1	55.2
Reduced flow shower head	22.5	21.8	34.1	32.3
Consumption considered in appliance purchase	na	na	69.0	71.3
Conserve water in garden (households with gardens)	na	na	52.3	58.3
Planting natives	na	na	61.3*	57.2
Using mulch	na	na	72.0*	67.7

Note: na = not available. *Only 10.3 percent of householders planting natives did so in order to conserve water. On the other hand, 61.4 percent of householders using mulch did so to conserve water.
(Source: ABS 1998c)

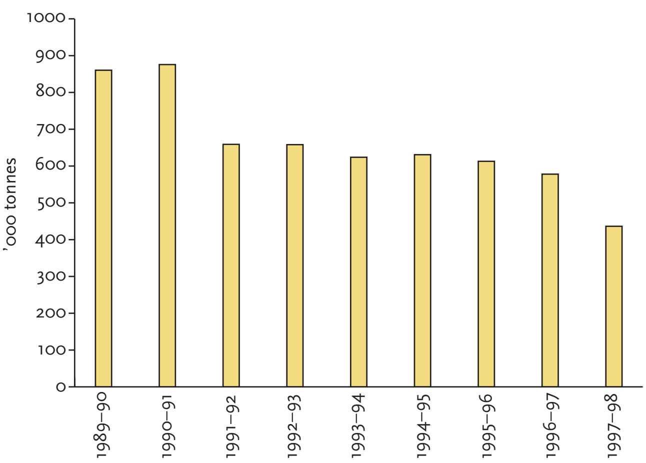


Figure 8-13 Waste to landfill, 1989–90 to 1997–98, Brisbane City Council. Waste excludes recycled waste, clean fill and construction and demolition waste.
(Source: BCC)

and agricultural waste, some of which can be classified as hazardous, have a responsibility to make appropriate disposal arrangements.

In Queensland, the waste cycle of hazardous industrial wastes from generation to transport, treatment and disposal can be regulated under the *Environmental Protection Act 1994* and the *Environmental Protection Regulation 1998*. Holders of, and applicants for, an environmental authority administered by the Environmental Protection Agency can be required to submit waste management plans. The aim of these plans is to ensure that waste generators critically assess how and why their waste is generated and how it might best be managed. This should lead to cost savings as generators reduce and recycle their waste and thus reduce disposal charges.

State Government programs

The State Purchasing Policy and State Government contracts encourage waste avoidance, recycling and use of recycled materials from suppliers; these provisions will soon be updated.

Environmental Protection Agency waste management initiatives include introducing statewide waste management/minimisation training programs for local governments and offering a range of activities to promote community interest in waste prevention and recycling. The Green Hospitals Awards, an initiative of Queensland Health and the Environmental Protection Agency, encourage segregation of waste, installation of energy management systems and waste auditing.

State Government initiatives in encouraging domestic recycling, in cleaner production to reduce industrial and commercial waste and in managing hazardous waste are discussed below.

Local government programs

Many local councils are active in waste reduction. For example:

- Brisbane City Council in 1991 adopted the national target of a 50 percent reduction by 2000 in the volume of waste going to landfill. The Council encourages waste reduction through setting appropriate price structures, providing information, giving recognition to business and public efforts, exploring options to increase the materials included in kerbside recycling, and facilitating the establishment of industries that use waste materials. The target was achieved in 1997–98 (figure 8-13); the most recent declines are not due solely to waste reduction but also to the fact that some waste is now being sent to private landfills outside the BCC area (BCC 1998).

- Maroochy Shire Council faces similar issues and has also adopted the 50 percent waste reduction target. The Council operates a recycling program which includes a rates rebate as an added incentive to recycle. A trial of green waste collection was begun after audits revealed that up to 60 percent of material found in domestic wheelie bins was green waste. In 1997–98, the Council also provided about 100 compost bins at cost price to residents. The Council, with 17 other local governments and five waste contractors, has established a Working Group on Recycling Sustainability which works to coordinate waste management planning and deal with waste issues (MSC 1998).

Councils across the State are generally improving waste management processes. More than half are now involved in planning for waste management on a regional basis. Incentives are provided by the State Government under the Regional Waste Management Planning Funding Scheme. Several councils (for example, Redland, Hervey Bay and Caloundra) are also investigating and implementing innovative wastewater reuse strategies. Logan City Council has introduced sorting, recycling and sale facilities at its landfill and is pioneering the recovery of landfill gas to generate electricity.

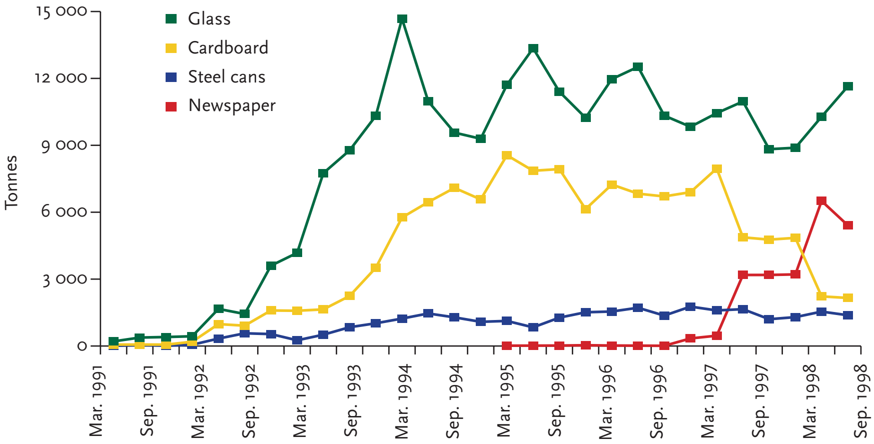


Figure 8-14 Recovery of glass, cardboard, steel cans and newspaper under the Recycling Grants Scheme
(Source: QRAC)

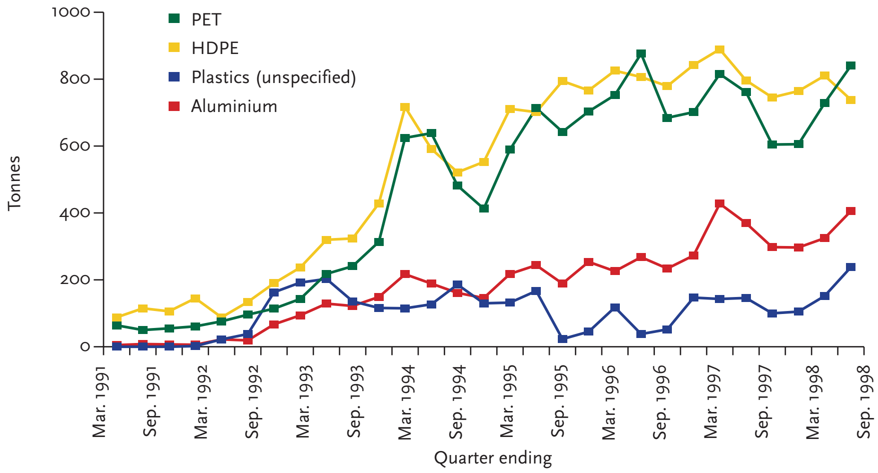


Figure 8-15 Recovery of PET, HDPE, unspecified plastics and aluminium under the Recycling Grants Scheme
PET = polyethylene terephthalate; HDPE = high-density polyethylene
(Source: QRAC)

Household recycling

The community continues to support recycling. Between May 1992 and March 1996, the proportion of Queensland households reporting recycling increased. Household paper recycling increased from 37.2 to 71.3 percent, glass from 43.3 to 76.8 percent, cans from 34.3 to 70.2 percent and plastic from 34.6 to 75.8 percent. The percentage of households reporting that they did not recycle fell from 18.1 to 7.9 percent (ABS 1996a).

The Queensland Recycling Advisory Council (QRAC) is a joint State and local government and industry initiative to facilitate a shared approach to effective and efficient waste management, and is committed to developing sustainable waste minimisation and resource recovery programs. QRAC uses a range of programs to educate Queenslanders about waste minimisation and litter abatement. For example, its 'Great Garbage Grab' competition in schools from 1992 to 1997 resulted in almost 2882 tonnes of glass and plastic bottles and aluminium cans being collected for recycling, with benefits of increasing awareness in schools and flow-on effects in the community (QRAC 1998). Data collected by local governments receiving grants under the Queensland Recycling Grants Scheme are shown in figures 8-14 and 8-15.

In recent years recycling commodity prices have dropped and collection costs have increased. Nevertheless, local governments have retained recycling services in line with community wishes and are now reassessing their services to find ways to improve efficiency.

Community support for recycling continues to grow. The number of households reporting that they did not recycle fell from 18.1 percent to 7.9 percent between 1992 and 1996.

Industrial and commercial waste

Industry can also recycle its wastes. From 1993 to 1997, the Department of Environment and Heritage and the Department of Business, Industry and Regional Development conducted a successful Recycling Industry Incentives Scheme in which more than 30 companies received grants to improve their recycling processes and develop recycling equipment. The program resulted in many participants improving their recycling rates and, in some cases, developing new products.

'Cleaner production' is a more holistic approach to reduce resource inputs and waste outputs and is an industrial trend developing worldwide (SEAC 1996). An ANZECC taskforce is developing a national cleaner production strategy for publication in 1999.

In Queensland, cleaner production is promoted by governments and the Queensland Cleaner Production Taskforce Association Incorporated. The Association has produced newsletters, brochures and a self-assessment guide, has conducted conferences and is working with educational institutions to prepare cleaner production curricula. The Environmental Protection Agency will publish case studies that demonstrate the savings and decreases in wastes and pollution provided by cleaner production practices. These include:

- a prawn farm which halved packaging and transport costs by packing prawns directly into polystyrene boxes containing ice;
- a recycling program involving cardboard, compostible organic wet waste and landfill material which saved Conrad Jupiters Hotel and Casino $34,000 a year; and
- a waste minimisation and recycling plan at the BHP mine at Cannington, Cloncurry, where construction scrap and other marketable recyclable materials were sorted, stored and transported to Mount Isa or Townsville, waste cardboard was mulched for landscaped areas, and kitchen waste was composted.

The Environmental Protection Agency is a major sponsor of the United Nations Environment Program Working Group for Cleaner Production at The University of Queensland. This group focuses on the food industry.

In 1996, ANZECC directed the key packaging industry organisations to develop a voluntary covenant or agreement for the recovery and reprocessing of recyclables. During negotiations, industry members indicated concern about their competitiveness with non-signatories to the agreement; as a consequence, the voluntary covenant is to be supported by a proposed National Environment Protection Measure (NEPM) for Used Packaging Materials.

Management of regulated wastes

Some wastes are relatively harmless environmentally, while many others have the potential to cause serious environmental harm and require special attention. 'Regulated wastes' are listed in Schedule 7 of the *Environmental Protection Regulation 1998*. A licence is required to transport, treat, store or dispose of these wastes.

The State Government is developing a Waste Industry Development Strategy for Queensland which aims to encourage improved opportunities for the waste management industry.

The Environmental Protection Agency uses a non-statutory waste tracking system to track the movement of regulated and hazardous waste within south-east Queensland and interstate. It will help ensure that all parties involved in the generation, transport and disposal of waste take responsibility for appropriate disposal measures.

In 1998, the National Environment Protection Council established the 'Movement of Controlled Waste Between States and Territories National Environment Protection Measure'. This provides for the tracking of wastes between States and Territories and describes the procedures to be followed, which include prior notification of the consignment of waste across State and Territory borders. It also provides mutual recognition of transport licences (NEPCSC 1998).

Population health

The health of Queensland communities is protected by a network of infrastructure and services, laws, policies and community practices. These are so well established that most people take them for granted. Queenslanders are fortunate to live in a society where, for the most part, sewage and industrial emissions are tightly controlled, where drinking water and food quality are protected by rigorous legislation and inspection processes, and where legislated standards control such things as the labelling and use of dangerous chemicals, construction safety and vehicle emissions.

Queensland Health has a public health program which aims to improve health and reduce disease for the whole community using preventive strategies at a population level, with particular attention given to priority issues and groups. Priorities include immunisation; communicable disease prevention and diabetes prevention and management in indigenous communities; breast cancer and cervical cancer screening; control of key infectious diseases such as tuberculosis and hepatitis; quality assurance in the food industry; and preventing smoking uptake by children (Qld Health 1997).

Indigenous health

In 1997–98, Queensland Health advanced the development of protocols and action plans for dealing with the major illness conditions associated with indigenous health: cardiovascular disease, diabetes and respiratory disease. The Aboriginal and Torres Strait Islander Food and Nutrition Strategy includes a variety of initiatives focused on healthy weight programs, nutrition and food education. Emphasis has been placed on vaccinating people at risk of pneumococcal pneumonia, as well as on childhood immunisation strategies. A future focus is the career development and training of indigenous health workers and cross-cultural awareness training for front-line clinical and administrative service delivery staff (Qld Health 1998).

Rural health

The Centre for Rural and Remote Health in Mount Isa provides opportunities for medical students to pursue studies in a remote environment to better equip them for their careers. Queensland Health has earned recognition and been praised for innovation in its use of telemedicine — that is, the use of video conferencing — both to provide clinical services and to communicate with health professionals (Qld Health 1998).

Community education and information programs

Provision of information to and education of all sectors of the community are important to foster sustainable behaviours. Table 8-30 lists the environmental information sources reported by the community in 1992 and 1998. Thirty-nine

Promotion of Healthy Waterways

The Healthy Waterways Plan, produced by the Brisbane River Management Group (BRMG) in 1998, is a cooperative effort of State and local governments, science, industry and the community (BRMG 1998). The plan outlines a vision that all the waterways of the Moreton Bay Catchment will be healthy by 2020. It is a long-term action plan of waterways improvement projects, including reduction of nutrients from sewage effluent, stormwater management and wastewater reuse (see 'Regional and local government initiatives' in chapter 4, 'Inland waters').

A public relations and community education campaign to raise awareness of issues and encourage the community to play its part is an important component of the Healthy Waterways Plan. The campaign aims to inspire stakeholder ownership of and community identification with the Healthy Waterways project and its vision.

The Healthy Waterways logo was launched in May 1998 with the theme 'because we're all in the same boat', chosen to emphasise the need for cooperation and the need for a whole-of-catchment solution to achieve the vision. The logo can be used by all stakeholders who are working to improve the waterways of the Moreton Bay catchment.

Media outlets are encouraged to be part of the campaign, a strategy which has resulted in regular community service announcements about the waterways. The business sphere is urged to become involved through adopting waterways-friendly practices in the workplace and through corporate sponsorship of waterways improvement and education projects. The campaign also targets community groups and plans to develop project packages for schools.

To raise community appreciation and awareness of the waterways as significant social and cultural features, the campaign supported the inaugural Brisbane River Festival in 1998. At this festival, BRMG launched the 'Healthy Waterways Crew', a club for people who care about the health of the waterways. Members of the public were invited to sign a pledge to protect the waterways and received information about how they can make a positive contribution by adopting waterways-friendly practices around the home. This highly successful strategy resulted in more than 1000 individuals and households joining the crew in the first month.

The Healthy Waterways campaign's emphasis on making clear how individual behaviours contribute, on cooperation between stakeholders, on the need for strong identification and on corporate sponsorship illustrates many of the trends in environmental education in the 1990s.

percent of the 1998 survey respondents felt that not enough information was available on the environment, compared with 37.8 percent in 1992. Only 59.6 percent of those who had obtained information about the environment said their behaviour and actions had been influenced (ABS 1998c).

The Environmental Protection Agency provides publications, radio and television programs, community service announcements, public meetings and presentations, and information at events such as agricultural shows. Examples of its community information and education programs include:

- production of 28 new educational resources in 1996–97 and 17 in 1997–98. One program, AirWatch, helps schools investigate and act to improve air quality;
- environment segments presented on national TV programs such as 'Agro's Cartoon Connection' and 'Totally Wild' (238 in 1996–97 and 106 in 1997–98). Estimated audiences totalled more than one million each weekday. Radio activities include weekly segments on ABC radio and Brisbane's B105;
- provision of advice to tens of thousands annually by the Naturally Queensland Information Centre in Brisbane and by regional centres; and
- the Agency's Internet site *www.env.qld.gov.au*, launched in January 1998. The site had 963 297 successful 'hits' in its first year.

Other State Government departments also conduct environmental awareness programs. Queensland Transport promotes initiatives such as TravelSmart Week, Car Pool Connection and AirCare.

Table 8-30 Sources of environmental information, Queensland

Source of environmental information	Percentage of respondents May 1992	Percentage of respondents March 1998
TV or radio	86.0	72.8
Newspapers	included in 'TV or radio'	54.6
Government or local council	41.1	26.3
Library	7.6	3.1
School	18.8	3.0
Environmental interest group	21.6	5.0
Computer facilities e.g. Internet	nr	2.0
Friends or relatives	nr	4.3
Other	5.2	7.0
None of the above	10.6	17.5

More than one source can be specified. nr = not reported for this category
(Source: ABS 1998c)

Education Queensland plays an important role in providing long-term community education by including environmental issues in a broad range of studies. The Department operates several environmental education centres throughout Queensland in a range of environmental settings (rainforest, coastal and arid zones).

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CHAPTER 9

QUEENSLAND'S CULTURAL HERITAGE

Cultural heritage

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Contents

KEY ISSUES AND FINDINGS

The cultural heritage environment provides a key to understanding our past and is important in providing a sense of identity for all Queenslanders. It includes places and objects, both indigenous and non-indigenous, which provide a record of Queensland's historical development. A rich and diverse range of cultures has shaped Queensland's cultural heritage environment. This diversity should be reflected in the places and objects recognised and protected for their heritage value.

However, there is concern that the heritage environment is being adversely affected through inattention, a poor information base and inappropriate practices. The loss and deterioration of heritage places continue. The failure to identify cultural heritage places or to recognise their significance is a major limiting factor in their conservation.

Changing community attitudes towards cultural heritage issues in recent years and many positive actions by government and the community are changing the ways in which the cultural heritage environment is being managed and used.

- Relatively little of Queensland's cultural heritage has been properly surveyed, and consequently many unidentified places and objects of cultural value may not be granted adequate recognition and protection. While heritage registers include detail about heritage places, they are not yet comprehensive or representative of the full range of the State's heritage places.
- The physical condition of heritage places cannot be adequately assessed without a standardised data collection program for monitoring their condition. Many places have not been inspected and assessed in terms of their heritage integrity. There is little capacity for benchmarking and measuring changes in heritage integrity.
- Measures of pressures which contribute to the deterioration and destruction of the heritage environment are not well defined. Comprehensive data outlining the level of conservation pressures on collections of heritage objects are unavailable. In addition, comprehensive data about the physical condition of these collections have not been collected.
- Several pieces of Commonwealth and State Government legislation provide protection for cultural heritage in Queensland, although with varying effectiveness. The legislation attempts to protect both heritage places and objects and, where possible, preserve the unique relationship between them.
- Commonwealth legislation controls the export of the most significant aspects of Australia's movable cultural heritage, particularly that of Aboriginal and Torres Strait Islander origins. The legislation does not provide for the protection of heritage objects in place and applies only to items of national significance. No similar provisions for items of State significance exist.
- Both the Commonwealth and Queensland have passed native title legislation. The *Native Title Act 1993* (Cwlth) was created to recognise and protect Aboriginal and Torres Strait Islander peoples' native title rights and interests. At 24 April 1998, 205 native title claims had been lodged in Queensland. At 31 March 1998, of 14 national parks gazetted for claim under the *Aboriginal Land Act 1991*, 12 had been claimed.
- Between 1984 and 1995, applications by Queensland's Aboriginal and Torres Strait Islander communities for the protection of areas of heritage significance comprised 34 percent of all applications made in Australia under Commonwealth legislation. This relatively high proportion can be attributed in part to the limitations of the State's legislation — the *Cultural Record (Landscapes Queensland and Queensland Estate) Act 1987* — in providing effective protection in all circumstances.
- The Australian Heritage Commission compiles the Register of the National Estate for protecting significant cultural and natural heritage places in Australia. Queensland places entered in the Register or interim list numbered 1199 at 31 October 1998. Of these places, 61 percent are historic, 26 percent are natural and 13 percent are Aboriginal or Torres Strait Islander. Despite a rigorous significance assessment process, listing on the Register of the National Estate provides little statutory protection for heritage places.
- The primary legislation for protecting historic cultural heritage places in Queensland is the *Queensland Heritage Act 1992*. The Queensland Heritage Register, established under the Act, comprises 1099 permanent or provisional entries of historic places legally protected at November 1998. The Register is growing at 2.4 percent annually. Stop orders, four of which have been issued since 1992, can be served to stop work or other activities that might destroy or reduce a place's cultural heritage significance.
- An inventory of Aboriginal and Torres Strait Islander heritage places, recorded under the provisions of the *Cultural Record (Landscapes Queensland and Queensland Estate) Act 1987*, listed 8916 places at 30 June 1998. More than 750 permits for surveys and more than 300 permits for research were granted primarily for the survey of areas for Aboriginal and Torres Strait Islander heritage places between 1989–90 and 1996–97. Less than five percent of Queensland has been surveyed for Aboriginal and Torres Strait Islander heritage places.
- Although many local governments have undertaken heritage assessment studies, few studies have resulted in registers being established to protect cultural heritage places. Local government planning provisions help protect heritage places. Of 85 local governments surveyed in 1997, 20 had planning provisions for protecting Aboriginal and Torres Strait Islander heritage and 31 had provisions for protecting historic heritage. Local government heritage advisers provide free building conservation advice to owners and/or occupiers of heritage places in a local government area.
- Heritage is a major attraction for tourists, but increased visitation results in impacts on the sites. In particular, pressure is exerted on unoccupied heritage places, especially Aboriginal art sites and historic archaeological sites

including shipwrecks. Impacts include physical disturbance from development as well as intentional and inadvertent visitor damage. Information about visitor numbers and profiles for frequented heritage sites is largely unavailable. Neglect is a problem in isolated places without tenants or site managers. There are inadequate data to assess the impact of tourism.

- The loss and continuing decline of many indigenous languages represent a significant loss of heritage for Aboriginal and Torres Strait Islander peoples. An estimated 250 indigenous languages once existed in Australia. In Queensland there remain four strong and nine severely threatened languages. In 1994, only 15 percent of Queensland's Aboriginal and Torres Strait Islander population spoke an indigenous language. The Aboriginal and Torres Strait Islander Languages Initiatives Program provides funding for language projects.
- Quantitative information about illegal collection of cultural heritage objects is unavailable. Physical damage through inappropriate handling and inadequate storage can occur as a result of illegal collection. Such objects are without documentation, unavailable for interpretation and inaccessible to the public. This diminishes their value significantly.
- The support of over 200 museums throughout Queensland represents one of the most organised responses to the management of heritage objects and collections. These museums are mostly governed by historical societies (35 percent) and local governments (30 percent). Over 800 000 people visited the Queensland Museum and its branches during 1997–98.
- Lack of storage space and the use of outdated storage techniques most seriously affect large museums. Objects in most small museums suffer from a lack of climate control, limited access to conservation services and lengthy exposure to high light levels while on display. Access to professional conservation expertise is excellent for collections held in major government-funded institutions, but is more limited away from major centres.
- The Queensland Museum has a policy for the repatriation of human remains and other sensitive items of importance to Aboriginal and Torres Strait Islander communities. This policy allows the return of these cultural items to the traditional custodians.
- Queensland's underwater heritage includes 936 ships known to have been wrecked off the coast; 847 of these are protected by the *Historic Shipwrecks Act 1976* (Cwlth). The Queensland Museum knows the locations of 48 shipwrecks, of which 37 have had site surveys. Five historic shipwrecks off Queensland have protected zones requiring a permit to visit. Excavations of HMS *Pandora* will culminate in the establishment of the Pandora Museum in Townsville in 2000.
- Many community heritage groups are active in locally promoting heritage conservation, although the level of involvement by these groups across the State is not known. The level of involvement of cultural groups in the identification and conservation of their heritage is unclear. Indigenous Australians' involvement ranges from consultation on management plans and protected areas to day-to-day management of sites. Aboriginal and Torres Strait Islander peoples still have only limited involvement in the management of many indigenous places.
- The National Trust of Queensland, a community-based, non-government organisation, plays a significant role in promoting heritage and its protection. It maintains a register of places of heritage significance; at the end of 1997 the register comprised 1336 buildings, trees and precincts. While the register does not have any legal effect, it is widely recognised as an authoritative statement of the heritage significance of a place.
- Financial support for heritage programs, through base funding and heritage grant programs, is essential for identifying and conserving heritage places and objects. Since 1989 there has been great demand for funding for community grants programs. The demand has far outweighed the funds available.
- The State component of the Commonwealth's National Estate Grants Program was discontinued in 1996–97, reducing funding available and therefore the amount of heritage identification and conservation work that can be undertaken by the States. The Queensland Government provides funding for historic and Aboriginal and Torres Strait Islander heritage projects through three major grant programs: the Queensland Heritage Grants Program, the Queensland Community History Grants Program and the Queensland Community History (Indigenous Heritage) Grants Program.


