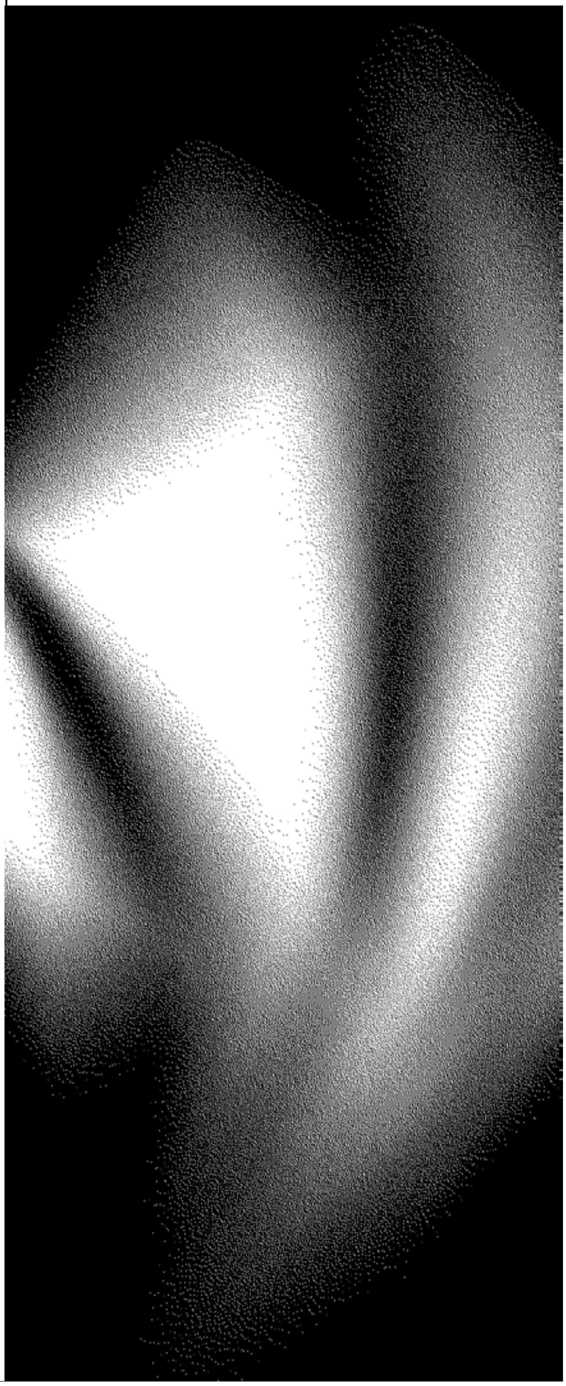
Industries, Land Use and Water Quality in the Great Barrier Reef Catchment

PRODUCTIVITY COMMISSION

Research Report



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The Productivity Commission

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Foreword

In August 2002, the Commonwealth and Queensland Governments announced a Memorandum of Understanding to protect the Great Barrier Reef (GBR) from land-sourced pollutants. In order to reverse the decline in water quality, the two Governments made a commitment to develop jointly a *Reef Water Quality Protection Plan*.

To assist the development of the Plan, the Commonwealth asked the Commission to undertake this study on the importance of industries in the GBR catchment and policy options to address declining water quality entering the GBR lagoon.

In conducting the study, the Commission benefited from information and views received from a wide range of interested parties. This included Commonwealth, Queensland and local government agencies; catchment and natural resource management groups; environmental and Indigenous organisations; industry associations; primary producers; and research institutions. The Commission held meetings in Brisbane, Canberra, Townsville, Rockhampton, the Charters Towers region, Cairns, Innisfail, and the Wet Tropics catchments. These included visits to farm properties and the inspection of council engineering works designed to manage water quality. The Commission also held two workshops in Brisbane in late November 2002 on policy options and industry projections.

This study was overseen by Commissioner Neil Byron and conducted within the Economic and Environmental Studies Branch under Greg Murtough. The Commission is grateful to all those who contributed to the report.

Gary Banks
Chairman

February 2003

Terms of reference

THE ECONOMIC IMPORTANCE OF INDUSTRIES IN THE GREAT BARRIER REEF (GBR) CATCHMENT AND THE COST AND BENEFITS OF ACTIONS TO ADDRESS DECLINING WATER QUALITY ENTERING THE GBR LAGOON

PRODUCTIVITY COMMISSION ACT 1998

The Productivity Commission is requested to undertake a research study examining the importance of different industries in the Great Barrier Reef (GBR) catchment and the cost/benefits of on-ground actions to address declining water quality entering the GBR lagoon. In undertaking the study, the Commission is to consult widely with interested parties including the Commonwealth Departments of Environment and Heritage, Agriculture, Fisheries and Forestry, Industry, Tourism and Resources and Transport and Regional Services; the Great Barrier Reef Marine Park Authority; the Queensland Government; industry associations; and, research institutions.

In undertaking the study the Commission is to:

1. outline the economic and social importance of the main industries in the Great Barrier Reef lagoon and adjacent catchment areas at the local, regional, State and national level;
   a) The industries examined in the report should include aquaculture, beef, commercial fishing, horticulture, recreational fishing, sugar, tourism, mining and mineral processing.
   b) The economic indicators used in the report should enable a consistent comparison across industries as far as possible and include, but not be limited to, gross value of production, gross value added and employment.
2. briefly discuss the current management approach by the main industries to activities that influence water quality entering the GBR lagoon;
3. estimate the economic importance of the main industries in 2010 and 2020 based on available growth projection scenarios and assuming that current management approaches are continued; and
4. analyse the likely costs and benefits at the local, regional, State and national level of policy options for addressing the issue of declining water quality entering the Great Barrier Reef lagoon.

The Commission is required to:

- provide an interim report, focussing on items 1, 2 and 3 in the terms of reference, within 3 months of commencing the study; and
- a final report, focussing on all items in the terms of reference, within 6 months of commencing the study.

IAN CAMPBELL

13 August 2002

Contents

APPENDIXES

BOXES

FIGURES

TABLES

Acknowledgments

The Commission wishes to thank those people who provided comments on drafts of this study. Dr Miles Furnas and Dr Laurence McCook (both employed by the Australian Institute of Marine Science) and Dr David Williams (Cooperative Research Centre for the Great Barrier Reef World Heritage Area) commented on the scientific aspects of water quality. Comments on the section dealing with Queensland Government policies were provided by Rosh Ireland (Queensland Environmental Protection Agency). Parts of the Commission's analysis of industry management practices were reviewed by Dr George Rayment (Queensland Department of Natural Resources and Mines) and Bob Shepherd (Queensland Department of Primary Industries). Bob Shepherd also provided comments on the Commission's analysis of policy options and the socioeconomic characteristics of land users. Dr Ian Prosser (CSIRO Land and Water) and Dr Jon Brodie (Australian Centre for Tropical Freshwater Research, James Cook University) provided comments on the prioritisation of threats. Professor Warren Musgrave reviewed the second part of this report (policy options). Comments from Richard Clarke, Lisa Gropp, Herb Plunkett and Vivek Chaudhri of the Productivity Commission are likewise gratefully acknowledged.

The Commission also acknowledges the assistance provided by various agencies in providing data. In particular, it wishes to thank staff from the Queensland Fisheries Service (Lew Williams, Ross Lobegeiger and Jim Higgs), Department of Natural Resources and Mines (Gerry Gentle, Phil Dash and Estelle Abbott), and Office of Economic and Statistical Research (Jim Hurley). Estimates of the future economic importance of industries were prepared with the help of the Australian Bureau of Agricultural and Resource Economics (on a consultancy basis). The Commission also wishes to thank Hugh Yorkston and Donna-Marie Audas from the Great Barrier Reef Marine Park Authority for their assistance.

Responsibility for the content of this study remains with the Commission.

Abbreviations and explanations

Abbreviations

ABARE	Australian Bureau of Agricultural and Resource Economics
ABGC	Australian Banana Growers Council
ABS	Australian Bureau of Statistics
AFFA	(Commonwealth) Department of Agriculture Fisheries and Forestry Australia
AIMS	Australian Institute of Marine Science
AMPTO	Association of Marine Park Tourism Operators
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZSIC	Australian and New Zealand Standard Industrial Classification
APFA	Australian Prawn Farmers Association
AQIS	Australian Quarantine Inspection Service
ASGC	Australian Standard Geographical Classification
BMP	Best Management Practice
BOD	Biochemical (or biological) oxygen demand
BSES	Bureau of Sugar Experiment Stations
CMA	Catchment management association
COMPASS	Combining Profitability And Sustainability in Sugar
CRC Reef	Cooperative Research Centre for the Great Barrier Reef World Heritage Area
CRC Sugar	Cooperative Research Centre for Sustainable Sugar Production
CSIRO	Commonwealth Scientific and Industrial Research Organisation

DITR	(Commonwealth) Department of Industry, Tourism and Resources
DLGP	(Queensland) Department of Local Government and Planning
DNRM	(Queensland) Department of Natural Resources and Mines
DPC	(Queensland) Department of Premier and Cabinet
DPI	(Queensland) Department of Primary Industries
DSD	(Queensland) Department of State Development
DTRS	(Commonwealth) Department of Transport and Regional Services
EA	Environment Australia (Commonwealth Department of the Environment and Heritage)
EIA	Environmental impact assessment
EMS	Environmental management system
EP Act	*Environmental Protection Act 1994* (Queensland)
EPA	(Queensland) Environmental Protection Agency
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999* (Commonwealth)
ERA	Environmentally relevant activity
FBA	Fitzroy Basin Association
FIFA	Fertilizer Industry Federation of Australia
GBR	Great Barrier Reef
GBRMPA	Great Barrier Reef Marine Park Authority
GBRMP Act	*Great Barrier Reef Marine Park Act 1975* (Commonwealth)
GPA	Gladstone Port Authority
GVA	Gross value added
HDRC	Horticultural Research and Development Corporation
HRIC	Herbert Resource Information Centre
IO	Input-output
IPA	*Integrated Planning Act 1997* (Queensland)
IPM	Integrated pest management

JCU	James Cook University
LWMP	Land and Water Management Plan
MCA	Minerals Council of Australia
MLA	Meat and Livestock Australia
MOU	Memorandum of understanding
NAP	National Action Plan for Salinity and Water Quality
NES	National Environmental Significance
NHT	Natural Heritage Trust
NLWRA	National Land and Water Resources Audit
NRM	Natural resource management
NSE	Net subsidy equivalent
NZDOS	New Zealand Department of Statistics
OECD	Organisation for Economic Cooperation and Development
OESR	(Queensland) Office of Economic and Statistical Research
PC	Productivity Commission
PCDD	Polychlorinated dibenzodioxin
PCQ	Ports Corporation of Queensland
PMP	Property management plan
PTEWG	Port of Townsville Environmental Working Group
QFF	Queensland Farmers' Federation
QFS	Queensland Fisheries Service
QFVG	Queensland Fruit and Vegetable Growers
QMC	Queensland Mining Council
QPWS	Queensland Parks and Wildlife Service
QSIA	Queensland Seafood Industry Association
R&D	Research and development
RIT	River Improvement Trust
RMAC	Reef Management Advisory Committee
ROP	Resource Operation Plan
RWUE	Rural Water Use Efficiency

SD	Statistical division
SMA	Statutory marketing arrangement
SSCRRA	Senate Standing Committee on Rural and Regional Affairs
SSD	Statistical subdivision
TAR	(Productivity Commission) Trade & Assistance Review
TFC	Tourism Forecasting Council
TPAWG	Tourism in Protected Areas Working Group
TSA	(Australian Bureau of Statistics) Tourism Satellite Account
VEPA	Victorian Environmental Protection Authority
WRP	Water Resource Plan
WUP	Water Use Plan
WWF	World Wide Fund for Nature

Explanations

Billion	The convention used for a billion is a thousand million (10^9).

Glossary

Acid sulphate soils	Derived from soils, sediments or rock containing elevated metal sulphide levels.
Benthos	Associated with the sea bed.
Best Management Practice	An economically viable management practice that has been determined to be the most effective and practical means of preventing or reducing pollution.
Biomass	The mass of all organic matter in an ecosystem.
Catchment	An area drained by a river or river system.
Coral	The calcium carbonate skeleton of certain marine polyps, found in masses forming reefs in tropical areas.
Cost-effective	Achieves an objective at least cost.
Diffuse pollution	Pollution for which it is difficult to identify the precise source, such as that linked to runoff from agricultural land.
Ecosystem	A community of organisms and the physical environment with which they interact.
Environmental management system	A system that is used to manage environmental impacts on a methodical and continuous basis.
Estuary	A semi-enclosed coastal body of water where salt water from the open sea mixes with freshwater draining from the land.
Eutrophication	Increase in the nutrient status of a water body, and consequently the rapid growth of plants, both natural and as a result of human activity.
Externality	A product or action whose creation by one party affects the wellbeing of others without being reflected in market prices.

Flood plume	A flowing mass of sediment-laden water.
GBR lagoon	The body of water located between the reefal region of the GBR World Heritage Area and the mainland coast of Queensland.
Gross value added	The value of the output produced by an industry, less the value of the inputs the industry used.
Gross value of production	The value of output produced by an industry calculated by multiplying the quantity of output by an average price.
Index of relative socioeconomic disadvantage	An ordinal index calculated by the ABS which measures the socioeconomic disadvantage of geographic areas by considering variables such as income, unemployment and skills.
Leachate	Solution of material leached from a solid.
Market failure	Individuals acting in their own private interest produce an outcome that is inefficient in the sense that it is possible to make somebody better off without making others worse off.
Nonpoint source pollution	Diffuse pollution.
Point source pollution	Pollution that arises directly from an identifiable source, such as a pipe or other conveyance.
Pollution	For the purpose of this study, the term pollution is used to refer to above-natural levels of sediment, nutrients, and other materials in watercourses draining into the GBR lagoon that are potentially harmful to organisms.
Property management plan	A plan that documents resources and management practices on a property.
Salinity	The amount of mineral salts dissolved in waters.
Riparian area	Land adjoining a river, directly influencing or influenced by water quality.
Runoff	Materials carried by water discharged from land that enters a body of water.

Sheet erosion	Erosion of soil across a surface by uniform action of rain or flowing water.
Suspended sediment	Any solid substance present in water in an undissolved state, usually contributing directly to turbidity.
Taxa	Categories in a system for classifying plants or animals.
Turbidity	The clarity or degree of light absorption of water.
Water quality	The chemical, physical and biological condition of water.
Wetland	Land inundated with temporary or permanent water that is usually slow moving or stationary, shallow, and either fresh, brackish or saline.

OVERVIEW

Key points

- Water quality in rivers entering the Great Barrier Reef (GBR) lagoon has declined because of *diffuse* pollutants, especially sediments, nutrients and chemicals from cropping and grazing lands in relatively small areas of the adjacent catchments. This diffuse pollution threatens inshore reefs and associated ecosystems.
- Because of the World Heritage values at risk, a strategy to identify, prioritise and manage risks is warranted, notwithstanding remaining scientific uncertainty about the condition of reefs and the effectiveness of remedial actions.
- Existing water quality policies largely ignore diffuse pollution and involve prescriptive end-of-pipe controls. Prescription is not the answer. Because of the complexity, heterogeneity and dispersion of the diffuse sources, and the inability to monitor them, governments cannot prescribe land management practices that are both viable and cost-effective.
  - Solutions will have to be built up from local knowledge and insights, within a general framework set by the Commonwealth and Queensland Governments.
- Some primary producers (from each industry) have already demonstrated that it is possible and viable to reduce land and water degradation on their own lands. The challenge is for these practices to be more widely adopted or adapted.
- No single solution will control diffuse pollution entering the GBR lagoon. Various combinations of measures — tailored to particular land uses, locations, and pollutants — will be necessary, giving land users flexibility to choose abatement actions best suited to their property.
- Local groups have an important role in designing and delivering programs and monitoring outcomes, but serious questions remain about the structure, transparency and accountability of proposed regional groups.
  - Regional groups should not create an additional layer of complexity but instead be part of a simplified approach that is integrated with the actions of other parties, notably the Commonwealth and Queensland Governments.
- Improving downstream water quality in rivers and estuaries flowing into the GBR lagoon will generate benefits apart from reducing the threat to the Reef. But zero discharge is unnecessary and, if possible at all, would be at prohibitive cost.

Overview

In August 2002, the Commonwealth and Queensland Governments announced a Memorandum of Understanding to protect the Great Barrier Reef (GBR) from land-sourced pollutants. The two Governments stated that:

- the catchments adjacent to the GBR have extensive land modification;
- this has led to increased pollutants in rivers draining into the GBR lagoon; and
- the resulting decline in water quality poses a significant threat to the Reef.

In order to reverse the decline in water quality, the two Governments made a commitment to develop jointly a *Reef Water Quality Protection Plan*. To assist the development of the Plan, the Commonwealth asked the Productivity Commission to undertake this study. The objectives of this study are to report on the importance of different industries in the GBR catchment and examine policy options to address declining water quality entering the GBR lagoon.

Governments are interested in the health of the GBR because of its significant natural, economic and social values. The GBR is the largest reef system in the world, comprising about 3000 reefs and extending approximately 2000 km along the Queensland coast. The GBR was proclaimed a Marine Park in 1975 and listed on the World Heritage Register in 1981. About a third of the GBR World Heritage Area is occupied by the GBR lagoon, which is located between the reefal region and the mainland coast of Queensland.

Land areas in the catchment adjacent to the GBR World Heritage Area are also highly valued. They are used for agricultural, pastoral, commercial, residential and recreational purposes. The GBR catchment (shaded area in figure 1) covers 22 per cent of Queensland's land area (an area over 50 per cent larger than Victoria) and contains 20 per cent of its population. It includes around 30 major rivers and hundreds of small streams that drain into the GBR lagoon. For analytical purposes, the catchments of individual rivers and streams are usually aggregated into about 35 drainage basins that are separated by natural topographic boundaries (shown in figure 1). About two-thirds of the GBR catchment is occupied by just two sub-catchments (Burdekin and Fitzroy).

Figure 1 **The Great Barrier Reef and its catchments**

Source: Great Barrier Reef Marine Park Authority.

Water quality in the GBR lagoon

There are many possible measures of water quality. This report focuses on sediments, nutrients, and contaminants (such as pesticides and herbicides) because the weight of scientific evidence — such as from the Queensland Government's Science Panel (2003) — suggests that they are the primary means by which human-induced changes in water quality may harm the GBR. It is acknowledged that there are other water-borne threats to the Reef (and threats to the Reef other than water quality).

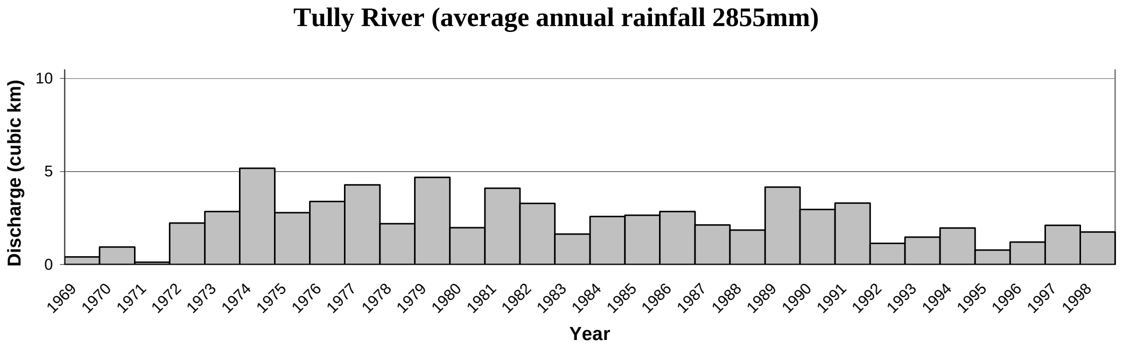
The delivery of sediments, nutrients and contaminants into the GBR lagoon occurs primarily through terrestrial (land) runoff, which is transported by rivers and streams that drain into the GBR lagoon. Runoff tends to be washed into rivers as a result of floods. Rivers in the wet tropics typically flood at least once and often several times a year. In contrast, it may be years or decades between major floods for rivers in the dry tropics. For example, the Burdekin River only experiences a significant flood every two to three years, and the Fitzroy River has floods of similar magnitude only every 10 to 20 years (Science Panel 2003). Nevertheless, the greatest average annual water discharges into the GBR lagoon are from the large dry tropics catchments of the Burdekin and Fitzroy.