The administration building of the former prison at St Helena Island National Park, Moreton Bay

INDICATORS

PRESSURE

Pressures on cultural heritage places

Number of places identified and recorded in Queensland heritage inventories

Percentage of places recorded which have been assessed for their cultural heritage significance

Percentage of indigenous heritage identification projects which actively involve indigenous people

Number of applications to demolish or remove a building in a residential zone inside Brisbane City Council's urban character area

Number of places demolished while nominated for inclusion in the Queensland Heritage Register

Number of heritage-registered places relocated

Number of permits issued by Queensland Transport for moving houses in the Greater Brisbane area

Number of survey permits granted under the Cultural Record (Landscapes Queensland and Queensland Estate) Act

Number of redundant/unoccupied heritage-registered buildings

Number of places in the Queensland Heritage Register which have an adaptive reuse

Number of railway stations/sidings closed each year

Number of applications for development of heritage-registered places under section 34 of the Queensland Heritage Act

Number of State properties developed against Heritage Council recommendations

Number of objections to Queensland Heritage Register entry

Number of appeals against Queensland Heritage Register entry

Number of places removed from the Queensland Heritage Register

Number of visitors to cultural heritage places

Number of Aboriginal rock art sites visited regularly

Number of permits granted to enter protected zones of historic shipwrecks

Number of dives to historic shipwrecks in protected zones

Pressures on cultural heritage objects

Percentage of collections accessioned

Rate of collection growth

Number of museums without collection policies

Percentage of collections surveyed by conservators/archivists at each institution annually/in total

Level of access to conservation services

Nature and level of government and community support for community museums

STATE

State of cultural heritage places

Number of Queensland places inscribed on the World Heritage list for cultural values

Number of Queensland cultural places entered in the Register of the National Estate (Aboriginal and Torres Strait Islander, historic)

Percentage of cultural places in the Register of the National Estate in Queensland

Number of wrecks off Queensland protected by the Historic Shipwrecks Act

Number of wrecks off Queensland located by Queensland Museum maritime archaeologists

Number of designated landscape areas under the Cultural Record (Landscapes Queensland and Queensland Estate) Act

Number of places recorded on the Aboriginal and Torres Strait Islander heritage places inventory

Land area surveyed for Aboriginal and Torres Strait Islander heritage places

Number of each type of Aboriginal and Torres Strait Islander place recorded (representativeness)

Number of places entered in the Queensland Heritage Register

Land area surveyed for historic heritage places

Number of each type of historic place in the Queensland Heritage Register

Number of places entered in the National Trust of Queensland lists

Number of Aboriginal and Torres Strait Islander heritage places protected by local government heritage registers

Number of historic heritage places protected by local government heritage registers

Number of heritage-registered places relocated

Number of heritage-registered places 'facade only'

State of cultural heritage objects and collections

Number of museums and collecting institutions in Queensland

Range of types of museums in Queensland

Number of items in cultural heritage items collections

Percentage of collections accessioned

Percentage of collections well documented

Percentage of collections partially documented

Percentage of collections undocumented

Percentage of collections catalogued on computer

Number of public art collections (members of RGAQ registered with collections)

Number and type of cultural heritage objects held by the Queensland Museum and branches

Number and type of Queensland works held by the Queensland Art Gallery

Number and type of Queensland cultural heritage objects held by the John Oxley Library

Amount of archival material held by the Queensland State Archives

Number of collections held by Queensland universities

Number of community museums in Queensland

Number of regional galleries in Queensland

Number of items held by community museums and regional galleries in Queensland

Available storage space for collection growth

Percentage of collections stored in full climate-controlled conditions

Percentage of collections stored in conditions with some climate control

Percentage of collections stored in conditions with no climate control

INTRODUCTION

INTRODUCTION

Cultural heritage is about identity, about knowing who we are as individuals, community, state or nation. In a world where attitudes and values are rapidly changing, and where the physical shape and presence of our surroundings are subject to change, we need to maintain tangible links with the past. These links serve as important physical reminders of the development of our society, culture and identity. Heritage places and objects — tangible expressions of ideas, values, tastes, technologies and economic and social relationships — help us understand the past and act as signposts for our future.

Each generation has a responsibility to ensure that the heritage entrusted to it is available to later generations. We must also continue to develop our cultural heritage for those who follow us.

The purpose of this chapter is to document the current state of Queensland's cultural heritage environment and the pressures our society imposes on it. The chapter will also explore society's response to these pressures. Recognition of the need to conserve aspects of Queensland's past is evident in government and community actions including legislation, grant funding and public education programs, as well as the growing number of small museums and 'keeping places' established by local communities.

Indicators are used to measure human pressures, the current state or condition of the cultural heritage environment and responses by society to alleviate those pressures and/or improve the state of that sector of the environment. This snapshot now can be used for comparison in future reports. In this way, changes in pressures, condition and responses can be monitored over time, so that accurate and timely information can be provided to decision makers.

Old Ithaca Fire Station, Brisbane

Places can be significant for their physical attributes shaped by humans, or for their intangible properties.

Cultural heritage significance

Cultural significance is defined in the Burra Charter as 'aesthetic, historic, scientific or social value for past, present or future generations' (Marquis-Kyle and Walker 1992). The cultural heritage significance of some places might also lie in their archaeological value, or in their anthropological or spiritual associations. For Queensland's historic places, the *Queensland Heritage Act 1992* defines the cultural heritage significance of a place or object as including 'its aesthetic, architectural, historical, scientific, social or technological significance to the present generation or past or future generations'.

Cultural heritage places

A heritage place is broadly an area of land with physical or intangible attributes of cultural heritage significance. Cultural heritage places include landscapes and buildings and their surrounds, as well as natural features of cultural significance. They include elements in our environment, such as a site which has played an important role in our history, a building which is a rare example of an architectural type, or a natural feature such as a rock formation or landscape which has spiritual significance to indigenous people. Cultural landscapes represent the 'combined works of nature and of man', and illustrate the evolution of human settlement over time as it is influenced by natural, social, economic and cultural forces (UNESCO 1996a).

While the state of Queensland's heritage places can be measured only in terms of those places which have been so identified, many places not formally recognised through legislative measures are culturally significant. The state of Queensland's cultural heritage places must therefore be examined in terms of the extent of knowledge and identification.

SCOPE

The cultural heritage environment incorporates everything we have from the past. It includes cultural landscapes shaped by indigenous and non-indigenous Queenslanders, along with the places of days long gone and those of the recent past. It includes everyday objects and artefacts, documentary records and works of art. It also includes the intangible elements of folklore, ideas, memories, skills and practices that are embodied in the physical evidence of the past. Whether of simple construction, 'rough-and-ready', exquisitely designed, ingeniously built, or in their natural state, they are all part of Queensland's cultural heritage. They are important to our communities and to the nation as a whole.

This chapter focuses on tangible aspects of Queensland's environment and the waters off the coast of Queensland under Commonwealth or Queensland jurisdiction which have cultural heritage significance. It discusses objects of significance to indigenous and non-indigenous people, whether found in place or in collections developed for conserving a particular aspect of past or present lifestyles, and places.

Cultural heritage objects

Most objects recognised for their Queensland heritage value are in museum collections. The term 'museum' is used broadly to include art museums. Collections of Queensland's historical documents and photographs held by libraries and archives are included in the scope of this chapter. General library collections are excluded.

For practical reasons, this chapter focuses on those heritage objects held by Queensland's public institutions responsible for collecting and presenting items of cultural heritage significance. These include major government-funded institutions and community museums managed by local volunteers. Heritage objects remaining in place are considered in the context of their unique relationship with heritage places.

DESCRIPTION

Queensland has a diverse cultural heritage. Those who have shaped Queensland's heritage environment range from indigenous inhabitants to pastoralist settlers, European and Asian migrants, and Pacific Islander labourers. People from these many cultural backgrounds have enhanced economic growth and community development, while leaving their imprint on our cities, towns and countryside.

Many places that have special associations with the diverse cultural groups making up modern Queensland are entered in the Queensland Heritage Register and protected under the Queensland Heritage Act. They include the Chinese temples in Atherton and Brisbane, the Jewish Synagogue in Brisbane, the South Sea Islander meeting hall in Homebush near Mackay, and the Marble Cafe in Childers, established by the Cominos brothers from Greece.

Queensland is fortunate in having a rich living heritage of Aboriginal and Torres Strait Islander cultures. Many places tell us a great deal about the way indigenous people have lived and about how they responded, and continue to respond, to diverse environments from islands and coastlines to mountains and deserts. Some natural places have special significance for Aboriginal and Torres Strait Islander people. Familiar features in the landscape are brought to life in stories about the creation of life and the organisation of social responsibilities. These links with past experience are part of our cultural landscape, a source of understanding of how people found life's physical and spiritual necessities in the environment surrounding them.

Indigenous places

Queensland's indigenous cultural heritage places include places with archaeological remains as well as places of spiritual significance to Aboriginal and Torres Strait Islander peoples.

Types of indigenous cultural heritage places in Queensland include:

- occupation places, including shell middens, artefact scatters, dwellings and hearths/ovens;
- modified landscapes, including bora grounds, carved or scarred trees, stone and earthen arrangements, pathways and sculptures;
- rock art sites, including paintings, engravings, stencils and drawings;
- resource areas, including quarries, grinding grooves, wells, hunting hides, fish traps and weirs;
- burial places;
- places with traditional associations, including identity association places, dreaming trails and story places;

Aboriginal fish trap. This stone fish trap, located in the tidal zone at Goold Island, near Ingham, is not under any perceivable human threat. However, it is slowly being covered by the naturally shifting beach sands, mangrove mud and silt.

The Dig Tree, located on the banks of Cooper Creek, has a message carved in it in 1861 by members of the tragic Burke and Wills expedition.

- historic indigenous places, including Macassan sites, reserves, missions, massacre sites, fringe camps, ration depots, children's homes, schools, protectorate stations and churches; and
- contemporary places, such as keeping places and meeting places.

Historic places

Queensland has a wide range of historic heritage (or non-indigenous) places, from cemeteries to schools, grazing properties to mines, parks to places of worship, hotels to hospitals. Not all of these types of places are currently recognised in formal registers.

Heritage objects

The diversity of Australian culture has contributed to an enormous range of material culture items in public and private collections. Collections now are filled not so much with curios as with evidence of everyday aspects of our past.

The range of museums and collections in Queensland is constantly expanding. However, many are outside the scope of this chapter. The focus here is on cultural heritage collections, in which there is substantial diversity.

Collecting institutions in Queensland include:
- State-funded museums such as the Queensland Art Gallery and the Queensland Museum, and regional or branch museums and galleries;
- university museums;
- community museums, often run by local historical societies or volunteer groups;
- thematic museums, such as those which focus on maritime, railway, aviation or military heritage;
- museums based on specialist collections, including house museums;
- keeping places for indigenous heritage items; and
- archives and libraries.

The types of heritage objects held in these collections include:
- art collections, including paintings, drawings, etchings, sculptures and cyberart;
- historical objects, comprising everyday items from the past, items recovered from excavations, and items associated with important people;
- Aboriginal and Torres Strait Islander artefacts, including artworks, stone tools, clothing, body ornaments, trade items, and secret and sacred material; and
- archival collections including government records, manuscripts, correspondence, publications, newspapers, photographs, drawings, architectural plans, maps, sound recordings, and film and cinematographic records, including news footage.

Archival collections are an important aspect of Queensland's heritage environment, providing an understanding of the past and of the significance of remaining heritage objects and places. They enable researchers to interpret and explain aspects of the past, and complement and enhance the wider material heritage environment.

Archival collections are maintained in various government institutions such as the John Oxley Library, the State Archives and the Australian Archives. Archival records are held in collections at university libraries, State Government- and community-funded museums, by church organisations, and in business and family archives.

Historical societies and community groups also collect and maintain material of local significance. Many documentary items are stored on microfilm and microfiche to preserve them. Other archival material is held privately, but information about its state is difficult to obtain.

CULTURAL HERITAGE VALUES

Many heritage places and objects hold different values for different people. A statement made in relation to movable cultural heritage applies equally to heritage places: '... heritage is an important element in the lives of all Australians. It is evidence of the cultural richness and diversity of Australian people, past and present. It helps define who we are.' (Commonwealth of Australia 1994)

The values of heritage places and objects relate to the way in which they might be used or appreciated, and to their cultural heritage significance. Recognition of the cultural heritage values integral to the nature of the place or object is an essential part of the significance assessment process. The significance of places should guide decisions about their management and use, including their display and interpretation.

Values used to assess the significance of Queensland's cultural heritage places and objects are described in table 9-1. Additional values are described in table 9-2.

Table 9-1 Values used to assess the significance of Queensland's cultural heritage places and objects

Value	Description
Aesthetic	Includes its visual merit or interest (*Queensland Heritage Act 1992*).
Architectural	Recognition of a building for its notable, rare, unique or early example of style or construction, the significance of the architect, the unique or attractive design or its age.
Historic	Encompasses the history of aesthetics, science and society. Historic value may be influenced by a historic figure, event, phase or activity. The historic value of a place will be greater where a place remains intact. However, some places may retain significance regardless of subsequent treatment (Australia ICOMOS 1992).
Scientific	Depends on the importance of the data involved, including rarity, quality or representativeness, and the ability of a place or object to contribute further substantial information (Australia ICOMOS 1992).
Social	Embraces the qualities for which a place has become a focus of spiritual, political, national or other cultural sentiment to a majority or minority group (Australia ICOMOS, 1992).

Table 9-2 Additional values of Queensland's cultural heritage places and objects

Value	Description
Cultural understanding	Cultural heritage conservation helps us understand and accept the cultural differences between people.
Education	Places or objects convey anthropological and historical knowledge which helps us understand the past and the present.
Financial value	Property values may rise with the research and recognition of the cultural heritage significance of a place. An accurate documented history of one's property can be passed on to future generations and may add monetary value to a property.
Identity	Places and objects provide tangible symbols of individual or community identity.
Spiritual value	Places and objects often have spiritual associations.
Tourism and recreation	Cultural heritage places are valued as recreational resources, and as an increasingly important aspect of Australia's tourism industry.

Queensland Heritage Register

The Queensland Heritage Register, established under the *Queensland Heritage Act 1992*, comprises entries of historic places which are legally protected. Places can be nominated for the Register by organisations or members of the public. For a place to be entered in the Register, it must be of cultural heritage significance and meet one or more of the Act's criteria. However, a place cannot be entered in the Register if there is no prospect of the cultural heritage significance of the place being conserved.

Criteria for entry in the Heritage Register are that the place:

- is important in demonstrating the evolution or pattern of Queensland's history;
- demonstrates rare, uncommon or endangered aspects of Queensland's cultural heritage;
- has potential to yield information that will contribute to an understanding of Queensland's history;
- is important in demonstrating the principal characteristics of a particular class of cultural places;
- is important because of its aesthetic significance;
- is important in demonstrating a high degree of creative or technical achievement at a particular period;
- has a strong or special association with a particular community or cultural group for social, cultural or spiritual reasons;
- has a special association with the life or work of a particular person, group or organisation of importance in Queensland's history.

Queensland Heritage Council

The Queensland Heritage Council was established under the Queensland Heritage Act to administer the Queensland Heritage Register. The Council consists of 12 people nominated by the Minister and appointed by the Governor in Council. One of these people is appointed by the Governor in Council as chairperson. Five members represent organisations or interest groups specified in the Act. Seven members have knowledge, expertise and interest in heritage conservation.

The Heritage Council is supported by subcommittees, including the Heritage Register Advisory Committee, the Development Committee, the Policy Committee and the Procedural Committee. The Heritage Register Advisory Committee has a membership independent of the Council. This committee provides advice on the research and documentation of significance of places nominated for entry in the Register. The Development Committee considers applications for the development of places entered in the Register.

PRESSURE

Factors contributing to the deterioration and destruction of the heritage environment are considered pressures. These can be natural or the result of human activity. Although the primary focus here is human activity, pressures that nature places on cultural heritage places and objects must also be considered. Natural pressures include ageing, climatic stress, decay and erosion. Other damage, less common but more severe, is caused by extreme events such as floods, rising sea levels, cyclones and storms, fire and earthquakes. Many responses outlined in the concluding section of this chapter reveal attempts to counter these natural pressures in conjunction with managing human-related pressures.

Pressures affecting the heritage environment are dealt with in terms of those which affect places and those which affect collections of objects. In the case of heritage objects, the principles of conserving cultural material require that preventive conservation be a priority over other actions. The extent of treatment should be that which is required and no more than is necessary (AICCM 1986). Similar principles apply to heritage places (Australia ICOMOS 1992).

PRESSURES ON CULTURAL HERITAGE PLACES

All cultural heritage places, regardless of cultural affiliation, are subject to similar environmental pressures. Therefore pressures affecting Aboriginal and Torres Strait Islander and historic heritage places are discussed together. The most notable contrasts in threats to places are between places in urban and in rural contexts (where population and isolation issues dominate) and between occupied and unoccupied places. Due to the fragile nature and isolated location of indigenous heritage places, pressures affecting these sites are common.

To date, quantitative measures of pressures on the heritage environment are not well defined. Hence the following discussion of such pressures is primarily a qualitative analysis.

Human-caused pressures identified as affecting cultural heritage places include:

- lack of identification and evaluation of significance;
- cultural change and conflicting heritage values;
- socioeconomic change and development;
- attitudes and perceptions;
- tourism and recreation; and
- neglect.

These pressures are discussed below, with quantitative indicators of their extent. Indicators of these pressures have been developed on the basis of their ability to reflect the trend of the pressure, and their ability to be collected. Some indicators outlined are not available at this stage but are included to show the type of information required for future reporting and trend analysis.

Some indicators used might be used in future reports to measure responses. An example is the level of documentation of museum collections. Where this is low, it represents a pressure on that aspect of the environment because it places the cultural meaning of objects at risk of being lost. A high level of documentation of collections represents a 'response', a measurement of positive actions to improve the state of cultural heritage objects.

The Bookkeeper's Cottage at Eidsvold Station. Conservation work is urgently needed to prevent rapid deterioration of this building following its damage during a storm.

Lack of identification and evaluation of significance

Indicators

Number of places identified and recorded in Queensland heritage inventories

Percentage of places recorded which have been assessed for their cultural heritage significance

Percentage of indigenous heritage identification projects which actively involve indigenous people

The failure to identify heritage places, or to recognise the significance of such places, is a major impediment to the conservation of Queensland's cultural heritage. This issue is at the core of many other pressures which affect heritage places. Without knowledge of the nature and significance of places in a region, heritage values cannot be considered in regional economic and cultural planning. This lack of knowledge, combined with last-minute consideration in the planning and development process, gives rise to reactive management of places. Details of the number of places recorded in Queensland heritage inventories are provided in the 'State' section of this chapter. Information about assessing the significance of these places is not available.

Where Aboriginal and Torres Strait Islander peoples are not involved in managing an indigenous heritage place, knowledge of the place's significance is usually lacking. As a result, sites cannot be assessed accurately and sympathetically. The problem is exacerbated where visitation occurs and the sites are not interpreted, or are interpreted incorrectly. Culturally inappropriate visitation can also be a problem.

Cultural change and conflicting heritage values

Cultural change in a region can lead to conflicting cultural and heritage values and disintegration of cultural traditions.

Aboriginal and Torres Strait Islander cultures have undergone widespread change since Australia was colonised. The progressive alienation of indigenous people from their cultural roots has led to a loss of indigenous language and tradition. Because languages were the medium of transmission of cultural knowledge, the loss of language places considerable pressure on Aboriginal peoples' ability to pass on cultural knowledge and traditions to future generations.

The introduction of a cultural group to a region can lead to conflict between cultural values. For example, some Aboriginal art sites also contain historically significant graffiti which are not valued by the Aboriginal community, who wish to see them removed.

The values of a built heritage place can be compromised when the place is used by a different cultural group to accommodate new uses and beliefs. The Heritage Council can, however, approve an application to change a property if it considers the change will not be detrimental to the significance of the whole property.

Historic industrial sites, such as those used for mining and forestry, are susceptible to demands for rehabilitation and revegetation of the natural environment. Alternatively, mine shafts might be reopened for mining, or tailings dumps might be mined to extract further minerals. Such change can lead to the removal of the fabric of a place and therefore diminish its cultural heritage significance. Technological changes also mean that the original fabric is removed to be replaced by new materials — for example, wooden railway bridges of historic value can be replaced with new bridges or crossings.

Socioeconomic change and development

Economic growth has both positive and negative effects on Queensland's heritage. On the positive side, many buildings and structures are well maintained. On the negative side, some heritage places are under increasing threat of demolition, removal or alteration. Economic growth affects rural and urban areas and Aboriginal and historic heritage in different ways and to varying extents.

Population dynamics

Indicator

Number of applications to demolish or remove a building in a residential zone inside Brisbane City Council's urban character area

Population growth results in urban sprawl as well as increased density of inner suburbs. Demographic change puts pressure on the cultural landscape when the rural landscape is replaced by an urban one. In 1947, 59.7 percent of Queensland's population was based in urban centres. By 1995 this figure had increased to 80.1 percent. This shift leaves Queensland's rural cultural landscapes open to the threat of change.

Urbanisation is particularly evident in south-east Queensland, where Aboriginal and historic archaeological sites and cultural landscapes are threatened before their heritage value is assessed. Without identification and assessment surveys, the sustainability of Queensland's cultural heritage resources is severely limited.

Changes in residential zoning in urban areas as a result of population increases may also constitute a form of pressure. The rezoning of an area to increase population density can put heritage buildings in jeopardy because the new zoning might contradict the present and traditional use of sites. Houses located in areas rezoned for high-density residential use are at risk of demolition, redevelopment or removal to another area, resulting in loss of context. Similarly, differences between building heights specified in regulations and heights of existing buildings in an area pose a threat to the preservation of original streetscapes. Provisions of the *Integrated Planning Act 1997* restrict the ability of local governments to enforce character control in such zones if that action would affect an owner who wished to redevelop.

Other factors altering the character of Brisbane's earlier suburbs include the development of small-lot housing in areas zoned residential A, and unsympathetic alterations to existing traditional houses. Brisbane City Council estimates that about 70 percent of applications to demolish or remove a building in a residential zone inside Brisbane City's urban character areas are approved. Between October 1995 and January 1997, Brisbane City Council received 585 applications to demolish or remove a building in a designated character area.

Demolition and removal of heritage buildings

Indicators

Number of places demolished while nominated for inclusion in the Queensland Heritage Register

Number of heritage-registered places relocated

Number of permits issued by Queensland Transport for moving houses in the Greater Brisbane area

Large developments, driven by economic growth and demographic change, often lead to the degradation and demolition of heritage places. Between July and December 1996, three places identified as being of local heritage significance were demolished in the Brisbane City Council area before Brisbane City Council's approval of their applications for development.

Since the Queensland Heritage Act was proclaimed in 1992, about three percent of places nominated for entry in the Register have been demolished before assessment was completed. A 60-day stop order can be issued but the Act lacks adequate provisions for protecting a place between nomination and Queensland Heritage Council decision.

Redevelopment in some regional centres has conflicted with the preservation of heritage values. In Warwick a heritage-registered stone church was relocated so that a major shopping centre could be built. Removal destroyed the church's original context and diminished its significance, so it was removed from the Register. The issues of context and sense of place, highly valued in heritage significance, are not always appreciated by developers and some in the community who see the removal of buildings from their original context and surrounds as desirable.

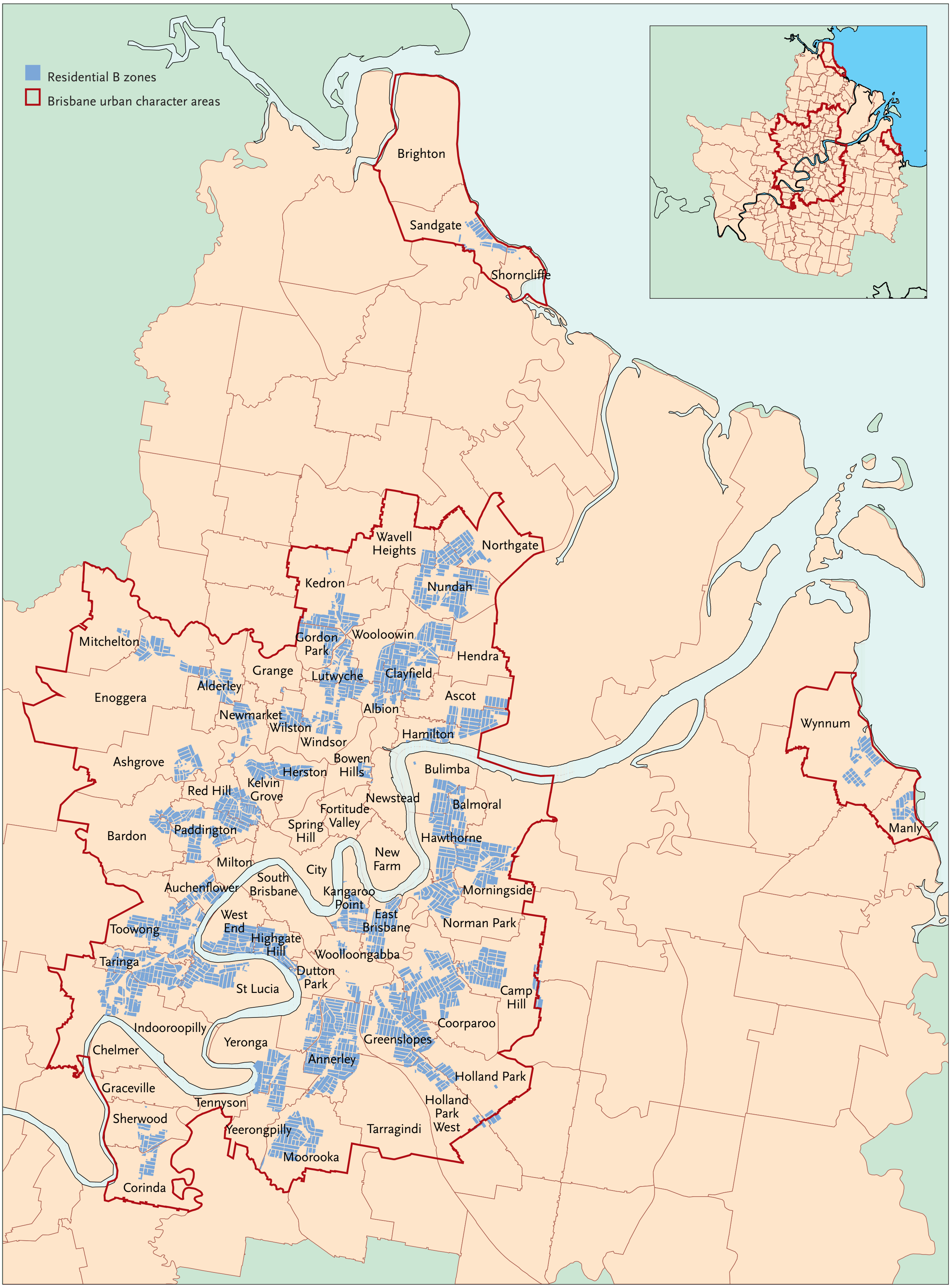


Figure 9-1 This map shows where Brisbane City Council urban character areas and land zoned for higher residential densities (residential B zones) coincide. Since the 1960s, many of Brisbane's inner and middle suburbs have been zoned for higher-density residential use, posing a threat to Brisbane's characteristic single-storey 'timber and tin' houses.
(Source: Map provided by BCC)

Eight heritage-registered places were approved for relocation in the five-year period 1992–97. Four were churches. Generally, the number of houses moved in the Brisbane region exceeds 600 a year. From January to November 1996, 631 applications for permits to move houses were made to Queensland Transport. These were concentrated in the area around Brisbane, ranging from Beenleigh to Caboolture and Toowoomba.

Replacement of traditional industries

Indicators

Number of survey permits granted under the Cultural Record (Landscapes Queensland and Queensland Estate) Act

Number of redundant/unoccupied heritage-registered buildings

Number of places in the Queensland Heritage Register which have an adaptive reuse

Number of railway stations/sidings closed each year

In Brisbane, the refurbishment of the Teneriffe Woolstores into residential apartments is indicative of the effect of changing social and economic conditions. In rural areas, the development of new industries as a result of changed socio-economic and technological conditions brings changes to the landscape. An example of such change is the shift from sheep grazing to cotton growing on the Darling Downs. Spin-off effects of new industries may be changes to or closure of traditional transport infrastructure such as railways and roads. This kind of pressure is particularly acute in south-west Queensland and could result in the loss of historic features of the landscape.

A quantitative indicator of the pressure of development in remote and rural areas, particularly on indigenous heritage places, is the number of permits issued under the *Cultural Record (Landscapes Queensland and Queensland Estate) Act 1987* for cultural heritage assessments undertaken as part of environmental impact assessment studies. During 1996–97, 187 permits were granted for this purpose (table 9-3). Often, no follow-up work with a developer is undertaken after completion to ensure that cultural heritage sites are conserved in accordance with study recommendations. Hence the extent to which cultural heritage findings and recommendations made during impact assessment are taken into account or adhered to cannot be measured.

Redundancy of urban buildings is a substantial pressure on heritage places brought about by changes to standards of work practices and social, economic and technological changes. Redundancy often occurs as changes in quality standards and business practices affect requirements for facilities. For example, upgrading of the Warwick watch-house meant that the original building could not be retained, despite its heritage value. A further example of redundancy is mental hospitals, such as Challinor Park, which are closed as a result of the shift towards decreased use of institutional care for mentally ill or intellectually handicapped people. Redundancy in churches results from amalgamation, reduction and relocation of congregations. Other building types made redundant in the 1990s include large houses and government buildings, and industrial and warehouse buildings made redundant by changing technology. If adapted sympathetically, these buildings can be retained as reminders of our past.

Redundancy also occurs as business practices shift towards information-based services. Banks and post offices are affected in this way, requiring internal alteration or disposal of their buildings. Many buildings traditionally used as banks, post offices or government offices are being sold as such services move into shopping centres. Similarly, changes in technology and business needs have meant that many town courthouses have closed, or moved to new purpose-built premises. This is the case with the Rockhampton Supreme Court, which outgrew its building.

Figure 9-2 Department of Environment and Heritage administrative boundaries and Regional Offices, and National Trust of Queensland branch offices at October 1998

Table 9-3 Number of survey and research permits issued under the *Cultural Record (Landscapes Queensland and Queensland Estate) Act 1987* by Department of Environment and Heritage region at October 1998. Permits to survey an area for items of the Queensland Estate are granted primarily for environmental impact assessment surveys and indicate the pressure of development on areas where cultural heritage resources might exist but are unidentified.

Year	Central Coast	Far Northern	Northern	Southeastern	Southwestern	Total
1992–93	11	8	5	37	1	62
1993–94	11	13	14	27	7	72
1994–95	16	22	24	53	5	120
1995–96	21	43	52	68	13	197
1996–97	28	30	48	58	23	187

Griffith University (AES)

Old Woolloongabba Post Office, Brisbane

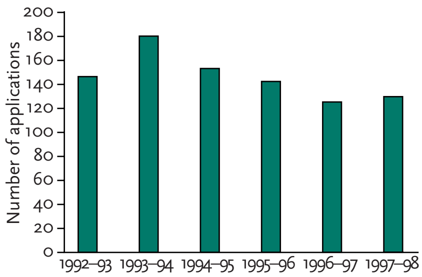


Figure 9-3 Applications to the Queensland Heritage Council for development of properties entered in the Queensland Heritage Register under the Queensland Heritage Act. Most applications were for places in south-east Queensland.

Adaptive reuse of buildings is often needed to retain heritage places. This process is both a pressure and a response. The process is evident through Brisbane's recent 'urban renewal' schemes which reflect change in industries in and around Brisbane's city centre. Inner-city churches are used as galleries, restaurants and houses, and industrial warehouses are converted into residential places. The process requires early identification of heritage places and their values so that development can be managed sympathetically without compromising cultural heritage significance. Where such developments are approved by the Queensland Heritage Council, conservation architects assist in planning and adapting heritage-registered places. Comprehensive quantitative information on the adaptive reuse of heritage buildings in Queensland is not available.

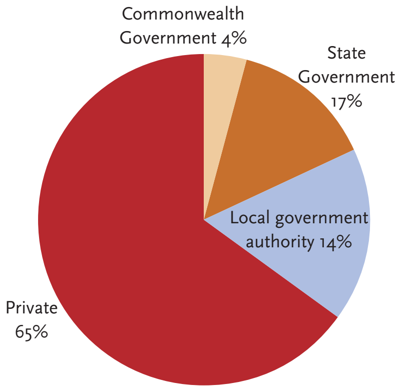


Figure 9-4 Tenure of places entered on the Queensland Heritage Register at 4 November 1998. Of these, 64.5 percent are privately owned. The remainder are owned by the Commonwealth Government, the Queensland Government or local government.

Development of heritage buildings and structures

Indicators

Number of applications for development of heritage-registered places under section 34 of the Queensland Heritage Act

Number of State properties developed against Heritage Council recommendations

The pressure of unsympathetic development of heritage places is accentuated by a lack of appreciation or understanding of the value of heritage places culturally, socially and financially. This is due primarily to a lack of knowledge of how to develop a place sympathetically while understanding the history or background of a structure. Unsympathetic development can be reduced through consultation with conservation architects.

Development proposals for places entered in the Queensland Heritage Register are subject to approval by the Queensland Heritage Council. Of the 124 applications lodged during 1996–97, 27 were for Crown properties. Of the remaining 97 private applications, 98.5 percent were approved immediately (figure 9-3). In 1997–98, 182 applications were processed.

Government is required to seek the advice of the Queensland Heritage Council for development proposed on Crown properties owned by the Queensland Government or the Commonwealth Government, but it is not subject to the Council's approval for development as is development on private places (figure 9-4). Data regarding Crown developments are not available.

Objections and appeals against Queensland Heritage Register entries

Indicators

Number of objections to Queensland Heritage Register entry

Number of appeals against Queensland Heritage Register entry

When the Queensland Heritage Register was established under the Queensland Heritage Act in August 1992, 970 places were transferred from the schedule of the *Heritage*

Buildings Protection Act 1990. Under transitional provisions, 140 objections to entry in the Register were lodged. Many were lodged to allow discussions to resolve issues of heritage boundaries. About 65 percent of the places with transitional objections were entered permanently, 41 percent after discussions with the Queensland Department of Environment and Heritage and 23 percent after independent assessments of their heritage value. A small percentage of the objections proceeded to become appeals to the Planning and Environment Court; some of these were withdrawn after negotiation.

A significant number of places nominated in response to specific development proposals have been the subject of objection. These nominations are given some priority because the places are under threat. Entry in such circumstances inevitably generates conflict in the form of objections and appeals. In contrast, entry where no change is contemplated by the owner does not usually generate an objection or appeal. Therefore the number of objections and appeals might reflect a distorted view due to the one-off reactive process of listing. Fewer objections might result from a systematic process covering all places of cultural heritage significance in an area rather than only those places that are at risk, which might or might not be of cultural heritage significance.

Places removed from Queensland Heritage Register

Indicator

Number of places removed from the Queensland Heritage Register

A place can be removed from the Queensland Heritage Register by the Queensland Heritage Council. An application for removal is generally lodged when the owner wishes to develop a place in a way that would be unsympathetic to its heritage values (and which would not be approved by the Heritage Council), or wishes to demolish it. A place can also be removed from the Heritage Register if its heritage integrity has been substantially compromised by removal of the original fabric of the place, or by removal of a building from its original context and surrounds. Several places have been removed from the Register because of extensive fire damage.

Places removed from the Register include the Wesley Uniting Church, Warwick, as a result of approval to relocate; 95 Russell Street, Toowoomba, subsequently demolished; and part of Magnolia Farm, Sunnybank, which has now been subdivided. Eight properties were removed from the Register in 1996–97.

As a result of the lack of heritage controls before enactment of the Heritage Buildings Protection Act, a number of places scheduled under this Act and later transferred to the Queensland Heritage Register had been demolished or substantially altered. Little checking of the existence or condition of places was conducted when the schedule was established. Subsequently these places were removed from the Heritage Register.

Some places on the earlier list also failed to meet the Heritage Register's more stringent requirements and were removed, in some cases following owner objections. In the two years to 30 June 1994, 48 places were removed from the Register, most as a result of the transitional objection process. One was removed in 1994–95 and one in 1995–96.

Attitudes and perceptions

Detrimental and negative attitudes to heritage places exist in professional and private spheres. These can be attributed to a lack of understanding of the values of heritage places in general, of the potential for adaptive reuse of heritage places, and of the principles of heritage conservation, including heritage legislation.

Despite the high percentage of development approvals, many people still believe nothing can be done to a heritage place. Such attitudes and perceptions limit the potential for heritage places to be conserved and interpreted. They also serve to exclude everyday places from heritage protection.

Lack of understanding of heritage conservation

A lack of understanding of cultural heritage principles is epitomised by the idea that all heritage places must be old. Culture is a living thing and should not necessarily be waning before we attempt to preserve its tangible aspects. Similarly, familiar places are often taken for granted. A familiar place may not be appreciated for its heritage value until that value is highlighted, often as a result of the place being threatened.

Lack of respect for cultural traditions

Some negative attitudes to cultural groups are evident in Queensland. In western Queensland significant Aboriginal places are reported to have been destroyed under suspicious

Before: The former Townsville Supreme Court was once a grand Queensland building.

After: The building was destroyed by fire in early 1998 after becoming redundant.

circumstances. One such place was a stone arrangement at Bierbank, west of Charleville, destroyed by bulldozing.

Tourism and recreation

Indicators

Number of visitors to cultural heritage places

Number of Aboriginal rock art sites visited regularly

While few physical impacts of cultural tourism can be identified for occupied historical buildings, much pressure is exerted on unoccupied heritage places, particularly Aboriginal art sites, and historical archaeological sites including shipwrecks.

These pressures include physical disturbance from tourism developments and visitor damage, both intentional and inadvertent. The extent and effect of visitation for frequented Aboriginal and historic heritage sites are unknown because no measuring systems are in place.

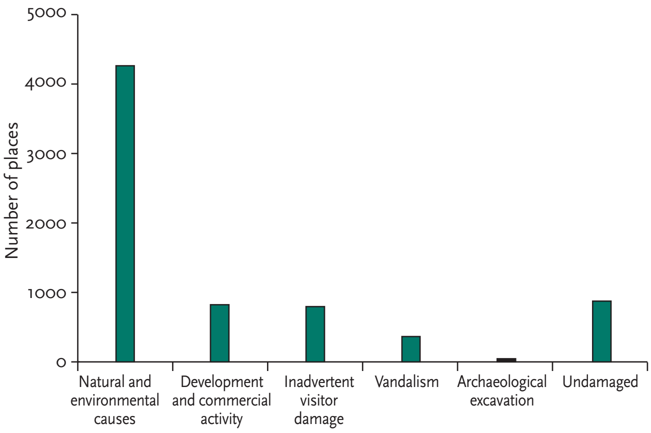


Figure 9-5 Number of indigenous places recorded by the Department of Environment and Heritage at October 1998 under the Cultural Record (Landscapes Queensland and Queensland Estate) Act affected by various pressures

Intentional damage

Intentional damage to Aboriginal heritage places by visitors includes:

- graffiti, such as the carving of names and initials at art sites;
- vandalism and theft, such as the removal of designs from art sites; and
- collecting or stealing artefacts from sites as keepsakes or for sale.

A problem at all visited Aboriginal rock art sites is graffiti, in the form of carved or scratched initials, names and random scribbles. Graffiti detract from the visitor experience, a fact often noted in visitor books (Horsfall 1991b). Such desecration of heritage places is also offensive to Aboriginal people.

Graffiti dating from the early 1900s can be seen at places such as the Chillagoe art sites and Blacks' Palace in the Central Highlands. Attitudes seem to be changing for the better, however: while visitation here is increasing, the ratio of graffiti to visitation is clearly decreasing (Godwin 1992b).

The main forms of intentional damage at historic archaeological places include collecting scrap metal, souvenirs and bottles. Historical sites in far north Queensland, including the Palmer River Goldfields, have been plundered for scrap metal (Horsfall, N., pers. comm.).

Inadvertent damage

Inadvertent damage to heritage places is caused primarily by ignorance, but is also attributed to over-enthusiasm and inappropriate visitor numbers. Over time, more damage can be done to Aboriginal art sites inadvertently than by the occasional act of vandalism.

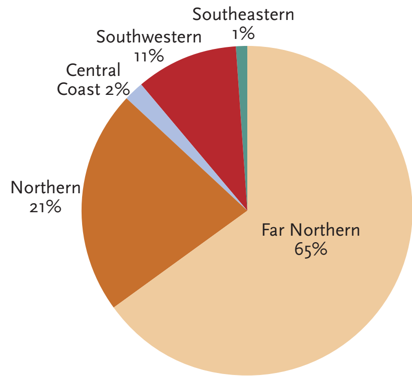


Figure 9-6 Location of visited rock art sites in Queensland (by DEH region at October 1998); 65 percent are located in the far north of the State.

Forms of inadvertent visitor pressure at Aboriginal art sites in Queensland include:

- dust due to foot traffic — for example, at Split Rock art site;
- visitors touching the art surface and flaking off paint;
- destabilisation caused by visitors trampling protective vegetation;
- accidental damage caused by visitors brushing against low shelter ceilings;
- damage caused by over-enthusiastic researchers fixing scales to pigmented surfaces for photography;
- attempts to remove non-original touch-ups; and
- cleaning to enhance images and colour.

Aboriginal heritage places can even suffer degradation at the hands of those who most appreciate them. According to a Queensland rock art conservator, '... rock art enthusiasts have long assumed a right to walk over, measure, mark and chalk outlines on faded images for their celluloid and other purposes' (Brown 1992). This tendency is being reduced gradually through the educative process and practical measures.

Surveys and field observations show that the most damaging categories of visitors at Aboriginal art sites are local residents and organised tour groups, including school groups — particularly those who lack suitable guides and management procedures (Jacobs and Gale 1994).

Some places are not suited to large numbers. For example, the management plan for the Blacks' Palace art site recommends a maximum of 30 visitors a week (Godwin 1992a).

Blacks' Palace art site complex

Nearly 90 years after its first dated visitation by Europeans, the Blacks' Palace art site complex north of Tambo in the Central Highlands remains one of the largest Aboriginal art sites recorded in Australia. It is the single largest collection of stencilled art anywhere in Australia, and probably the world. The complex is also a large burial site where numerous examples of distinctive bark cylinder coffins were found in caverns in the cliff face. This unique heritage place provides a discrete example of visitor pressure on Queensland's remote indigenous heritage. Continued monitoring of this pressure, the condition of the fabric of the place, and the effectiveness of management actions will provide a clearer picture of how the cultural heritage environment can be better managed in remote parts.

Blacks' Palace art site complex: a unique Aboriginal site under pressure from vandalism

Heritage values

Aside from its size and antiquity, Blacks' Palace has heritage value because of its spiritual significance to Aboriginal people, as a burial ground and as a tangible link with the past. The site also has substantial scientific value for the wealth of information it contains. Analysis of the artistic styles and the material culture such as the tools, weapons and dillybags depicted can reveal much about traditional Aboriginal culture in the Central Highlands. Blacks' Palace is also an important aesthetic, educational and recreational resource.

Visitor pressure

The greatest threat to conserving the site has been intentional damage as a result of uncontrolled human visitation. Names dating from 1907 to 1986 have been carved into the soft sandstone. Local people, attempting to rectify some of the graffiti damage by erasing the names of forebears, have caused further damage. (Walsh, undated). Other damaging activities have included shooting at the art, and attempts to hack out motifs. Burial crypts were pillaged early this century.

High levels of visitation at Blacks' Palace are due to its reputation as a spectacular art site. The site is well known locally and is indicated on tourist maps. It is accessible by car, although only through private property, and the elderly and disabled are not restricted. Visitor book entries indicate that at least 2500 people visited the site from 1967 to 1989. Initially, two-thirds were local people, but by 1989 almost 60 percent of visitors were non-locals. Factors contributing to this change included waning local interest, action by the landholder to limit visitation, increased outback tourism and the availability of 4WD vehicles (Godwin 1992b).

Management

In 1933, the Queensland Government declared Blacks' Palace a Scientific and Recreational Reserve. No mechanisms existed for issuing visitor permits or policing the site, however, and vandalism persisted. The *Aboriginal Relics Preservation Act 1967* was the first legislation enacted to protect Aboriginal cultural material, and was one of the first examples of Aboriginal cultural heritage legislation in Australia. Under this Act, ownership of all relics, including art sites, was vested in the Crown.

In July 1970, Blacks' Palace was cancelled as a Reserve for Scientific Purposes and gazetted as a permanent Aboriginal Site under section 13 of the Aboriginal Relics Preservation Act, with trusteeship vested in the Director of Aboriginal and Islander Affairs. From that time, a permit was required to visit the site, but no attempts were made to formally police the permit requirements. In 1971 the property owner was appointed as an honorary warden to manage the site.

Despite the introduction of the legislation, vandalism doubled across sites in the Central Queensland Highlands for about five years after 1967. Blacks' Palace contains 30 percent of all dated vandalism recorded in a sample of 12 sites for which such data have been collected (Godwin 1992b). It was five times more likely to be vandalised than any other site in the Central Queensland Highlands.

The site was declared a designated landscape area under the *Cultural Record (Landscapes Queensland and Queensland Estate) Act 1987*. The Queensland Department of Environment and Heritage took responsibility for the site in 1989 but trusteeship was not transferred. A site management plan involved Aboriginal people from the region. Its strategy was to restrict visitor access to formal guided tours conducted by an operator adhering to guidelines, with an Aboriginal person on each tour, and with a maximum of 30 people a week. Fencing, gates and viewing points were provided.

Management issues — including trusteeship, traditional custodianship, providing a gazetted access road and resources for continuing management — are unresolved.

The *Aboriginal Land Act 1991* provided for the return of land in the form of reserves such as Blacks' Palace to Aboriginal people. Native title issues also arise.

A major factor contributing to the continuing conservation of Blacks' Palace is the goodwill of the interested parties, including the landowner, the Aboriginal community, the Environmental Protection Agency as cultural heritage management agency, the tourist operator and the public.

The common view is that this work of art must be preserved for posterity.

(By Luke Godwin)

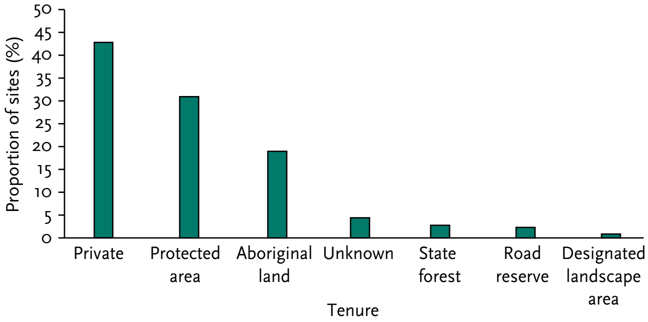


Figure 9-7 Tenure of Aboriginal rock art sites in Queensland known to be visited regularly
(Source: Franklin 1996)

Figure 9-7 shows the tenure of Aboriginal rock art sites in Queensland that are known to be visited regularly. Landholders taking tourists to see sites on their own land facilitate most of the known visitation in north Queensland (Horsfall, N., pers. comm.). While private landowners encourage visitation, cultural heritage managers can do little to police it. Small-scale tours on private land are conducted with little or no contact with management agencies or Aboriginal groups.

Underwater cultural heritage and tourism

Indicators

Number of permits granted to enter protected zones of historic shipwrecks

Number of dives to historic shipwrecks in protected zones

The dive tourism industry is booming, particularly in Queensland's northern regions. While this is due largely to the international fame of the Great Barrier Reef, spectacular wreck dives such as SS *Yongala* are also drawing many divers (see figure 9-17). Despite the *Historic Shipwrecks Act 1976* (Cwlth), recreational divers still pose a threat to the integrity of Queensland's shipwrecks.

Diver pressures on shipwrecks include pilfering of artefacts and relocating artefacts in a site. Trapped air pockets due to scuba divers penetrating wrecks also cause metals to deteriorate and increase the rate of decay. Factors influencing the type and extent of tourism and recreational pressures on shipwrecks include their remoteness and their depth. The more difficult the access, the better will wrecks be preserved.

All wrecks over 75 years old in Commonwealth waters are protected by the Act whether their locations are known or not. However, wrecks lying in Queensland waters have no protection because the Queensland Government has not authorised the application of the Commonwealth Act. Most accessible wrecks are in Queensland waters and are therefore most susceptible to disturbance by recreational divers or treasure hunters.

Because the number of divers visiting shipwrecks in Queensland is not measured, the extent of diver pressure is unknown. Data collected for the wreck of the *Yongala* will provide an indication of the pressures imposed by a large-scale diver tourism operation.

Little wilful damage or theft is reported for shipwrecks and this behaviour is difficult to detect. Two prosecutions have been instituted for illegal activity at historic shipwreck sites in Queensland. As a result of alleged wreck pillaging at Cape Bedford, Coastwatch surveillance and historic shipwrecks inspectors have been alerted, and the level of aerial surveillance by the Great Barrier Reef Marine Park Authority has increased.

Further pressures on submerged sites, including shipwrecks and indigenous fish trap sites, arise from recreational boating activities and include mooring and fishing over sites. These pressures are reported for numerous shipwrecks and for fish traps at Hinchinbrook Island. Other pressures include the impacts of the natural environment such as wash, saltwater corrosion and the extreme conditions of cyclones.

Neglect

Although pressures from the natural elements are beyond the scope of this report, a society's lack of response to such pressures can be considered a pressure in itself. Where conservation action as a result of natural pressures is considered to be a response, failure to act must be considered a human pressure. Failure to act to conserve cultural heritage, particularly where a mandate is given to do so, is indeed a human pressure on the heritage environment. Such pressure applies mostly to isolated Aboriginal and Torres Strait Islander heritage places, and may also apply to remote historic archaeological places in Queensland.

The main causes of neglect of cultural heritage places in Queensland include a lack of financial resources and a lack of incentives for property owners to spend funds on capital works to conserve heritage components. Geographic isolation, the lack of tenants in buildings or on-site managers to conduct regular maintenance, and community attitudes which fail to value a place for its historical or heritage values also lead to neglect of our cultural heritage.