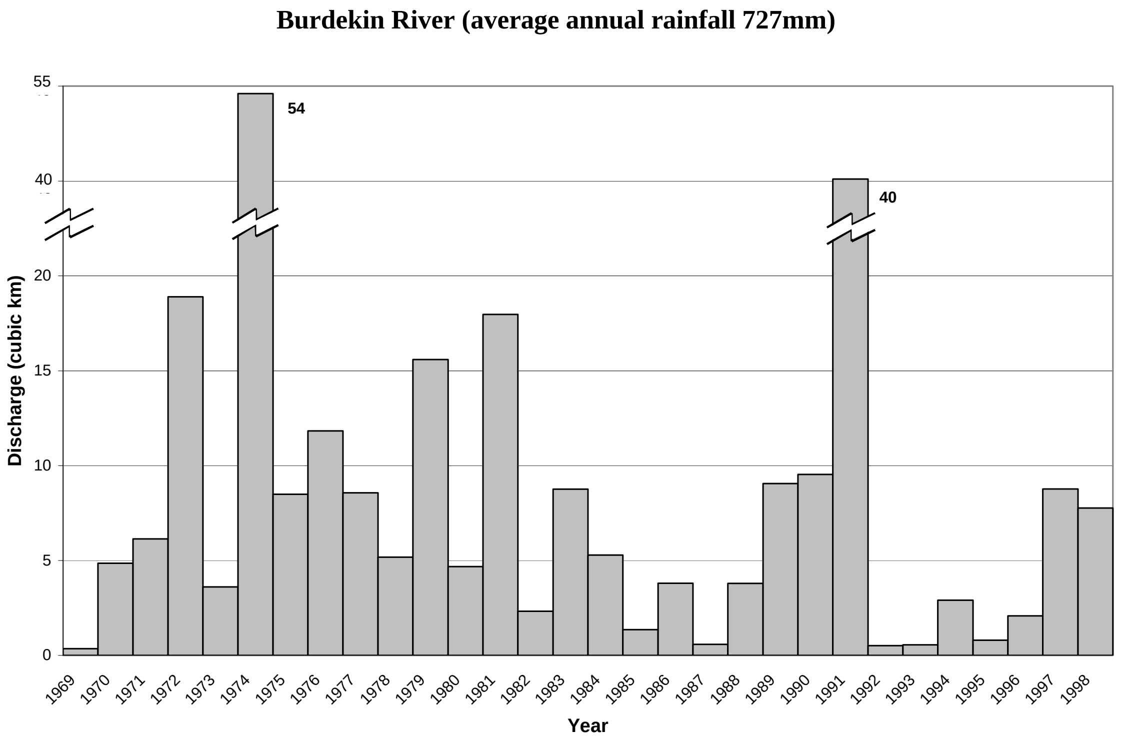
On average, the Burdekin and Fitzroy catchments accounted for around a quarter of annual freshwater flows from the GBR catchment between 1968 and 1994. However, discharges from these catchments can vary enormously from one year to the next. Year-to-year changes in the quantity (cubic km) discharged from wet tropics catchments, such as the Tully, tend to be far smaller (figure 2).

When river flows reach the coast, flood plumes form in the GBR lagoon. These plumes (and the sediments, nutrients and contaminants they carry) tend to move north and remain within 20 km of the coast. This means that *the impacts of terrestrial runoff are likely to be concentrated around inshore reefs*, which account for about a quarter of the reefs in the GBR World Heritage Area.

A consensus statement by a group of eminent scientists (appendix D) argued that *the greatest risk areas are from Port Douglas to Hinchinbrook and from the Whitsundays to Mackay*. This region contains about 28 per cent of the inshore reefs in the GBR World Heritage Area. The region was identified as being at greatest risk because it is influenced more regularly by flood plumes, contains reefs close to the coast, and adjoins catchments with substantial agricultural activity. The Tully, Herbert, Johnstone and O'Connell catchments are among those that drain directly into the region.

Figure 2 **Differences in water discharge variability between the Tully and Burdekin Rivers[a]**





a 1 cubic km (km^3) = 1 million megalitres.

Data sources: King et al. (2002) and Furnas (2002).

Pollutant discharges

The term ‘pollution’ is used in this study to refer to above-natural levels of sediment, nutrients, and other materials in watercourses draining into the GBR lagoon that are potentially harmful to organisms. This definition is used because the transport of sediment, nutrients and other materials through rivers is to some extent a natural phenomenon.

There is now clear evidence of an increase in sediment and nutrients entering the GBR lagoon since European settlement. However, the absence of a comprehensive monitoring program means that the precise quantity of sediment and nutrients entering the GBR lagoon is open to debate. This report has drawn mainly on estimates of sediment and nutrient discharges into the GBR lagoon that were made by Dr Miles Furnas (2002) at the Australian Institute of Marine Science, and by the National Land and Water Resources Audit (NLWRA 2001a). These appear to be the two most authoritative, and recent, sources for such estimates, and were also used by the Queensland Government's Science Panel (2003).

The estimates indicate that current sediment discharges are much higher than prior to European settlement. Around 14 million tonnes of sediment is estimated to be discharged into the GBR lagoon from the catchment each year. More than half of this comes from the dry tropics.

Trends in nutrient levels entering the GBR lagoon can be difficult to identify because of strong seasonal and year-to-year variations. However, the Science Panel (2003) estimated that, since 1850, annual nitrogen exports from GBR catchments have at least doubled and phosphorus exports have at least tripled. The dry tropics are the main source of these nutrient discharges, accounting for around 60 to 70 per cent of nitrogen and 60 to 80 per cent of phosphorus inputs on average. However, the wet tropics catchments are closest to the vulnerable inner reefs.

Herbicides and pesticides, and their derivatives, have been found in shallow-water sediments at several sites along the coast adjoining the GBR, although generally in low to very low concentrations. For example, various chemicals have been detected in coastal waterways of the Burdekin Delta, in agricultural drains of the lower Burdekin, Johnstone River, upstream of Mackay in the Pioneer River, in sediments of the Bassett Basin in the Pioneer River estuary, and in downstream locations of the Mary River (Science Panel 2003).

Recent analysis of coral samples by researchers at the Research School of Earth Sciences (Australian National University) and the Australian Institute of Marine Science provides unequivocal evidence of substantially increased levels of suspended sediment, and hence nutrient fluxes, to the inner GBR since European settlement (McCulloch, sub. DR74). Hence, *there has been a decline in water quality not only down to river mouths but also in waters surrounding reefs in the GBR World Heritage Area.*

Impact of water quality decline

The Queensland Government's Science Panel (2003) noted that the 'extant evidence for runoff effects on reefs in the GBR is circumstantial'. However, the Panel also observed that reefs at a number of inshore locations along the coast have been disturbed and remain in a disturbed state. The Panel concluded that these reefs exhibit characteristics consistent with altered ecological function, due to enhanced nutrient availability or sedimentation. There is a significant body of evidence regarding coral reef systems in other countries that demonstrates the harmful effects of excess nutrient availability and sedimentation.

The impacts of water quality decline on the Reef and associated ecosystems are difficult to determine because of a range of factors, including:

- limited monitoring and research, especially for inshore reefs;
- natural variations — such as frequent natural disturbances of inshore reef environments, and cycles in the health of coral reefs — that make human-induced changes difficult to identify;
- adaptation of inshore reefs to naturally higher sediment and nutrient levels than experienced by the more comprehensively researched outer reefs;
- the possibility that water quality decline will initially reduce ecosystem resilience rather than lead to a discrete readily observable effect; and
- potentially significant lags between causes and effects.

As the Science Panel (2003) has noted, it is possible that conclusive proof that water quality decline has damaged the GBR and associated ecosystems will only become evident after irreversible damage has occurred.

The probable effects of increases in pollutant discharges into the GBR lagoon range from reduced growth, reproduction and recruitment in organisms to major shifts in the community structure and health of coral reef and seagrass ecosystems (GBRMPA 2001c). The Science Panel (2003) noted that the principal effects of excess sedimentation and/or nutrient availability are through disruptions to normal ecological processes in reef systems, especially the capacity of coral-dominated reef communities to recover from natural disturbance events and to maintain naturally biodiverse communities.

Increased sediment discharges could smother corals (when particles settle) or diminish light availability. Elevated nutrient levels promote phytoplankton growth (which supports other organisms competing for space with coral) and macroalgal blooms (that overgrow coral structures). The stress of being subjected to increased sediment and nutrient loads may also diminish the ability of coral to recover from natural events, such as cyclones.

There are other ecosystem impacts from declining water quality. For example, dugongs are affected by changes in the health of seagrasses, which are their main food source. Similarly, estuarine and shallow-water coastal seagrass beds are important nursery habitats for juvenile prawns and fish.

In summary, there is strong evidence of declining water quality in the GBR lagoon due to higher sediment and nutrient loads. While there is no conclusive evidence yet of widespread damage to inner reefs, there is circumstantial evidence of impacts in some areas. *Further monitoring and research is an urgent priority, but will need to continue for some years. Meanwhile, there are strong grounds for caution about any activities that lead to elevated pollutant discharges into the GBR lagoon,* because of the World Heritage values at stake, as well as the future of dependent communities and industries. Policy decisions must be made, recognising that we will never know everything about the complex ecological relationships within the GBR World Heritage Area, nor about the impacts of activities in its catchment area on the World Heritage Area (Science Panel 2003).

Water quality and management practices

There are many possible causes of declining water quality in the GBR lagoon. However, estimates provided to the Commission suggest that *diffuse sources, particularly cattle grazing and crop production, are the most significant contributors to pollutant discharges into the GBR lagoon*. In addition, it appears that natural runoff is an important source of sediment, and sewage accounts for a notable proportion of phosphorus discharges.

For a given industry, there are many possible management practices that can contribute to pollutant discharges into the GBR lagoon. There are also a range of practices that can help mitigate pollutant discharges. The mix of practices actually used seems to vary enormously between different managers. For example, *some primary producers have already demonstrated that it is possible and viable to adopt practices that improve water quality entering the GBR lagoon.* Thus, it is misleading to stereotype any industry as uniformly adopting an approach that is either good or bad. It is more useful to view each industry as having a distribution of managers, some of whom may be very successful in minimising their water quality impacts; others whose management skills are mixed; and a number whose practices might cause a disproportionately large share of pollutant discharges.

There is limited information on the distribution of management practices within each industry. While most industry associations have developed codes of practice to encourage particular management practices, these are usually voluntary and so do not necessarily indicate what managers are actually doing.

Table 1 provides examples of practices that can either contribute to or help mitigate water quality decline. Practices considered by the Commission to have the greatest impact on water quality in the GBR lagoon are highlighted (shaded) in the table.

The highlighted practices in table 1 tend to involve cattle grazing, sugar cane production, or other crops. The Commission has not been able to find information about the precise quantity of pollutant discharges associated with particular management practices.

Cattle grazing

The main potential consequences for the GBR lagoon from grazing stem from soil erosion, which can be affected by overgrazing, woodland removal, and streambank erosion.

Maintaining ground cover (vegetation) is critical in limiting erosion because it can intercept and absorb the energy of falling rain drops, impede the flow of runoff water and thereby increase infiltration, and resist the erosive force of flowing water. However, this does not mean that tree clearing necessarily increases erosion. Some studies have shown that native woodlands generate higher runoff and soil movement than cleared areas with well maintained pasture.

Research studies have shown that, as ground cover declines, runoff increases at an accelerating rate. This suggests that properties with lower levels of ground cover than their neighbours are likely to account for a disproportionate share of discharges of sediment and accompanying nutrients.

Managing the pasture utilisation rate — share of forage growth consumed by cattle — is important in maintaining ground cover on a grazing property. This depends in large part on stocking rates (area per animal) and whether cattle are rotated between different areas on a property. Limiting the use of riparian zones by cattle is also important. This can be achieved by, for example, installing dispersed watering points and fencing off riparian zones.

Table 1 **Examples of current management practices relevant to GBR water quality**

Water quality concerns and possible causes	*Main industries/ activities*[a]	*Potentially harmful practices*	*Potentially beneficial practices*
Sediments			
Loss of groundcover	• Beef • Sugar • Horticulture	• Overstocking • Land clearing • Frequent and intensive crop cultivation • Leaving ground bare during fallow	• Spelling • Spreading cattle via feed and watering points • Keeping or planting natural vegetation • Minimum tillage • Cover crops between rows and during fallow periods • Harvesting leaving debris (eg green cane trash harvesting) • Buffer zones between activity and waterways
Streambank erosion	• Beef • Dairy • Sugar • Horticulture	• Excessive cattle access to waterways • Cultivation close to waterways	• Fence riparian strips • Moderate riparian grazing pressure • Erosion control structures • River bank restoration and revegetation • Buffer zones between activity and waterways
Large-scale earth works	• Coastal development	• Poor site selection and timing of works	• Minimise wet season works • Build erosion control structures during and after construction
Nutrients[b]			
Overuse or misapplication of fertilisers	• Sugar cane • Horticulture • Cotton	• Application beyond plant needs • Application near waterways	• Precision methods and scheduling application (eg soil tests, account for weather and irrigation timing) • Use of more benign fertilisers
Loss of riparian filters	• Beef • Dairy • Sugar cane • Horticulture	• Activity close to waterways (eg cropping, grazing)	• Moderate grazing pressure near riparian zones • Buffer zones between activity and waterways
Urban sewage and stormwater	• Coastal development	• Discharge into rivers or directly into the GBR World Heritage Area • Leakage from septic tanks or overflow of sewage system	• Secondary and tertiary treatment of sewage • Use of gross pollutant traps and artificial and natural wetlands

(Continued next page)

Table 1 (continued)

Water quality concerns and possible causes	*Main industries/ activities*[a]	*Potentially harmful practices*	*Potentially beneficial practices*
Effluent discharge from aquaculture	• Aquaculture	• Direct discharge • Poorly designed prawn ponds	• Revegetating pond walls • Sediment and bioremediation ponds
Other pollutants[c]			
Overuse or misapplication of herbicides and pesticides	• Sugar cane • Horticulture • Cotton	• Over application of chemicals	• Weed and pest monitoring • Integrated Pest Management • Use of more benign chemicals • Coordinating application with irrigation activities
Disturbing acid sulphate soils	• Sugar cane • Horticulture • Coastal development • Aquaculture	• Poor site selection	• Planning site selection • Maintaining vegetation and ground cover
Loss of filter functions in coastal areas[d]			
Clearing and drainage of wetlands	• Sugar cane • Coastal development	• Poor site selection	• Withdrawing activity and rehabilitating wetlands • Effective site selection (eg away from sensitive areas) • Protecting remaining filters (eg buffer zones)
Other			
Irrigation	• Sugar cane • Horticulture • Cotton	• Over irrigating	• Irrigation scheduling • Use of more efficient irrigation systems (eg drip irrigation and use of tailwater)
Increased impermeable surfaces and fresh water runoff	• Coastal development	• Poor urban planning	• Effective stormwater systems (eg gross pollutant traps, artificial wetlands)
Leaching of chemicals from mines	• Mining and mineral processing	• Poor mining and mine closure practices	• Retention ponds and concrete walls • Use of lime to neutralise acid

[a] The industries highlighted are believed to be the major current sources, in aggregate terms, considering extent, location and predominant management practices. [b] The main nutrients of concern are nitrogen and phosphorus. Elevated nutrients may also be caused by sediment runoff that mobilises ‘natural’ nutrients existing in the landscape. [c] Other pollutants include herbicides, pesticides, heavy metals, acidic runoff from acid sulphate soils, and storm water runoff. [d] Examples include loss of mangroves and other wetlands.

Sugar cane

Most of the sugar cane in Queensland is grown along coastal plains and river valleys. High rainfall in many of these areas raises the potential for sediment, nutrients and contaminants to be transported through the river system and ground water.

As the Science Panel (2003) concluded, sugar cane production contributes to water quality problems in the GBR lagoon through soil erosion; the application of chemicals and fertilisers; and the release of cane juices and sugars during harvesting (which can deplete oxygen in adjacent waters). The destruction in previous decades of natural filters and buffers along the coast (particularly mangroves and melaleuca wetlands, which trapped sediment and nutrients in their roots, and slowed the pace of discharge), and water control works (dams and drainage canals) have profoundly altered patterns and rates of water discharge into the lagoon, and exacerbate the adverse impacts of current land uses.

Soil erosion was a major source of sediment discharges under conventional sugar cane harvesting methods but has been significantly reduced by recent innovations. The delivery of nutrients from cane lands is now of greater concern than their sediment discharges. Sugar cane production has traditionally involved the use of significant amounts of fertilisers, particularly nitrogen. Although recent changes to management practices are likely to have beneficial consequences, it appears that sugar cane production currently contributes a high proportion of nutrient loads in the GBR catchment.

Other crops

Other crops grown in the GBR catchment include cotton, bananas and mangos, some of which can involve high nitrogen fertiliser application rates. Banana crops use the equivalent of 6.5 per cent of the total nitrogen fertiliser used by sugar cane per year but application rates are higher. Soils in banana paddocks are generally kept cleared and, because bananas can be grown on steeper, more elevated, slopes their per hectare contribution to erosion and leachate is higher. Discharges of nitrogen have also been detected downstream from cotton growing areas.

Implications

In summary, there is a great diversity of management practices within and across industries. Some primary producers have already demonstrated that it is possible and viable to adopt practices that (as well as providing other benefits) improve water quality entering the GBR lagoon. In addition, most industry associations are developing codes of practice or Best Management Practice (BMP) guidelines. However, at present there is little evidence of either the adoption rates of these codes or what the overall impacts on water quality might be if high adoption rates were achieved.

Importance of the main industries

Mining and tourism are the largest industries in the GBR catchment in terms of the value of production (table 2). The gross value of minerals produced ($7052 million in 1999-00), in particular coal ($5969 million), dominates the value of production in the catchment. In 1999, tourism expenditure ($4269 million) exceeded the gross value of agricultural production ($3023 million) by about 40 per cent. Within the agricultural sector, the gross value of beef cattle production ($1017 million) exceeded sugar and horticulture.

Table 2 **Importance of industries in the GBR catchment and lagoon**
1999-00, unless otherwise stated

Industry	*Gross value of production*[a]	*Employed persons*[b]
	$m	no.
Mining[c]	7 052	10 380
Tourism[d]	4 269	47 660
Mineral processing	1 392	3 918
Beef	1 017	8 728
Sugar cane	803	8 736
Horticulture	708	9 006
Recreational fishing	240	na
Commercial fishing	119	641
Aquaculture	38	378
All industries	**na**	**396 581**

[a] See chapter 4 and appendix E for industry definitions and estimation methods. [b] August 2001. [c] Gross value of production is for 2000-01. [d] Employed persons is for 1998-99. Tourism expenditure is used as a proxy for gross value of production and is for 1999. **na** Not available.

Sources: ABARE (2001); ABS (unpublished data); DNRM (unpublished data); QFS (unpublished data).

Value added — the value of outputs less the value of inputs — would be a more meaningful measure of the contribution of each industry to the regional economy than the gross value of production. However, value added data are unavailable at the regional level. Also, the gross value of production (and value added) only takes account of goods and services traded in markets. So-called nonmarket values, such as the ecosystem services provided by wetlands on a farm property, could be significant for the GBR catchment and lagoon. However, nonmarket values are by definition unobserved and so have to be estimated. There are various approaches that can be used for such estimation and they can lead to very different results. Developing robust estimates of nonmarket values for industries operating in the GBR lagoon and catchment would therefore be a major undertaking, which was beyond the time and resource constraints of this study.

Another limitation of using the gross value of production is that it includes government assistance and so can distort the relative importance of industries. The Commission has prepared assistance estimates for industries in the GBR catchment and lagoon by extending the methodologies it uses in its annual Trade and Assistance Review. The estimates for 1999-00 range from an amount equivalent to 3.0 per cent of the gross value of production for sugar to 0.2 per cent for tourism. It should be noted that these estimates exclude some forms of assistance, such as that provided by the Queensland Government. Nevertheless, the estimates suggest that allowing for government assistance would not significantly change the relative size of most industries.