PRESSURES ON CULTURAL HERITAGE OBJECTS

Heritage objects in place

Cultural heritage objects remaining in place are at risk of illegal collection. Pressures associated with illegal collection include:

- inappropriate handling of objects;
- inadequate storage conditions for long-term conservation;
- loss of accessibility to the public; and
- risk of objects being bought and sold privately without documentation, thus diminishing knowledge of their cultural heritage significance.

Due to the unique relationship between a heritage place and objects that remain in place, other pressures relating to in-place objects have been identified for heritage places.

Heritage object collections

Most collecting institutions aim to provide a stable and accessible environment for heritage objects, but non-profit institutions often lack the necessary resources. Pressures affecting

The wreck of the passenger steamer *Yongala* off the coast near Townsville is the site of one of Queensland's worst maritime transport disasters. The vessel sank during a cyclone in 1911, with the loss of 120 lives. Subsequently, the vessel has been colonised by a rich variety of marine plants and animals, to the extent that the structure has become a living entity. This makes for a spectacular and moving underwater cultural heritage experience. However, its increasing popularity among divers means that site managers must balance the public demand for this sport diving experience with the conservation requirements of the wreck and its associated artefacts.

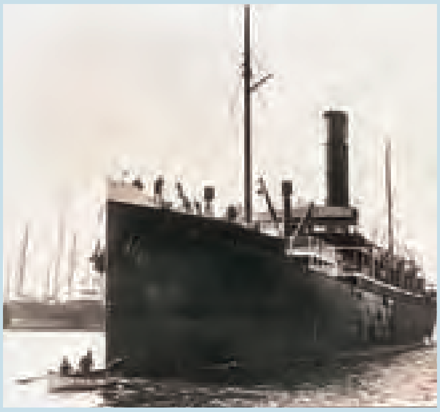
The *Yongala* lies entirely underwater at between 16 and 30 metres, depending on tide. The steel hull is 300 feet (about 90 metres) long and is remarkably intact, although there are several large holes in its sides. The name of the vessel remains on the bow and both anchors are in place. Many original compartments are intact and can be identified from deck plans.

HERITAGE VALUES

Culturally, the wreck is important for its social, aesthetic, scientific, historic, educational and recreational values (Queensland Museum 1992). Its social values relate to the fact that it is the grave of the 120 people lost. Some of their relatives still live in the region and are concerned about the site's future. The wreck is historically significant because of the scale of the disaster and the effect it had on the public and the maritime transport industry. It also provides a highly intact time capsule of maritime transport in the Edwardian era. Archaeologically, the wreck can provide material evidence of the social and economic conditions of the passenger trade during the first decade after Federation. As a major drawcard for Townsville's dive tourism industry, the wreck is also a significant economic asset.

PRESSURES

Aside from any impact from cyclones, the main pressures affecting the *Yongala* are caused by humans. Old and new anchor damage has been detected along the hull and at the mast (Illidge 1996). Before permit conditions were applied in 1990, vessels visiting the site would tie onto the wreck rather than anchor. Descent lines now must be buoyed and of diameter no greater than 10 mm. However, this means that the wreck is now at a greater risk of anchor damage.



JOHN OXLEY LIBRARY

SS *Yongala* before 1911

A large number of divers represents increased pressure on the wreck's fabric, and leads to a diminished visitor experience due to overcrowding. With 16 permits in operation in 1997, estimated dives may have exceeded 20 000 in the year. Currently dive numbers are not limited.

Queensland Museum maritime archaeologists are concerned that some deterioration of the fabric of the *Yongala* has been caused by oxidisation, the result of divers' air bubbles being trapped inside the wreck. Dives into the wreck are no longer allowed.

QUEENSLAND MUSEUM

Wreck of the *Yongala*

Salvagers and souvenir hunters removed numerous items before legislative protection in 1981. These included portholes, the ship's bell, safe and propeller, lanterns and dinnerware. In spite of legislative protection and a 'do not touch' policy, some material is being moved around on the site (Illidge 1996). The extent of artefact removal and relocation is difficult to ascertain without a comprehensive baseline study of the wreck and regular monitoring.

Fishing is prohibited within a 500 metre radius of the wreck. Snagged lines and lines hooked in the mouths of some of the wreck's resident groper provide evidence of illegal fishing (Queensland Museum 1992). People caught fishing in the protected zone have been prosecuted.

MANAGEMENT

The *Yongala* has greater legal protection than many of Queensland's other historic wrecks because of its location in the Great Barrier Reef Marine Park. The wreck is protected by the *Historic Shipwrecks Act 1976* and Great Barrier Reef Marine Park zoning. The code of practice distributed with permits to dive advises:

- look but do not touch;
- do not enter the wreck;
- exercise proper weight and buoyancy control;
- be aware of fin placement;
- ensure that dive equipment does not hang loosely;
- do not feed the fish;
- take care with anchoring; and
- dive only at the turn of the tide to avoid strong currents.

The *Yongala* is in a marine national park B zone of the Central Section zoning plan. Activities such as fishing, collecting and traditional hunting are banned. While diving, boating and photography are allowed in such areas, research, tourist and education programs require a permit.

Responsibility for conserving the *Yongala* rests with the Queensland Museum. However, the Great Barrier Reef Marine Park Authority and the Environmental Protection Agency make a joint effort in their role as marine park managers. A memorandum of understanding about the roles and responsibilities of the agencies in shipwreck management in the Great Barrier Reef Marine Park has been drafted.

In 1992 the Queensland Museum developed a draft management plan for the *Yongala* wreck. Some aspects have been implemented but the plan is under review and will be consolidated in consultation with interested parties. Integral to this will be the continued cooperation of dive charter operators.

QUEENSLAND MUSEUM

An item from the Oceanic anthropology collection of the Queensland Museum is inspected by curatorial staff.

cultural heritage objects in Queensland's collecting institutions include:

- inadequate collections management, including collection documentation and policy;
- inadequate environmental and storage conditions, exacerbated by rapid collection growth;
- limited opportunities for the professional development of community museum staff; and
- insufficient government and community support.

Repatriation of cultural collections has also been identified as a pressure on cultural heritage objects where the number of keeping places and their conservation provisions are limited. However, repatriation is considered a positive response to requests from Aboriginal and Torres Strait Islander peoples to return sacred material to its rightful place in the community, where its significance will be maintained. This aspect is discussed further in the 'Response' section of this chapter.

Collections management

Indicators

Percentage of collections accessioned

Rate of collection growth

Number of museums without collection policies

Inadequate collections management is one of the greatest threats to heritage objects held in public collections in Queensland. Many of Queensland's small museums are staffed by volunteers.

Table 9-4 Percentage of museum collections accessioned in Queensland, 1996. Accessioning does not include full documentation of an object.

Recorded (%)	Museums (no.)
<10	10
10–25	6
25–50	4
50–75	7
75–100	70

(Source: Commonwealth Department of Communications and the Arts 1996)

These museums often lack the facilities and training required to provide a stable environment for the storage and display of collections.

The registration and documentation of collections are among the greatest challenges facing museums and collecting institutions in Queensland. Of the 158 museums in Queensland which responded to a survey in 1996, 70 claimed to have accessioned more than 75 percent of their collections (table 9-4).

Rapid growth of a collection can have an adverse impact on the state of the collection, particularly where staff and facilities to record and store incoming material are limited. Rapid growth places increased pressure on already limited museum staff resources to document collections, and places storage conditions under greater strain.

Small museum collections often grow at a faster rate than available funding. Many small museums lack clear collection policies, and can become the repositories of unrelated items.

Conservation issues

Indicators

Percentage of collections surveyed by conservators/archivists at each institution annually/in total

Level of access to conservation services

No comprehensive data are available on the level of conservation pressures on collections of heritage objects throughout Queensland. However, the main conservation issues identified include the nature of the physical environment of objects, access to conservation services, and security levels (table 9-5).

Problems associated with the physical environment of objects in storage and on display include:

- lack of storage space;
- use of non-archival materials and techniques;
- high levels of humidity and large fluctuations in temperature;
- exposure to high levels of light, causing brittleness in textiles and paper-based items; and
- damage from pest infestations.

These problems are found in both small and large museums. The factors most affecting large government-funded museums are the lack of storage space, and the use of outdated storage techniques including non-archival materials, particularly for large, long-established collections. Most small museums suffer from these pressures, and from

Table 9-5 Causes of damage to heritage objects held in a selection of Queensland's collecting institutions

Cause of damage	Queensland Art Gallery (Brisbane)	Queensland Museum (Brisbane)	Museum of Tropical Queensland* (Townsville)	Cobb & Co. Museum* (Toowoomba)	Museum of Lands, Mapping and Surveying* (Brisbane)	Community museums (statewide)
Storage	Y	Y	N	N	N	Y
Display	N	Y	Y	N	N	Y
Use/handling	Y	N	N	N	N	Y
Theft	N	Y	N	N	Y	Y
Vandalism	Y	Y	N	N	N	Y

*Branches of the Queensland Museum. Y = yes; N = no.

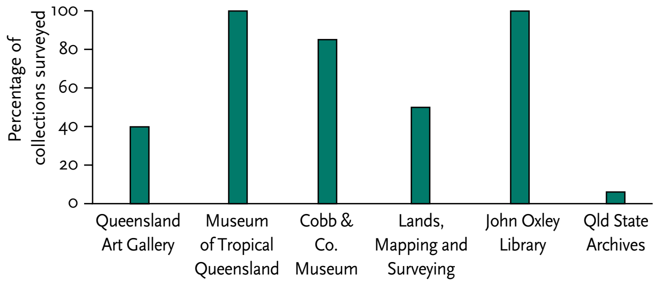


Figure 9-8 Percentage of collections surveyed by conservators in Queensland's collecting institutions. In addition, the Queensland Museum surveyed an estimated 2 percent of its cultural heritage collections in 1996.

widespread lack of climate control and lengthy exposure of objects to high light levels when they are displayed. Conservation surveys have been conducted in all of Queensland's collecting institutions to varying extents (figure 9-8).

Small museums in regional areas have extremely poor access to conservation services, due to limited availability of service providers and to high costs.

Material conservation services are lacking in Queensland. Only one independent commercial service exists. Conservation services are offered through the State Library of Queensland, but the waiting list is long. The Queensland Museum provides conservation services for its own collections and those of its regional branches, but the Museum's conservation resources are limited.

Queensland Museum

Items from the Queensland Museum's social history collection

Queensland Museum

This 1911 Garrett Steam Traction Engine was used to power a rock crusher from 1914 until the mid 1930s. It was then used in sawmilling and logging until 1960, before being restored by the Queensland Museum.

Museum training

Queensland's community museum workforce consists largely of volunteers. They often lack formal museum training, yet they are the lifeblood of Queensland's small museums. Such staff have limited opportunities to gain practical museum skills due to the lack of courses available in country areas. This has been recognised in a major study (Lennon 1995).

Government and community support

Indicator

Nature and level of government and community support for community museums

Support at the local level is essential for the survival of small museums throughout Queensland, and for the continued preservation of their collections. However, the level of support provided for community museums varies considerably across local governments. This may be due to a limited appreciation of the value of a museum to a community (Lennon 1995). Of the 86 small museums returning questionnaires as part of the *Hidden Heritage* study (Lennon 1995), 35 (41 percent) were housed in buildings owned by local governments.

Greenmount Historic Homestead

Greenmount Historic Homestead, at Walkerston, near Mackay, has unique cultural heritage significance. The complex is one of the few heritage places in Queensland where movable cultural heritage items have been retained in their original context.

The property belonged to the Cook family, pioneers of this rural Queensland district. The complex — the homestead, built in 1915, outbuildings and items collected and used by Cook family members — now operates as a museum and picnic area.

Background

In 1984, Thomas Cook's widow Dorothy presented the homestead, outbuildings and gardens on 11 hectares of land to the then Pioneer Shire Council. She donated the contents of the homestead and outbuildings to the Mackay Historical Society Museum Fund, together with an archive of some 30 000 items documenting the history of the Cook family over at least three generations.

In 1987, Mackay City Council leased the Greenmount buildings to the Mackay Historical Society and Museum, on condition they were to be maintained and made available for visits by the public.

Greenmount was permanently entered in the Queensland Heritage Register in 1993. It has since been recognised as an Integrated Historic Home Collection of national significance (Black 1996).

Pressures

Numerous pressures face Greenmount Historic Homestead. Primarily, these stem from the harsh environmental conditions of Queensland's tropical north.

Different conservation requirements add to the complexity of management. As components of a house museum, objects should be kept in context, but there are conservation problems associated with storing more fragile items. While adapting buildings to suit museum needs might impinge on heritage integrity, the collection's conservation requirements need to be carefully managed within these constraints.

Documentation, conservation and display are undertaken by a dedicated and enthusiastic but small and untrained group, receiving limited outside support. This is the spirit driving many community museums in Queensland.

The complex relationship between the Mackay City Council and the Mackay Historical Society has been a major issue in management.

The museum is used extensively by local school groups and is an increasingly popular tourist attraction. Local groups have used the homestead as a venue for fairs and festivals. Changes made to accommodate visitors must not detract from the buildings or their surrounds.

Greenmount's unique style and functional design are at risk of being compromised by five additional buildings and subdivision since 1984. Urban expansion is encroaching on the farmland surrounding the property, and this may result in a loss of context of the place within the cultural landscape.

Finally, many articles donated to the Mackay Historical Society, but not connected with the Cook collection, are housed at Greenmount. These detract from the collection's integrity.

Management

Initial accessioning of some 19 000 items was carried out primarily by Mackay Historical Society researcher Betty Clark. The Society's efforts were acknowledged in 1985 when Greenmount won the National Trust's John Herbert Award for Conservation.

The National Estate Grant Program provided $12,500 for building conservation work in 1994–95. Maintenance work was carried out on outbuildings to conserve these significant structures and their contents. Funding was matched by the Mackay City Council.

In 1996, a consultant funded through the Regional Arts Development Fund, Arts Queensland and Mackay City Council completed a strategic plan. The Mackay Conservation Report was also completed at this time. This project was coordinated with similar projects across the nation and funded by the Heritage Collections Committee.

The Greenmount Review Committee, consisting of the Mackay City Council, the Mackay Historical Society, the then Department of Environment and the National Trust, met first in August 1996. Reports and further information are being compiled and additional consultants may be used to develop an integrated comprehensive conservation and management plan for the collection and buildings for the next 10 years and beyond.

Greenmount Historic Homestead

Comprehensive quantitative measures of the physical condition of Queensland's cultural heritage environment are not available. Hence the major indicators are limited to the number of places recorded and protected and the number of objects held by collecting institutions. This is an important reflection of the state of knowledge, recognition and protection of heritage. More data collection procedures are needed to provide indicators that reflect the physical condition of Queensland's cultural heritage.

CULTURAL HERITAGE PLACES

The physical state of any of Queensland's cultural heritage places cannot be measured effectively without substantial knowledge of the extent of that particular environment. Until the heritage resource is identified and assessed we cannot know what is to be measured.

State of knowledge, recognition and protection

At present, the most effective indicator of the state of Queensland's heritage environment is the level of knowledge and recognition of heritage places through inventories and registers. While identification of places of cultural heritage significance is fundamental to their protection, the extent of identification and knowledge reveals much about the state of the heritage environment.

Heritage places are recorded in various registers and inventories at the international, Commonwealth, State and local government levels. These lists are a means of identifying and protecting places of universal, Australian, Queensland and local significance. The number and types of places recorded indicate the 'representativeness' and 'comprehensiveness' of these registers. In Queensland, heritage registers and inventories are developing constantly as more heritage places are identified and assessed.

World Heritage

Indicator

Number of Queensland places inscribed on the World Heritage list for cultural values

The World Heritage list, established under the World Heritage Convention (1972), provides for the protection of those cultural and natural properties deemed to be of outstanding universal value. Although it was intended that the proportion of cultural and natural places inscribed on the list should remain relatively even, this has not been the case. At 6 November 1998, the World Heritage List included 552 sites in 112 countries. These comprised 418 cultural sites, 114 natural sites and 20 mixed sites. An analysis of cultural heritage places included on the list indicates that the industrialised world, Christian monuments, historical cities and

QUEENSLAND MUSEUM

The Windmill Tower, Brisbane, built in 1828, is Queensland's oldest remaining convict structure.

'elitist' architecture are over-represented, while traditional cultures and non-monumental structures are under-represented (UNESCO 1996b).

Fourteen Australian places are entered on the World Heritage List. Five of these — the Great Barrier Reef, the Wet Tropics, Fraser Island, the Central Eastern Rainforests Reserves, and Riversleigh — are located in Queensland. (Riversleigh, in north-west Queensland, is jointly listed with the South Australian Fossil Mammal Site at Naracoorte.) All Queensland sites are listed for their natural values, but the issue of renominating the Great Barrier Reef and the Wet Tropics for both natural and cultural values has been raised, because there is currently no formal recognition of Queensland's cultural places for 'universal' cultural heritage value. None of the Australian sites listed is included in the 'List of World Heritage in Danger'.

Register of the National Estate

Indicators

Number of Queensland cultural places entered in the Register of the National Estate (Aboriginal and Torres Strait Islander, historic)

Percentage of cultural places in the Register of the National Estate in Queensland

Table 9-6 Places entered in the Register of the National Estate at 3 November 1998

Area	Aboriginal and Torres Strait Islander	Historic	Natural	Total
New South Wales	217	3 011	486	3 714
Victoria	106	2 289	219	2 614
Tasmania	78	1 182	247	1 507
Western Australia	75	916	344	1 335
South Australia	146	1 096	384	1 626
Queensland	151	735	313	1 199
Northern Territory	105	149	67	321
Australian Capital Territory	27	165	30	222
External territories	0	37	19	56
Total	**905**	**9 580**	**2 109**	**12 594**

(Source: Australian Heritage Commission)

The Australian Heritage Commission's Register of the National Estate, established in 1976, covers historic, Aboriginal and Torres Strait Islander and natural heritage places throughout Australia, either listed or interim listed. At 3 November 1998, 1199 Aboriginal and Torres Strait Islander, historic and natural places in Queensland were entered (table 9-6). Of the Queensland entries, 12.6 percent were Aboriginal heritage places, 61.3 percent were historic heritage places and 26.1 percent were natural places. Queensland places comprise 9.5 percent of the cultural heritage places entered.

During the period 1986–96, about seven Queensland Aboriginal and Torres Strait Islander heritage places were added each year. About 8 percent of historic places entered in the Register during the same period were in Queensland.

Register of Historic Shipwrecks

Indicators

Number of wrecks off Queensland protected by the Historic Shipwrecks Act

Number of wrecks off Queensland located by Queensland Museum maritime archaeologists

Queensland Museum

HMS *Pandora* captain's fireplace after conservation work by the Queensland Museum

All shipwrecks and associated relics (including jettisoned material from ships not wrecked) that are more than 75 years old and in Commonwealth waters are protected under the *Historic Shipwrecks Act 1976* by listing in the Register of Historic Shipwrecks.

Through Queensland Museum archival research, 936 ships are known to have been wrecked off the Queensland coast. HMS *Pandora*, associated with the mutiny on the *Bounty* and wrecked in 1791, was the earliest of these wrecks.

While 847 wrecks are entered in the Register of Historic Shipwrecks, the Museum's Maritime Archaeology Section knows the locations of only 48 (5.7 percent). Many of the wrecks not found will have disintegrated. Monitoring of the condition of known wrecks is done on an ad hoc basis.

Aboriginal and Torres Strait Islander heritage places inventory

Indicators

Number of designated landscape areas under the Cultural Record (Landscapes Queensland and Queensland Estate) Act

Number of places recorded on the Aboriginal and Torres Strait Islander heritage places inventory

Land area surveyed for Aboriginal and Torres Strait Islander heritage places

Number of each type of Aboriginal and Torres Strait Islander place recorded (representativeness)

The Queensland Government maintains an inventory of Aboriginal and Torres Strait Islander heritage places recorded under the provisions of the *Cultural Record (Landscapes Queensland and Queensland Estate) Act 1987*. This Act provides for the declaration of designated landscape areas to which access might be restricted. At December 1996, nine designated landscape areas were declared.

Unlike the Register of the National Estate, the places inventory does not require that places be assessed for their significance before entry. Places are added as they are reported. At 30 June 1998, 7523 places were recorded.

Categories by which the data are organised in the database define types of places which might be represented. Table 9-7, which gives the number of each type, shows that the inventory is highly representative of archaeological rather than anthropological places. This is due primarily to the way the inventory has developed rather than to policy choice.

Less than 5 percent of Queensland is believed to have been surveyed for Aboriginal and Torres Strait Islander heritage places. While many reports have been prepared as part of development approval processes, the areas involved are very small. At November 1998 no systematic overview survey had been conducted. Therefore the inventory cannot be considered in any way comprehensive. The distribution of places reflects the areas where most research has been conducted (figure 9-9). This is linked closely with the development approval and environmental impact assessment process.

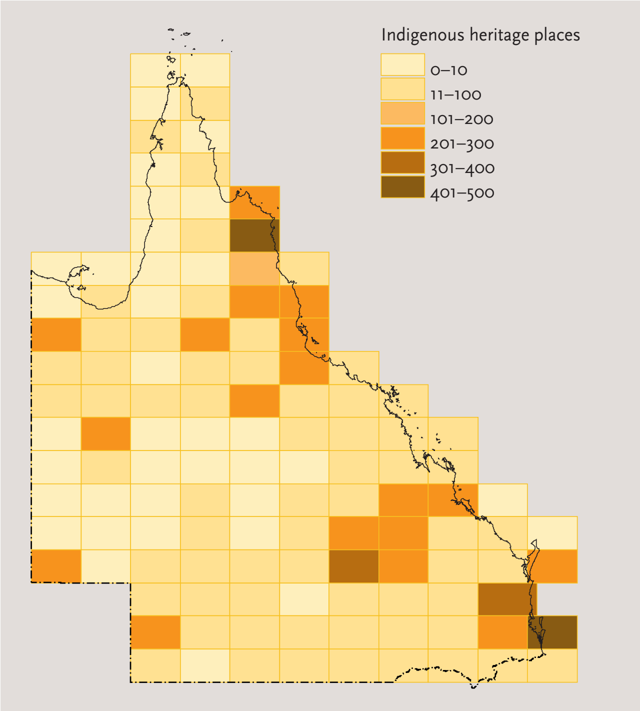


Figure 9-9 Density of Queensland's Aboriginal and Torres Strait Islander heritage places reported to the Environmental Protection Agency

Table 9-7 Number and percentage by category of the 7523 places entered on the inventory of Aboriginal and Torres Strait Islander heritage places at 30 June 1998

Type of place	Number	Percentage
Artefact scatters	2482	25.8
Paintings	2195	22.8
Shell middens	1252	13.0
Stone arrangements	485	5.0
Scarred trees	440	4.6
Engravings	414	4.3
Burials	359	3.7
Axe grinding grooves	255	2.6
Quarries	221	2.3
Hearths/ovens	125	1.3
Story places	105	1.1
Wells	84	0.9
Fish traps	59	0.6
Earthen arrangements	58	0.6
Dwellings	46	0.5
Pathways	34	0.4
Stone circles	33	0.3
Earthen circles	25	0.3
Carved trees	24	0.2
Other	930	9.7

Queensland Heritage Register

Indicators

Number of places entered in the Queensland Heritage Register

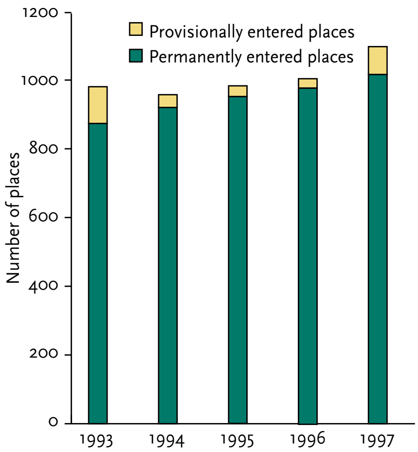
Land area surveyed for historic heritage places

Number of each type of historic place in the Queensland Heritage Register

The Queensland Heritage Register was established under the *Queensland Heritage Act 1992*. At March 1998, 1059 places were entered in the Heritage Register, 991 permanently and 68 provisionally (figure 9-10). Once a place is entered permanently or provisionally in the Register, it is formally protected by the Act.

About 100 nominations are made each year. Of these, approximately 20 percent are added to the Register following research, significance assessment and Heritage Council decision. Hence, the Register grows by about 2.5 percent a year. The Queensland Heritage Register is not yet mature, and as a result cannot be considered comprehensive or representative of the full range of heritage places in Queensland (table 9-8). This is due partly to the fact that places are added by public nomination rather than as a result of systematic survey and assessment. Historic themes not well represented in the Register include social, industrial, archaeological, ethnic and scientific.

Figure 9-10 Entries in the Queensland Heritage Register, 1993–97. While the size of the Register may indicate the extent of cultural heritage protection for historic places, only the content can show its representativeness or comprehensiveness.



Because no systematic survey program has been conducted to identify and assess the heritage values of Queensland, the state of knowledge of historic heritage places is limited. This is reflected in the nature and distribution of places in the various historic registers.

Historic heritage places are dispersed widely, although the density is greatest in the south-east (see figure 9-11). A relatively large number of registered places are in the local government areas of Brisbane, Ipswich, Townsville, Rockhampton, Toowoomba, Maryborough and Warwick, due to the historic nature of these areas and the amount of heritage assessment activity undertaken. Other local government areas such as Isis and Eacham Shires have large numbers of places entered due to much identification and assessment work undertaken in local communities.

Lighthouse properties

In 1996–97, the Queensland Government negotiated the transfer of 23 Commonwealth lighthouse properties to Department of Environment and Heritage management for a nominal $18. While lighthouse structures are being retained by the Australian Maritime Safety Authority, many lighthouse properties have significant cultural heritage values. Options are being explored for their management and use.

Table 9-8 Categories of the 1059 places on the Queensland Heritage Register at March 1998. An entry can be listed under more than one category. While categories indicate historical uses of places protected, they are too broad to allow a detailed analysis of representativeness.

Category	Number
Commercial	351
Residential	351
Religion	184
Transport	147
Memorial/cemetery	141
Social	76
Education	68
Industrial	65
Law/order	64
Recreation	57
Mining	49
Health	47
Communication	46
Government — State	40
Parks and gardens	37
Defence	36
Government — local	31
Settlement	26
Exploration/survey	16
Farming	16
Government — Commonwealth	15
Pastoral	7
Political	5
Scientific	4

The National Trust of Queensland lists

Indicator

Number of places entered in the National Trust of Queensland lists

The National Trust of Queensland maintains several lists of heritage places in Queensland. These lists include buildings, trees and precincts which have historical significance. At 5 November 1998, the National Trust had 1384 places listed, compared with 962 at 30 June 1986. While this number includes precincts, listings also contain items that could be listed individually under the other categories. For example, the township of Ravenswood is listed as a precinct but also contains buildings entered in the Queensland Heritage Register.

Local government heritage registers

Indicators

Number of Aboriginal and Torres Strait Islander heritage places protected by local government heritage registers

Number of historic heritage places protected by local government heritage registers

An increasing number of local governments have introduced cultural heritage provisions into their strategic and development control plans. Such provisions are usually a result of a cultural heritage survey of the local government area. Some plans carry more stringent provisions than others. Table 9-9 lists the local governments which have established registers to identify and/or protect places.

Of a sample of 85 (68 percent) of 126 local governments, 18 (21 percent) had register provisions for historic heritage places and seven (8 percent) had register provisions for Aboriginal and Torres Strait Islander heritage places. At June 1997, 2997 places were identified or protected through the register provisions, 98 percent being historic places.

Historic Raine Island beacon, with resident turtles. Raine Island is on the outer Great Barrier Reef, south-east of Cape York. The beacon was constructed in 1844 and once served as as landmark for ships travelling north using the outer passage.

Table 9-9 Local governments with heritage registers and the number of places identified and/or protected. The majority of local government registers (62 percent) identify places only. Protection is provided for places listed on eight of the registers established by local government.

Local government	Aboriginal and Torres Strait Islander places	Historic places
Booringa	–	10
Boulia	1	2
Brisbane	–	555
Bungil	–	1
Burnett	–	167
Cairns	15	130
Caloundra	–	–
Cook	1	18
Douglas	–	27
Gladstone	–	18
Ipswich	6	1770
Kilcoy	–	1
Kilkivan	–	–
Mackay	–	50
Mirani	–	–
Mornington	23	–
Mount Morgan	–	11
Redland	–	184
Warroo	–	5
Total	**46**	**2949**

Physical condition

As no standardised data collection program for monitoring the physical condition of heritage places is in place, a report on the physical condition is not possible. It can only be assumed that the physical state of Queensland's heritage ranges across various categories of condition from demolished, deteriorated, fair, good to excellent, depending on the physical materials and composition, environmental factors, and level of maintenance.


Griffith University (AES)

Hanphretts House, Coopers Plains

Heritage integrity

Indicators

Number of heritage-registered places relocated

Number of heritage-registered places 'facade only'

The heritage integrity or 'intactness' of a place can be assessed in terms of the extent to which it retains its original fabric and remains in the context of its surrounds. Heritage integrity can also be influenced by the way a place continues to provide evidence of historical developments.

While development of a heritage-registered place might change the physical fabric of the place, it might also involve the removal of later intrusive fabric and therefore increase its integrity and cultural heritage significance. Due to the way the Queensland Heritage Register was established, many places have not been inspected and assessed in terms of their integrity. Hence there is currently little capacity for benchmarking and measuring subsequent changes in heritage integrity for the whole of the Register. The number of heritage-registered places that have been relocated does, however, indicate the extent to which the heritage integrity of historic places has been compromised. This is also indicated by the number of heritage-registered places that consist of original facades only.

The level of remaining heritage integrity of indigenous heritage places is also difficult to measure. This is due to the largely archaeological nature of such places, but also to the lack of reporting processes associated with impact assessments. This issue is being dealt with through cultural heritage management plans and monitoring procedures.

Similarly, it is difficult to measure the extent to which cultural landscapes retain their heritage integrity, particularly where they are not well defined in terms of significance or geographic boundaries.

Continuous human interaction with the natural environment in forming and transforming landscapes also limits our ability to measure the integrity of cultural landscapes. Indicators are required and might be developed for measuring components such as fencelines, mullock heaps, or type and extent of vegetation cover.

Conservation practice

Australian guidelines for conserving places of cultural significance — the Burra Charter — were developed by the Australian Committee for the International Council on Monuments and Sites (Australia ICOMOS) in 1979. The Charter defines the basic principles and procedures to be followed in conserving heritage places. These can be applied to a monument, a courthouse, a garden, a shell midden, a cottage, a whole district or a region. Although written as a guide for practitioners such as architects and historians, the Charter is also useful for property owners, heritage administrators

Figure 9-11 Density of places entered on the Queensland Heritage Register by local government area at July 1998

Burra Charter

The Australia ICOMOS Charter for the Conservation of Places of Cultural Significance — the Burra Charter — is the widely adopted standard for heritage conservation practice in Australia. It defines the basic principles and procedures to be observed in the conservation of significant places including monuments, ruins, middens, rock paintings and engravings, and buildings.

The Charter embodies seven basic precepts of cultural heritage conservation (Marquis-Kyle and Walker 1992):

1. The place itself is important.
2. Understand the significance of the place.
3. Understand the fabric.
4. Significance should guide decisions.
5. Do as much as necessary, as little as possible.
6. Keep records.
7. Do everything in logical order.

The Charter points out the importance of recognising that a place itself has significance which cannot be replaced merely by documents, photographs or video. The significance of the place and its fabric should guide decisions about its conservation. Cultural significance often stems from a place's relationship with its surroundings. Assessment of significance might require knowledge of the context of the place in the history of the local area or, in the case of buildings, of architectural design.

Article 3 of the Charter states: 'Conservation is based on a respect for the existing fabric and should involve the least possible physical intervention...and should not distort the evidence provided by the fabric' (Australia ICOMOS 1992). In line with the Australian Institute for the Conservation of Cultural Material code of ethics for the conservation of cultural material, the Burra Charter advocates doing as much as necessary and as little as possible to conserve a cultural heritage place, while documenting everything that is done to the place and by whom.

and community organisations concerned with the care of cultural heritage.

Since publication, the Burra Charter has been reviewed three times to ensure that it is up to date with conservation practice. Guidelines to the Charter have been prepared to explain the major tasks involved in the conservation of individual places. The standard of conservation practice in Queensland can be assessed in terms of the degree of conformity to the Burra Charter by heritage practitioners and property owners.

Guidelines for Aboriginal and Torres Strait Islander cultural heritage management have been drafted. These are intended to perform a role in the conservation of indigenous heritage places similar to the role of the Burra Charter in the conservation of historic heritage places.

Cultural heritage objects and collections

Extent of collections and knowledge about them

Indicators

Number of museums and collecting institutions in Queensland

Range of types of museums in Queensland

Number of items in cultural heritage items collections

Percentage of collections accessioned

Percentage of collections well documented

Percentage of collections partially documented

Percentage of collections undocumented

Percentage of collections catalogued on computer

Number of public art collections (members of RGAQ registered with collections)

It is possible to analyse the extent of public and private collections of heritage objects in Queensland and the level of knowledge about those objects. The number and types of museums and collecting institutions in Queensland may be a useful indicator of the extent to which items are collected for research, conservation and display.

Queensland has more than 200 museums. Despite several attempts in recent years to survey museums and collecting institutions, the total number of collecting institutions and, therefore, the number and range of heritage objects in Queensland are unknown. The difficulties can be attributed in part to differences in the scope of the definition of a museum, but also to the nature of the museums.

As noted by Dr Richard Robins, Curator of Australian Archaeology, Queensland Museum: 'Many museums do not stand alone but are combined with a number of other functions, such as cultural centres, libraries and theatres. A museum may not even be a building. It may be a railway carriage, it may be in the open air or it may even be in a suitcase. Whatever its aims and association, all museums have two things in common — they are about objects and they are about communication of information' (Robins 1992).

Information collected by national survey in 1996 indicates that the most common types of museum in Queensland are social history museums and historic displays (table 9-10).

Historic Ozanam House, Ipswich, is an example of Queensland's traditional 'timber and tin' character housing.

They are governed mostly by historical societies (35 percent) and local governments (30 percent) (table 9-11). Many have collections of fewer than 500 items (table 9-12). Of 158 museums surveyed, 70 claimed to have accessioned more than 75 percent of their collections (Commonwealth Department of Communications and the Arts 1996).

Table 9-10 Types of museums in Queensland

Museum type	Number
Social history museum	75
Historic display	35
Outdoor museum	19
Public gallery	19
House museum	18
Historic site	13
Art museum	13
Art space or art display	9
Natural history museum	8
Science museum	2

(Source: Commonwealth Department of Communications and the Arts 1996)

Table 9-11 Parent or governing bodies of museums in Queensland

Parent body	Museums
Historical societies	42
Local government	36
Business, association owners	10
Educational bodies	8
Private individual owners	6
Larger museums	5
Government agencies (except trusts)	2
National Trust	2
Military bodies	1
Other (boards, trusts etc.)	7

Queensland Museum collections

Indicator

Number and type of cultural heritage objects held by the Queensland Museum and branches

Since its establishment in 1862 the Queensland Museum has expanded its Brisbane-based cultural heritage collections to include some 462 000 objects. Between 1991 and 1996, about 107 000 items were added. The Museum supports cultural heritage collections in the fields of Aboriginal studies, Australian archaeology, Oceanic anthropology, maritime archaeology, social history, applied arts and cross-cultural studies (table 9-14).

Of nine Queensland Museum branches, all except the Scien-Centre and Glenlyon Dam hold cultural heritage collections.

Toowoomba's Cobb and Co. Museum opened in 1987. It is the home of Australia's foremost collection of horse-drawn vehicles. At October 1996 the collection comprised 45 horse-drawn vehicles, 125 ancillary items and 1000 photographs.

Table 9-12 Size of Queensland's museum collections

Collection size (items)	Museums
0–499	34
500–999	17
1000–2499	15
2500–4999	16
5000–9999	13
10 000–49 999	13
50 000–99 999	2
>100 000	1

(Source: Commonwealth Department of Communications and the Arts 1996)

Table 9-13 Condition of objects held in Queensland Government museum collections at various dates in 1996, 1997 and 1998. The state of heritage objects is measured by the number of objects collected and the extent to which the collections are accessioned, documented and catalogued on computer. Figures have been rounded to the nearest 1 percent.

	Queensland Museum and branches			Other institutions		
	Queensland Museum cultural heritage collection	Cobb & Co. Museum	Museum of Lands, Mapping and Surveying	John Oxley Library	Queensland State Archives	Queensland Art Gallery
Number/extent of objects	462 563	45 horse-drawn vehicles; 125 ancillary items; 1000 photographs	400 objects; 7000 photographs	1 million photographs; 100 000 printed items	33 236 linear metres	10 610
Percentage of items not accessioned	5	0	0	0	13	0
Percentage catalogued on computer	57	100	0 (objects); 100 (photographs)	100 (printed collection); 25 (manuscripts); 0 (photographs and ephemera)	90	100
Percentage well documented	25	90	50	50	90	52
Percentage partially documented	60	10	50	0	0	48
Percentage undocumented	15	0	0	50	10	0

Table 9-14 Size and state of the Queensland Museum's cultural heritage collections, October 1996. The Australian archaeology collection is by far the largest. This is due to the nature and availability of the material and the *Cultural Record (Landscapes Queensland and Queensland Estate Act) 1987*, which requires all artefacts collected to be deposited at the Queensland Museum. The maritime archaeological collection has the smallest number of items due to high costs involved in recovering and conserving underwater heritage items.

	Aboriginal studies	Australian archaeology	Oceanic anthropology	Maritime archaeology	Social history	Applied arts	Cross-cultural studies
Number of objects	16 400	361 000	21 557	2 325	47 731	8 000	5 550
Percentage well documented	40	0	65	60	2	10	0
Percentage partially documented	50	90	35	25	86	80	50
Percentage undocumented	10	10	0	15	12	10	50
Percentage catalogued on computer	40	30	100	70	85	70	0
Number of items not accessioned	300	10 000	567	68	5 000	500	300
Percentage of items not accessioned	2	3	3	3	10	6	5

(Source: Queensland Museum)

The Museum of Lands, Mapping and Surveying, established in 1982 and administered jointly by the Department of Natural Resources and the Queensland Museum, holds about 400 objects and 7000 photographs connected with the survey and mapping of Queensland.

Queensland Art Gallery

Indicator

Number and type of Queensland works held by the Queensland Art Gallery

Between 1989 and March 1998, the Queensland Art Gallery's collection grew from 6593 items to 10 610 items. Queensland items now represent 29 percent of the Gallery's total collections. In terms of the Gallery's collection strengths, Queensland art is the strongest of all areas in the collection. At 31 March 1998, the Gallery held 1467 prints, drawings and photographs specific to Queensland. At the same time, 462 items in the Australian art collection and 117 in the contemporary Australian art collection were specific to Queensland. There were 426 decorative art items specific to Queensland and 32 indigenous Australian art items recorded as being specific to Queensland.

Queensland Museum

North Queensland Aboriginal artefacts. The Queensland Museum has approximately 377 400 indigenous items in its collections.

Table 9-15 John Oxley Library collections. The library's photographic collection is one of the largest and most comprehensive of its kind.

Collection type	1989–90	1996–97
Photographs	584 900	1 000 000
Monographs	44 910	70 646
Manuscripts	290	877
Ephemera	26 340	35 000

(Source: John Oxley Library)

John Oxley Library

Indicator

Number and type of Queensland cultural heritage objects held by the John Oxley Library

The John Oxley Library, established in 1926, is a major repository of non-government historical documentation about Queensland's history. The collection includes books, periodicals, newspapers, government publications, pamphlets, ephemera, manuscripts, photographs and original art. Legal deposit requirements and general collecting activities have built the John Oxley Library to more than 70 000 monographs and serials and more than 1 000 000 photographs. The printed collection grows by an estimated 10 percent a year.

The John Oxley Library also operates an Aboriginal and Torres Strait Islander Resource Unit to help Aboriginal and Torres Strait Islander people trace their family and community histories. Resources used for this task include copies of original records relating to Queensland from Norman Tindale's genealogical studies during visits to Australian Missions in 1938–39, and the Don Cameron Military Index of Aboriginal and Torres Strait Islander people who served in the armed forces in times of war.

JOHN OXLEY LIBRARY

Much of Queensland's history, including that of the South Sea Islander labour trade during the late 19th century, is documented in the collection of historical photographs held by the John Oxley Library.

Queensland State Archives

Indicator

Amount of archival material held by the Queensland State Archives

At June 1997 the Queensland State Archives held 33 236 linear metres of public records of Queensland Government agencies, courts, local governments, commissions of inquiry and statutory authorities. The collection grew by 3 percent between 1996 and 1998.

University museums and collections

Indicator

Number of collections held by Queensland universities

Queensland's five universities maintain 27 collections of cultural material (University Museums Review Committee 1996). These are of varying sizes and types. While some choose to call their collections museums, others do not. Many of the collections are based on art collections.

Community museums and galleries

Indicators

Number of community museums in Queensland

Number of regional galleries in Queensland

Number of items held by community museums and regional galleries in Queensland

Although the size and scope of Queensland community museum collections are not known, information supplied to the Queensland Museum in grant applications since 1985 indicated that more than 492 000 items were held in 152 museums (Lennon 1995). The largest collection reported was Brennan and Geraghty's Store Museum in Maryborough, reported to hold 69 650 items. However, the Greenmount collection is thought to have approximately 80 000 items.

Most community museums hold items of local significance. However, an estimated 10 percent of items are of no significance (Lennon 1995). Aboriginal groups, such as those at Yarrabah and Kuranda, have important indigenous collections on display in their keeping places.

At January 1997, the Regional Galleries Association of Queensland had registered 59 member organisations with collections.

Aboriginal and Torres Strait Islander languages are an important part of Australia's cultural heritage. Their unique linguistic features are also significant in terms of world heritage. Before colonisation there were many Aboriginal languages, each with a number of dialects. The loss of most of these languages represents a loss of heritage of those peoples because the culture, values and world view of the group were embedded in each language.

Given the reliance on the oral tradition, the loss of indigenous languages has reduced the ability of Aboriginal and Torres Strait Islander peoples to pass on cultural knowledge. Language maintenance is integral to conserving cultural heritage values and to asserting cultural identity.

Of the estimated 250 indigenous languages that existed in Australia before white settlement, only 20 strong and 70 severely threatened languages remain (Schmidt 1990). 'Strong' languages are those which have at least 200 fluent speakers and which are transmitted to and actively spoken by children. 'Severely threatened' languages have between 10 and 200 fluent speakers.

Four strong and nine severely threatened languages remain in Queensland (table 9-16). Many people in the communities where these languages persist know a few words and have a keen interest in the revival of the languages. A 1994 National Aboriginal and Torres Strait Islander survey found that 15 percent of Queensland's Aboriginal and Torres Strait Islander population spoke an indigenous language (ABS 1994).

Table 9-16 Strong and severely threatened Aboriginal and Torres Strait Islander languages in Queensland, with estimated numbers of speakers

Category	Number of speakers
Strong	
Kala Lagaw Ya	3000–4000
Wik Mungkan	900–1000
Thayore	500
Kuku Yalanji	300
Severely threatened	
Guugu Yimithirr	400
Meriam Mir	100+
Wik Nganthana	100–200
Wik Nganjara	100
Umpila	100
Koko Bera	50
Oykangand	50
Yir Yoront	50
Dyirabal	40

(Source: after Schmidt 1990)

Causes of loss

The loss of indigenous languages can be attributed directly to colonisation. Factors include fewer speakers, displacement of people from their cultural groups, eradication action, mixed language groups and use of Aboriginal English and Torres Strait Creole.

The shift toward a western economy of education and employment, rather than traditional hunting and gathering, continues to threaten remaining languages. Children now spend more time at school, and parents spend more time at work, effectively isolating older and younger generations and reducing the ability of Aboriginal and Torres Strait Islander peoples to pass on language and cultural knowledge.

Language maintenance and revival

The Commonwealth Government established the National Aboriginal Languages Program in 1987. Responsibility for the program was passed to the Aboriginal and Torres Strait Islander Commission in 1991–92.

The Aboriginal and Torres Strait Islander Languages Initiatives Program (ATSILIP), as it is now known, funds community-initiated and community-driven language maintenance and revival projects. In 1996–97, $3.4 million was allocated to the program. Queensland received $490,950 (14.4 percent of the total). Funding is divided equally and administered through sponsor organisations in five regions:

- Kombumerri Aboriginal Corporation for Culture, Beenleigh (south-east Queensland);
- Wondunna Aboriginal Corporation for Culture, Pialba (central Queensland);
- Jibbabul Aboriginal Housing Cooperative, Mission Beach (north-east Queensland);
- Gugu Yimidihirr Language Centre, Hopevale (far north and north-west Queensland); and
- Mangani Malu Kes, Townsville (Torres Strait).

Torres Strait Islander experience

The Torres Strait Islanders' experience of church missionaries differed from that of most indigenous Australians. Their language was preserved when the London Missionary Society translated the Bible and hymn books into their languages. Parts of the Bible were translated into Kala Lagaw Ya between 1884 and 1900. However, a continued language maintenance program is required to ensure their survival as living languages.

In 1994, the Torres Strait Islander Language Centre was established in Townsville, where many Islanders now live. The Centre is helping stem the loss of Torres Strait languages following the movement of so many Islanders to mainland Australia. Its first project was to translate a complete hymn book into the two indigenous languages of the Torres Strait — Meriam Mir, from the eastern islands, and Kala Lagaw Ya, from the western islands.

Djabugay language, Kuranda

Many traditional languages of the Bama (Aboriginal) people in far north Queensland, including the Djabugay, were declared dead. However, the Djabugay language is now being revived. It is spoken around Kuranda and is being taught to Aboriginal and non-Aboriginal students at the Kuranda State School from Preschool to Year 7. In 1996 Education Queensland recognised it as part of the school's Year 10 curriculum. Smithfield State High School and the nearby Cairns West State School have also begun Djabugay language and culture programs.

Kuranda's Djabugay revival has been aided by the work of linguists who documented much of the language in the 1970s. It has developed with a broader cultural revival, with focus points at the Jilli Binna Cultural Resources Centre and the Tjapukai dance centre. It has raised the profile of Djabugay in the community and enriched the sense of identity of the Aboriginal people.

Prospects

While a complete revival or reinstatement of severely threatened languages as the vernacular language of communities is an unrealistic expectation, language revival programs are vital to reconciliation. However, funding alone will not maintain a language if its speakers are not committed to increasing their own and their children's use of the language (Dixon 1989; Jolly 1995).

For a language to be maintained or revived, conditions which foster its use need to be established in order to ensure that it is revived in the context of daily use (Jolly 1995).

There is now recognition that language maintenance involves more than just education. This is implicit in the transfer of ALIP (now ATSILIP) to ATSIC,

thus providing for more control of the program by the Aboriginal communities.

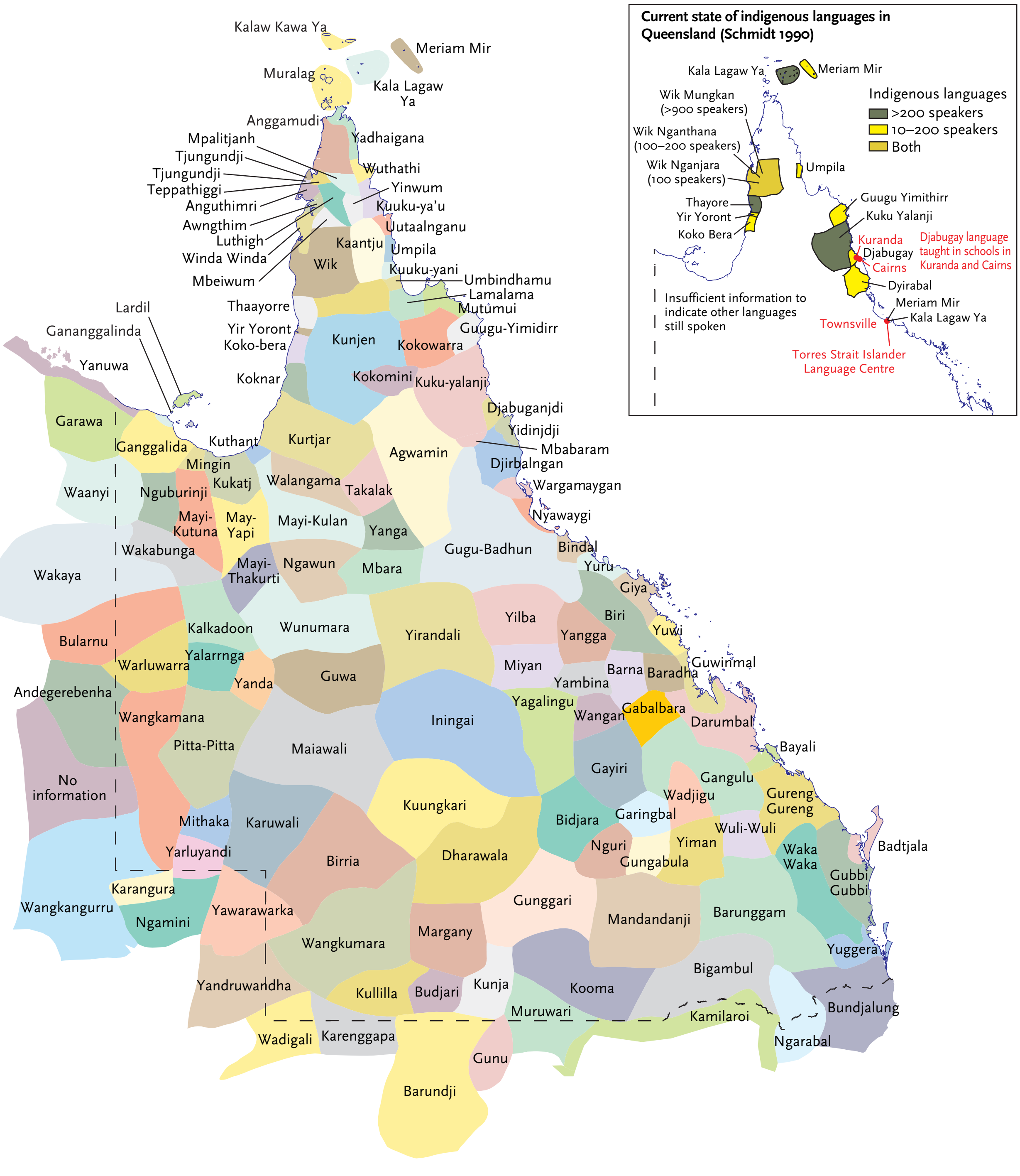


Figure 9-12 Indigenous language areas of Queensland and current state of indigenous languages (large map after Horton 1994; small map after Schmidt 1990). These maps indicate only the general location of larger groupings of people which may include smaller groups such as clans, dialects, or individual languages in a group. Boundaries are not intended to be exact.