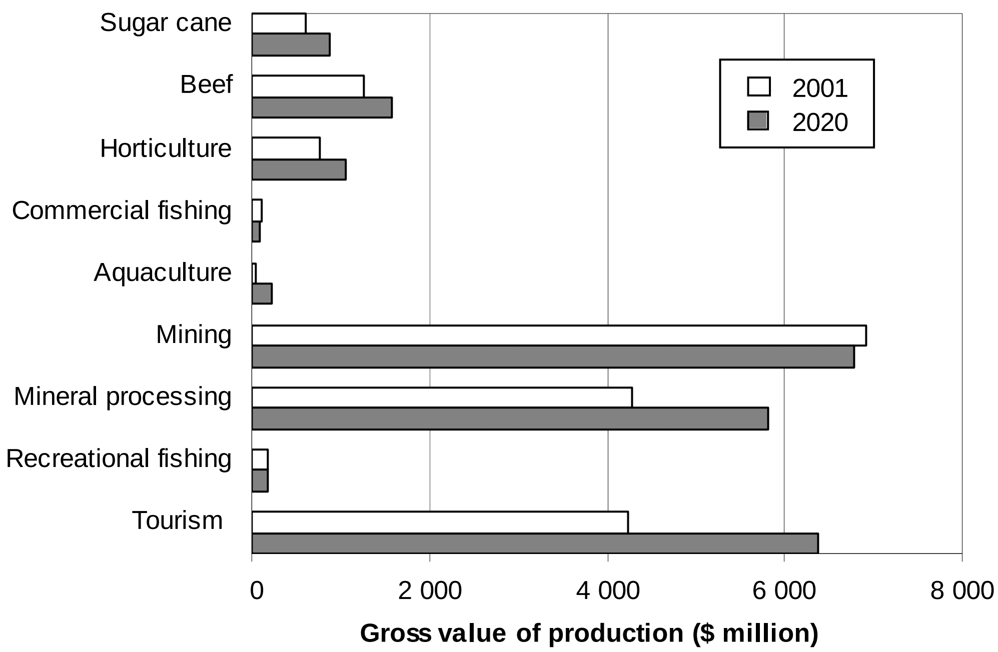
Tourism is by far the largest employer among the GBR industries analysed in this study, with around 47 600 employed persons in 1998-99. Collectively, the agricultural industries accounted for around 32 000 employed persons in 1999-00. Mining is a relatively small employer compared to tourism and agriculture. However, people working in mining and mineral processing have the highest median incomes among the industries studied. In August 2001, the median individual income for employed persons in the coal industry was $78 000 per annum, while in agriculture the median income was around $21 600.

Different industries occur or dominate in different regions within the GBR catchment. As a result, the sources of water quality decline (and hence appropriate policy responses) are likely to differ across the GBR catchment. Cattle grazing tends to occur inland of the coastal plains and often in upper catchment areas. Sugar cane production is primarily located on the narrow coastal plains and the rich river flats of many of the lower catchments. Horticulture is generally found in highly localised areas where sufficient labour, fertile and arable soils, and high rainfall or irrigation, combine to enable intensive cropping. The economic performance of each industry varies greatly across the region. Major booms (or downturns) in any industry are likely to have very strong localised impacts.

Projections prepared for this report indicate that tourism and mineral processing could be expected to increase substantially in the GBR catchment between 2001 and

2020 (figure 3). Base case projections indicate that tourism expenditure would be likely to increase by around $2.1 billion (growth of over 50 per cent) and the gross value of production by the mineral processing industry could rise by about $1.5 billion (growth of 36 per cent). In contrast, little growth is in prospect for the value of mining production in the GBR catchment. *The gross values of production of sugar cane, beef, horticulture, commercial fishing, and aquaculture (combined increase of $1 billion) are expected to remain much smaller than that of tourism, mining, and mineral processing.* Nevertheless, the gross values of production of beef and sugar cane — two of the most significant sources of discharges into the GBR lagoon — are projected to expand by 25 and 43 per cent respectively between 2001 and 2020.

Figure 3 **Projected gross value of production for industries in the GBR catchment and lagoon[a]**



[a] See chapter 4 and appendix G for industry definitions and estimation methods.

Data source: ABARE projections.

These projections should be interpreted with caution, since they depend on assumptions that are subject to considerable uncertainty. While they provide useful background, the projections are not the basis for developing or assessing policy options in this study. This is because an industry's projected economic importance is not an appropriate criterion for deciding which land users should or should not abate diffuse pollution entering the GBR lagoon. As noted below, abatement options should be selected on the basis of their effectiveness in reducing threats to reefs and associated ecosystems, and their cost per unit reduction of those threats. These criteria are not necessarily related to industry size.

Current government policies and programs

At present, there are few policies that explicitly target water quality in the GBR lagoon. Where such policies exist, they are largely confined to activities that occur within or directly adjacent to the GBR lagoon.

The Queensland Government has jurisdiction over virtually all land-based activities in the GBR catchment that lead to discharges into rivers and ultimately the GBR lagoon. Queensland policies relevant to water quality tend to be directed at issues in catchments and coastal waters, rather than the GBR lagoon. They have also tended to focus on point sources like sewage plants and aquaculture farms (which are relatively easy to control) rather than diffuse sources like grazing and cropping (which account for the majority of discharges into the GBR lagoon). This raises questions about the cost-effectiveness of current policies. For example, the Queensland Environmental Protection Agency has not been given a mandate to control diffuse source discharges from agricultural activities, which appear to be the greatest source of pollutants entering the GBR lagoon. There would appear to be significant scope for re-examining the current approach so as to include all activities responsible for significant discharges, and to ensure that the level of control is consistent with the threat posed by each activity and the relative costs of abatement.

Governments have developed a large number of ad hoc environmental plans that are not yet well integrated and some of which may be redundant. This led Queensland Fruit and Vegetable Growers (sub. 49, p. 3), the peak body representing the horticulture industry in Queensland, to comment that it was 'seeking the development of an integrated sustainability strategy for rural industries in Queensland that overhauls the current approach in which single issues are being tackled through a series of disjointed planning processes'.

Some policies unintentionally provide incentives for actions which reduce water quality entering the GBR lagoon. For example, various parties expressed concerns that the Sugar Industry Infrastructure Package has led to the extensive clearing of wetlands and riparian vegetation; and that the Queensland drought relief scheme unintentionally discourages graziers from reducing stock early in a drought, while rewarding those who overgraze.

Framework for policy analysis

Given the above concerns about current policies, the second part of this report places emphasis on developing an appropriate policy framework to address declining water quality entering the GBR lagoon. The proposed framework has five steps:

1. clarify objective;
2. prioritise threats;
3. understand the relevant land users;
4. short list and rank pollution abatement options; and
5. identify suitable institutional arrangements to implement the options chosen.

These steps are outlined below.

Clarify objective

Ideally, the objective would be to reduce pollutants entering the GBR lagoon until the cost of further abatement outweighs the additional benefits. However, such an objective is impractical because the benefits of improved water quality are extremely difficult to measure in dollar terms, and the degree of improvement attainable from any specific action is very difficult to measure.

In practice, a more useful objective is cost-effectiveness: achieving a measurable goal — such as a certain level of water quality or the adoption of particular management practices — at least cost. This is broadly the approach that has been proposed by the Commonwealth and Queensland Governments for their forthcoming *Reef Water Quality Protection Plan*. In particular, regional natural resource management (NRM) bodies are expected to set targets for their region, and develop an investment strategy to achieve them (with assistance from the Commonwealth and Queensland Governments).

Prioritise threats

Ranking the physical threats that declining water quality poses to reefs and associated ecosystems could provide an indication of which land use changes warrant consideration in an assessment of cost-effectiveness. While a thorough ranking of threats has yet to be undertaken, *preliminary evidence suggests that a large proportion of the threats can be attributed to a relatively small proportion of the GBR catchment, land uses, and time periods*. For example:

- the most significant sources of diffuse pollution appear to be soil erosion on grazing properties, and the overuse/misuse of fertilisers and chemicals by cropping industries;
- around 80 per cent of sediment exported to the GBR lagoon is generated from less than 30 per cent of the catchment area (figure 4); and
- floods that break a long drought can lead to sediment loads several times those of other floods of similar size.

Ranking threats is best done using multiple criteria, since numerous factors could determine the level of damage caused by declining water quality and its probability of occurring. The criteria used will need to cover relevant characteristics of both the hazard (discharges from land use) and receiving areas (rivers and the GBR lagoon).

An example of how receiving areas might be incorporated into a prioritisation of threats is provided by Devlin et al. (2001a), who calculated risk indices for individual reefs. Their methodology summarised, in a single index, a wide range of complex factors that influence the threat to individual reefs. This included the level and variability of discharges from particular rivers; the movement of flood plumes from those rivers; and proximity of the river mouths to individual reefs. Their results showed that there are significant differences in the risks faced by individual reefs (figure 5). Such an approach inevitably involves making assumptions and relying on estimates. For example, all pollutants were assumed to decline in a linear fashion with distance from a river mouth. It may be possible to address such limitations by further refinement of the methodology.

In setting priorities, it would be useful to link a risk assessment for individual reefs back to the contributing discharge areas and land uses. It would also be desirable to take account of factors that affect the probability of damage occurring; the current condition of reefs; stresses from factors other than declining water quality; and the economic and cultural (including Indigenous) values of individual reefs.

Figure 4 **Predicted rate of sediment discharges to the coast from different regions of the GBR catchment**

tonnes/hectare per year*Source:* Adapted from Prosser et al. (2001).

Figure 5 **Risk assessment map**

Source: Devlin et al. (2001a).

Understand the people involved

While there are many parties with an interest in land uses in the GBR catchment and/or water quality in the GBR lagoon, it is individual land users whose decisions and behaviours will have to change if management practices that cause diffuse pollution are to be altered. Past research has shown that the capacity and willingness of land users to adopt more sustainable management practices varies with socioeconomic characteristics, such as their income, debt, education, and participation in a community Landcare group. If a proposed pollution abatement option ignores such characteristics among the land users it is targeting, then it is more likely to fail. Thus, before formulating abatement options, policy makers should ensure that they have sought advice and suggestions from, and are well informed about the socioeconomic characteristics of, the land users whose behaviour they seek to change.

In the GBR catchment, land users and their properties are very diverse. Hence, their capacity and willingness to adopt practices that abate diffuse pollution could vary considerably. This has implications for the level of compulsion and/or financial incentives required to change behaviour. In particular, a one-size-fits-all approach is unlikely to be cost-effective. In any case, land users are more likely to adopt voluntarily practices that reduce diffuse pollution if they are also profitable, compatible with existing practices, easily understood, can be readily tested, and their results are easily observed. For example, green trash blanketing, which has many of these characteristics, has been widely adopted by sugar cane growers in the GBR catchment. This practice has markedly reduced soil erosion.

Another important consideration is how farming communities' social capital — the social and industry relationships and networks (such as participation in a Landcare group) and the norms and trust that accompany them — facilitate wider adoption of new practices. The nature of these relationships will vary across the catchment, such as between large geographically dispersed grazing properties and smaller, more geographically concentrated, cropping enterprises. Well-designed policies will take account of and support such relationships, but poorly designed policies that ignore or inadvertently damage social capital will be less effective (PC forthcoming).

Formulate abatement options

As noted above, the Commonwealth and Queensland Governments have made a commitment to reverse the decline in water quality entering the GBR lagoon and are currently formulating a *Reef Water Quality Protection Plan* for this purpose. The process of developing abatement options for diffuse pollution can be characterised as having three components:

- what to target;
- who to target; and
- what instruments to use.

With respect to what to target, it is impractical to target actual emissions due to the inability to meter diffuse pollution regularly at reasonable cost. Instead, it is necessary to use an alternative target that is correlated with emissions. The literature on diffuse pollution control focuses on three possible targets:

1. *inputs or practices known to lead to pollution* — such as the quantity of fertiliser used or practices that affect their movement into the environment;
2. *emission proxies or other site-specific environmental indicators* — such as estimates of field losses of fertiliser residuals to surface water; and
3. *ambient pollution* — concentrations of pollutants in the environment, such as the quantity of dissolved inorganic nitrogen in an estuary.

Targeting inputs or practices is the only practical option at present, due to limitations with existing emission proxies and the restrictive conditions under which an ambient target would be cost-effective. In the longer term, new monitoring technologies — such as remote sensing — may make it feasible to target emission proxies or other site-specific environmental indicators, or even to directly monitor emissions.

Who to target is best determined on a case-by-case basis, because sometimes it will be more cost-effective to target parties other than the land users causing diffuse pollution. For example, restrictions could be placed on the fertilisers that input suppliers sell to farmers.

With respect to what instruments to use, there are many possibilities. Table 3 provides examples for various broad categories of instruments, according to what is targeted.

Market-based instruments (taxes, subsidies, and markets) are often seen as being superior to other approaches because they can give land users an incentive to minimise abatement costs. However, there may be barriers to the adoption of market-based instruments, such as high administration or monitoring costs. Thus, other instruments — such as regulation — cannot be ruled out, being more cost-effective in some cases. In addition, there has been little research on the efficiency or effectiveness of voluntary measures (OECD 1999; Weersink et al. 2001).

Table 3 **Examples of policy instruments to control diffuse pollution**

	What to target		
Category	*Inputs or practices*	*Emission proxies*	*Ambient pollution*
Regulations and standards	Pesticides registration Restrictions on fertiliser application rates Mandatory use of property management plans that include approved pollution control practices	Restrictions on modelled nutrient loads Regulations on fertiliser applications in excess of estimated crop needs	
Taxes and subsidies	Charges on pesticide purchases Taxes on fertiliser applications Subsidies for inputs or practices that reduce pollution Rate rebates for adopting approved pollution control practices	Taxes on modelled net soil loss Penalties for fertiliser applications in excess of estimated crop needs	Taxes imposed on all land users within a catchment when its water quality falls below a threshold level
Markets	Tradeable permits to use inputs such as fertilisers Land users compete in an auction to maintain riparian vegetation in return for a subsidy	Tradeable permits for predicted emissions	
Contracts and bonds	Land retirement contracts Contracts to adopt particular land management practices		
Liability rules	Negligence liability rules for failure to meet duty of care	Strict liability rules based on modelled emissions	Joint liability rules based on ambient pollution
Education and information provision	Best Management Practice (BMP) training Extension services Peer group learning		
Guidelines	Voluntary codes of practice		

Source: Adapted from Shortle and Horan (2001).

Assessment of abatement options

The terms of reference for this study required an analysis of the likely costs and benefits of options to address declining water quality entering the GBR lagoon. However, as argued above, there are many very different options to be evaluated. As a result, a qualitative assessment of costs and benefits is provided for a sample of abatement options. It was not, however, feasible to quantify costs and benefits even for this sample of measures. As noted above, the benefits of improved water quality are extremely difficult to measure in dollar terms. Abatement costs are also very difficult to quantify because they can vary markedly between different properties, depending on factors such as soil type, topography, rainfall, and income forgone by changing management practices.

At the time of writing this report, the Commonwealth and Queensland Governments were still undertaking an assessment of which regions, land uses, and time periods pose the greatest threats to reefs and associated ecosystems. Thus, it was unclear which properties warranted consideration in an assessment of abatement options. Even if this information had been available, it is possible that detailed case studies of many individual properties would have been required to obtain an accurate estimate of total abatement costs.

While a thorough ranking of threats to reefs and associated ecosystems has yet to be completed, it does appear that the most significant sources of diffuse pollution entering the GBR lagoon are:

- soil erosion on grazing properties; and
- overuse/misuse of fertilisers and chemicals by cropping industries.

Therefore, this report provides a qualitative assessment of abatement options to control the above mentioned problems. The abatement options examined here may not be those short listed when more information is available from a prioritisation of threats, but they do provide a useful illustration of the issues that need to be considered in assessing options.

Soil erosion

Management practices that maintain ground cover on grazing properties, particularly at the end of the dry season, are likely to be effective in reducing soil erosion. A range of policy instruments would probably be required to encourage graziers to adopt these practices. Some graziers may have little incentive to adopt the practices because they believe — rightly or wrongly — that the practices are not profitable. For other graziers, there are various practices — such as spelling and conservative stocking rates — that will be profitable and also reduce soil erosion. In these cases, abatement options could place greater emphasis on increasing graziers' knowledge and skills.

To illustrate the potential of a range of approaches, five options to abate soil erosion were examined:

1. subsidise the erection of internal and riparian fencing and watering points to facilitate the spelling of stock between paddocks;
2. change drought assistance arrangements to discourage the retention of non-breeding stock as prolonged drought develops;
3. hold an auction where graziers can bid for public funds to retire land or adopt certain practices;
4. provide more generous pastoral lease conditions in return for adopting approved management practices; and
5. education, extension, and trialing of conservative stocking practices.

An assessment of these options revealed that there is no single instrument that can be used in isolation. Each of the options examined is likely to have some effect on graziers' management practices and could feasibly be implemented. But their relative merits will probably vary between land users and properties.

Subsidising internal and riparian fencing and watering points may encourage greater adoption of spelling but the cost to taxpayers could be high, given the size of grazing properties. This cost could be reduced by only providing subsidies in priority hazard areas, and to graziers for whom spelling is not otherwise profitable. It would be extremely challenging, however, to target the appropriate properties and select the level of subsidy that is just sufficient to encourage the required level of spelling.

Modifying drought assistance arrangements, to discourage the retention of non-breeding stock as prolonged drought develops, could be effective. New arrangements could also be designed so that there is no reduction in the total amount of drought assistance provided. However, it may be difficult for governments to determine the incentives required to alter stocking levels when there is uncertainty about the length of a drought.

The advantage of auctions is that they can overcome an information asymmetry between governments (better informed about hazard areas) and land users (better informed about abatement costs) that may otherwise lead to inefficient outcomes. If a government simply were to ask individual land users to enter into a contract to adopt a certain practice, then its ignorance of abatement costs could lead it to pay far more than in an auction. Hence, an auction can increase the cost-effectiveness of subsidies. A drawback of auctions is the administrative, monitoring and enforcement costs associated with selecting land users and ensuring that they deliver what has been promised. In addition, there may be few bidders in a given hazard area because of the large size of grazing properties. An auction could also be costly when it involves land retirement, since it is unlikely to be profitable for graziers and so a large subsidy may be required.

As many properties in hazard areas are leasehold, providing more generous lease terms in return for the adoption of approved practices could be effective. In addition, it should not require a significant increase in government expenditure. But there would be monitoring and enforcement costs, in addition to the costs involved in adopting the practices themselves.

In isolation, education, extension, and trialing of conservative stocking practices could be cost-effective, provided that the relevant practices are profitable for graziers. But there are limits to how much voluntary measures can achieve.

Combining abatement options may be a good way to deal with the diversity of properties and graziers. For example, some land users may require regulatory approaches to facilitate change whereas others respond better to incentives or education. An important first step may be to consider the removal of perverse incentives created by existing policies, such as those that might be created by existing drought assistance. Tying abatement actions to more favourable lease terms is likely to have a lower cost to government, and be more flexible and effective than prescriptive options in hazard areas where pastoral leases are the main form of land tenure. This option will, of course, have negligible influence where hazards arise on freehold land. A fencing subsidy is likely to be useful but not sufficient to increase spelling and may be costly for taxpayers unless carefully targeted (targeting may itself also be costly). Education and extension are likely to be important to support the effectiveness of other abatement options.

Overuse/misuse of fertilisers and chemicals

Changing management practices in cropping industries has the potential to significantly reduce discharges of nutrients and chemicals into the GBR lagoon. This includes raising the nitrogen uptake of crops; improving the location, timing and techniques of fertiliser and chemical application; and greater use of buffer zones near water courses. While a ban on all fertilisers and chemicals would also reduce discharges, it would have enormous costs and in most cases be unnecessary, since much of the potential to cause environmental damage derives from how, when and where fertilisers and chemicals are applied rather than their use per se. Possible reasons why practices to abate nutrient and chemical runoff are not adopted are that farmers see them as being risky or unprofitable; they are not well informed about any resulting financial benefits; or there is a lack of acceptance that fertiliser and chemical runoff is being transported to the GBR lagoon.

Six options to abate pollution resulting from the overuse/misuse of fertilisers and chemicals were examined:

1. require mandatory riparian buffer zones between crops and major water courses;
2. introduce nutrient sensitive zones where fertiliser users have to be licensed and have a nutrient management plan;
3. impose a fertiliser tax;
4. provide subsidies for pollution abatement practices that are not otherwise profitable;
5. hold an auction where farmers can bid for public funds to reduce nutrient and chemical levels in runoff; and
6. sugar mills only accept cane from growers who adopt approved BMPs.

An assessment of these options revealed that, like soil erosion, using a single instrument in isolation is unlikely to be very cost-effective.

Mandating riparian buffer zones across the GBR catchment would help to trap and absorb excessive nutrients and chemicals, reducing their entry into waterways. However, requiring this for the whole catchment is unlikely to be cost-effective.

A more targeted regulatory approach would be to identify nutrient sensitive zones and then apply licensing requirements which could be flexible in terms of the practices required. For example, licences could require a nutrient management plan that includes a number of pollution abatement practices. On its own, however, such an approach may impose substantial costs on farmers, raising questions over its practicality and likely level of compliance.

A tax on fertiliser use is unlikely to be cost-effective. It would target only one aspect of the problem (quantity), may raise the use of substitute inputs, and increase cost pressures which may lead to less sustainable practices. There are probably also constitutional difficulties in imposing a fertiliser tax based on geographic location.

Subsidising the adoption of practices that are not otherwise economically viable could change land user behaviour. If a range of practices were subsidised, then land users could also have the flexibility to use their unique site-specific knowledge to adopt the most cost-effective practices to abate pollution. Restricting the availability of subsidies to nutrient sensitive zones should raise their cost-effectiveness.

As for soil erosion, auctions could involve significant administrative, monitoring and enforcement costs in selecting land users and ensuring that they deliver what has been promised. However, the smaller size of cropping enterprises means that there is greater likelihood of getting multiple bidders in an auction. In addition, the cost-effectiveness of auctions could be increased by limiting them to nutrient sensitive zones, where the greatest benefits are expected.

A requirement by sugar mills that cane growers adopt approved BMPs could be very effective in changing land user behaviour. A similar arrangement already exists between cane growers and mills in New South Wales. In that case, the contracts that cane growers enter into with their mill require the adoption of BMPs for activities that may disturb acid sulphate soils. Millers and growers were partly motivated to adopt this approach because of the prospect of direct regulation if they did not address the problem of acid sulphate soils. A similar impetus may be required for Queensland cane growers to abate emissions linked to the overuse/misuse of fertilisers and chemicals.

Combining abatement options may be a good way to deal with the diversity of land users and properties, and to ensure that all potential loss pathways for nutrients and chemicals are addressed. Focusing on only a single practice in the application of a fertiliser or chemical is less likely to be cost-effective because it may lead to an increase in emissions due to greater use of another practice.

The order and timing of implementation may also be important. For example, significant uncertainty about the cost-effectiveness of different instruments may justify an initial focus on low cost options, such as an information campaign or the development of a code of practice. A second stage may involve an auction. A third stage could involve a negative licensing scheme (those without accredited farm plans require licenses to purchase fertilisers and chemicals).

In summary, the effectiveness and cost-effectiveness of the options examined for fertilisers and chemicals will vary depending on where and how they are implemented. However, the most attractive options among those examined are likely to be licensing and auctions in nutrient sensitive zones; and a requirement by sugar mills that cane growers adopt approved BMPs. These options provide flexibility in the practices adopted (and hence opportunities for land users to minimise abatement costs); can be used to target high hazard areas; and involve either minimum or efficient allocation of public funds. In the case of auctions, however, pilot schemes may be required given the relative newness of such an approach.

General findings on abatement options

While a limited number of abatement options were examined in this report, they were sufficiently diverse to reach the following general conclusions.

- There is no single land use change and associated policy instrument that will be effective and cost-effective in all cases. Thus, a combination of land use changes and instruments will be required.
- There may be a case for sequencing the implementation of different abatement options, rather than combining them all at once.
- Considering the removal of perverse incentives created by existing policies should be a priority.
- Abatement options that take account of the information asymmetry between governments and land users are likely to outperform those that do not. Thus, prescriptive regulations that specify exactly which practices a land user should adopt are unlikely to be cost-effective.
- Instruments that are strongly linked to property rights are more likely to change behaviour. One way to do this is to provide more favourable leasehold conditions in return for the adoption of approved management practices.
- Cost-effective abatement options do not necessarily have to be implemented by governments, provided that there are appropriate incentives. One example examined in this report is an arrangement where sugar mills only accept cane from growers who adopt BMPs.
- Taxes and subsidies are unlikely to be cost-effective if they need to be tailored to site-specific conditions and this is costly.
- It is important to consider the timing of costs and benefits. For example, spelling on grazing properties can be profitable over the long term, but involves a high initial cost for erecting new fencing and watering points. Graziers are less likely to make such an investment if they have a strong preference for receiving benefits now rather than later. If spelling generates net benefits for society as a whole, then there may be a case for targeted subsidies for fencing and watering points.

Roles and responsibilities

The roles and responsibilities assigned to different parties in developing and implementing abatement options will be an important determinant of their cost-effectiveness.

Existing water quality policies focus almost exclusively on controlling point sources of pollution and tend to involve governments imposing prescriptive end-of-pipe regulation. Extending this end-of-pipe approach to control diffuse pollution entering the GBR lagoon is unlikely to be effective, since emissions from individual properties cannot be metered regularly. Furthermore, prescribing exactly what management practice land users should adopt to abate diffuse pollution is unlikely to be cost-effective, since governments are not well-informed about abatement costs. This informational deficiency is likely to persist, since abatement costs can vary between catchments, within catchments, and even between neighbouring properties, and are likely to change over time. This suggests that policy options that harness local knowledge are likely to have important advantages.

In recent times, there has been a general shift in environmental policy towards greater emphasis on decision making at the regional level. This shift is reflected in the Memorandum of Understanding signed by the Commonwealth and Queensland Governments for the *Reef Water Quality Protection Plan*, which envisages a major role for regional NRM bodies in abating diffuse pollution entering the GBR lagoon. While there appears to be merit in such an approach, its effectiveness and cost-effectiveness will depend on how it is designed and implemented.

There are few precedents for how responsibilities might be devolved to regional bodies. As a result, a process of experimentation and adaptation is probably required. If regional bodies are to have a major role, then they will need sufficient resources and powers to develop, implement and monitor abatement options. Regional bodies in Queensland currently have limited statutory responsibilities and powers. If they are given additional powers, then they would need to be accountable for their actions. Furthermore, regional bodies should not create an additional layer of complexity but instead be part of a simplified approach that is integrated with the actions of other parties, notably the Commonwealth and Queensland Governments.

The Commonwealth will continue to have a role where there are economies of scale, and cross-jurisdictional or funding issues. One example is the Commonwealth Government's funding (in conjunction with the Queensland Government) of major studies to prioritise hazard and receiving areas across the GBR catchment and lagoon.

While the Queensland Government may need to devolve some powers and responsibilities to regional groups, there will be circumstances where it should retain a direct implementation role. For example, one of the abatement options considered in this report was to link leasehold conditions to the adoption of approved management practices. The Queensland Government would obviously need to take the lead if this option was implemented, given that it is responsible for overseeing the management of leases. Regional bodies could play a supporting role by advising on the most appropriate practices for particular regions or industries.

Other groups could also play important roles in controlling diffuse pollution entering the GBR lagoon. These groups include local government for local planning and development schemes; industry associations for BMP guidelines; and processors for ensuring that certain production standards are met.

Finally, it is highly desirable to have ongoing monitoring and review of policies and the roles assigned to different parties (Adaptive Management). This is important for two reasons. First, as noted above, there are few precedents for how responsibilities might be devolved to regional bodies. Thus, a process of trial and adaptation is probably required. Second, future research and experience could be expected to resolve some of the uncertainties about the benefits and costs of abating diffuse pollution entering the GBR lagoon. This could in turn reveal a need for future modification of policies and the roles assigned to different parties.

PART I – THE CONTEXT

1 Introduction

This report contains an analysis of:

- the economic and social importance of the main industries in the Great Barrier Reef (GBR) lagoon and adjacent catchments;
- the current management approach by those industries to activities that influence water quality entering the GBR lagoon; and
- policy options to address declining water quality entering the GBR lagoon.

This study was requested by the Commonwealth Government in response to concerns that water quality in the GBR lagoon has declined and that this threatens the health of inner reefs and associated ecosystems (Campbell 2002). The findings of this study will be used by the Commonwealth and Queensland Governments in their development of a *Reef Water Quality Protection Plan* (Reef Protection Steering Committee 2002).

This chapter provides an overview of the GBR and its catchments, explains the background to the study, and then outlines the research methods used and the structure of the analysis.

1.1 The Great Barrier Reef and its catchments

The GBR extends approximately 2000 kilometres along the Queensland coast, and is the largest reef system in the world (GBRMPA 2001c) (figure 1.1). It consists of about 3000 reefs, the majority of which are situated on the mid- and outer-continental shelf, 20 to 150 kilometres from the mainland. However, approximately 750 reefs exist at inshore or nearshore sites close to the coast within the GBR lagoon.

The GBR region supports a wide diversity of marine life including several endangered species, such as dugongs, cetaceans and turtles. It also supports inshore and deeper water seagrass beds and intertidal mangrove forests (GBRMPA 2001c). In addition to offering habitat for marine life, the GBR also offers recreational, aesthetic and educational benefits, sustains commercial and recreational fishing, and is seen as being of significant cultural importance by many Indigenous and non-Indigenous Australians.

Figure 1.1 **The Great Barrier Reef and its catchments**

Source: Great Barrier Reef Marine Park Authority.

The GBR was proclaimed a Marine Park in 1975 and listed on the World Heritage Register in 1981 in recognition of its outstanding universal value. The GBR World Heritage Area is slightly larger than the Marine Park because it also includes some:

- islands under state jurisdiction;
- internal waters of Queensland; and
- small areas (mainly located around major ports and urban centres) which were excluded from the Marine Park (GBRMPA, sub. 27, p. 4).

The GBR World Heritage Area covers 347 800 square kilometres (Lawrence et al. 2002), which is an area over 50 per cent larger than Victoria. Coral reefs constitute just 6 per cent of the GBR World Heritage Area. The remainder is comprised of the following three regions:

1. the continental shelf, which accounts for about 36 per cent of the World Heritage Area;
2. the reefal region, which surrounds most of the known coral reefs and accounts for about 25 per cent of the World Heritage Area; and
3. the GBR lagoon, located between the reefal region and the mainland coast of Queensland, accounting for 33 per cent of the World Heritage Area.

Land areas adjacent to the GBR World Heritage Area are also highly valued. They are used for commercial, residential and recreational purposes. Tourism is a major industry in the Cairns and Whitsunday regions, while agriculture, manufacturing and mining are significant in other areas (chapter 4).

The GBR catchment (shaded area in figure 1.1) covers 22 per cent of Queensland's land area (more than 50 per cent larger than Victoria) and contains 20 per cent of its population (GBRMPA, sub. 27, p. 5). It includes around 30 major rivers and hundreds of small streams that drain into the GBR lagoon (Furnas 2002).

For analytical purposes, the catchments of individual rivers and streams are usually aggregated into about 35 drainage basins that are separated by natural topographic boundaries (see, for example, Furnas 2002; NLWRA 2002; GBRMPA 2001b). Unless stated otherwise, this study defines catchments within the greater GBR catchment as being one of these basins (boundaries are shown in figure 1.1). Most of the catchments so defined are less than 10 000 km^2 in area (table 1.1). Notable exceptions are the Fitzroy (142 537 km^2) and Burdekin (130 126 km^2) catchments, which together comprise about two-thirds of the total GBR catchment.

The main regional centres in the GBR catchment are Townsville-Thuringowa (population of around 130 000), Cairns (116 000), Mackay (66 000), Rockhampton

(64 000), and Gladstone (40 000) (OESR 2002b). These are all located in close proximity to the coast, and hence the GBR lagoon.

Table 1.1 **Population and area of selected GBR catchments**

Catchment	*Population*[a]	*Area*	*Population density*
	persons	km^2	persons/km^2
Baffle	447	3 996	0.1
Barron	23 814	2 902	8.2
Black	1 579	1 057	1.5
Boyne	5 009	2 590	1.9
Burdekin	17 497	130 126	0.1
Burnett	59 284	33 248	1.8
Calliope	24 387	2 236	10.9
Daintree	738	2 192	0.3
Don	237	3 695	0.1
Endeavour	1 344	2 104	0.6
Fitzroy	114 536	142 537	0.8
Haughton	10 343	4 044	2.6
Herbert	8 778	9 843	0.9
Johnstone	13 428	2 325	5.8
Kolan	1 471	2 901	0.5
Mossman	17 177	466	36.9
Murray	1 296	1 107	1.2
Normanby	na	24 408	na
O'Connell	5 082	2 387	2.1
Pioneer	44 159	1 570	28.1
Plane	6 911	2 539	2.7
Proserpine	16 286	2 535	6.4
Ross	106 445	1 707	62.4
Russell-Mulgrave	75 400	1 983	38.0
Styx	na	3 012	na
Tully	5 585	1 683	3.3

[a] Population numbers are for 1996. **na** Not available.

Source: GBRMPA (2001b).

1.2 Study background

In August 2002, the Commonwealth and Queensland Governments announced a Memorandum of Understanding (MOU) on cooperation to protect the GBR World Heritage Area from land-sourced pollutants (Beattie 2002). In the MOU (see appendix C for details), the two Governments noted that:

- the catchments adjacent to the GBR have extensive land modification, with a focus on developing land and infrastructure for urban centres, agricultural production, tourism and mining;
- this development has led to increased pollutants in rivers draining into the GBR lagoon; and
- the resulting decline in water quality entering the GBR lagoon poses a significant threat to the natural, economic and social values of the Reef.

For the purpose of this study, the term 'pollution' is used to refer to above-natural levels of sediment, nutrients, and other materials in watercourses draining into the GBR lagoon that are potentially harmful to organisms. This definition is used because the transport of sediment, nutrients and other materials through rivers draining into the GBR lagoon is to some extent a natural phenomenon.

The Commonwealth and Queensland Governments agreed that, as a first stage in protecting the Reef, a major goal would be to stabilise and then reverse the decline in water quality entering the GBR lagoon as soon as practicable. In order to achieve this goal, the two Governments made a commitment to develop jointly a *Reef Water Quality Protection Plan* (the Plan).

The Plan will set objectives, outline priorities, and set a clear way forward for addressing water quality (Reef Protection Steering Committee 2002). The Commonwealth and Queensland Governments will work with regional natural resource management bodies (established under the National Action Plan for Salinity and Water Quality) to set water quality targets and develop catchment-specific actions in accordance with the Plan.

The MOU also stated that the Commonwealth and Queensland Governments would pursue initiatives individually towards the joint goal of protecting the GBR from land-sourced pollutants. Actions by the Queensland Government included the establishment of a Science Panel (2003) to:

- summarise existing evidence on water quality impacts;
- advise on a methodology for setting end-of-river targets; and
- identify the most practical options to reduce water quality impacts on the GBR.

The Commonwealth Government listed several actions in the MOU that it could undertake individually, including this study. As a result, the Productivity Commission was requested to report on the importance of different industries in the GBR catchment and the costs and benefits of policy options to address the declining quality of water entering the GBR lagoon (Campbell 2002). The terms of reference for this study (see pages IV to V for details) specify four objectives:

1. outline the economic and social importance of the main industries in the GBR lagoon and adjacent catchment at the local, regional, state and national level;
2. discuss current management approaches by the main industries that influence water quality entering the GBR lagoon;
3. estimate the economic importance of the main industries in 2010 and 2020 assuming that current management approaches are continued; and
4. analyse the likely costs and benefits of policy options to address declining water quality entering the GBR lagoon.

The following nine industries were to be included in the analysis:

- aquaculture
- beef
- commercial fishing
- horticulture
- recreational fishing
- sugar
- tourism
- mining
- mineral processing

1.3 Research methods

The research methods used in this study included:

- consultations with interested parties;
- analysis of industry statistics;
- review of past research;
- use of the expertise of an external consultant to estimate the future economic importance of industries; and
- consideration of written submissions made in response to an issues paper sent to interested parties.

Consultations and information collection

Shortly after the Commission received the terms of reference, an issues paper was sent to more than 200 individuals to alert them about the study and to encourage them to participate by sending a written submission. An e-mail message was also sent to more than 400 people informing them about the study and how they could access the issues paper from the Commission's web site. The Commission advertised the study in the national press (*The Australian*) and local papers in Brisbane (*Courier Mail*), Rockhampton (*Morning Bulletin*), Mackay (*Daily Mercury*), Townsville (*Townsville Bulletin*), and Cairns (*Cairns Post*).

The Commission released an interim report for comment in November 2002 that reported on the first three objectives in the terms of reference (current and future importance of industries, and current management practices). Interested parties were invited to make further submissions in response to the interim report. A total of 81 submissions were received over the life of the study (see appendix A for details).

The Commission met with a wide range of interested parties to discuss this study (see appendix B for details). Those consulted included:

- Commonwealth, Queensland and local government agencies;
- catchment and natural resource management groups;
- environmental and Indigenous organisations;
- industry associations;
- primary producers; and
- research institutions.

Meetings occurred in Brisbane, Canberra, Townsville, Rockhampton, the Charters Towers region, Cairns, Innisfail, and the Wet Tropics catchments. This included visits to farm properties and the inspection of council engineering works designed to manage water quality.

Approximately sixty people from the above groups also attended a workshop on policy options hosted by the Commission in Brisbane on 25 November 2002.

The Commission directly approached a number of agencies to obtain data necessary to compare the importance of different industries. The primary data source was the Australian Bureau of Statistics. Additional information was obtained from the Office of Economic and Statistical Research (a portfolio office of Queensland Treasury), Queensland Fisheries Service, and Queensland Department of Natural Resources and Mines. Details are provided in appendix E.

Preliminary growth projections

The terms of reference for this study required the Commission to use available growth projection scenarios to estimate the economic importance of the main industries in the GBR catchment and lagoon in 2010 and 2020.

It was evident at an early stage in the study that it would not be possible to assemble a consistent set of industry growth projections from published sources. The Commission therefore decided to advertise for an external consultant to supply projections (see chapter 4 and appendix G for details). The contract was subsequently awarded to the Australian Bureau of Agricultural and Resource Economics (ABARE).

The ABARE projections were reviewed at a workshop in Brisbane on 26 November 2002. Approximately thirty people attended the workshop. Those attending included two consultants hired by the Commission to review the projections, industry association representatives, and officials from Queensland Government agencies.

1.4 Structure of analysis

The first part of this report provides the context for an analysis of policy options to address declining water quality. The first step in the analysis was to develop an understanding of what is currently known about the causes and effects of water quality changes in the GBR lagoon. The results of this review, presented in chapter 2, provide a foundation for the later analysis of how water quality is linked to industry management practices. The results are also an important input into the analysis of policy options.

In chapter 3, current government policies relevant to water quality in the GBR lagoon are examined. This provides insights into how governments influence water quality now and what potential role they could play in the future.

The current and future importance of different industries in the GBR catchment and lagoon is then documented in chapter 4. This analysis reports on industry importance at the national, state, regional and local level. Estimates of the future economic importance of industries are reported for 2010 and 2020. These estimates are based on the assumption that current management approaches are continued.

In chapter 5, the management practices used in individual industries are examined, with emphasis on activities that may affect water quality in the GBR lagoon.

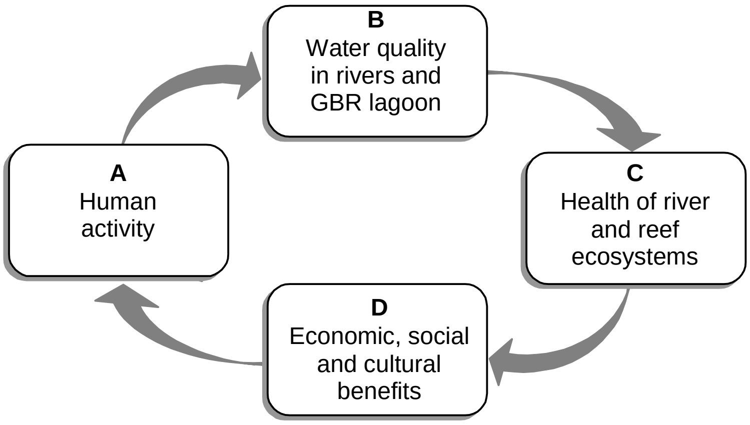
The second part of this report discusses policy options. Chapter 6 outlines the analytical approach. Aspects of this approach are then detailed in following chapters. These aspects are the prioritisation of threats (chapter 7); socioeconomic characteristics of land users (chapter 8); the formulation and assessment of abatement options (chapter 9); and the roles and responsibilities of different parties in improving water quality (chapter 10).

2 Water quality in the GBR lagoon

Water quality refers to the chemical, physical and biological condition of water. Concerns about water quality in the GBR lagoon have been noted in a number of government and non-government reports and forums, including the Memorandum of Understanding signed by the Commonwealth and Queensland Governments in August 2002 (appendix C).

These concerns arise due to the potential for human activities to contribute to a decline in water quality in the GBR lagoon (A, figure 2.1), and the potential ecological, economic and social impacts of such a decline. A decline in water quality (B, figure 2.1) could adversely affect the GBR’s ecosystem (C, figure 2.1). This may, in turn, affect a range of economic activities that depend on it, such as tourism and fishing, as well as the social viability and prosperity of regions that undertake these activities (D, figure 2.1). Indigenous peoples’ strong cultural links to the GBR could also be affected by anthropogenic changes to water quality. Thus, human activities in the GBR catchment can affect, and be affected by, water quality. If consequential damage to the GBR occurs, Australia would be in breach of its international obligations to preserve world heritage listed sites.