Physical condition of collections

Indicator

Available storage space for collection growth

The physical condition of collections of heritage objects cannot be measured consistently and meaningfully due to the diversity in the types of materials and their distribution. Comprehensive data have not been collected.

Collecting institutions aim to provide a stable environment in which to conserve heritage objects, but their degree of success often depends on space, resources and, in particular, funding. The most common conservation problems are overcrowding of objects, the use of unstable storage materials and outdated storage practices, a lack of staff to implement preventive conservation techniques, and generally unsuitable environmental conditions for storage.

Community museums are generally not well funded. Collections are therefore subject to conditions which may cause deterioration over time, particularly in museums in tropical areas. A lot of more fragile items, such as textiles and paper-based objects, suffer from light damage. Such damage can be exacerbated by excessive periods on display.

The physical condition of archive collections, many of which comprise inherently fragile items, is influenced by treatment and handling. Damage is often inflicted through poor storage and handling of archival materials before they are sent to institutions for archiving. Many also suffer from insect damage, mould and red rot. Queensland State Archives currently has ample storage, due to the recent provision of purpose-built premises.

Conservation practice

Indicators

Percentage of collections stored in full climate-controlled conditions

Percentage of collections stored in conditions with some climate control

Percentage of collections stored in conditions with no climate control

Collections held in major government-funded institutions have excellent access to professional conservation expertise, and those near the major centres of Brisbane and Townsville have reasonably good access (see table 9-17). However, the level of access to curatorial and conservation expertise and training is low for community museum workers in the more isolated areas. The cost of professional conservation services is prohibitive, particularly for impoverished community museums.


Bill Kitson, Department of Natural Resources

This sextant and tin cup belonged to Sir Augustus Charles Gregory, Queensland's first surveyor. It is reported that Gregory, rather than using mercury, used the reflective surface of black tea in his tin cup to make observations of latitude.


Queensland Museum

Queensland Museum curatorial staff registering artefacts from the cross-cultural collection

Table 9-17 Indicators of the storage category for collections in Queensland Government-funded institutions. The Queensland Museum has found that the majority of social history and cross-cultural studies collections are inadequately stored.

	Queensland Museum (%)	Museum of Tropical Queensland (%)	Cobb & Co. Museum (%)	Lands, Mapping and Surveying (%)	John Oxley Library (%)	Queensland State Archives (%)	Queensland Art Gallery (%)
Full climate control	100 (archaeological); 93 (non-archaeological)	100	60	50	100	100	95
Some climate control	1 (non-archaeological)	0	30	50	0	0	5
No climate control	6 (non-archaeological)	0	10	0	0	0	0
Collections surveyed by conservators	2 during 1996	100	85	50	100	–	60

RESPONSE

RESPONSE

Society's responses to the state of Queensland's cultural heritage and the pressures on it demonstrate a growing commitment to protecting and managing our heritage. All levels of government, heritage professionals and community groups have actively supported the identification, documentation, conservation and protection of cultural heritage. These responses are in accordance with Australia's international obligations under the World Heritage Convention and its membership of ICOMOS (the International Council on Monuments and Sites) which brings together countries concerned with the conservation and study of places of cultural significance.

Legislation, supported by appropriately resourced administrative mechanisms, is an important mechanism for the protection of heritage. Several pieces of Commonwealth and State Government legislation provide such protection for cultural heritage in Queensland, although with varying effectiveness. Local government planning provisions also help protect heritage places. The support of over 200 museums throughout Queensland represents one of the most organised responses to the management of heritage objects and collections. The role of local communities and private landholders as stewards of significant heritage places and objects is increasingly being recognised. Community heritage groups have continued to promote heritage identification and conservation activities.

Despite the many positive responses to managing and protecting cultural heritage, at this stage it is difficult to assess their effectiveness. This is due primarily to a lack of comprehensive data on the state of our heritage and the pressures affecting it. And despite the range of responses, no national or state heritage strategy exists as a means of providing an integrated and coordinated approach to heritage management in Queensland.

COMMONWEALTH AND QUEENSLAND HERITAGE LEGISLATION

Legislative protection of cultural heritage is a major government response to the pressures on that heritage. Major pieces of Commonwealth and Queensland legislation govern cultural heritage with varying degrees of effectiveness (table 9-18). The legislation seeks to protect heritage places and objects and, where possible, preserve the unique relationship between them. While some heritage legislation is generic, other Acts specifically deal with either Aboriginal and Torres Strait Islander heritage or historic heritage.

The *World Heritage Properties Conservation Act 1983* (Cwlth) provides for the protection and conservation of those properties in Australia and its external territories which are inscribed or nominated for inscription on the World Heritage list. The Act authorises the Commonwealth to prevent damage to or destruction of a property by regulation, by prohibiting prescribed activities. While the five Queensland sites on the World Heritage list are recognised for their natural heritage, no Queensland site is recognised for its universal cultural heritage value.

The *Australian Heritage Commission Act 1975* (Cwlth) established the Australian Heritage Commission, which compiles the Register of the National Estate for protecting significant cultural and natural heritage places in Australia. Between 1991–92 and 1995–96, the average annual rate of addition of Queensland's historic cultural heritage places to the Register of the National Estate was 21 (including a record 70 places in 1995–96). Over the same period the average annual rate of addition of Aboriginal and Torres Strait Islander places was seven. Despite a rigorous significance assessment process,

Table 9-18 Legislative protection for cultural heritage in Queensland. Many Acts protect heritage places and objects, and seek to preserve the relationship between the two. The legislation also covers issues facing Aboriginal and Torres Strait Islander (ATSI) and historic heritage places or objects.

Commonwealth legislation	ATSI	Historic	Places	Objects
Australian Heritage Commission Act 1975	✓	✓	✓	
Historic Shipwrecks Act 1976		✓	✓	✓
World Heritage Properties Conservation Act 1983	✓	✓	✓	✓
Aboriginal and Torres Strait Islander Heritage Protection Act 1984	✓		✓	✓
Protection of Movable Cultural Heritage Act 1986	✓	✓		✓
Native Title Act 1993	✓		✓	
Queensland legislation				
Queensland Museum Act 1970	✓	✓		✓
Cultural Record (Landscapes Queensland and Queensland Estate) Act 1987	✓	✓	✓	✓
Libraries and Archives Act 1988	✓	✓		✓
Aboriginal Land Act 1991	✓		✓	
Torres Strait Islander Land Act 1991	✓		✓	
Queensland Heritage Act 1992		✓	✓	✓
Nature Conservation Act 1992	✓	✓	✓	✓
Wet Tropics World Heritage Protection and Management Act 1993	✓		✓	
Native Title (Queensland) Act 1993	✓		✓	

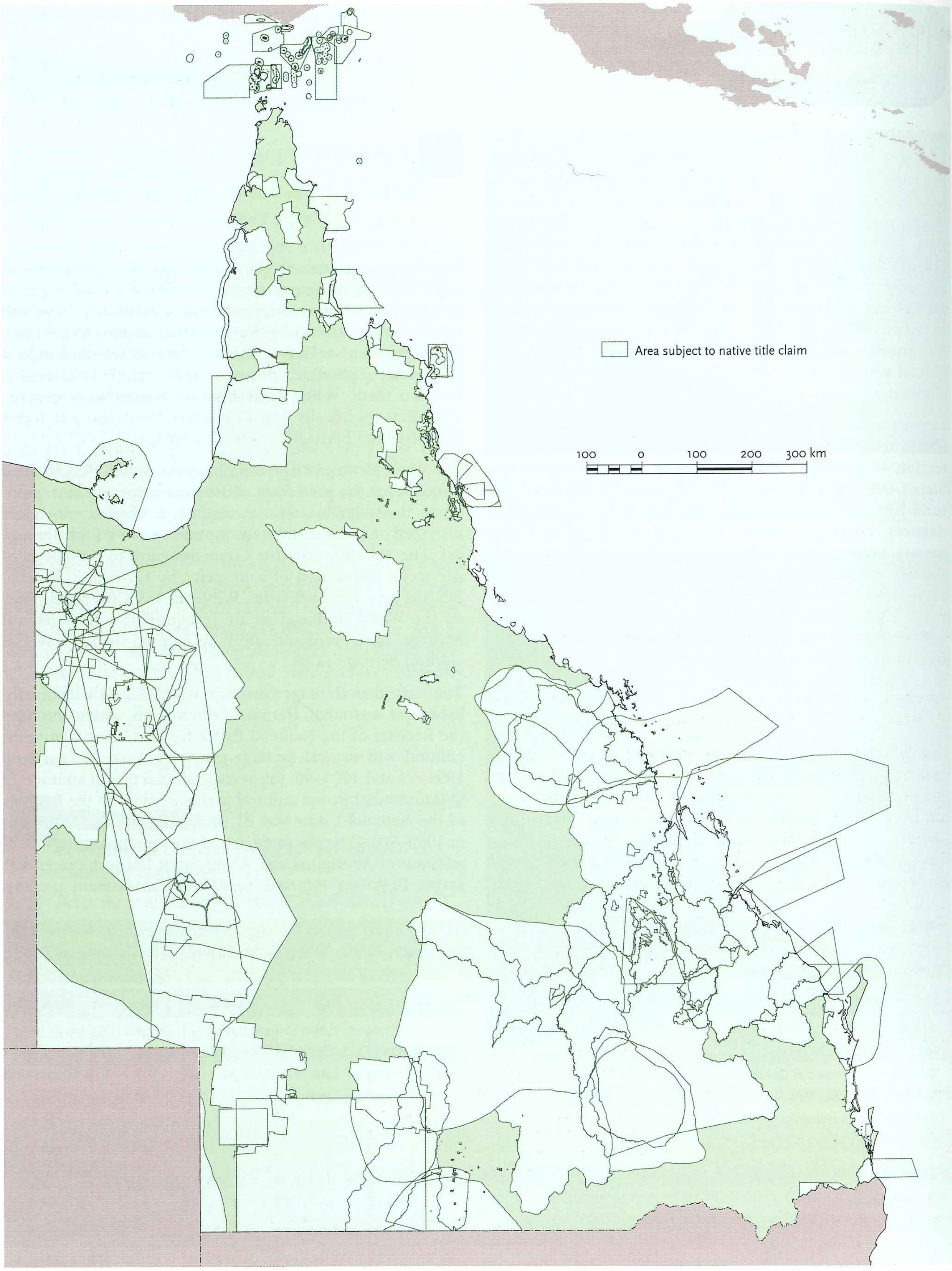


Figure 9-13 Queensland land and waters subject to native title determination applications lodged under the *Native Title Act 1993* (Cwlth) at 24 April 1998 *(Source: DNR)*

Aboriginal art in rock shelter near Princess Charlotte Bay, north Queensland

listing on the Register of the National Estate provides little statutory protection for heritage places.

The *Protection of Movable Cultural Heritage Act 1986* (Cwlth) controls the export of the most significant aspects of Australia's movable cultural heritage. The Act places particular emphasis on the protection of Aboriginal and Torres Strait Islander cultural heritage through the use of the National Cultural Heritage Control List. This list states the categories of objects for which permission to export must be sought, and also those categories that can never be exported. The legislation applies only to items of national significance. No similar provisions exist for items of State significance. The legislation does not provide for the protection of heritage objects in place.

Cultural heritage places and items of cultural significance are protected under Queensland legislation, the *Cultural Record (Landscapes Queensland and Queensland Estate) Act 1987*. The Act ensures that such places and items are protected regardless of whether they are precisely identified, and requires that any finds be reported to the Environmental Protection Agency. Items of cultural significance which are historic or prehistoric and more than 30 years old are part of the Queensland Estate. Places of cultural significance are called 'Landscapes Queensland'.

All parts of the Queensland Estate that constitute evidence of occupation by indigenous people, with the exception of human remains, or items for which there is no identifiable owner, remain the property of the State. Items of the Queensland Estate are not to be disturbed or collected unless this is carried out in accordance with a permit issued under the Act. The Queensland Museum is the receiving agency. An inventory of reported places and a register of designated landscape areas are maintained. Access to designated landscape areas is restricted to permit holders. The Act requires that permits be obtained for cultural heritage surveys, research and collection of artefacts as items of the Queensland Estate.

Protected area provisions

The *Nature Conservation Act 1992* protects cultural heritage places and objects in Queensland's national parks. The term 'cultural resources' is used to include 'places or objects that have anthropological, archaeological, historical, scientific, spiritual or sociological significance or value, including such significance or value under Aboriginal tradition or Island custom'. National park management principles aim to provide for the permanent preservation and presentation of cultural and natural values.

The *Great Barrier Reef Marine Park Act 1975* and the Great Barrier Reef Marine Park Regulations provide for the protection of 'cultural and heritage values held in relation to the marine park by traditional inhabitants and other people'. In addition, approaches to managing specific cultural heritage sites in the Great Barrier Reef Marine Park World Heritage area include:

- zoning provisions, such as those currently used to protect the wreck of the *Yongala*;
- special management areas;
- management planning for specific places; and
- regional agreements.

The Great Barrier Reef Marine Park Authority's 25-year strategic plan also has strategies for protecting cultural heritage places in the Great Barrier Reef World Heritage area.

Aboriginal and Torres Strait Islander heritage

Legislation

Both the Commonwealth and the Queensland Governments have passed native title legislation. The *Native Title Act 1993* (Cwlth) was created to recognise and protect Aboriginal and Torres Strait Islander peoples' native title rights and interests. It signalled the end of the *terra nullius* concept which denied the land tenure of indigenous people in Australia.

Native title legislation provides for indigenous Australians to make claim to native lands or waters where a continuous link with those lands or waters can be demonstrated. It provides a process by which native title rights can be established and compensation determined. It also sets out to protect native title rights in the future. The National Native Title Tribunal administers the Act by receiving and processing claims, identifying interested parties and providing mediation.

The issue of native title has been a major focus for heritage professionals in the Aboriginal and Torres Strait Islander heritage field, with numerous claims being submitted by particular groups of indigenous peoples. At 24 April 1998, 205 native title claims had been lodged in Queensland. Four native title compensation claims had also been lodged by this date. The total land area under claim in Queensland was 914 135 square kilometres, and the total sea area under claim was 157 292 square kilometres (DNR).

Queensland's *Aboriginal Land Act 1991* and *Torres Strait Islander Land Act 1991* provide for claims by Aboriginal and Torres Strait Islander peoples to State land (including national parks) and for the granting of land claimed. The broader aim of these complementary Acts is to foster the capacity for self-development, and the self-reliance and cultural integrity of the Aboriginal and Torres Strait Islander peoples of Queensland.

The native title legislation seeks to establish a legal regime that respects native title rights, and provides that native title holders should generally be treated in the same way as other title holders. It does not stop land management or economic development activities, but gives native title holders a special right to negotiate where mining and other activities are proposed on their land.

At 31 March 1998, of 14 national parks gazetted for claim under the Aboriginal Land Act, 12 had been claimed. Five hearings had been completed and recommendations made.

The *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (Cwlth) provides for the preservation and protection from injury or desecration of areas and objects in Australia and in Australian waters that are of particular significance to Aborigines in accordance with Aboriginal tradition. (The Act defines the terms 'Aborigines' and 'Aboriginal' as including Torres Strait Islanders.) The Act is intended to apply only where the relevant State or Territory legislation does not provide effective protection for the area or object/s from the threat of injury or desecration. Aboriginal or Torres Strait Islander people may make an application to the Commonwealth seeking the preservation or protection of an area or object/s.

Between 1984 and 1995 applications made by Queensland's Aboriginal and Torres Strait Islander communities comprised 34 percent of all applications made in Australia under the Act. Areas of concern were mythological sites, a spring, middens, burial sites, initiation grounds, fish traps, scarred trees, occupation sites and rock art sites.

Despite the large number of applications, only one declaration has been made under the Act. The large number of applications can be attributed to the limitations of the Queensland legislation, the *Cultural Record (Landscapes Queensland and Queensland Estate) Act 1987*, to provide effective protection in all circumstances compared with the Commonwealth legislation (Evatt 1996).

The Cultural Record (Landscapes Queensland and Queensland Estate) Act is the main piece of Queensland legislation used to protect Aboriginal and Torres Strait Islander cultural heritage. The Department of Environment and Heritage granted more than 750 permits for surveys and more than 300 permits for research between 1989–90 and 1996–97. These permits related primarily to the survey of areas for Aboriginal and Torres Strait Islander heritage places. Increased numbers of survey permits in 1994–95, 1995–96 and 1996–97 (table 9-3) can be attributed to more

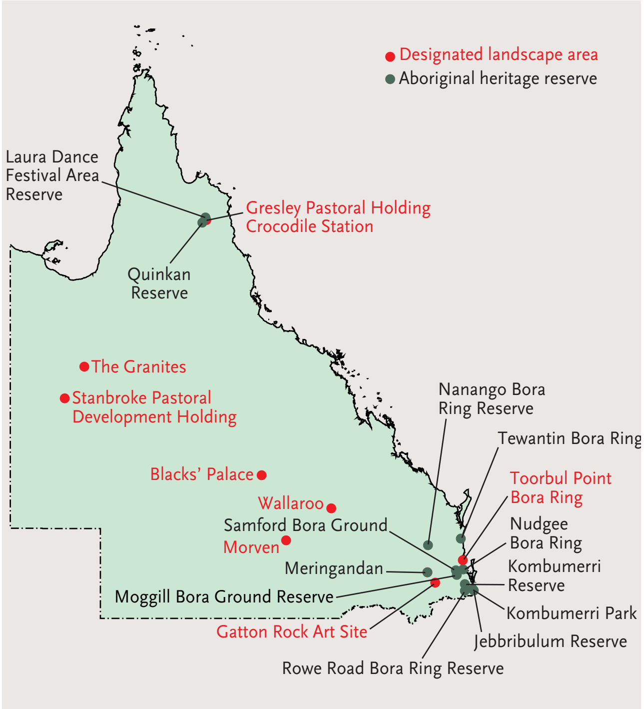


Figure 9-14 Designated landscape areas and Aboriginal heritage reserves of Queensland

development projects requiring cultural heritage surveys and to increasing awareness of the importance of cultural heritage issues in environmental planning and impact assessment.

The Environmental Protection Agency can permit the destruction of an Aboriginal or Torres Strait Islander site. Although the Act does not require it to consult with the Aboriginal or Torres Strait Islander community before issuing a consent to destroy, in practice this usually occurs. Under provisions of the Act, the Queensland Museum Board of Trustees is identified as the recipient of objects collected or excavated.

Indigenous Cultural Heritage Protection Program

The Indigenous Cultural Heritage Protection Program, established by the Commonwealth Government in 1993–94, seeks to improve the level and nature of protection for places significant to indigenous Australians. Guidelines for managing Aboriginal and Torres Strait Islander heritage places have been developed in consultation with Aboriginal and Torres Strait Islander people and State heritage management agencies.

Aboriginal heritage and cultural tourism

The increasing demand for Aboriginal cultural tourism, coupled with research and experience to date, indicates that Aboriginal heritage places are subject to increasing visitation. In many cases a lack of management has led to inadvertent destruction or deterioration of these places. While a permit system is in place for visiting the nine places formally recognised in Queensland, most Aboriginal heritage places have no protection.

Despite visits by independent cultural tourists, and more tour operators taking visitors to Aboriginal sites, no comprehensive permit or monitoring system is in place.

Construction of a boardwalk will protect this Aboriginal art site from inadvertent visitor damage and provide safe access for viewing the art.

Implementing such a system to monitor operators and measure pressures on sites is under consideration by the Environmental Protection Agency.

Tourists are known to visit numerous Aboriginal heritage places where the impact is not adequately buffered by provision of visitor facilities. While relatively few places have means to support large numbers of tourists, interim protective measures have been taken in some instances. More permanent visitor facilities have been installed at a number of indigenous heritage places which regularly attract visitors (figure 9-15). Evidence suggests that cultural tourism infrastructure has a positive impact on site management and in decreasing levels of graffiti.

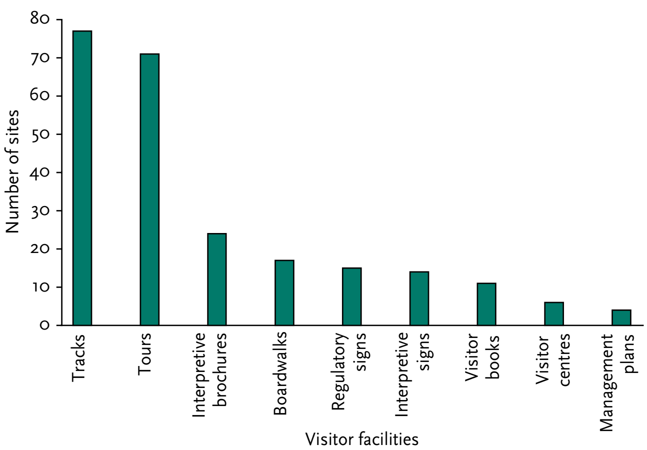


Figure 9-15 Visitor facilities at Aboriginal and Torres Strait Islander rock art sites where visitation is known to occur, based on 110 sites known to be visited regularly. Further research is required to determine the full extent of Aboriginal and Torres Strait Islander sites in Queensland that are visited regularly.

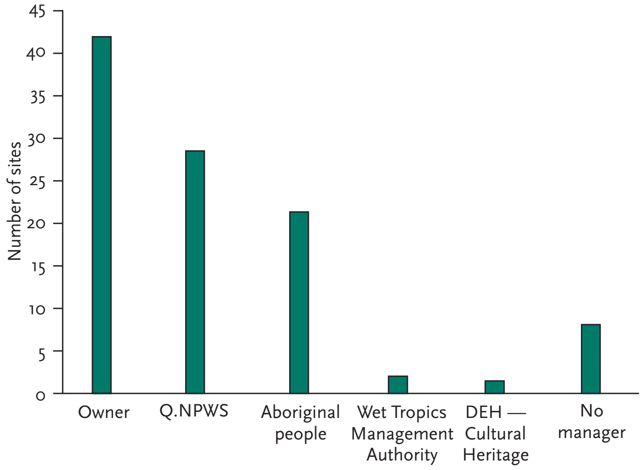


Figure 9-16 Management of Aboriginal rock art sites in Queensland at October 1998

The involvement of Aboriginal and Torres Strait Islander people in the management of their heritage ranges from consultation on management plans to day-to-day management of sites. Indigenous people are also consulted about managing protected areas in Queensland, including national parks, and have been involved extensively with management planning reviews in the Great Barrier Reef Marine Park and with the development of specific area management plans in Cairns and the Whitsunday Islands. Many heritage places, however, suffer from the traditional custodians having no involvement or limited involvement in management; more than 80 percent of rock art sites are managed by government agencies and private landowners or have no active management at all (figure 9-16).

HISTORIC HERITAGE PLACES AND OBJECTS

Legislation

The primary legislation for protecting historic cultural heritage places in Queensland is the *Queensland Heritage Act 1992*. Places nominated to the Queensland Heritage Register must meet criteria for entry. Development of such places requires Queensland Heritage Council approval. The Act also has provision for protecting declared relics and areas of historic archaeological interest.

Provisions for enforcing the Act include the use of stop orders, to stop work or other activities that might destroy or reduce the cultural heritage significance of a place. A place is not required to be entered on the Heritage Register for a stop order to be issued. Since the Act was introduced, four stop orders have been issued, along with one writ issued by the owner of a property to restrain the demolition activities of a lessee.

Under the Act, the remains of a ship or some other object situated in or recovered from the territorial waters of the State can be declared a protected relic. Land-based objects can also be declared protected relics in this way. Similarly, areas of archaeological interest can be declared protected areas if the Governor in Council believes a particular area might contain objects of cultural heritage significance.

Legislation and the public

Positive community attitudes are reflected in the fact that many owner nominations have been made to the Queensland Heritage Register, including the Cactoblastis Hall at Boonarga, Koongalba at Yandina, and Mellor's store at Gayndah.

While the number of places nominated indicates the level of public concern and interest in preserving cultural heritage, it may also reflect perceived threats to heritage places. At 30 June 1998, 581 nominations had been made to the Queensland Heritage Register since its establishment in 1992. In the absence of local government heritage provisions, concerned individuals and community groups have often tried to invoke the Act by making applications to enter places in response to an immediate threat.

Despite initial fears that the Act would impose an undue burden on private owners, opposition seems to have declined considerably. Tax incentives, reduced land tax and rates, and the successful recycling of heritage-registered places in the Brisbane central business district have been positive aspects. In 1994–95, no private owner development application was refused and only two out of 108 applications were altered or amended.