Figure 2.1 **Water quality: the environmental, economic and social linkages**



However, scientific and socioeconomic information on the nature, effects and causes of GBR water pollution is incomplete. Although broad links, such as those illustrated in figure 2.1, are known, the nature and extent of these links, and the lags between cause and effect — in theory and practice — are less clear. This makes it difficult to attribute water quality problems to particular human activities and to assess their seriousness.

Nonetheless, as noted in chapter 1, the Commonwealth and Queensland Governments have agreed that the decline in water quality entering the GBR lagoon poses a significant threat, that the major source of pollutants is from land use activities in the catchment, and that a precautionary approach is required. Given this, the purpose of this chapter is to identify the characteristics of the problem that need to be considered in assessing policy options. It briefly outlines issues in the measurement of water quality (section 2.1), before summarising what is currently known about water quality and its trends in the GBR lagoon (section 2.2), possible causes of water quality changes (section 2.3), and the effects of these changes (section 2.4).

2.1 Measuring water quality in the GBR lagoon

There are many potential measures of water quality. The most important for the health of coral reefs, and thus for assessing water quality in the GBR lagoon, include suspended sediment and nutrient concentrations, pesticides and herbicides, salinity, and water temperature (GBRMPA 2001c). The focus in this chapter is on the measures for which human activities in the GBR catchment can potentially be of most influence and for which most research has been done — sediments, nutrients and contaminants such as herbicides and pesticides. As noted in chapter 1, the transport of sediment, nutrient and other materials through rivers is to some extent a natural phenomenon. Therefore, the term ‘pollution’ is used here to refer to above-natural levels of sediment, nutrients and other materials in watercourses draining into the GBR lagoon that are potentially harmful to organisms.

Potential measures of water quality

Some of the measures of water quality outlined below, such as sediments and nutrients, can be expressed as quantities (loads) or as concentrations. Changes in either loads or concentrations may affect reef ecosystems. There may not be a direct link between loads in rivers, and loads or concentrations in the GBR lagoon. This is because not all the river load may find its way to the lagoon, while dilution or uptake by reef organisms can mean that increased inputs to the lagoon do not correspond to increased concentrations in lagoon waters. Because it can be difficult to obtain direct estimates of some measures, spatial modelling tends to be used (GBRMPA 2001b).

Sediments and turbidity

Sediments are solid materials, generally small particles that can be either ‘fine’ or ‘coarse’, that are transported by water. How they move in water, after being detached from soil, depends on factors such as energy of water flow and size of particles (NLWRA 2001a). Fine particles — sources of which include hillslope, gully or riverbank erosion (GBRMPA 2001b) — move more easily than larger or heavier ones (NLWRA 2001a), which may not move at all in slow flows (Woolfe and Larcombe 2000). Fine sediments, accounting for most material carried by rivers in the GBR catchment (Furnas 2002), are largely transported as ‘suspended sediment’, and are likely to have relatively strong downstream influences (Furnas 2002; GBRMPA 2001b). (In the GBR lagoon, suspended sediment can also be locally sourced from the seabed through resuspension.) Turbidity — the clarity or degree of light absorption (Meagher 1991) of water — can be used as a measure of suspended sediment load under certain conditions (Gippel 1995). There are natural differences in turbidity across reef environments. Carter (sub. 57, p. i) observed that coastal waters in North Queensland are naturally muddy. He noted further (p. 4) the dynamic relationship between sediment supply, sea-level change, and climatic events in the Cairns region.

Nutrients

Nutrients, such as nitrogen, phosphorus and potassium, are essential for plant and animal growth. In high concentrations, however, they can have deleterious effects on ecosystems. Potassium is naturally present at high concentrations in seawater (Fertilizer Industry Federation of Australia, sub. 32, p. 5), so phosphorus and nitrogen are the main nutrients of concern. Of these, nitrogen tends to be more mobile in soils (Ribaudo et al. 1999). There are organic and inorganic, dissolved and particulate, forms of nitrogen and phosphorus. Although particulate forms can affect ecosystems (Schaffelke 1999), dissolved inorganic forms, particularly of nitrogen, tend to be of most concern because they are completely ‘biologically available’ (that is, can be used directly by freshwater and marine plants and bacteria). Ammonium is the most readily used and produced form of inorganic nitrogen. Another form of dissolved inorganic nitrogen is nitrate. Fertilisers are one source of nitrate, although small amounts also occur in rain (Furnas 2002).

There are natural variations in nutrient levels across areas, making it difficult to establish the level that would lead to negative impacts in a particular area (McCook 1999). Because nutrients in GBR waters are rapidly taken up by phytoplankton, ambient nutrient levels tend to be low, even when high levels of nutrient input occur. Thus, chlorophyll *a*, a measure of phytoplankton biomass, is used as a proxy for measuring changes in nutrient levels (GBRMPA 2001b).

Other pollutants

Other substances potentially toxic to marine organisms can be transported to the GBR lagoon from the catchments. These include herbicides (such as diuron and atrazine); pesticides (organochlorines, such as DDT and lindane, now banned in Queensland; or modern organophosphates); and heavy metals (such as cadmium, arsenic and copper). In the case of heavy metals, some trace amounts are required by most animals but disorders can result from concentrations above these trace levels (Meagher 1991).

In addition, dioxins — chlorine-containing compounds formed during chemical and industrial processes — can have negative effects on the marine environment, although they can also be produced through some natural processes (GBRMPA 2001c).

Other water quality issues

Other measures of water quality include salinity, acidity and biological oxygen demand (BOD).

- *Salinity* is the amount of mineral salts dissolved in waters (Meagher 1991). Reef corals have been found in seawater salinities from 25 to 42 parts per thousand (‰) (Coles and Jokiel 1992). Surface water salinities in the GBR lagoon are generally close to 35‰ (Furnas 2002). Significant falls in GBR salinity occur only during flood or major rainfall events when large amounts of freshwater are deposited. This can cause stress to corals (GBRMPA 2001c) and can sometimes be compounded by other flood-related stresses, such as sedimentation (GBRMPA, sub. 27, p. 19).
- *Acid sulphate soils* are derived from soils, sediments or rock containing elevated metal sulphide levels (VEPA 1999). When the sulphide is exposed to oxygen through disturbance, exposure or drainage, it can generate sulphuric acid. This potentially acidifies surface water and groundwater, and contributes to low oxygen levels in water, as well as releasing heavy metals from soil and sediment (VEPA 1999). Although neutralised by seawater, acid runoff can have significant, but localised, negative impacts on estuarine environments.
- *BOD* is used as an index of organic pollution, including sewage. It measures the amount of dissolved oxygen (in (milli)grams per litre of water) that would be taken from the water through the decomposition of organic matter by microorganisms (Thain and Hickman 1996). Increased organic material in water leads to higher BOD, which reduces the oxygen available to other organisms, such as fish.

Who measures water quality in the GBR?

The measurement of water quality in the GBR lagoon has been researched for many decades, beginning with the Great Barrier Reef Royal Society Expedition in 1928-29. About thirty years lapsed before further work was completed in the 1960s and 1970s by organisations such as the Commonwealth Scientific and Industrial Research Organisation (CSIRO), James Cook University, the Australian Institute of Marine Science (AIMS), and the Great Barrier Reef Marine Park Authority (GBRMPA). These and other organisations continue to research and monitor water quality in the GBR World Heritage Area and its catchment (box 2.1).

As discussed in the following sections, despite this research, substantial gaps in knowledge about water quality in the GBR lagoon remain. Most monitoring and research has been conducted on outer reefs, which are not subject to as great a threat from land-based activities as are the inner reefs (section 2.2). Monitoring has focused on the flood-based transport of pollutants, although the steady transport of pollutants in normal or dry seasons may also be important (see, for example, Science Panel 2003). Further, there has been little assessment of how much of the sediment and nutrient discharges from catchments is due to recent management practices, rather than from decades (or even more than a century) ago.

2.2 Water quality changes in the GBR lagoon

As noted above, information about water quality (and its trends) in the GBR lagoon is incomplete. There are several reasons for this. In particular, a lack of baseline and continuous long-term time-series data not only makes it difficult to assess normal levels, but also to investigate trends over time. This section briefly discusses how pollutants can enter the GBR lagoon, before examining water quality changes in the GBR lagoon itself, by summarising the results of various studies for each (main) type of pollutant.

How pollutants can enter the GBR lagoon

Sediments and nutrients (at both ‘natural’ and above-normal levels) and other pollutants can enter, and move within, the waters of the GBR lagoon by various mechanisms. These include land (terrestrial) runoff, rain, tides, upwelling from the Coral Sea, sewage discharge, and recycling within the ecosystems (Furnas 2002).

Terrestrial runoff, transported by the rivers and streams that drain into the GBR lagoon, can be affected by factors such as soil type and vegetation, and has always been an important influence on the ecology of the GBR. It also tends to be seen as the main way that human-generated pollution can affect water quality. While such runoff can have implications for the quality of water in rivers, the extent of its impact on the quality of water that enters the GBR lagoon depends on the nature and amount of river discharge. As noted by Furnas et al., from AIMS:

> Water quality within a river system can be 'terrible' for a variety of reasons … but if there is little discharge, then this water quality will have little if any effect on ecosystems in the GBR. (Furnas et al., AIMS, sub. 12, p. 2)

Box 2.1 **Research and monitoring of GBR water quality**

Much research and monitoring of GBR water quality is undertaken by Townsville-based organisations, some of which are described below.

Australian Institute of Marine Science (AIMS). AIMS is a Commonwealth statutory authority governed by a Council appointed by the Australian Government. It has a wide-ranging research program for water quality issues in the GBR lagoon, including assessing the impact of sediments and nutrients on coral reefs, and modelling flood plume patterns in northern catchments adjacent to the Marine Park. It is a founding and continuing member of the Cooperative Research Centre for the Great Barrier Reef World Heritage Area (CRC Reef).

***CRC Reef*.** CRC Reef is a knowledge-based partnership of coral reef managers, researchers and industry. Its research includes assessing the impact of land use on the GBR and assessing coral bleaching events. It undertakes a range of finite-period water quality monitoring as part of its research program.

***Great Barrier Reef Marine Park Authority (GBRMPA)*.** GBRMPA, a Commonwealth statutory authority, is the principal adviser to the Commonwealth on the care and development of the GBR Marine Park. In addition to its management role, GBRMPA has conducted and sponsored research into GBR water quality causes and effects, including the effect of nutrient enrichment and flood plumes on coral reefs. GBRMPA also undertakes some monitoring activities, such as long-term chlorophyll monitoring in the GBR lagoon and finite-period monitoring as part of individual research projects. GBRMPA is a joint-venture partner of CRC Reef.

***James Cook University (JCU)*.** JCU is based in Townsville and has close links to AIMS, GBRMPA and CRC Reef through its School of Marine Biology and Centre for Coral Reef Biodiversity. Its School of Earth Sciences also houses a Marine Geophysical Laboratory.

Research School of Earth Sciences (RSES). RSES is based in Canberra and is part of the Institute of Advanced Studies at the Australian National University. RSES conducts research into the nature and behaviour of the earth, emphasising the subdisciplines of geophysics and geochemistry and links to geology.

Sources: AIMS (2001); CRC Reef (2002a, b); Furnas et al. (AIMS, sub. 12, pp. 1–2); GBRMPA (2002a); JCU (2002a, b, c); RSES (2003).

Thus, the nature (as well as the content) of water flows into the GBR lagoon is important in determining the extent to which events in particular catchments affect the GBR. Environment Australia (Commonwealth Department of the Environment and Heritage, EA, sub. DR58, p. 5) commented, for example, that sediment may reach the coast when hydrological conditions naturally provide limited opportunities for sediment to settle within the river, or where floodplains are lost to development. The Science Panel (2003) noted that the construction of dams and weirs and surface drainage works can alter the flow regime of rivers, which has implications for the flow of inputs to the GBR lagoon.

Water flows into the GBR lagoon and their influence on water quality

Water flows into the GBR lagoon vary across catchments, seasons and years. Volumes are dominated by floods associated with tropical cyclones and monsoonal rains (Mitchell et al. 1997; Mitchell and Furnas 1997), although the extent to which chronic inputs may also be important is uncertain. The intensity and average annual level of rain (as well as the proportion of rain that leaves as runoff) are highest in the wet tropics, where floods can occur several times a year (table 2.1). In contrast, it may be years or decades between major floods for rivers in the dry tropics. For example, the Burdekin River only experiences a significant flood every two to three years, and the Fitzroy River has floods of similar magnitude only every ten to 20 years (Science Panel 2003). At times, especially during droughts, there may be no flow in some individual rivers in the dry tropics. However, the *average annual* volume of discharge tends to be greater in the dry tropic catchments that are much larger in area. The estimates in table 2.1, for example, imply that the Fitzroy and Burdekin rivers accounted for over 23 per cent of annual freshwater discharge, on average, between 1968 and 1994. But the year-to-year variability of runoff is higher in the dry tropics (figure 2.2).

When freshwater flows from the rivers reach seawater, flood plumes form. Because freshwater is less dense than seawater, these plumes float in a layer above the lagoon waters, before eventually being dispersed by turbulent mixing (Furnas 2002). Plumes following heavy rainfall are observed well into the GBR lagoon (Science Panel 2003), and tend to occur when most inputs to the lagoon are at peak concentrations (Devlin et al. 2001b). Concentrations of nutrients in plumes reflect increased concentrations in river waters (Science Panel 2003), although concentrations can fall rapidly over distance (Devlin et al. 2001b). Although plumes from the dry tropics occur less frequently than they do from the wet tropics, they tend to last for longer periods (Devlin et al. 2001b).

Table 2.1 **Rainfall and runoff in mainland basins[a] of the GBR**

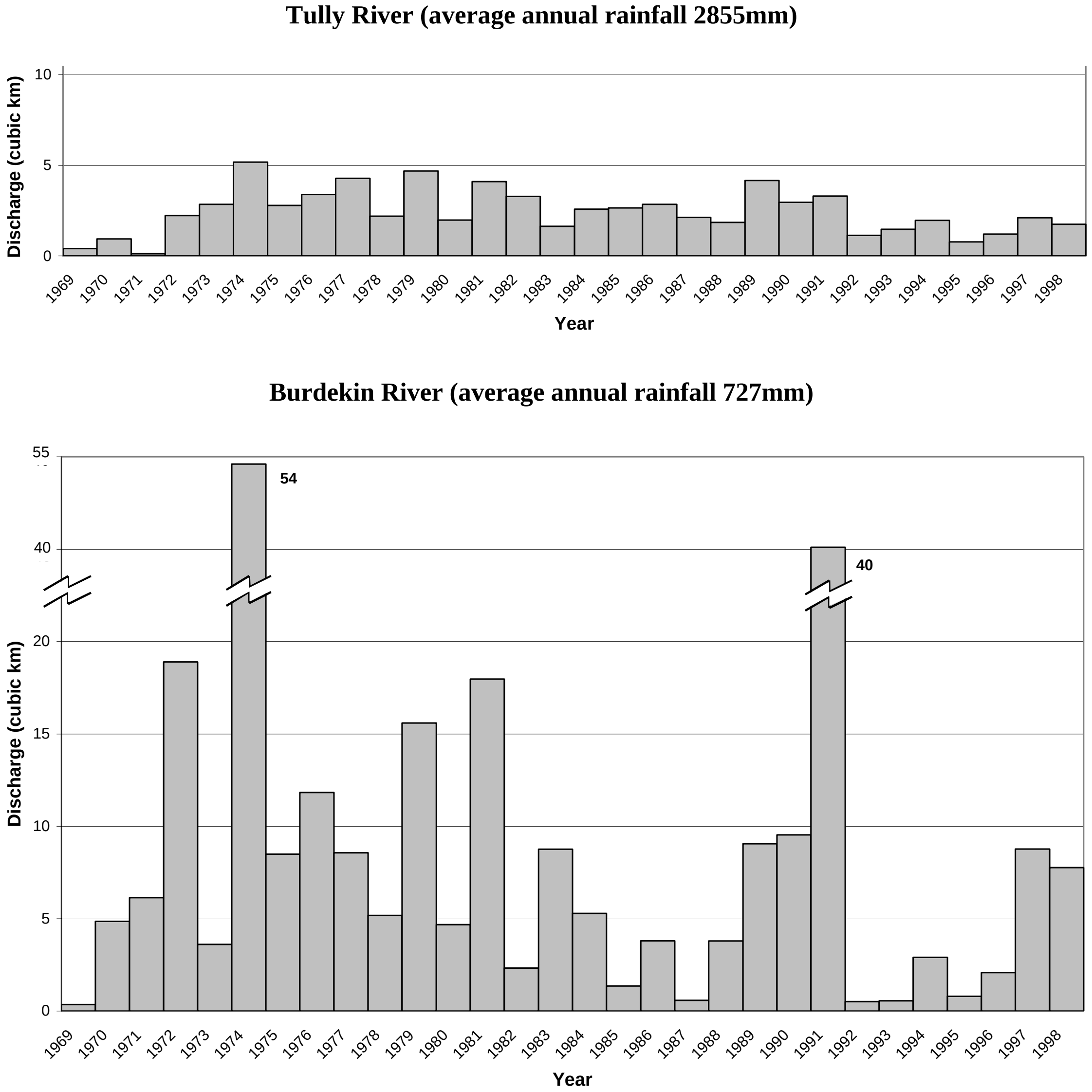
Based on rainfall data for 1968–1994

Basin name	*Wet or dry*	*Average annual rainfall*	*Average annual runoff*	*Proportion of rainfall as runoff*	*Minimum annual runoff*	*Maximum annual runoff*	*Average annual runoff*
		mm	mm	%	km^3 [b]	km^3 [b]	km^3 [b]
Baffle Creek	Dry	893	195	22	0.08	3.03	0.78
Barron River	Wet	1 453	279	19	0.16	2.66	0.81
Black River	Dry	1 530	360	23	0.00	1.54	0.38
Boyne River	Dry	968	112	12	0.00	2.40	0.29
Burdekin River	Dry	727	79	11	0.52	54.46	10.29
Burnett River	Dry	763	35	5	0.12	6.37	1.15
Burrum River	Dry	766	164	21	0.03	2.36	0.55
Calliope River	Dry	790	134	17	0.02	1.08	0.30
Daintree River	Wet	2 492	575	23	0.11	3.52	1.26
Don River	Dry	1 045	203	19	0.00	3.66	0.75
Endeavour River	Wet	1 939	865	45	0.44	4.92	1.80
Fitzroy River	Dry	735	43	6	0.18	23.22	6.08
Haughton River	Dry	888	183	21	0.02	3.18	0.74
Herbert River	Wet	1 506	407	27	0.53	11.99	4.01
Jacky Jacky Creek	Wet	1 467	na	36[c]	na	na	1.56[c]
Jeannie River	Wet	1 344	423	32	0.13	4.69	1.54
Johnstone River	Wet	2 996	2 009	67	1.65	9.12	4.67
Kolan River	Dry	1 065	141	13	0.02	2.10	0.41
Lockhart River	Wet	1 225	na	55[c]	na	na	1.94[c]
Mary River	Dry	1 174	288	25	0.26	9.27	2.72
Mossman River	Wet	2 208	1265	57	0.18	1.21	0.59
Mulgrave-Russell River	Wet	3 016	1 836	61	1.32	7.21	3.64
Murray River	Wet	2 098	958	46	0.38	2.60	1.06
Normanby River	Wet	1 185	203	17	0.60	17.49	4.95
O'Connell River	Dry	1 469	645	44	0.07	4.19	1.54
Olive/Pascoe Rivers	Wet	1 187	888	75	0.27	7.14	3.71
Pioneer River	Wet	1 385	758	55	0.00	5.15	1.19
Plane Creek	Dry	1 125	587	52	0.05	4.97	1.49
Proserpine River	Dry	1 360	426	31	0.02	3.95	1.08
Ross River	Dry	1 027	287	28	0.01	3.37	0.49
Shoalwater Creek	Dry	975	na	52[c]	na	na	1.83[c]
Stewart River	Wet	1 222	441	36	0.01	2.30	1.21
Styx River	Dry	1 010	na	52[c]	na	na	1.58[c]
Tully River	Wet	2 855	1 954	68	1.24	5.37	3.29
Water Park Creek	Dry	860	605	70	0.23	2.68	1.11
Total							**70.79**

a As noted in chapter 1, unless stated otherwise, this study defines catchments within the greater GBR catchment as being one of these basins. **b** 1 cubic km (km^3) = 1 million megalitres. These figures estimate how much water leaves the basin, taking into account factors such as rainfall, runoff and basin size. **c** Estimates in areas that are not gauged. **na** Not available in estimates from Furnas (2002), because these areas were not gauged.

Source: Furnas (2002).

Figure 2.2 **Annual discharge from the Tully and Burdekin Rivers, 1969–1998[a]**



a 1 cubic km (km^3) = 1 million megalitres. Average annual rainfall data are taken from Furnas (2002), and are for the period 1968–1994. All other data are taken from King et al. (2002).

Data sources: Furnas (2002); King et al. (2002).

The movement of plumes is influenced by factors including the discharge volume of the river, and wind strength and direction (due to the plume's buoyancy and the Coriolis effect) (Williams 2001). (Wind strength and direction also influence the nature of sediment resuspension.)

- Prevailing winds in the GBR (for about nine months of the year (Woolfe and Larcombe 2000)) come from the south-east, tending to push surface waters north, as well as toward the shore. Winds during the wet season tend to be lighter and more variable, except during cyclones (Larcombe and Woolfe 1999).

When winds blow from the north, surface waters can be moved offshore (and to the south). Headlands can also move plumes offshore.

- In the Southern Hemisphere, the Coriolis effect — the force induced on moving water by the Earth's rotation — pushes the moving water of the plume anticlockwise (that is, toward the coast for water pushed north by southerly winds). This effect dominates the movement of plumes from the Burdekin, which almost always move north, whereas the movement of plumes from smaller rivers is more dependent on wind force and so these frequently travel south with the wind (King et al. 2001).

The movement of the plumes means that their impacts may not be isolated to areas immediately around the river mouth. Large floods derived from the Burdekin, for example, have been detected as far north as Cape Grafton (Furnas 2002). In addition, plumes occasionally extend beyond inshore reefs (see, for example, Devlin et al. 2001b; King et al. 2001; Brodie 1996), although most of their impact is likely to be concentrated inshore. Brodie (2000) observed that a boundary layer between inshore and offshore areas of the GBR usually prevents mixing between them, contributing to the retention of terrestrially-derived inputs inshore.

Overall, the impacts of plumes (and runoff) are likely to be restricted predominantly to a relatively small part of the GBR World Heritage Area (figure 2.3). Nonetheless, the potential impacts are not unimportant. The ecosystems in these areas contain inshore reefs, which account for 750 of the 3000 reefs in the GBR; coastal mangroves; soft-bottom communities; seagrass; and nursery areas for some animal species (GBRMPA 2001b; sub. DR77, p. 4).

Williams (2001), and the consensus statement signed by scientists ('the consensus statement', reproduced in appendix D), suggested that the areas from Port Douglas to Hinchinbrook, and from the Whitsundays to Mackay, are a particular cause for concern. This is because they are influenced more regularly by flood plumes and adjoin catchments used for agricultural purposes (the Tully, Herbert, Johnstone and O'Connell are among the catchments that drain directly into this region). This region contains about 209 reefs, or 28 per cent of the inshore reefs of the GBR. Recent work by Devlin et al. (2001a) also identified these as the areas at greatest risk (chapter 7).

Wetlands, water flows and water quality

The extent, and content, of runoff reaching the GBR lagoon can also be affected by the state of mangroves and other wetlands. As well as providing a habitat for many forms of marine life, wetlands trap and stabilise sediment in their roots (reducing turbidity), absorb nutrients and pollutants in their roots, and help to lower the rate of discharge. Clearing mangroves and other wetlands can thus contribute to water quality deterioration, although the Science Panel (2003) observed the difficulty in precisely quantifying the impact of such clearing on the quality of water reaching the GBR lagoon.

Figure 2.3 Nearshore areas influenced by terrestrial runoff

Source: GBRMPA (sub. 27, p. 6).

The extent to which the area covered by mangroves has changed in the GBR catchment since pre-European times is unknown (GBRMPA 1999). Clearing currently is managed in Queensland under the *Queensland Fisheries Act 1994*, and GBRMPA (1999) reported no major declines in mangroves in the previous 40 years. There have been reductions in some areas, however — for example, in Trinity Inlet, Cairns, where about 600 hectares were lost to industrial development in the 1970s

(GBRMPA, sub. 27, p. 20). Nonetheless, Brodie (sub. DR75, p. 2) commented that most mangroves along the GBR coast are in natural condition and extent. In contrast, about 80 per cent of freshwater wetlands have been cleared between Port Douglas and Brisbane since European settlement (Brodie, sub. DR75, p. 2). Previous clearing may continue to have an impact in the future, while the health of wetlands can also be affected by water quality (herbicides were identified as a probable cause of mangrove dieback in the Mackay region in 2000, for example (Duke et al. 2001)).

Changes in sediments

The most recent estimates suggest that between 13.6 million (NLWRA 2001a) and 14.4 million (Furnas 2002) tonnes of sediment are transported to the GBR lagoon from mainland catchments each year (table 2.2).[1] Most of this sediment comes from the dry tropics — about 85 per cent of current sediment exports according to Furnas (2002) (despite dry tropics accounting for only 47 per cent of runoff volumes, table 2.1), and about 59 per cent according to the NLWRA (2001a) estimates. In discussing sediment discharge in the dry tropics, the Science Panel (2003) noted that a large proportion of sediment delivered to the mouth of major rivers appears to derive from a small proportion of the catchments.

Although the magnitude of the increase in sediment discharge that this represents is uncertain, what is not in dispute is that there has been an increase in sediment discharge since pre-European times. Williams (2001) noted that most estimates suggest an increase between 1.6 and 4.1 times. The estimates from Furnas (2002) suggest a three to fourfold increase (consistent with the earlier estimates), although a ninefold increase since 1850 is suggested by the NLWRA (2001a) figures.

Trends do not appear to have been uniform across catchments. For example, there is no evidence of large increases in sedimentation rates in the last century in Hinchinbrook Channel or Missionary Bay (Williams 2001). Some sediment cores show declines in terrestrial sediment supply rates in the past 20 years (which may be related to changed agricultural practices in the Herbert River valley) (Williams 2001).

1 Earlier estimates, calculated using different methodologies, had suggested sediment inputs of between 15 and 28 million tonnes per year (Furnas 2002).

Table 2.2 **Estimates of annual sediment and nutrient exports from mainland GBR basins[a]**

Basin name	*Furnas (2002) estimates*			*NLWRA (2001a) estimates*		
	Sediment	*Nitrogen*	*Phosph.*	*Sediment*	*Nitrogen*	*Phosph.*
	million tonnes/year	tonnes/ year	tonnes/ year	million tonnes/year	tonnes/ year	tonnes/ year
Baffle Creek	0.29	654	128	0.10	499	68
Barron River	0.03	321	34	0.15	718	168
Black River	0.14	319	63	0.08	409	54
Boyne River	0.11	243	48	0.02	147	19
Burdekin River	3.77	8 633	1 695	2.44	10 314	2 538
Burnett River	0.42	965	189	0.73	2 397	429
Burrum River	0.20	461	91	0.03	262	31
Calliope River	0.11	252	49	0.06	207	56
Daintree River	0.05	499	53	0.09	684	83
Don River	0.27	629	124	0.51	1 367	372
Endeavour River	0.07	721	76	0.49	1 370	228
Fitzroy River	2.23	5 101	1 001	2.64	8 831	2 002
Haughton River	0.27	621	122	0.17	653	137
Herbert River	0.54	1 588	168	0.66	3 415	702
Jacky Jacky Creek[b]	0.06	620	66	0.33	1 243	223
Jeannie River	0.06	610	65	0.36	1 207	159
Johnstone River	0.18	1 849	196	0.31	1 998	430
Kolan River	0.15	344	68	0.06	294	48
Lockhart River[b]	0.08	769	81	0.04	267	28
Mary River	1.00	2 292	448	0.27	1 638	229
Mossman River	0.02	234	25	0.02	164	20
Mulgrave-Russell River	0.14	1 441	153	0.22	2 121	486
Murray River	0.04	420	44	0.02	195	17
Normanby River	0.50	1 960	208	1.62	4 988	920
O'Connell River	0.56	1 282	254	0.37	1 277	221
Olive/Pascoe Rivers	0.14	1 469	156	0.71	2 875	432
Pioneer River	0.05	471	50	0.29	1 073	276
Plane Creek	0.55	1 250	245	0.11	401	67
Proserpine River	0.40	906	178	0.23	637	185
Ross River	0.18	411	81	0.06	269	38
Shoalwater Creek[b]	0.67	1 533	301	0.05	220	45
Stewart River	0.05	479	51	0.16	295	49
Styx River[b]	0.58	1 327	261	0.14	463	109
Tully River	0.13	1 303	138	0.09	617	72
Water Park Creek	0.41	931	183	0.01	57	6
Total	**14.40**	**42 907**	**7 090**	**13.62**	**53 572**	**10 947**

[a] The two sets of estimates are based on different models and assumptions. As noted in chapter 1, unless stated otherwise, this study defines catchments within the greater GBR catchment as being one of these basins. [b] Because these areas are not gauged, estimates from these basins need to be treated with particular caution (discussed further in chapter 7).

Sources: Furnas (2002); NLWRA (2001a).

Even where increased sediment export is evident, this does not necessarily mean that suspended sediment *concentrations* in the GBR lagoon are higher (GBRMPA 2001c). Much turbidity in inshore waters is caused by resuspension of sediment that has accumulated over thousands of years on the seabed, rather than from the supply of new sediment (see, for example, Larcombe and Woolfe 1999; Carter, sub. 57, p. 8). Indeed, Woolfe et al. (1998) found that, despite higher loads of sediment being discharged from rivers, inshore reefs were likely not experiencing higher concentrations of sediment or sedimentation. On the other hand, Wolanski and Spagnol (2000) concluded that near-surface visibility near the Low Isles appeared to be about half that found in a 1928-29 research expedition. As they noted, the validity of this result depends on whether the 1928-29 data were representative of underlying conditions at that time.

Recent work by Professor Malcolm McCulloch and others at the Research School of Earth Sciences (Australian National University) and at AIMS (McCulloch, sub. DR74) used a new approach, involving geochemical tracers in corals, to obtain a direct measure of sediment loads reaching the inner GBR. The coral cores examined (which were in areas affected by Burdekin River discharges) indicated ‘unequivocally’ that a significant increase in suspended sediment loads is reaching the inner reef compared to pre-European times.

Terrestrially-derived sediments may not need to persist to have an impact — corals may be smothered even if sediments do not persist (McCook, L., pers. comm., 9 October 2002). In addition, as noted by GBRMPA (2001c), the composition of sediment is also important. McCook (AIMS, sub. 12, p. 10) observed the possibility that the proportion of fine sediment has increased, which has consequences for future resuspension, and the transport of material associated with this sediment (see also GBRMPA, sub. DR77, p. 4). On this, McCook (AIMS, sub. 12, p. 10) argued that the synergistic effects of multiple stressors are likely to be more significant than increased sedimentation alone (this is discussed further in section 2.4).

Changes in nutrients

The majority of nutrients in GBR ecosystems are recycled within the GBR, with about 5 per cent added annually. The largest external source of nutrients to the GBR lagoon is terrestrial runoff.

Recent estimates (table 2.2) suggest that between 42 000 and 54 000 tonnes of nitrogen, and between 7000 and 11 000 tonnes of phosphorus, are exported to the GBR from its catchments, on average, each year. The dry tropics are the main source of terrestrial nutrient input to the GBR lagoon, delivering about 57 to 66 per cent of nitrogen and 61 to 78 per cent of phosphorus inputs on average

(NLWRA 2001a; Furnas 2002). This compares with 19 to 21 per cent and 12 to 21 per cent respectively from the wet tropics (excluding the Cape York region). Overall, the particulate forms are the main forms of both nitrogen and phosphorus entering the GBR lagoon (Furnas 2002).

The main form of nitrogen exported varies across catchments. Most of the nitrogen exported from the wet catchments is in dissolved form, especially nitrate and dissolved organic nitrogen, whereas particulate nitrogen is the most common form exported from the dry catchments (Furnas 2002). Phosphorus exports tend to exhibit similar patterns in wet and dry catchments (Furnas 2002). Particulate nitrogen and phosphorus concentrations are strongly correlated with suspended sediment loads (Furnas 2002).

Although trends in nutrient levels can be difficult to identify, given strong seasonal and year-to-year variations in nutrient levels, a number of studies indicate that there has been an increase in both nitrogen and phosphorus exports since pre-European times. The various estimates suggest that the increase has been between two and four times for nitrogen, and between three and 15 times for phosphorus (Furnas 2002; NLWRA 2001a; Williams 2001; GBRMPA 2001b; Science Panel 2003). A report prepared for GBRMPA (cited in Haynes and Michalek-Wagner (2000)) suggested that most of the increased nutrient export has occurred in the past 40 years.

The World Wide Fund for Nature (WWF 2001) suggested some potential indicators of increased nutrient (and sediment) loads entering the GBR lagoon — the spread of mangroves in some areas over the past century; and an apparent increased regularity of outbreaks of the Crown of Thorns starfish since the 1960s. The extent to which these do in fact reflect decreased water quality, rather than other causes, is unclear, however.

The extent to which increased nutrient loads from the rivers have led to increased nutrient availability in the marine environment is uncertain. A GBRMPA program begun in 1992 to monitor chlorophyll *a*, a proxy for measuring nutrient levels (section 2.1), has not been able to identify trends in concentrations, partly due to the short duration of monitoring data (Williams 2001; GBRMPA 2001c). It has shown, however, that chlorophyll *a* concentrations are elevated in the inner section of the GBR lagoon, between Townsville and Port Douglas. Others have also cited higher dissolved inorganic nitrogen concentrations in catchments that are more developed (in terms of population or intensity of agriculture) (Williams 2001), and higher nutrient, chlorophyll and sediment concentrations in nearshore areas, particularly bordering the wet tropics and southern areas of the GBR lagoon (Furnas et al., AIMS, sub. 12, p. 6; McCook, sub. DR69, p. 6; GBRMPA 2001c). These patterns could be consistent with increased nutrient availability since pre-European times (given the development in the catchment since that time) but may also reflect natural regional differences. The only published study looking at chlorophyll trends over the longer term (Brodie et al. 1997) did not include inner shelf waters, but found no increasing trend in the mid- and outer-shelf reefs. This might be expected given the generally limited extent to which flood plumes enter these waters. According to McCook (sub. DR69, p. 6), comparisons of phytoplankton data in the Low Isles from 1928-29 with more recent observations do, however, 'provide cause for concern, although they are insufficient to prove long-term change'.

CRC Reef (2001, p. 5) noted that the fact that:

> … studies have failed to detect increases in the nutrient and chlorophyll levels in coastal and shelf waters in the last 25 years … suggests that natural processes are dispersing or removing nutrients delivered to the reef ecosystem at rates similar to inputs.

On the other hand, it has been suggested that a failure to detect increased nutrient levels may reflect inadequacies with current measurements, combined with large background variation (McCook, L., pers. comm., 9 October 2002). Even if the system currently is assimilating nutrients, however, the extent to which it can continue to do so is not clear.

Changes in herbicides and pesticides

Studies cited by the Science Panel (2003) have detected chemicals in coastal waterways of the Burdekin Delta, in agricultural drains of the lower Burdekin, Johnstone River, and upstream of Mackay in the Pioneer River; in sediments of the Bassett Basin in the Pioneer River estuary; and in downstream locations of the Mary River. Although herbicides and pesticides, and their derivatives, have been found at several sites along the coast adjacent to the GBR, these generally have been in low to very low concentrations (Haynes et al. 2000a).

The herbicides atrazine and diuron were both detected in sediments collected in the GBR during 1998 and 1999 (Haynes et al. 2000a). Atrazine was only found in sediment samples around the mouth of the Herbert River. Low concentrations of diuron were more widely spread along the wet tropics, potentially at levels that could inhibit seagrass photosynthesis (Haynes et al. 2000a), with levels highest adjacent to the mouth of the Herbert and Johnstone Rivers. Large levels of diuron were also found in flood flow in a study of the Pioneer River in February 2002 (White et al. 2002). The fact that atrazine was found at relatively low concentrations is consistent with its greater solubility and faster breakdown (Haynes et al. 2000a; Furnas 2002).

The pesticides DDT and lindane were only detected in very low concentrations in the subtidal sediment samples taken by Haynes et al. (2000a) (but they are still found in many soils in the area (Cavanaugh et al. 1999), despite the use of most organochlorine pesticides being banned in Queensland since the 1980s). DDT and its metabolites were the most widespread. Some dieldrin concentrations exceeded effects levels (Haynes et al. 2000a), although concentrations in freshwater fish appear to have declined between the 1970s and 1990s (GBRMPA 2001c). Concentrations of dieldrin and DDT have also been consistently reported in mud crabs (Haynes et al. 2000a) (though not at levels that are dangerous to human consumption (Williams 2001)). (Crabs are selected as indicator organisms because they are abundant and relatively immobile (GBRMPA 2001b).) No detectable organochlorine pesticide contamination in the GBR, from historic agricultural activities in the Herbert and Burdekin catchments, is evident (Cavanaugh et al. 1999).

Changes in other pollutants — heavy metals and dioxins

There has been little research into the concentrations of heavy metals in the GBR lagoon, and improvements in analytical techniques make it difficult to make comparisons with results gathered prior to the late 1980s (Haynes and Michalek-Wagner 2000). Studies that have been conducted indicate variations in subtidal concentrations along the Queensland coast. For the most part, these concentrations are low. Some concentrations exceed Australian guidelines for low and median effects levels (GBRMPA 2001c) but high concentrations of some heavy metals occur naturally in some areas.

There appear to have been local increases in concentrations of some heavy metals: mercury concentrations in some surface sediments in Bowling Green Bay have been found to be up to three times higher than pre-1850 background concentrations (mainly attributed to gold mining late in the 19th century, although fungicide use in the sugar cane industry may also have contributed (Haynes and Michalek-Wagner 2000)); and trace increases in cadmium and arsenic concentrations have been detected in marine sediments in the Hinchinbrook region (GBRMPA 2001c).

Some types of dioxins have also been detected in some sediment samples in the GBR lagoon, as well as in the tissue of dugongs (GBRMPA 2001c; sub. 27, p. 17), although the source is unknown and may be natural. Concentrations of a range of pollutants tend to be higher in areas adjacent to human activity such as urban centres, ports and intensive agriculture (Williams 2001; Haynes and Johnson 2000).

2.3 Causes of water quality changes

As discussed above, spatial and temporal variations in water quality are a natural part of the GBR lagoon ecosystem. A critical issue for policy makers trying to address water quality issues is understanding the role human activities play in the water quality of the lagoon. There are three broad potential sources of pollution arising from human activities:

- ‘nonpoint source’ (or diffuse) pollution from land uses — such as from runoff linked to cattle grazing and cropping;
- ‘point source’ pollution from land uses — such as from coastal developments, sewage, port activity, and industrial and mining activities; and
- marine-based activities — such as from fishing and shipping.

Diffuse sources tend to be less regulated than point and some marine-based sources, which are subject to various planning and regulatory mechanisms (chapters 3 and 5; appendix H).

The extent to which particular human influences are contributing, or have contributed, to water quality changes is not clear. There are several difficulties in assessing the impacts of particular activities on water quality. Some of these relate to the problems of measuring water quality in the first place. As noted in the consensus statement (appendix D), it is difficult to distinguish or quantify the relative impact of anthropogenic disturbances against strong natural disturbances, such as cyclones, experienced in the GBR lagoon. Additional problems are created by the (sometimes significant) lag that exists between the time that an action takes place in a catchment and the time that effects are felt in the GBR lagoon. Further, the Science Panel (2003) noted that it is more difficult to attribute in-stream sediment loads to specific land uses than it is to measure property-level soil erosion. Finally, Williams (2001) noted that the cycling of nutrients between the water column and benthos (seabed), and from particulate to dissolved forms, in the GBR is not well understood, but is crucial to understanding the impact of terrestrial runoff.