Diver excavating the hearth cover from the Captain's cabin of HMS *Pandora*

Interest in cultural tourism is growing, with some local governments actively promoting their heritage places as part of district or regional identities. Twenty-nine of 89 responses to a local government survey indicated that heritage studies had been undertaken for planning purposes in local government areas.

Queensland's historic shipwreck program

Five historic shipwrecks off Queensland have protected zones. A Historic Shipwrecks Act permit is required to visit them (table 9-19).

The Director of the Queensland Museum is delegated responsibility for administering the *Historic Shipwrecks Act 1976* (Cwlth) in waters off Queensland. Enforcement is undertaken by appointed inspectors — marine park rangers, Great Barrier Reef Marine Park Authority officers and police officers. Great Barrier Reef Marine Park zoning plans have been used to provide additional protection to shipwrecks such as the *Yongala* off Townsville. Although wrecks in waters off Queensland are not covered by the Commonwealth legislation, wrecks in Queensland marine parks are protected under the *Marine Parks Act 1982*.

Archaeological site surveys of wreck sites are an essential element of the underwater heritage management process undertaken by the Queensland Museum. Site surveys have been done on 37 of the 48 wrecks whose locations are known to the Queensland Museum,

Table 9-19 Shipwrecks with protected zones requiring permits

Vessel	Location	Year wrecked	Dived by public with permit
Pandora	Off Cape York	1791	Yes
Foam	Myrmidon Reef, near Townsville	1893	No
Aarhus	Smith Rock, near Moreton Island	1894	Yes
Gothenberg	Near Townsville	1875	Yes
Yongala	Near Townsville	1911	Yes

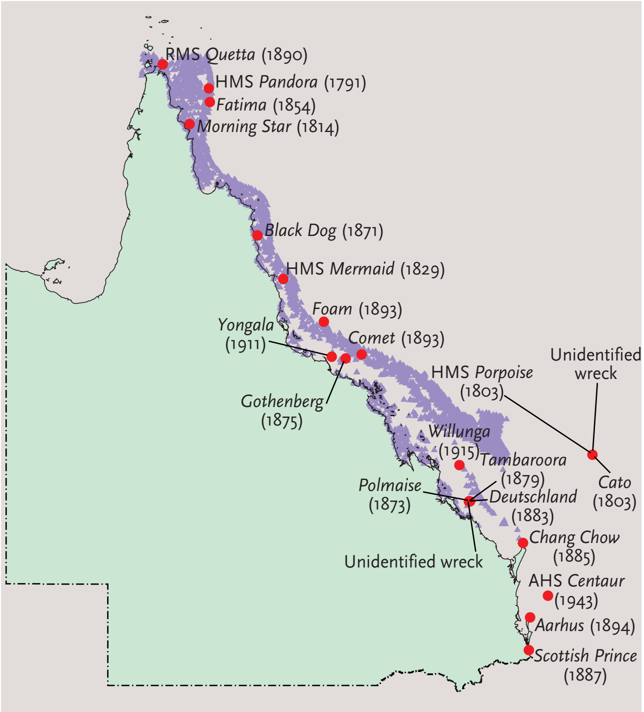


Figure 9-17 Locations of some of Queensland's historic shipwrecks

and 11 follow-up surveys have been conducted. The main findings were that deterioration of condition of wrecks could be attributed to human impact such as anchor damage, and to natural impact from cyclonic activity. Other agencies or individuals have conducted five additional wreck surveys.

Artefacts have been collected from five shipwrecks in Queensland waters by the Queensland Museum. Another wreck, HMS *Pandora*, has been partially excavated. The *Pandora* excavations, funded by the Commonwealth Government, the Queensland Government and the Pandora Foundation, will culminate in a major *Pandora* display in the expanded Museum of Tropical Queensland in Townsville in 2000.

MUSEUM AND ARCHIVE COLLECTIONS

One of the most organised responses to the management of cultural heritage objects and collections has been provided by over 200 museums throughout the State. Activities in the museum industry are coordinated at all levels of government and community. To a large extent, this is brought about by national programs. Queensland Government initiatives include legislation and policies plus funding for conserving heritage objects and collections.

Queensland's primary museum legislation is the *Queensland Museum Act 1970*. This establishes a Board of Trustees to administer the Queensland Museum and defines its functions and powers over the Museum's collections. Details for managing object collections are given in an approved collection policies and procedures document.

The *Libraries and Archives Act 1988* provides for the administration of the State Library of Queensland (including the John Oxley Library) and the Queensland State Archives, and promotes libraries and archives and the preservation of public records in Queensland. Parts of the Act provide for the preservation, custody, deposition, inspection and disposal of public records, and preservation of deposited material published in Queensland.

Heritage Collections Committee

The Heritage Collections Committee is a product of collaboration between the Commonwealth, the museums sector through Museums Australia, and the State and Territory Arts Ministries. At the State and local government levels there is coordination through the Queensland Office of Arts and Cultural Development and local governments. Through its three working parties, the committee is implementing a program of projects aimed at increasing access to the heritage collections of Australian museums.

Collections management by collecting institutions

All six major collecting institutions in Queensland have developed collection policies to define their roles. Five have developed conservation policies, and one has adopted the AICCM guidelines. Loans policies have been defined by all institutions except the Queensland State Archives, where loans are not made. All but two institutions have established display procedures. A disaster management plan has been developed for three of the institutions and is under development or review for two others.

Recommendations of the development plan for Queensland museums 1995–2001, including consolidation of grant programs and the appointment of regional museum resource officers, are being implemented. As a result, community museums are being encouraged to develop collections policies.

The Queensland Museum conserved 3044 items in 1997–98. In the same year, the museum spent more than $26,768 adding to its collections.

Museum conservation
QUEENSLAND MUSEUM

In 1996–97, Queensland Art Gallery acquisitions totalled 178. Each year, many significant donations of material are made to Queensland's collecting institutions by the public as gifts and bequests. The Queensland Art Gallery includes gifts, bequests and purchases in its acquisitions total. The State Library receives books and serials produced in Queensland and legally deposited. It received 4838 items in 1996–97.

Repatriation of cultural collections

A key issue for the Queensland Museum is the need to continue repatriation of human remains and other sensitive items of concern to the Aboriginal and Torres Strait Islander communities. The Museum's policy on returning cultural

Queensland Museum

A coach from the Cobb & Co. Museum, Toowoomba

items allows the custody of secret sacred items to be transferred to appropriate Aboriginal and Torres Strait Islander persons, where rights under Aboriginal and Torres Strait Islander customary law can be substantiated (Queensland Museum 1994). The Museum's policy also deals with the sensitive issue of Aboriginal and Torres Strait Islander human remains and burial items, by indicating that the Museum will retain only those remains which are of scientific or educational value, and only where consent of the Aboriginal community is granted. A procedure for the return of all other human remains is currently in place. Any human remains held by the Museum are stored in a restricted area dedicated to that use. Items collected illegally for the Queensland Museum will also be returned to their rightful owners.

By October 1996, the Queensland Museum had received 15 formal requests for the return of indigenous cultural material. As a result, 75 items were de-accessioned and returned to Aboriginal communities and 100 items were loaned to communities.

In 1997–98, 30 Aboriginal human remains items were de-accessioned and repatriated to locations in Queensland and Victoria. Torres Strait Islander remains were repatriated to Badu Island.

Regional services

In 1996–97, the Queensland Museum prepared six travelling displays and 20 regional centres were serviced. In an attempt to improve access to collections, major museums, including the Queensland Museum, are installing computer interactive facilities. In April 1997, the Queensland Museum launched a Web page covering a diverse range of cultural and natural heritage collection issues. However, traditional means of increasing access to collections such as touring exhibitions maintain their appeal for improving education about and awareness of heritage issues.

University Museums Review

The Australian Vice-Chancellors' Committee recently published a review of university collections throughout Australia. This examined the full range of issues associated with collections in universities, and made numerous recommendations for national coordination based on common requirements of university collections.

Museum training

Volunteers comprise most of Queensland's community museum workforce. They often lack formal museum training, and have limited opportunities to gain practical museum skills due to the lack of courses available in country areas.

Lennon (1995) prepared *Hidden Heritage: A Development Plan for Museums in Queensland 1995–2001*. TAFE Queensland followed the recommendations in this report and offers a certificate-level course in museum and art gallery administration to current museum/art workers and volunteers.

James Cook University, Townsville, offers the only university training course in Queensland. This is available externally to community museum workers.

LOCAL GOVERNMENT PLANNING PROVISIONS

Assessments of the natural and built environment and the 'social and cultural features of the population' are required in each local government planning study. Although many local governments have undertaken heritage assessment studies, few studies have resulted in registers being established to protect Aboriginal and/or historic cultural heritage places.

Forty-one percent of 85 local governments surveyed in 1997 had provisions for protecting cultural heritage places. Of these, 20 had planning provisions for protecting Aboriginal and Torres Strait Islander heritage and 31 had provisions for historic heritage. About 21 percent of local governments had provisions to protect both types of heritage places.

Brisbane City Council (BCC) has a variety of planning control mechanisms to protect historic buildings and structures. These include the town plan, development control plans and local area plans. In 1997 three development control plans with stringent heritage provisions were in place, and another two were awaiting endorsement.

BCC also uses 'heritage and character building demolition and removal controls' to provide blanket protection in the inner and middle suburbs residential zones. In addition, local area plans are developed for specific areas to provide more direction to the blanket controls. These identify heritage places, but places are not given any special protection.

Local government heritage advisers provide free building conservation advice to owners and/or occupiers of heritage places in a local government area. They also advise local governments on heritage matters, normally through a Heritage Advisory Committee with local government and community representation. At 31 March 1998, heritage advisers had been appointed in six local government areas: Ipswich, Charters Towers, Maryborough, Mackay, Toowoomba and Townsville.

COMMUNITY RESPONSES

People in the community express their concern for the protection of heritage places by joining interest groups, such as national heritage organisations like the National Trust, residents' action groups and local historical societies. These groups provide a focus for community involvement in a wide range of heritage activities including the documentation of local history projects, education and local heritage activities.

Community groups have frequently responded to perceived threats to Queensland's heritage with organised protests, petitions and demonstrations. The numbers of people in major heritage associations and attendance levels at museums provide some indication of community support for cultural heritage. The actual number of people involved in all community heritage groups across Queensland, while believed to be substantial, is unknown.

The National Trust of Queensland

The National Trust of Queensland plays a significant role in promoting heritage and its protection. It is a community-based, non-government organisation committed to conserving Australia's heritage for the benefit of the public. The Trust maintains a register of places of heritage significance. While the register does not have any legal effect, it is widely recognised as an authoritative statement of the heritage of a place. During 1997 the Trust had 18 branches and 9449 members. It managed 18 properties and held another 19. For financial support, it relies on community support through membership subscriptions, sponsorship, donations, retail sales, volunteer efforts and government grants.

Associations and volunteers

Museums Australia Incorporated is the major lobby group for museums in Australia. This organisation is funded nationally. Museums Association (Queensland) is provided with operational funding through Arts Queensland. Its main functions are to provide policy advice to the museum sector and government, to provide advice on training standards and programs, to increase professional development opportunities, and to provide maximum support to the community museum sector. Membership grew from 83 in 1992 to 217 in 1996.

The Regional Galleries Association of Queensland is a Queensland Government-funded organisation which provides a networking and advocacy service for Queensland's galleries. Membership in January 1997 stood at 82 organisations — 60 local governments and 22 associate members.

In 1996–97, Friends of the Queensland Art Gallery were estimated at more than 1960. In 1997–98, the Queensland Museum received 5179 volunteer days from 734 honorary staff.

Attendance

A Museums Australia 1994–95 survey of museums with paid staff recorded 1 195 000 visits to 26 museums in Queensland and 746 000 visits to 21 art museums.

In 1996–97, 423 296 people attended the Queensland Art Gallery. Increasing numbers of people are visiting the John Oxley Library (18 660 in 1996–97) and enquiries are constantly increasing (14 321 in 1996–97). In addition, in the same period the Library received 10 957 enquiries across its special collections.

Demand for information services from the Aboriginal and Torres Strait Islander Information Resource Unit continues to grow (263 written enquiries, 328 telephone enquiries and 387 personal visits in 1996–97).

Public use of the Queensland State Archives has risen steadily since its new building opened in 1993. A total of 9470 researchers used the public search room in 1997–98, and during that year 27 730 records were issued.

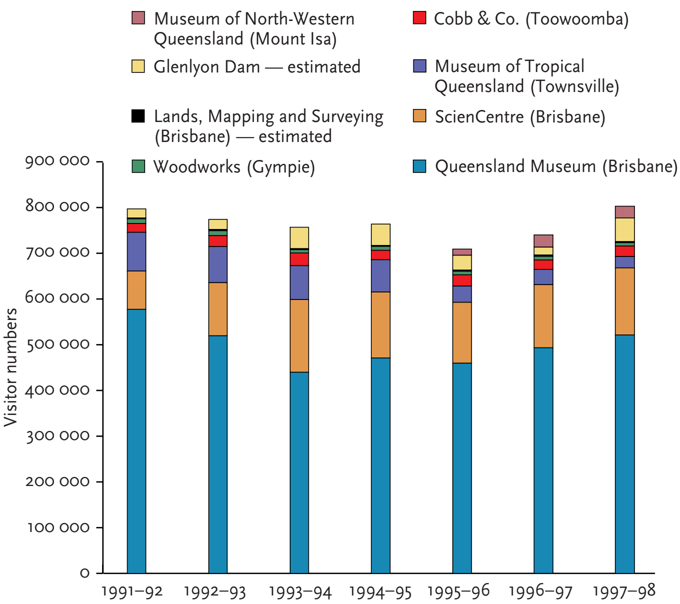


Figure 9-18 Queensland Museum and branches visitor statistics, 1991–92 to 1997–98. Sixty-five percent of all visitors during 1997–98 attended the Queensland Museum in Brisbane. *(Source: Queensland Museum)*

FUNDING FOR CULTURAL HERITAGE

Financial support for heritage programs is essential for identifying and conserving heritage places and objects. Funding levels are a useful indicator of government response to cultural heritage management requirements. These can be analysed in terms of base funding levels and amounts for heritage grant programs.

Base funding

Base funding provided for the Department of Environment and Heritage Cultural Heritage subprogram in 1997–98 totalled $2,868,399 (figure 9-19). Base funding allocated to Queensland's collecting institutions for 1997–98 amounted to $12.2 million for the Queensland Museum, $8.8 million for the Queensland Art Gallery, $4.758 million for the Queensland State Archives and $32 million for the State Library of Queensland.

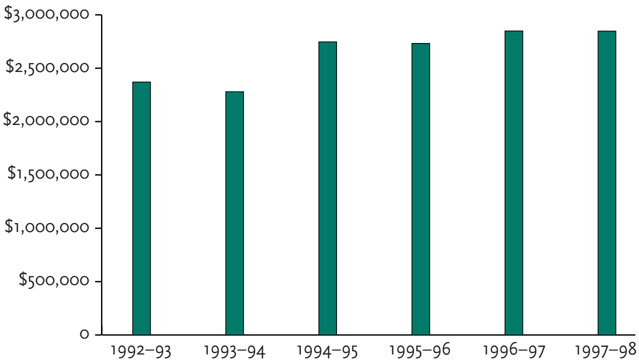


Figure 9-19 Base annual funding for the Cultural Heritage subprogram, Department of Environment and Heritage, 1992–93 to 1997–98

Commonwealth Government grant programs

The major grant program administered by the Commonwealth is the National Estate Grants Program (NEGP). Until recently, the NEGP, administered by the Australian Heritage Commission with State heritage agencies, provided funds for identifying, conserving and presenting natural, historic and indigenous places entered on the Register of the National Estate. Each year priorities were set for allocating funds. However, funds sought far exceeded those allocated each year.

In 1995–96, four of the eight projects funded for the indigenous section were for conservation work or site-specific studies on places listed in the Register of the National Estate. In the historic section, 13 out of 22 projects were for places listed as needing urgent conservation action.

The NEGP also funds projects for collections of objects housed in a place listed on the Register of the National Estate. However, these funds are not available for conserving collections unless the collection is an integral part of the fabric of the place.

The State component of the NEGP was discontinued in 1996–97, reducing the total allocation to $2.1 million. The amount available in the program was reduced to $1.3 million for 1997–98. Reduced funding will have an adverse impact on the amount of identification and conservation work that can be undertaken each year in every State.

The Commonwealth invited applications for grants for projects of national importance in 1998–99, with emphasis on historic and indigenous projects and on-the-ground conservation projects for nationally important cultural places.

The Aboriginal and Torres Strait Islander Commission (ATSIC) provides support services for Aboriginal and Islander heritage. These include financial support for

The ruins of Carcory homestead were stabilised using funds provided by the National Estate Grant Program.

communities to document their heritage and to establish and maintain keeping places. Funding is available for the repatriation of cultural material, and training and employment programs are available for the Aboriginal and Torres Strait Islander heritage sector.

In 1996–97 the Heritage Properties Restoration Program provided funding assistance to St John's Cathedral in Brisbane. Total Commonwealth expenditure on this program decreased from $4.1 million in 1996–97 to $2 million in 1997–98 (Commonwealth of Australia 1997).

A number of other Commonwealth grant programs include the Visions Australia program (an annual grant program for touring exhibitions), the Tax Incentives for the Arts Scheme, grants in aid, and Heritage Collections Committee projects. These programs have had a limited impact on Queensland's community museums (Lennon 1995).

Queensland Government grant programs

Since 1989, the Queensland Heritage Grants Program has provided funds for historic and Aboriginal and Torres Strait Islander heritage projects. Application totals exceed available funding significantly (table 9-20). The Program provides funding for places used as museums, such as Greenmount Historic Homestead near Mackay. A Queensland Government grant is provided each year to maintain Newstead House, Brisbane, and its collection.

The Queensland Community History Grants Program has been highly successful in improving the level of community involvement in heritage identification and conservation projects. However, it too was able to fund only a small proportion of projects. In 1996–97, six projects were granted a total of $25,650. In 1997–98, applications amounted to $417,000 but only 10 projects, totalling $31,020, were granted.

The Queensland Community History (Indigenous Heritage) Grants Program encourages indigenous people to research and document the history of the relationships between people and places, and thereby increase understanding of Queensland's indigenous history. In 1996–97, 20 projects were granted a total of $231,215. In 1997–98, applications totalled $1.8 million. Twenty projects were granted $195,785.

Queensland Museum

A museum worker gives a demonstration at the Woodworks Museum, Gympie.

Museum Development Program

The museum sector has had access to grant funds initially through the Queensland Museum's Grants Towards Local Museum Activities Scheme, and now through the Museum Development Program. Following a review of community museums in Queensland in 1996, Arts Queensland took responsibility for the scheme. A total of $2,031,442 was allocated between 1982–83 and 1995–96. While $253,337 was granted in Museum Development Grants in 1997, applications were received for funds totalling more than $956,121.

The grants available include individual projects to help professional development of individuals working with Queensland collections. Funding for organisations' projects supports professional management of Queensland collections of movable cultural heritage. In 1996–97, projects were eligible to receive funding of up to $30,000 each. However, projects without any other source of financial support are not eligible. The program also provides funds for commission of

Table 9-20 Overview of Queensland's cultural heritage grants programs. The figures show the high level of demand for funding for community grants programs. The demand far outweighs the level of funds available. Although the Commonwealth's National Estate Grants Program was discontinued for the States during 1996–97, two new grant programs were established by the Queensland Government to meet the demand for heritage conservation funds.

	NEGP* (Qld)		QHGP*		QCHGP*		QCHGP (IH)*	
Year	Applied for ($)	Granted ($)	Applied for ($)	Granted ($)	Applied for ($)	Granted ($)	Applied for ($)	Granted ($)
1989–90	3,989,358	614,000	3,975,912	500,000	–	–	–	–
1990–91	7,427,695	599,350	–	–	–	–	–	–
1991–92	5,165,445	618,666	2,500,000	236,000	–	–	–	–
1992–93	5,790,478	649,936	4,557,943	250,000	–	–	–	–
1993–94	5,720,535	658,132	5,414,709	21,725	–	–	–	–
1994–95	4,950,776	671,215	2,842,213	205,930	417,609	46,700	–	–
1995–96	8,114,591	681,009	6,491,106	220,000	672,725	41,478	–	–
1996–97	3,929,463	discontinued	2,676,377	143,008	541,327	25,650	1,654,389	195,785
1997–98	–	–	2,037,335	180,046	416,524	31,020	1,812,841	231,215

*NEGP — National Estate Grants Program; QHGP — Queensland Heritage Grants Program; QCHGP — Queensland Community History Grants Program; QCHGP (IH) — Queensland Community History (Indigenous Heritage) Grants Program works, artist/cultural workers in residence, exhibition touring and publications.

In the five years to June 1995, the museum sector experienced the highest growth rate in funding by Arts Queensland; in 1997 museums accounted for 4 percent of the total arts grants budget.

The National Trust of Queensland

While the National Trust largely represents a community response to the need to protect heritage places, the Commonwealth and Queensland Governments support it financially. In 1996–97, the Trust received $124,351 in heritage and administration grants from the Commonwealth and $95,105 in heritage and administration grants from the Queensland Government.

Local government grant programs

Brisbane City Council Local History Grants were offered for the first time in 1996. Townsville and Ipswich City Councils offer grant programs for conserving historic heritage places.

Tax Incentives for Heritage Conservation

The Tax Incentives for Heritage Conservation scheme introduced in 1994–95 was developed specifically for heritage buildings and structures. The scheme aims to encourage conservation and restoration work that complies with the heritage conservation guidelines outlined in the Burra Charter. It is available only to people who own buildings or structures listed in the Register of the National Estate or in a State/Territory statutory heritage register, such as the Queensland Heritage Register. In 1997–98, about $800,000 of work in 15 applications was expected to be approved for tax incentives for conserving places in Queensland.

Donations of significant cultural items, including artworks and heritage objects, to art galleries, libraries and museums are encouraged through the Commonwealth Government's Tax Incentives for the Arts Scheme. The scheme offers donors a tax deduction for the market value of their gifts. During 1996–97, tax deductions to the value of $1,730,474 were granted to 17 of 19 applicants.

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glossary

GLOSSARY

Units and measurements

µg microgram, a unit of weight equal to 10^{-6} grams

µm micrometre, a unit of length equal to 10^{-6} metres

µmol/L micro (10^{-6}) moles per litre

cumec cubic metres per second, measure of water flow at a particular point

dS/m deciSiemens per metre. Siemens are a derived measure of electrical conductivity of a liquid.

g gram, a unit of weight

Gg gigagram, a unit of weight equal to one thousand million (10^9) grams

GJ gigajoule, a unit of energy equal to one thousand million (10^9) joules

GL gigalitre, a unit of volume equal to one thousand million (10^9) litres

GW gigawatt, a unit of power equal to one thousand million (10^9) watts

GWh gigawatt hour, unit of electrical energy, equivalent to 3.6×10^{12} J

h or **hr** hour

ha hectare, a unit of area equivalent to 10 000 square metres. There are 100 ha in one **km^2**.

hPa hectopascals, a measure of air pressure

J joule, unit of work and energy

kg kilogram, a unit of weight equal to one thousand (10^3) grams

KJ kilojoule, a unit of energy equal to one thousand (10^3) joules

KL kilolitre, a unit of volume equal to one thousand (10^3) litres

km kilometre, a unit of length equal to one thousand metres

km^2 square kilometre

kW kilowatt, a unit of power equal to one thousand (10^3) watts

kWh kilowatt hour, unit of electrical energy, equivalent to 3.6×10^6 J

L litre, a unit of volume

m metre, a unit of length

m^2 square metre

m^3 cubic metre

mg milligram, a unit of weight equal to one-thousandth (10^{-3}) of a gram

MJ megajoule, a unit of energy equal to one million (10^6) joules

mL millilitre, a unit of volume equal to one-thousandth (10^{-3}) of a litre

ML megalitre, a unit of volume equal to one million (10^6) litres

mm millimetre, a unit of length equal to one-thousandth (10^{-3}) of a metre

MW megawatt, a unit of power equal to one million (10^6) watts

MWh megawatt hour, unit of electrical energy, equivalent to 3.6×10^9 joules

ng nanogram, a unit of weight equal to 10^{-9} grams

nm nanometre, a unit of length equal to 10^{-9} metres

PJ petajoule, a unit of energy equal to one thousand million million (10^{15}) joules

ppb parts per billion

ppbv parts per billion by volume

ppm parts per million

ppmv parts per million by volume

R^2 a statistical measure used in regression analysis to describe the proportion of variation accounted for in a dependent variable by considering changes in the independent variable

s second

t tonne, a unit of weight equal to one million (10^6) grams

W watt, a derived unit of power, defined as one joule per second

y or **yr** year

Terms and abbreviations

AATSE Australian Academy of Technological Sciences and Engineering

ABARE Australian Bureau of Agricultural and Resource Economics

abiotic non-living, e.g. rocks

ABS Australian Bureau of Statistics

ADR Australian design rule

AGL Australian Gas Light Company

AGO Australian Greenhouse Office

AICCM Australian Institute for the Conservation of Cultural Material

air emissions inventory detailed listing of the estimated amount of emissions to the atmosphere by type and source over time and area

airshed a body of air bounded by topographical and/or meteorological features

air toxics a range of pollutants, mainly organic compounds, that cause or are suspected of causing long-term health effects in humans

algal bloom a concentration of phytoplankton sufficient to impair water quality

ambient air surrounding outdoor air

ANCA Australian Nature Conservation Agency

anthropogenic produced or caused by human activity *see also* **biogenic**

ANZECC Australian and New Zealand Environment and Conservation Council

ANZMEC Australian and New Zealand Minerals and Energy Council

AQIS Australian Quarantine and Inspection Service

aquaculture the commercial culture of aquatic plants or animals in fresh or salt water

aquifer rock or sediment in a geological formation capable of being permeated so that it can transmit and store water *see* **groundwater**

arable suitable for crop production

arachnids a class of arthropods (segmented invertebrates having jointed legs) that includes the spiders, scorpions and mites

ARMCANZ Agriculture and Resource Management Council of Australia and New Zealand

ASGC Australian Standard Geographic Classification

ATSI Aboriginal and Torres Strait Islander

ATSIC Aboriginal and Torres Strait Islander Commission

bagasse fibrous remains of sugarcane after juice extraction

ballast water water carried in tanks to maintain stability in a ship. It is normally discharged when the ship is loaded with cargo.

bare-surface farming system where vegetation is removed from soil surface between cropping or pasture growth cycles. Includes cropping where land is ploughed to bare soil after each harvest. Used principally for grains, oilseed, fodder crops and sugarcane.

baseline a specific time or defined area from which trends or changes can be assessed

BCC Brisbane City Council

benthos marine organisms living on or in the sea floor

BHC benzene hexachloride

BHP Broken Hill Pty Ltd

bioavailability the ease with which a chemical is absorbed into plants or animals

biocides generic term to cover pesticides, insecticides, herbicides, fungicides

biodiversity the variety of all life forms: the different plants, animals and micro-organisms, the genes they contain and the ecosystems they form

biogas fuel gas such as methane and carbon dioxide derived from the decay of organic matter

biogenic originating from the natural environment *see also* **anthropogenic**

biological control controlling a pest by the use of natural or introduced enemies, for example, predators, parasites or disease-producing organisms

biomass total mass of an organism or organisms living in a particular area, for example the biomass of all the trees, grasses and shrubs

biomass burning the combustion of waste organic matter such as stubble, **bagasse**

bioregion (biogeographic region) an extensive region distinguished from adjacent regions by its broad physical and biological characteristics

biosolids organic products from the treatment of sewage; also known as sewage sludge

biota all the organisms in a given area

blue-green algae microscopic, photosynthetic aquatic organisms; term commonly used to represent **cyanobacteria**

BOD biochemical oxygen demand, a measure of the oxygen-depleting capacity of an **effluent** due to decomposition by micro-organisms

BoM Bureau of Meteorology

BP British Petroleum

broadacre (farming) farming on large tracts of land as a single operation, usually of sheep, cattle and/or cereals

broadscale relating to an activity that is carried out over a large area

Burra Charter the Australia **ICOMOS** Charter for the Conservation of Places of Cultural Significance; a document prepared by the Australian Committee for the International Council for Monuments and Sites (Australia ICOMOS) to guide conservation philosophy and practice for cultural heritage places in Australia

bycatch species taken incidentally in a fishery where other species are the target; often discarded

CAMBA China/Australia Migratory Bird Agreement

carrying capacity maximum stocking rate that an area of grazing land can support throughout the greatest period of stress each year

catchment the area within which rainfall contributes to runoff to a particular water body

CBD central business district

CD Census Collection District, an Australian Bureau of Statistics area for data collection

CFC **chlorofluorocarbon** synthetic **greenhouse gas** that contains chlorine and fluorine

chlorophyll *a* plant photosynthetic pigment (used as a measure of algal concentrations in water)

CITES Convention on International Trade in Endangered Species

cleaner production a holistic approach to reducing source inputs and waste outputs in the production process

climate change recent trends that are believed to result from human interference with the natural radiative properties of the atmosphere, due to increased greenhouse gas emissions

closed forest forest in which the tree crowns cover 81–100 percent of the land area when viewed from above *see* **forest**

CO **carbon monoxide** a poisonous, colourless gas produced by incomplete combustion of petrol and diesel fuels

CO_2 **carbon dioxide** an odourless, colourless gas produced during respiration, decomposition of organic material and combustion

CO_2 equivalent the amount of carbon dioxide that would cause the same amount of global warming as the greenhouse gas under discussion

COAG Council of Australian Governments

co-generation the production of two forms of useful power, usually electricity and heat, from a single fuel source in a single process

collembola an order of wingless hexapods, commonly known as springtails, most of which feed on fungi and bacteria found in rotting organic material, especially in leaf litter

CPM Act *Coastal Protection and Management Act 1995*

CPUE catch per unit of effort; the quantity by weight of fish taken by a fishing operation each day

CRC Cooperative Research Centre

CRCWMPC Cooperative Research Centre for Waste Management and Pollution Control

Crustacea a phylum of chiefly aquatic arthropods, such as lobsters, prawns, barnacles etc., commonly having the body covered with a hard exoskeleton or carapace

cryptogamic crust surface layer over unvegetated areas composed of mosses, lichens, algae and bacteria which protects soil from erosion, absorbs moisture, provides nutrients for plant growth and provides germination sites for seeds

CS Energy Callide Swanbank Energy

CSIRO Commonwealth Scientific and Industrial Research Organisation

CSR Colonial Sugar Refinery

cultural landscapes areas or features within Queensland that: (a) have been or are being used, altered or affected in some way by humans; and (b) are of significance to humans for any anthropological, cultural, historic, prehistoric or societal reason

cultural tourism travel oriented toward culturally significant destinations; might be broadly motivated by the desire to experience cultural diversity or to immerse oneself in the culture of a region

cyanobacteria microscopic, photosynthetic aquatic organisms; commonly referred to as **blue-green algae**

DEH Department of Environment and Heritage (Qld)

DES Department of Emergency Services (Qld)

DEST Department of the Environment, Sport and Territories (Commonwealth)

diffuse source source of pollution from a broad area or many small sources, such as runoff from fields or urban areas *see* **point source**

displaced refers to species that are not native to an area but originate elsewhere in Australia *see* **translocation**

diversion in water issues refers to the physical redirection of water from a water body producing an alteration of its natural flow regime. Diversion activities include the construction of dams, barrages and weirs, and water abstraction and harvesting for water supply, irrigation and power generation.

DME Department of Mines and Energy (Qld)

DNR Department of Natural Resources (Qld)

DoE Department of Environment (Qld)

domestic animals animals directly managed by humans *see also* **feral animals**

DPI Department of Primary Industries (Qld)

DSE dry sheep equivalent (usually 50 kg)

dryland land (usually cropping or grazing land) that is not irrigated

ecosystem a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit

ecosystem services the role played by organisms in creating a healthy environment for human beings, for example, in production of oxygen, soil formation, maintenance of water quality

EEA European Environment Agency

effluent a discharge or emission of a waste product

El Niño (Southern Oscillation) a warm water current that periodically flows southwards along the coast of Ecuador and Peru in South America, replacing the usually cold northwards-flowing current. It occurs when the **SOI** is strongly negative. The name refers to the Christ child as the current usually appears around Christmas. The opposite phase is named **La Niña**.

EMP environmental management plan

EMR Environmental Management Register

endangered species a plant or animal that is in danger of becoming **extinct** or whose survival in the wild is unlikely if threatening processes continue

endemic native to a particular area and found (naturally) nowhere else

enhanced greenhouse effect *see* **greenhouse effect**

ENSO El Niño Southern Oscillation *see* **El Niño**

environmental flows minimum flows of water (by volume and by season) necessary to maintain all aquatic biota and ecosystem processes

EO environmental order

EP Act *Environmental Protection Act 1994*

EPO environmental protection order

EPP environmental protection policy

ERA environmentally relevant activity

ERDC Energy Research and Development Corporation (Commonwealth Government)

ESAA Electricity Supply Association of Australia

ESD ecologically sustainable development: using, conserving and enhancing resources so that ecological processes, on which life depends, are maintained and the total quality of life, now and in the future, can be improved

estuary area of a coastal river mouth, characterised by tidal effects and mixing of fresh with sea water

eutrophic (a description usually applied to water) over-enriched by nutrients, primarily nitrogen and phosphorus, stimulating excessive growth of organisms and depletion of dissolved oxygen

exceedance an occasion when a goal, guideline or standard is exceeded

exotic species a non-native species that has been introduced to a region

extinct species *see* **presumed extinct species**

extraction withdrawal of water for agriculture, mining, industry or urban uses

faecal coliforms indicator organisms used to test for the presence of enteric bacteria

fallow (of land) not being cropped

family a group of species of common descent higher than the **genus** and lower than the order

fauna all of the animals found in an area *see also* **flora**

FCCC *see* UNFCCC

feral animals animals that have reverted to a wild state from domestication *see also* **domestic animals**

ferrosols well-drained red or yellow-brown clay loam and clay soils. Occur mainly around Kingaroy and Atherton where they are used for intensive agriculture such as maize, peanuts, potatoes and dairying.

floodplain a nearly flat plain along the course of a stream naturally subject to flooding at high water

flora all of the plants found in an area *see also* **fauna**

FNQ far north Queensland

forest an area that is dominated by trees usually having a single stem and a mature stand height of over two metres and in which the tree crowns cover at least 20 percent of the land area when viewed from above *see* **woodland, open forest, closed forest**

fossil fuel any hydrocarbon deposit that can be burned for heat or power, such as coal, oil and natural gas

fragmentation when used in the context of vegetation or habitat, refers to division and isolation of vegetation/habitat by vegetation clearing, isolating species and limiting genetic flow

freehold land owned privately *see also* **leasehold**

fuel cell device that converts one form of energy into another, for example, chemical energy into electrical energy

GAB Great Artesian Basin, the largest system of groundwater aquifers in Australia

GBRMP(A) Great Barrier Reef Marine Park (Authority)

gene the basic unit of heredity

genus (plural **genera**) a group of closely related species

GHG *see* **greenhouse gas**

gibber (terrain covered with) the smoothed and rounded weatherworn stones of the arid Australian centre

global warming a rise in world temperature expected from increased concentrations of greenhouse gases

greenhouse effect the natural warming of the Earth's atmosphere as a consequence of the concentration of trace gases that retard the escape of heat radiation. The 'enhanced greenhouse effect' is the expected increase in the Earth's temperature as a result of the increase in **greenhouse gas** concentrations. The term 'greenhouse effect' is popularly used for the 'enhanced greenhouse effect'.

greenhouse gas gas occurring naturally or produced by human activity which enhances the natural 'greenhouse effect'. Greenhouse gases include **carbon dioxide**, **methane**, **halocarbons**, **nitrogen oxides**, **ozone** and water vapour.

green waste garden, food and wood wastes that are compostable and/or can be shredded and used for mulching

greywater wastewater usable for a limited range of purposes such as garden irrigation or industrial cooling

ground truth to verify on-site data deduced from a model, satellite picture or aerial photograph

groundwater water occurring below the ground surface *see* **aquifer**

growout a stage in aquaculture production where individual fish are grown to marketable size

habitat the place where an animal or a plant normally lives and reproduces

halocarbons generic term for bromo-, chloro- and fluorocarbons, synthetic **greenhouse gases**, used in various technologies. Some halocarbons also deplete stratospheric ozone.

hardwood in this report, refers to native timbers such as eucalypts, wattles and most rainforest species *see also* **softwood**

hazard-reduction burning deliberate burning of forests and grasslands in calm or near-calm conditions to reduce the level of flammable material on the ground to limit the potential for destructive wildfires under other conditions

heritage places, objects and indigenous languages that have aesthetic, architectural, historical, scientific, technological or social significance or other special value for future generations as well as for the community today. The value of that heritage might or might not be fully recognised.

HFC hydrofluorocarbon

hydrocarbon an organic molecule containing hydrogen and carbon, the major components of petroleum

hydrological dealing with water on the land or under the Earth's crust, its properties, laws and geographic distribution

hospital separation rate the number of patients who are treated for a certain health problem at a hospital, counted when patients leave the hospital rather than when they are admitted

IBRA Interim Biogeographical Regionalisation of Australia

ICOMOS International Council for Monuments and Sites

IDAS Integrated Development Approval System

IGAE Intergovernmental Agreement on the Environment

IMCRA Interim Marine and Coastal Regionalisation for Australia

impervious surface roofed, paved or compacted areas of the ground that prevent water runoff from penetrating underlying soil

indicator species a species that is used to assess the health of an entire ecosystem

indigenous (people) in this report, indigenous Australians are Aboriginal people and Torres Strait Islanders

in situ conservation conservation of ecosystems, species or objects within their natural or original environment *see also* **off-site conservation**

intergenerational equity the principle that the present generation should pass on to future generations an environment that is not impoverished and degraded and that will not reduce the quality of life for future generations

intertidal between the levels of low and high tide

inversion (temperature) occurs when air temperature increases rather than decreases with height

invertebrate an animal without a backbone composed of vertebrae, that is, segments or bone comprising a column through which the spinal cord passes, not including protozoans *see also* **vertebrate**

IP Act *Integrated Planning Act 1997*

IPCC Intergovernmental Panel on Climate Change

IRTP Integrated Regional Transport Plan

IUCN International Union for Conservation of Nature and Natural Resources

JAMBA Japan/Australia Migratory Bird Agreement

kandosols red, yellow and grey soils with 'earthy' porous loamy subsoils which have low fertility levels and poor water-holding capacity. Kandosols are found in mulga areas around Charleville and support cattle and sheep grazing on native pastures.

keeping place a community museum housing Aboriginal or Torres Strait Islander social history collections

LADM Lagrangian Atmospheric Dispersion Model

lake area of open water, generally over one metre deep, with little or no persistent emergent vegetation

La Niña the opposite of an **El Niño** phase; occurs when the **SOI** is strongly positive. La Niña phases are associated with higher-than-usual rainfall in eastern and northern Australia.

LANDSAT the land and earth resources satellite system

leaching act of percolating through, as water through a porous material

leasehold land owned by government but leased to a specific person or organisation for a specific purpose *see also* **freehold**

LGA local government area

LGAQ Local Government Association of Queensland

littoral relating to a shore, usually a sea shore

LPG liquid petroleum gas

LPU **local pasture unit** a localised area of distinctive pasture communities. There are 19 pasture communities and 46 LPUs in Queensland as defined by Tothill and Gillies (1992).

LWRRDC Land and Water Resources Research and Development Corporation

macro-invertebrates animals without backbones, visible to the naked eye

macrophytes plants visible to the naked eye

mesoscale all scales ranging from 20 km to 200 km above the Earth

methane a combustible gas, methane is a major component of natural gas and also a **greenhouse gas**

MIM Mount Isa Mines

modelling mathematical simulation of wind flows, air pollutant dispersion and chemical reactions requiring sophisticated and powerful computers

Montreal Process the informal agreement by the Montreal Process Group of countries (currently 12 including Australia) to work towards the implementation of a comprehensive set of criteria and indicators for forest conservation and sustainable management

MRHI Monitoring River Health Initiative

multiparameter monitoring monitoring where more than one aspect of the environment is measured simultaneously at a recording station to give comparative results of different parameters, for example, air quality and weather conditions

multiple use managing an area (national or marine parks or forests) to achieve multiple goals or multiple outputs, usually conservation with recreation and/or commercial activities

na or **n.a.** (in tables) where not otherwise specified, means not applicable or not available

NASA National Aeronautics and Space Administration (United States of America)

National Estate Grants Program a Commonwealth Government funding program to assist the identification, conservation and presentation of heritage places across Australia that are recognised by the Register of the National Estate or by State Heritage Registers

native title recognition of rights held by Aboriginal or Torres Strait Islander people according to their laws and customs involving location of land, the rights held, and identification of the holder of the rights

naturalised species a species introduced to an area outside its natural range and that has established self-sustaining populations

NEGP National Estate Grants Program

NEPC National Environment Protection Council

NEPM National Environment Protection Measure

NGS National Greenhouse Strategy

NHMRC National Health and Medical Research Council

NHT Natural Heritage Trust. A Commonwealth Government fund, sourced from the partial sale of Telstra, the national communications company

NLP National Landcare Program

NOAA National Oceanographic Atmospheric Administration

non-point source *see* **diffuse source**

NO_x nitrogen oxides. Nitrogen monoxide (NO) and nitrogen dioxide (NO_2) are the most common.

NPI National Pollutant Inventory

NSW New South Wales

NTU nephelometric turbidity unit

OECD Organisation for Economic Cooperation and Development

off-site conservation conservation of a species or an object outside its natural or original environment
see also **in situ conservation**

old-growth forest ecologically mature **forest**

open forest forest in which the tree crowns cover 51–80 percent of the land area when viewed from above
see **forest**

organochlorine a hydrocarbon compound containing chlorine. Many pesticides and industrial chemicals are organochlorines.

orographic pertaining to rain or clouds caused by the effects of mountains on airstreams that cross them

OSE Office of Sustainable Energy, Department of Mines and Energy (Qld)

otter trawling trawling using a particular type of equipment used to capture prawns and scallops

ozone a gas molecule made of three oxygen atoms which occurs naturally in the atmosphere, where it protects the Earth from solar **UV radiation.** Is also a **greenhouse gas.**

ozone hole loss in concentration of **ozone** in some part of the ozone layer

PAH polycyclic aromatic hydrocarbon

Pb lead

PCB polychlorinated biphenyls

PFC perfluorocarbon

pH a measure of acidity or alkalinity, expressed on a logarithmic scale from 1 to 14. 1 is most acid, 7 is neutral and 14 is most alkaline.

phytoplankton microscopic plants and **cyanobacteria** that live free-floating in an aquatic environment

point source source of pollution that can be pinpointed such as a drain or chimneystack *see also* **diffuse source**

precautionary principle a principle that states that when there are threats of serious irreversible damage, scientific uncertainty shall not be used to postpone cost-effective measures to prevent environmental degradation

presumed extinct species a plant or animal that has not been seen in the wild for a period critical to its life cycle despite thorough searching

primary treatment removal (from wastewater) of gross and settleable solids and stabilisation of the organic component of these solids. Primary treatment processes include screening, comminution, maceration, grit and detritus removal, pre-aeration, grease removal, primary sedimentation and sludge digestion, including the addition of chemicals.
see also **secondary treatment** and **tertiary treatment**

pristine aquatic ecosystem aquatic ecosystem that has not been or is not subject to human interference through releases (direct or indirect) into a water forming part of the ecosystem or activities in the water's catchment area

protected area an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means

QCB Queensland Coal Board

QCPTA Queensland Cleaner Production Taskforce Association

QDCILGP Queensland Department of Communication, Information, Local Government and Planning

QDEH Queensland Department of Environment and Heritage

QDHLGP Queensland Department of Housing, Local Government and Planning

QDLGP Queensland Department of Local Government and Planning

QFMA Queensland Fisheries Management Authority

QHGP Queensland Heritage Grants Program

Qld Queensland

Q.NPWS Queensland National Parks and Wildlife Service

QPWS Queensland Parks and Wildlife Service

QRAC Queensland Recycling Advisory Council

QT Queensland Transport (a Queensland Government department)

QTSC Queensland Transmission and Supply Corporation

QTTC Queensland Tourism and Travel Corporation

Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitat, entered into force in 1975. The Convention, including the List of Wetlands of International Importance established under it, is administered by the **IUCN**.

rangelands land used for grazing livestock on native pastures where rainfall is too low for more intensive agriculture

rare species a plant or animal whose population is represented by a relatively large population in a restricted range or a smaller population thinly spread over a wider range

reach environs those lands immediately adjacent to the riparian zone and including the floodplain and valley flat

recharge downward flow of water through soil and underlying rock to an aquifer

recruitment the general addition of fish, plants or animals to an existing stock or population

refugia areas protected from environmental changes such as increasing aridity or fire

Register of the National Estate a national heritage register that covers significant natural, historic and Aboriginal and Torres Strait Islander places across Australia

regulated watercourse watercourse whose flow is regulated by dams, weirs and other works

RFA Regional Forest Agreement

RFGM Regional Framework for Growth Management, a population growth management strategy under the **SEQ 2001** project

riparian relating to the bank of a river or other water body

runoff the portion of rain not immediately absorbed into the soil which becomes a surface flow

saltflat wide expanse of flat country in which the soil is very salty

saltmarsh an intertidal plant community complex dominated by herbs and low shrubs

saltpan a basin flooded by salt deposits; the remains of evaporated salt water

savanna a vegetation type with scattered trees over a grassland, usually found in subtropical areas

SD Statistical Division, an Australian Bureau of Statistics area for data collection

seagrass flowering plant adapted to living wholly submerged in seawater

secondary treatment conversion and stabilisation of non-settleable organic matter (in water) into settleable organic matter. Secondary treatment can include carbon removal, carbon and nitrogen removal, or carbon, nitrogen and phosphorus removal. Secondary treatment processes include activated sludge, biological treatment using solid media, sludge digestion, lagoons and wetlands.

sediment matter that settles to the bottom of a water body

sedimentation deposition or accumulation of sediment

SEQ 2001 a project, initiated in 1991 by the Queensland Government, to plan for projected population growth in south-east Queensland to the year 2001.

SEQRAQS South East Queensland Regional Air Quality Strategy

sewage waste matter discharged into a **sewerage** system

sewerage a system for collecting, treating and disposing of wastewater and refuse, usually with underground pipes and fittings

sink places or processes that remove or absorb materials from a system

SLA Statistical Local Area, an Australian Bureau of Statistics defined area for data collection

sodosols texture contrast soils with impermeable subsoils due to the accumulation of sodium. Sodosols occur in large areas of inland Queensland and mainly support grazing, timber and honey production. They are highly prone to erosion and dryland salinity.

softwood timbers from pines and cypresses, generally sourced from plantation forests

SOI Southern Oscillation Index

sp. (singular) and **spp.** (plural) species, a group of similar organisms that can generally interbreed only amongst themselves to produce fertile offspring

stakeholder someone who is affected by or involved in the issue under discussion

storages impoundments and ponds designed as water supplies for irrigation, urban water supply or electricity generation and for flood mitigation

STP sewage treatment plant

stratification layering of a body of water due to physical differences in upper and lower layers. It is common in deep, still water bodies due to the density gradient between cooler deep water and warmer upper layers that can develop in spring and summer months.

stratosphere the region of the atmosphere roughly 15 to 20 km above the Earth's surface *see also* **troposphere**

suspended solids suspended particles in a water body *see* **turbidity**

tailings leftover material after extraction of a mineral

taxon (plural **taxa**) the named classification unit to which individuals, or sets of species are assigned such as species, genus, family, phylum etc.

tertiary treatment removal of fine non-settleable matter (in wastewater) and additional biological treatment over and above **secondary treatment**

threatened species a plant or animal that is **endangered**, **vulnerable** or **presumed extinct**

tillage mechanical disturbance of the soil by processes such as ploughing

TOC total organic carbon

translocation the movement of native organisms from their native range to another region

transpiration loss of water through the leaves of plants to the atmosphere

troposphere the lower layer of the atmosphere extending to roughly 15 km above the Earth's surface. This is the layer in which weather processes occur. *see also* **stratosphere**

TSP total suspended particles (in air). Includes all particles from the smallest up to those 50µm in diameter. Particles less than 10 µm (PM_{10}) and particles less than 2.5 µm ($PM_{2.5}$) are of greatest concern for human health because they are inhaled deeply into the lungs.

turbidity optical measure of light-absorbing materials in a water sample; surrogate measure of **suspended solids**

UNEP United Nations Environment Programme

UNESCO United Nations Educational, Scientific and Cultural Organization

UNFCCC United Nations Framework Convention on Climate Change

USEPA United States Environmental Protection Agency

UV **ultraviolet radiation** electromagnetic radiation of higher frequencies and shorter wavelengths than visible light

vascular plants a grouping of plants that include the flowering plants, ferns and gymnosperms

vertebrate an animal with a backbone composed of vertebrae, that is, segments or bone comprising a column through which the spinal cord passes *see also* **invertebrate**

vertosols clay soils that swell when wet and shrink when dry, leaving open cracks on the surface. Vertosols are found in floodplain areas and generally have high fertility and water-holding capacity and are suited to intensive dryland agriculture, where rainfall permits, and irrigation.

VOC **volatile organic compound** an organic compound with a boiling point between 50ºC and 260ºC

VPO Vegetation Protection Order

vulnerable species a plant or animal whose population is decreasing, has been seriously depleted or is at risk due to threatening processes

water harvesting pumping of water from streams into storages during periods of high flow

watertable the upper limit of the portion of ground saturated with water

weir obstruction in a stream or river to detain water and/or raise the water level for irrigation

wetlands an area permanently or intermittently inundated with fresh or saline waters

WHO World Health Organization

wilderness remote area that is substantially undisturbed by human activities

woodland forest in which the tree crowns cover 20–50 percent of the land area when viewed from above *see* **forest**

World Heritage a term applied to sites of outstanding universal natural or cultural significance adopted as World Heritage under the World Heritage Convention (1972) index

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