Nonetheless, many studies have focused on the effects of diffuse sources. Haynes and Michalek-Wagner (2000, p. 430), for example, suggested that ‘diffuse source pollutants originating from agricultural land clearly constitute the greatest chronic pollutant source influencing the Great Barrier Reef World Heritage Area’. Others, such as Marohasy and Johns (2002), have questioned the validity of such links, with the Johnstone Shire Council (sub. 20, p. 2) arguing that agriculture is ‘being accused of problems for which it may not be entirely responsible’. Estimates provided by the Australian Prawn Farmers Association (APFA, sub. 45, p. 16) and reproduced in table 2.3, support the view that diffuse sources are the most significant contributor to water quality concerns in the GBR lagoon (although a relatively important source of suspended solids is 'natural'). Some limitations with these data have been suggested, including that:

- they are based on less recent estimates of overall loads than those presented in table 2.2, which may affect the estimated relative contributions of different sectors (Furnas, sub. DR68, p. 2);
- the loads were estimated for the whole Queensland coast, not just the GBR (GBRMPA (sub. DR77, p. 5) suggested that sewage and agricultural loads are likely to be lower in the GBR region); and
- prawn farming loads are not based on standards met industry-wide (GBRMPA, sub. DR77, p. 5), although whether this materially affects the proportionate contribution of aquaculture is not clear.

Table 2.3 **Estimates of the relative contribution of selected land uses to water quality in the GBR lagoon[a]**

	Suspended solids		*Nitrogen*		*Phosphorus*	
Sector	*Quantity*	*Share*	*Quantity*	*Share*	*Quantity*	*Share*
	tonnes/year	%	tonnes/year	%	tonnes/year	%
Grazing	18 480 000	66	18 108	55.8	5 544	57
'Natural'[b]	7 280 000	26	na	na	na	na
Cropping	2 240 000	8	na	na	na	na
Sugar cane	*1 250 000*[c]	*4*[c]	8 800	27.2	1 300	13
Other agriculture	na	na	3 502	10.8	880	9
Sewage	na	na	1 928	6	1 928	20
Prawn farming	1 314	0.00005	53	0.163	6.6	0.0006
Total	**28 000 000**	**100**	**32 301**	**100**	**9 659**	**100**

a Based on different estimates of overall loads than those presented in table 2.2. No estimate of the contribution of 'Other agriculture' (other than cropping) to suspended solids is provided in APFA (sub. 45). The figures are, nonetheless, suggestive of the potential relative contribution of different land uses. **b** 'Natural' refers to undeveloped and uncleared lands, natural parks and other areas (Furnas, sub. DR68, p. 2). **c** These sugar cane data were not provided separately in the APFA submission. The quantity estimate has been taken from CRC Sugar (2002), with the share estimate calculated using this figure. **na** Not available.

Sources: APFA (sub. 45, p. 16); CRC Sugar (2002).

Some of these issues may be addressed in the future, given that the relative contribution of various land uses to runoff is 'now the subject of active research' (Furnas, sub. DR68, p. 2). Nonetheless, as noted by GBRMPA (sub. DR77, p. 5), more accurate data are not yet available. In the rest of this section, various views on how, and the extent to which, these (and other) sectors influence water quality are discussed. Where possible, comparisons are made with other estimates of the relative contribution of particular land uses.

Diffuse pollution from land uses

A range of agricultural industries operates in the GBR catchment (chapter 4). As described in section 2.2, runoff from these industries can enter the river system and, eventually, the GBR lagoon. The main ways by which agricultural practices potentially can contribute to water pollution problems include:

- soil erosion;
- vegetation clearing;
- clearing or alteration of riparian areas and wetlands; and
- the excessive use (and/or inappropriate application and management) of fertilisers and other chemicals.

GBRMPA (sub. 27, p. 2) argued that land use, mainly agriculture (including grazing), contributes around 80 per cent of the pollution loads to the GBR lagoon, which appears consistent with the estimates in table 2.3. Furnas (2002) noted the circumstantial nature of linkages between disturbed nearshore reefs and adjacent land use, although McCook (sub. DR69, p. 7) commented that there were few plausible alternative sources of some pollutants, such as pesticides.

The main sectors that tend to be identified as contributing to water quality problems in the GBR lagoon are grazing (primarily through soil erosion due to overgrazing and/or clearing of vegetation and riparian strips), and sugar cane cultivation (primarily through application of chemicals and fertilisers, encroachment of riparian strips, and wetland destruction and other land clearing). Other forms of cropping have also been identified in the past as having a potential influence.

Grazing

Although cattle are grazed in all catchments, grazing is particularly significant in the dry tropics — the highest stock numbers being in the Fitzroy and Burdekin catchments. The main *potential* consequences of grazing on the health of the GBR lagoon stem from soil erosion that can be affected by overgrazing, streambank erosion and woodland removal (GBRMPA 2001c). Removal of vegetation and ground cover has been the main driver of increased susceptibility to erosion, although the movement of cattle, by loosening soils, can also have an effect (Furnas 2002).

Estimates of the increase in soil erosion above its natural level range from 0.9 to 27–30 tonnes per hectare, depending on the level of gully erosion (GBRMPA 2001c). The Queensland Seafood Industry Association (sub. 31) submitted data from studies indicating that runoff is higher in grazed than in ungrazed lands. Sediments lost through erosion also carry nitrogen and phosphorus. Of the estimated fourfold increase in these nutrients, compared with pre-European levels, most is estimated to be due to soil erosion from rangeland grazing (GBRMPA 2001c; see also table 2.3). Little or no herbicides have been found in areas used mainly for grazing (Furnas 2002).

As noted by the Queensland Department of Primary Industries (sub. 1), however, the degree of runoff is not consistent across grazing lands. It depends on landform, soil type, vegetation community and, importantly, grazing management practices, with the level of surface cover being the most important controlling factor (Scanlan and Turner 1995). Generalisations about the level of tree cover and surface soil erosion are not possible, however. Studies in the Upper Burdekin have shown lower runoff in cleared areas (with dense pasture cover) compared with timbered areas (Scanlan and Turner 1995). Heavy grazing may exacerbate sheet erosion (erosion of a relatively uniform layer of soil by rain or flowing water) regardless of the presence of trees.

Sugar cane cultivation

Sugar cane tends to be grown in the wet tropics — mainly on coastal floodplains south of the Daintree, with smaller areas in the Atherton Tablelands (GBRMPA 2001c). Recently, there has been some expansion into coastal plain areas in both the wet and dry tropics (Furnas 2002; Brodie, sub. DR75, p. 2), with the Burdekin catchment accounting for about one quarter of Queensland’s cane production (Bureau of Sugar Experiment Stations (BSES), sub. DR79, p. 25).

Sugar cane cultivation can contribute to water quality problems in the GBR lagoon through soil erosion, the use of fertilisers and other chemicals, the release of cane juices and sugars during harvesting (which can deplete oxygen in adjacent waters), and wetland removal and water control works (dams and drainage canals) that can alter the nature of water discharge. That sugar cane tends to be grown in high rainfall areas can increase the potential for sediment and nutrient transportation through the river system (Agricultural Research Technologies (N.Q.) Pty Ltd, sub. 46, p. 2).

The overall contribution of sugar cane cultivation to sediment and nutrient loads is not as significant as is the contribution of grazing, but its relative contribution (that is, on a per hectare basis) tends to be more significant (CRC Sugar 2002). The wet tropics and O’Connell/Pioneer/Plane Creek catchments dominate losses of nitrogen, phosphorus and sediment to the sea from cane lands (CRC Sugar 2002).

On average, sugar cane has apparently contributed about 4 per cent of sediment exports (table 2.3). Soil erosion was a major source of sediment under conventional sugar cane harvesting methods but recent changes to practices have led to significant reductions in soil erosion — from up to 500 to an average of 10 tonnes per hectare per year according to studies cited by GBRMPA (2001c). BSES (sub. DR79, pp. vi, 2–3) reported that sediment discharges from some cane lands are about one hundredth of the level of a few decades ago, due to the adoption of green cane harvesting. Further, some sediment cores appear to have shown declines in terrestrial sediment supply rates, at a time when green cane harvesting practices were adopted in the Herbert River valley (Williams 2001). Although erosion has been reduced, however, the effects of previous erosion will continue to be felt. Further, CSIRO (2002b) noted that sediment, as such, was less of a concern than the delivery of nutrients from sugar growing areas.

Sugar cane cultivation traditionally has involved the use of significant amounts of inorganic fertilisers, particularly nitrogen. EA (sub. DR58, p. 4) commented that the 'highly bioavailable and bioreactive' nature of the nitrogen derived from fertilisers makes it potentially 'dangerous to marine ecosystems'. These fertilisers can enter the river system through runoff and seepage into groundwater. A study on the Herbert River floodplain (Bohl et al. 2000, cited in Furnas 2002) found that 43 per cent of the applied fertiliser was removed in harvested cane, with 37 per cent lost through surface runoff and gaseous losses (although a large proportion of losses is likely to be due to gaseous loss (BSES, sub. DR79, p. 13)).

GBRMPA (2001c) concluded that sugar cane cultivation potentially contributes about 25 per cent of additional nitrogen loads to the GBR, similar to the figures cited by APFA (table 2.3). Nitrates sourced from sugar cane have been identified as a particular issue. The Science Panel (2003), for example, cited evidence from several catchments that nitrate concentrations in rivers increase as water passes through intensive sugar cane growing areas. Furnas (2002) also concluded that there was 'no credible natural source' for increases in nitrates in the Johnstone River, where sugar cane and bananas are extensively grown in the lower catchment. BSES (sub. DR79, p. 13) noted, however, that, although sugar cane is a large contributor to overall nitrogen and nitrate loads in the Johnstone, its *proportionate* contribution is lower than some other land uses. GBRMPA (2001c) pointed to increases in nitrate and particulate nitrogen concentrations over a 13-year period in the Tully River, at the same time as cane and banana production were expanding. BSES (sub. DR79, pp. iv, 5–6) noted, however, that although there was a deterioration in some water quality parameters during the study period, the increasing trend of nitrate was not significant; and the location of most sugar expansion in the district at the time meant that this was not likely to be a contributor to any increasing trends.

Although there has been an increase in soil phosphorus fertility in most cane lands (CRC Sugar 2002), much of the phosphorus contained in fertilisers remains bound to their soils (Furnas 2002), so this has not had a significant impact on waterways, nor on the GBR lagoon. As noted by GBRMPA (sub. DR77, p. 5), however, eroded soil particles that become suspended in waterways can release the bound phosphorous, which becomes bioavailable, although research has shown that phosphorus in some soils is more strongly held in marine than in freshwater (Bramley et al. 1998, cited in Science Panel (2003)).

There is some evidence of other pollutants associated with sugar cane cultivation — for example, it has been suggested that the likely cause of some of the increase in heavy metal concentrations in Hinchinbrook Channel and Missionary Bay sediments can be related to sugar cane farming, although concentrations are still 'very low' compared with North America and Europe (Williams 2001). In their study of flood flow in the Pioneer River, White et al. (2002) concluded that sugar cane was the main contributor to the pesticide levels found there (as it was the area's only major user of the detected herbicides). Furnas (2002) also cited generally higher levels of atrazine and diuron, in coastal sediments and intertidal seagrasses adjacent to the coast between Townsville and Cairns, as being consistent with their use in sugar cane and higher rainfall in those areas. CRC Sugar (2002) noted, however, that diuron has uses other than in sugar cane cultivation, such as on fishing boats (discussed below). Indeed, Canegrowers (sub. DR67, p. 6) argued that sites with the highest concentrations of diuron in seagrass were not near cane areas but near marinas, and that the study of Haynes et al. (2000a) did not provide evidence of the likely source of diuron. The Science Panel (2003) also concluded that studies have not conclusively proven the source of diuron. Further, BSES (sub. DR79, pp. v, 2) observed that a reduction in herbicide use has resulted from the adoption of green cane harvesting, and that less persistent forms of chemical pesticides are now used. This may reduce future impacts.

Polychlorinated dibenzodioxin (PCDD) contamination is also sometimes attributed to sugar cane farming, although there are doubts as to its source (Williams 2001). CRC Sugar (2002) and the Science Panel (2003) reported that elevated concentrations of some dioxins found in dugongs are not related to sugar cane farming.

Other cropping

Other crops grown in the GBR catchment include cotton, bananas and mangos (chapter 4), some of which can involve high nitrogen fertiliser application rates (GBRMPA 2001c). In total, banana crops use 6.5 per cent of the nitrogen fertiliser used by sugar cane each year, although fertiliser application rates per hectare are higher (GBRMPA 2001c). Soils in banana paddocks are generally kept cleared (Furnas 2002) and, because bananas can be grown on steeper, more elevated slopes, their proportionate contribution to erosion and leachate (matter lost from, and washed down through, soil) is more significant (GBRMPA 2001c; Furnas 2002; BSES (sub. DR79, p. 12)). ‘Considerable’ loss of nitrogen has also been detected downstream from cotton cropping areas (cited in GBRMPA 2001c). Further, chlorophyll *a* concentrations in waters of the inshore GBR tend to be higher adjacent to regions with substantial amounts of intensive cropping (GBRMPA 2001c; WWF 2001). However, given the available data, it is not possible to determine the extent to which this reflects a long-term change in nutrient levels.

Point source pollution from land uses

Point sources of pollution from land uses tend to be seen as locally significant, but of lesser overall significance to water pollution in the GBR lagoon than agriculture (see, for example, GBRMPA 2001c). They also tend to be more tightly regulated than are diffuse sources (chapters 3 and 5; appendix H).

Coastal development — stormwater and sewage discharge

Coastal areas that are more developed and heavily populated can be potential sources of pollutants, particularly excess nutrients, to the GBR lagoon through:

- sewage discharge from treatment plants;
- septic tank contamination;
- industrial wastes and stormwater runoff, containing hydrocarbons, lawn fertilisers and animal waste; and
- discharge of freshwater (carried by stormwater and sewage) to the marine environment (Furnas 2002; GBRMPA, sub. 27, p. 9).

Sewage discharge is the most important of these; its environmental impacts depending on factors such as volume and treatment of effluent, timing of discharges relative to river flows, and the location of the effluent discharge point (GBRMPA, sub. 27, p. 18). EA (sub. DR58, p. 4) commented that sewage outflow can constitute the entire stream flow in some areas in the dry season. There is no inventory of the quantity of nutrients exported to the waters of the GBR lagoon from sewage plants, so estimating these levels is particularly difficult. The estimates in table 2.3 suggest that sewage may account for 6 per cent of nitrogen and 20 per cent of phosphorus loads to the GBR lagoon (with 1928 tonnes of each exported, compared with the ‘upper limit’ estimates of Furnas (2002) — 2250 tonnes of nitrogen and 600 tonnes of phosphorus inputs annually, on average). Furnas (2002) concluded that the large-scale impact of sewage on nutrients is likely to be small relative to diffuse sources, although potentially locally significant. Nonetheless, Brodie (sub. DR75, p. 3) suggested that, although the chronic nature of sewage discharge presents different environmental problems to the more episodic nature of agricultural runoff, it should not be ignored.

Two suggested examples of local impacts of sewage in the GBR lagoon are:

- the impact of discharge of secondary treated sewage from Hayman Island in the Whitsunday Group (GBRMPA, sub. 27, p. 18; Cape York Marine Advisory Group, sub. 22, p. 2); and
- the growth of seagrass in the coral reefs at Green Island near Cairns in the 1970s, due to the discharge of primary treated effluent (GBRMPA, sub. 27, p. 19), although this may have been due to influences other than sewage outflow, particularly increased nutrient availability due to terrestrial runoff (Udy et al. 1999).

Mining and mineral processing

Mining operations principally are located inland from Townsville, Rockhampton and Gladstone. Potentially, mining could have an impact on the quality of water in the GBR lagoon through the quantity and content of its discharge (appendix H). The Queensland Mining Council (sub. 13, p. 7) argued, however, that the stringent regulations currently applied to mining operations (appendix H) mean that the main water quality issue relates to the transport of commodities. Shipping issues are discussed below. EA (sub. DR58, p. 6) also argued that mining is not a 'major polluter' in the GBR catchment.

There have been concerns, however, about the impact in the GBR catchment of mines that are no longer operational. GBRMPA (sub. 27, pp. 9–10) and the Wowan Dululu Landcare Group (sub. 8) commented on the environmental impact of acid mine drainage from the disused Mount Morgan mine into the Dee River, where thousands of fish were killed following rain in 2000-01. Fish were killed up to 65 kilometres downstream from the minesite (sub. 8). Given the distance from the coast, however, the extent to which such events affect the GBR lagoon is unclear. That said, Reid (sub. 73, p. 5), Burdekin Dry Tropics Waterwatch Coordinator, commented that fish kills in the upper catchment may affect downstream fauna that rely on the health of the upstream ecosystem.

Heavy industry

Most heavy industry in the GBR catchment can be found in Calliope, Gladstone and Townsville/Thuringowa (GBRMPA 2001c). Two industrial effluent outfalls (a nickel refinery in Thuringowa and wharf in Gladstone) discharge into the marine environment (GBRMPA 2001c; sub. 27, p. 9). Stormwater discharges are covered by regulation (appendix H). The atmospheric release of industrial pollutants could also be an important source of pollutants but, given the nature of the winds in these areas, they tend to be carried inland rather than to the GBR lagoon (GBRMPA 2001c).

Marine-based sources of pollution

Marine-based activities that can affect water quality include shipping and fishing.

Shipping

As noted by GBRMPA (sub. 27, p. 12), two types of risk to the GBR lagoon can arise from shipping activities:

- pollution from normal operations; and
- pollution from shipping accidents/incidents, two of which have occurred per year on average in the GBR lagoon since 1985 (GBRMPA, sub. 27, p. 13).

These risks can arise in transit, or in port, and can involve marine oil spills, water discharge, and contaminated runoff (Ports Corporation of Queensland, sub. 26, p. 4).

Shipping operations tend to be the source of acute rather than chronic impacts, however — oil spills from large vessels being the single most significant point source pollution threat in the GBR lagoon (GBRMPA 2001c). Increased concentrations of some chemicals associated with antifouling paints have been discovered in some GBR marinas and harbours (GBRMPA 2001c). Nonetheless, shipping-sourced pollutant loads in the GBR lagoon are considered to be low.

Fishing

The types of 'fishing' that occur in the GBR catchment and lagoon are commercial (including trawl) and recreational fishing, and aquaculture (although, in most cases, aquaculture can be considered an intensive land use). Their potential impacts include:

- discharge of oil and petroleum, and material and biological waste from boats in the recreational sector;
- discharge and sediment disturbance in the commercial sector (Cape York Marine Advisory Group, sub. 22, p. 2); and
- contamination of water with diuron (Marohasy and Johns 2002), which is used as antifouling on fishing, as well as yachting, boat hulls.

The Queensland Seafood Industry Association (sub. 31, p. 23) submitted that, in practice, fishing has an 'immaterial impact' on water quality, and that this view is supported by water quality studies. It argued further that no diuron residues have been found in heavy fishing areas, such as Princess Charlotte Bay (commercial) and the Whitsundays (recreational), although significant levels have been found adjacent to agricultural catchments.

In terms of aquaculture, the effluent — nitrogen and phosphorus — produced through prawn harvesting and water management currently is pumped into coastal waters, either directly or through pond settling (Furnas 2002). Although discharges per hectare of pond are high (compared with sugar cane, for example), there is currently a small area of ponds adjacent to the GBR lagoon (appendix H), so the overall impacts are relatively low. Furnas (2002) suggested that the upper limit on discharges would be 200 tonnes of nitrogen and 20 tonnes of phosphorus annually, based on 'once-through' circulation designs. These are higher than the estimates provided by APFA (table 2.3), but Furnas (2002) noted that his upper limits were likely to be overestimates.

The potential clearing of mangroves, and release of acid sulphate soils (Wildlife Preservation Society of Queensland (Cairns Branch), sub. 35, p. 9), are also seen as potential problems of aquaculture. Although large-scale mangrove clearing has characterised aquaculture in other countries, this has not been the case in Australia (GBRMPA 2000c), partly because most farms have been located on former cane and grazing land (APFA, sub. DR59, p. 4). Despite the potential for environmental impacts, GBRMPA (sub. 27, p. 11) noted that large-scale impacts in the GBR lagoon have not been identified. It did suggest, however, that there had been some examples of impacts on a local scale, although this was questioned by APFA (sub. DR59, p. 6).

2.4 Impacts of water quality changes on the GBR ecosystem

As discussed above, the evidence suggests that sediment and nutrient discharges to the GBR lagoon have increased since pre-European times. It also appears that human influences, particularly agricultural sources, have influenced this trend. However, evidence about the current impacts of this on GBR ecosystems is not unequivocal. GBRMPA (2001c, p. 1) noted that the *potential* impacts:

> … of elevated pollutant concentrations in Great Barrier Reef waters range from reduced growth and reproduction in organisms, to major shifts in community structure and health of coral reef and seagrass ecosystems.

The Science Panel (2003) also noted that the main effects of excess sediments and/or nutrients arise through disruptions to normal ecological processes in reef systems, especially the capacity of coral-dominated reef communities to recover from natural disturbance events and to maintain naturally biodiverse communities.

As noted in the consensus statement (appendix D), difficulties in assessing the impact of water quality in practice arise from factors such as the relatively short duration of available monitoring data, and the frequent natural disturbances to which the GBR is subject. In addition:

- the assimilative capacity of the GBR lagoon is not known with certainty (Williams 2001), making it difficult to ascertain the point at which impacts might be manifested;
- most studies on coral reef ecology have been conducted on mid- and outer-shelf reefs, where the potential impacts of lower-quality river discharges are less significant (Williams 2001);
- inshore reefs tend to be naturally more variable environments, and are more adaptable to higher sediment and nutrient levels than are reefs occurring offshore (GBRMPA 2001c);
- the tendency for most nutrient-enhancement experiments to be conducted in laboratories rather than *in situ* potentially limits the insights that can be gained about reef responses (Koop et al. 2001);
- it may not always be possible to use the experience of reefs in other regions to discern when potential impacts of water quality may be manifested in the GBR lagoon, because habitats can naturally differ quite markedly (see, for example, Williams 2001; CRC Sugar 2002; Brodie et al. 1997);
- there is uncertainty about the process by which impacts are manifested (appendix D);

- there are potentially significant lags between cause (actions in catchments) and effect (water quality changes and their subsequent impacts in the GBR lagoon); and
- although the impact of increased sediment or nutrient loads, in isolation, may not be immediately significant or apparent, the combined effect, both direct and indirect, may be important, although less easy to detect.
  - McCook (1999, p. 362) observed, for example, that 'many of the effects … may interact in complex ways, and where different factors synergise, positive feedback may amplify otherwise relatively small or short-term changes, and the community may fail to recover'; and
  - the consensus statement (appendix D) observed that it 'is likely that adverse human impacts from enhanced runoff will be first observed in the reduced capability, or failure, of coral reefs or seagrass beds to recover from natural disturbance rather than as direct impacts'; that is, a decline in ecosystem resilience.

Different parts of the GBR ecosystem (in terms of species, as well as location) are affected differently by different types and levels of inputs. Impacts that tend to be the focus of research include those on corals and seagrasses, although there are also other ecosystem effects, such as those on fish.

Impacts on coral

Both turbidity and elevated nutrient levels potentially can have deleterious effects on coral communities.

- Turbidity may harm corals by diminishing light availability, or because corals may be smothered as particles settle (GBRMPA 2001c).
- Elevated nutrient levels are seen to be a threat to coral (and the balance of the ecosystem) through, among other things, their promotion of phytoplankton growth (which supports other organisms that compete for space with coral); macroalgal blooms that may overgrow coral structures (GBRMPA 2001c); and restriction of recruitment.
  - There is, however, disagreement about the nature of some of these impacts empirically.
    - The Science Panel (2003, p. 83) noted that, overall 'only abnormally high nutrient concentrations, which would be very unlikely to occur, appear to have a *direct* harmful effect on corals' (emphasis added).

- McCook (1999) argued that nutrient overloads can contribute to reef degradation by a variety of processes but, unless ‘herbivory is unusually or artificially’ low (p. 357), the ‘specific process of nutrient enhanced algal overgrowth of corals is unlikely’ (sub. DR69, p. 7). He thus concluded that dissolved inorganic nutrient concentrations alone were poor indicators of reef status. He submitted (sub. DR69, p. 7), however, that the inshore reefs of the GBR, particularly the reef flats, were particularly vulnerable, given their ‘exceptionally low’ abundance of herbivorous fishes and proximity to nutrient runoff, and the fact that fish abundance decreases with turbidity (which can be affected by runoff).

- In combination, turbidity and elevated nutrient levels can contribute to a phenomenon called marine snow — ‘high densities of sticky, suspended particles embedded in a mucus-like matrix’ (GBRMPA, sub. 27, p. 17). The energy required by corals to rid themselves of large particles, compared to the normal smaller sediment particles found in nutrient poor waters, may reduce their capacity to grow and reproduce (GBRMPA 2001c; sub. 27, p. 17).
- Pollutants such as pesticides, heavy metals and hydrocarbons may also contribute to coral reef decline, by interfering with reproduction and recruitment processes, for example (Wolanski et al. 2003). However, Haynes and Michalek-Wagner (2000) observed that the impacts of organochlorines on corals are still unclear, although their potential for toxicity was of concern.

In addition, being subjected to increased sediment and nutrient loads may diminish the ability of coral to recover from acute impacts, such as cyclones. This reduced ability to recover is, however, difficult to identify. As McCook (1999, p. 362) observed:

> Human impacts which lead to failure to recover from acute disturbances are likely to be very important in terms of reef management … Natural disturbances on coral reefs are frequent but very patchy and unpredictable in time and space … This means that human impacts on recovery are likely to be expressed piecemeal, as a gradual, ‘ratchet fashion’ accumulation of small impacts, which are very difficult to detect and attribute …

This conclusion has been reinforced by computer modelling work undertaken by McCook et al. (2001) and Wolanski et al. (2003). McCook et al. (2001), for example, showed that short-term (acute) disturbances can obscure long-term patterns. They also found (p. 119) that ‘although the acute natural disturbances had the most severe short-term impacts, the system rapidly recovered, whereas the chronic human impact resulted in a long-term decline’.

Thus, studies examining the status of reefs in the GBR lagoon have faced the difficulty of identifying ‘incremental declines or slower rates of recovery’ resulting *from changes in water quality 'against … a background of [natural] acute impacts' (Williams 2001, p. 36). In addition, they often have to do this without information on the 'natural' state of the reefs.*

Nonetheless, evidence has been presented suggesting a decline in the health of some coral reefs in the GBR lagoon. Some of this evidence has been anecdotal — for example, that cited by WWF (2001), which suggested that some nearshore reefs in the GBR lagoon are muddier and have less coral and more algae than they did ten to 20 years ago. Lee & Co (sub. 18) also pointed to a visual deterioration in inshore reefs between Townsville and Cape Tribulation (with outer reefs less affected). In addition, there have been unconfirmed accounts of coral being buried by sediment in some areas (Williams 2001). On the other hand, the effect of pollution may present as a reduction in diversity, rather than as a reduction in total coral cover. Fabricius and De'ath (2001) found that, although the total cover of soft and hard coral was unaffected by turbidity and sedimentation in the GBR, species replacement could occur — with more resistant taxa (groups/species) becoming more prominent.

Williams (2001), however, reported findings of a study that indicated that, between 1985 and 1995, there was no evidence of decreased hard coral cover or changed coral composition, on the fringing reefs subjected to more than one survey. Nor was there significantly increased algal cover on reef slopes. In response, McCook (sub. DR69, p. 7) submitted that:

> … as this study focused on reef slopes, which have the highest abundances of algae-eating herbivorous fishes, this may reflect the ability of the fish to absorb increased algal growth, and may not represent the situation on the reef flats, which have few fish, and are at greater risk from other stresses, such as bleaching.

Another study in 1995, which compared historical and modern photographs of reef-flats exposed at low tide, suggested that, of the 14 locations that could be examined, four had shown definite deterioration (at least one of which had recently been subjected to cyclones), while four appeared to be subject to partial decline (cited by Williams 2001; McCook, AIMS, sub. 12, p. 7). This indicated a decline in some reefs, although the authors of the study suggested that it did not imply widespread decline throughout the whole GBR (see Williams 2001, pp. 35–6).

Recent work undertaken for CRC Reef (see GBRMPA, sub. DR77, attachment 3, p. 1) has identified 'a number of community ecological properties that can be used as early-warning indicators for reef degradation', including declining biodiversity in the Princess Charlotte Bay and Innisfail regions.

To the extent that declines in coral health have been evident, it is difficult to assess the extent to which this has or has not been the result of a decline in water quality, or other human influences, or natural disturbance. Nonetheless, McCook (AIMS, sub. 12, p. 8) and Furnas et al. (AIMS, sub. 12, p. 9) pointed to studies, comparing reef status adjacent to developed and undeveloped areas in the wet tropics, that are strongly suggestive of human impacts (see also section 2.3). Lower coral cover, diversity and settlement of new corals in developed areas suggest a lower capacity to recover from other disturbances (McCook, sub. DR69, p. 8). Modelling undertaken by Wolanski et al. (2003) suggested an increased 'zone of damage' caused by runoff, relative to the natural state, due to land-based activities (although the authors acknowledged that the model had some limitations).

The Science Panel (2003, p. 84) noted the 'circumstantial' evidence of impacts from runoff, concluding (p. 80) that:

> There are many coral reefs in these [inshore] areas of high risk from run-off events that appear to be degraded, and/or slow to recover from other disturbances.
>
> However, it is not practicable to link this situation unequivocally to the effects of river run-off alone, on the basis of the scientific evidence.

It continued, however:

> Experiences elsewhere … show that by the time the amount and nature of dissolved and suspended pollutants reaching corals and coral reefs, can be easily detected and unambiguously linked to coral deaths, the system is severely degraded and unlikely to recover to its former state and function, within several to many years, and without significant changes to land-use practices. (Science Panel 2003, p. 80)

Impacts on seagrasses

Seagrasses are important to the ecology of the GBR, providing food for the dugong (an endangered species), as well as a nursery habitat for some species of fish and crustaceans, including important commercial species (WWF 2001; GBRMPA, sub. 27, p. 21). There are diverse ranges of seagrass habitats within the GBR lagoon, with some different issues arising for each.

Elevated nutrient levels, turbidity and other pollutants can have detrimental impacts on seagrass habitats, although the relative contribution of each is uncertain. Williams (2001) concluded that the main cause of seagrass decline is reduced light availability, caused by increased phytoplankton concentrations or suspended sediment loads (although the main seagrasses of the GBR lagoon are to an extent adapted to turbid water). Furnas (2002) argued, however, that agricultural herbicides, not sediments and nutrients, were likely to have the greatest potential effect on seagrasses in the GBR. Exposure to herbicides, such as atrazine and diuron, has been found to result in leaf loss and reduced photosynthesis (Williams 2001), but Hall and Kenway (AIMS, sub. 12, p. 5) noted that herbicides have sometimes incorrectly been blamed for declines in seagrass communities in other countries. Experiments have indicated that different herbicides are likely to have different toxicities, ranging from complete inhibition of photosynthesis to little impact (Ralph 2000), and that different types of seagrass are affected differently (Haynes et al. 2000b). McCook (sub. DR69, p. 8) noted the potential synergistic effects of different pollutants.

How, and the extent to which, seagrasses in the GBR lagoon have been affected by changes to water quality is not certain. In some areas, seagrass communities have declined in the past 50 years; in other areas (Green Island near Cairns), seagrasses have become more abundant, partially due to increased nutrient levels, putting pressure on coral communities in those areas (McCook, AIMS, sub. 12, p. 7; GBRMPA, sub. 27, p. 19). Nutrient levels in some species of seagrass between Townsville and Cairns are higher than elsewhere in the world. Much of this appears to be converted as 'luxury uptake' (that is, taken and temporarily 'stored' because levels are above those needed for immediate growth), rather than increasing seagrass biomass (Williams 2001).

Other ecosystem impacts

A variety of other ecosystem impacts may result from changes to water quality entering the GBR lagoon. Some of these may be indirect, and may not yet be apparent. The dugong could be affected by changes in the health of its main food source — seagrass. Indeed, although pollutants have been found in fat tissue of dead dugongs (GBRMPA 2001c), GBRMPA (sub. 27, pp. 17–18) suggested that indirect effects (through the impact of herbicides on seagrass) were likely to be more important. Williams (2001) also noted possible implications of nutrient uptake by seagrass for the nutrition of dugong. The grazing habits of dugong may in turn have benefits for the health of seagrass communities (Australian Democrats, Senator Andrew Bartlett, sub. 44, p. 3).

On the coast, south of Cooktown, between 1988 and the mid-1990s, there was a significant decline in the number of dugong — about 50 per cent, with the figure as high as 80 per cent in some areas (Williams 2001). The direct and indirect effects of fishing are sometimes used to explain this mortality rate, although it has been suggested that the magnitude of the losses implies 'undocumented habitat degradation — specifically loss of seagrasses — may be part of the cause' (Williams 2001, p. 39). The extent to which human influences may have contributed to the 'undocumented habitat degradation' is uncertain (Williams 2001).

Estuarine and shallow-water coastal seagrass beds are also important nursery habitats for juvenile prawns and fish (GBRMPA, sub. 27, p. 21). Loss of this habitat may lead to displacement of fish and crustacean species (GBRMPA, sub. 27, p. 21), but water quality changes in estuaries and mangrove swamps, such as through the disturbance of acid sulphate soils, may also have direct impacts on fish. GBRMPA (2001c) noted that acid sulphate soil disturbance contributed to 35 confirmed fish kills along the North Queensland coast between 1997 and 1998, although these were not expected to have long-term effects on fish stocks. In addition, GBRMPA (sub. 27, p. 22) noted the potential impacts on aquaculture of declining water quality in freshwater courses and estuaries.

Regardless of the ecosystem impacts in the GBR lagoon itself, significant impacts of declining water quality may be felt in particular catchments and estuaries, and this may be of (immediate) concern.

2.5 Summing up

Knowledge about the nature, causes and effects of water quality in the GBR lagoon is incomplete. Nonetheless, some broad conclusions are suggested by this chapter.

- There is strong evidence that there has been a decline in water quality (particularly increased sediments and nutrients) reaching the GBR lagoon.
  - Most types of water pollutant can come from multiple locations and from the activities of multiple sectors, but:
    - dry tropics catchments have the greatest (and most variable) discharges; and
    - the principal sources of the main types of pollutants (sediments, nutrients and agricultural chemicals) appear to be diffuse (agriculture).
  - The destruction of natural filters and buffers along the coast can contribute to declining water quality entering the GBR lagoon.
- The potential impact of pollutants suggests that there is a threat to the GBR and associated ecosystems from the decline in water quality entering the GBR lagoon.
  - The greatest potential threat is to the inner reefs, and of these the greatest risk areas appear to be from Port Douglas to Hinchinbrook, and from the Whitsundays to Mackay.
- There is no conclusive evidence of the current extent of impacts caused by the decline in water quality entering the GBR lagoon, although there is some circumstantial and anecdotal evidence.

- There is great diversity among receiving ecosystems, even within the inner reef zone, and components of each are affected differently by different types and levels of pollutants.
- There has been very limited monitoring of, and research on, the inner shelf reefs.
- There are lags between cause (runoff in catchments) and effect (damage to the inner reef). *This implies that the full impact of past human activities in catchments may not yet have occurred or been detected in the GBR lagoon; conversely, changing current practices may not yield immediate, observable effects.*

Gaps in knowledge suggest a need for improved monitoring and research, particularly of the inner reef. In the meantime, there are grounds for caution in protecting the Reef, given the threat it faces, and the World Heritage values at stake.

3 Government policies and programs

The Commonwealth and Queensland Governments have identified land-use activities as being the major source of pollutants entering the GBR lagoon and endangering GBR World Heritage Area ecosystems (appendix C). Yet this is rarely reflected in the financial incentives that land users face. Those who take voluntary actions to limit discharges are rarely rewarded for the benefits they provide in the GBR lagoon, while those who degrade water quality are unlikely to bear any significant part of the costs they impose on others. This phenomenon is termed an *externality* and can lead to what is known as *market failure*. This means that allowing parties to act in their own private interest can result in lower water quality and adverse consequences for society as a whole.

In theory, the problems arising from market failure can be remedied by government intervention. In practice, it may be difficult for governments to intervene to correct a specific market failure in a way that raises society's welfare. Government intervention is more likely to succeed, the more informed policy makers are about the causes of market failure and any tradeoffs involved with different policies (Murtough et al. 2002).

In the case of GBR water quality, a major constraint for governments is the limited information on how particular land uses affect the Reef and associated ecosystems. This informational problem is compounded by regional differences within the GBR catchment, which probably require governments to tailor their interventions to suit relatively small geographic areas. An additional challenge is that activities causing declining water quality occur primarily within the jurisdiction of Queensland, while the GBR lagoon is largely a Commonwealth responsibility:

- the Commonwealth is responsible for activities that influence water quality entering the GBR lagoon directly, such as sewage discharges from island resorts and development activities within and adjacent to the GBR World Heritage Area; and
- Queensland (including local government) has jurisdiction over the majority of activities that affect water quality entering the GBR lagoon indirectly from catchments adjacent to the lagoon, including most land-based activities.

Thus, cooperation between three tiers of government (national, state, and local) is crucial. Such cooperation was formalised in the Memorandum of Understanding

(MOU) between the Commonwealth and Queensland Governments (appendix C). This commits both governments to develop jointly a *Reef Water Quality Protection Plan*.

This chapter examines current policies and programs relevant to water quality in the GBR lagoon. What emerges is that few policies explicitly target water quality in the lagoon.

3.1 Managing water quality in the GBR lagoon

Great Barrier Reef Marine Park Authority

The Great Barrier Reef Marine Park Authority (GBRMPA) plays a prominent role in most policies directly addressing water quality in the GBR lagoon. It is a Townsville-based Commonwealth statutory authority established under the *Great Barrier Reef Marine Park Act 1975* (GBRMP Act) as the principal adviser to the Commonwealth on the care and development of the Marine Park. The Authority's goal is:

> … to provide for the protection, wise use, understanding and enjoyment of the Great Barrier Reef in perpetuity through the care and development of the Great Barrier Reef Marine Park. (GBRMPA 2002a, p. 5)

GBRMPA operates under the direction of the Commonwealth Minister for Environment and Heritage and has an annual budget of approximately $30 million. A Ministerial Council, consisting of two Ministers each from the Commonwealth and Queensland Governments, helps to coordinate policy related to the Reef (GBRMPA 2001a).

The Queensland Parks and Wildlife Service (QPWS) has joint responsibility with GBRMPA for day-to-day management of the Marine Park, subject to GBRMPA's authority. QPWS provides services including surveillance, monitoring and enforcement of reef use regulations.

GBRMPA has management responsibility over water quality issues as they occur within and directly adjacent to the Marine Park. This includes management of point source discharges, such as sewage treatment outfalls from island resorts and coastal areas. GBRMPA (sub. 27, p. 24) currently manages six island ocean outfalls and four coastal ocean outfalls (*Great Barrier Reef Marine Park Regulations 1983*).

GBRMPA confines its oversight of point source discharges outside the Marine Park to aquaculture. The *Great Barrier Reef Marine Park (Aquaculture) Regulations*

2000 require aquaculture proposals operating after 1 October 1999, with ponds greater than 5 hectares or including a hatchery to have a permit from GBRMPA in addition to other permits, such as from the Queensland Environmental Protection Agency (EPA) (section 3.2). The Regulations apply to aquaculture facilities located within the 'controlled area', which is 5 kilometres inland of the point of the high water mark as this occurs adjacent to or within the Marine Park boundary (DPI 2001c). GBRMPA (sub. 27, p. 24) stated that the Regulations were developed under s. 66 of the GBRMP Act, which provides:

> … for the regulation or prohibition of activities outside the GBRMP [GBR Marine Park] that may pollute water in a manner harmful to plants and animals in the GBRMP.

In theory, this could be used to control other industries in the GBR catchment in addition to aquaculture. However, there would need to be clear and demonstrated net benefits for this to occur.

Agriculture, Fisheries and Forestry Australia (AFFA, sub. 53, p. 9) noted that there is 'regulatory duplication' between GBRMPA and Queensland aquaculture regulations that needs to be addressed. Similar concerns were raised by the Australian Prawn Farmers Association (APFA, sub. 45, p. 23):

> It is evident that there are a significant number of agencies regulating aquaculture establishment and operational activities and that their processes are poorly coordinated.

Prior to the decision by the Commonwealth and Queensland Governments to develop jointly a *Reef Water Quality Protection Plan*, GBRMPA (2001b) prepared a *Great Barrier Reef Catchment Water Quality Action Plan* which recommended end-of-river load targets for the year 2011 for discharges of sediment, nitrogen, and phosphorous for 26 Queensland rivers (table 3.1). This plan was developed in response to a GBR Ministerial Council request for advice about what impact the decline in water quality entering the GBR lagoon was likely to have on the World Heritage values of the Marine Park, and the required actions to eliminate the threat. The GBRMPA Plan is a key part of the existing body of work that will be used in determining a joint way forward under the *Reef Water Quality Protection Plan* (Reef Protection Steering Committee 2002).

The GBRMPA Plan categorised sediment, nitrogen and phosphorous levels for each river into a risk group (low, medium or high) based on the estimated increase from 1850 to the present. A uniform percentage reduction was then assigned to each pollutant in a given catchment according to its risk category — low risk (no change), medium risk (33 per cent reduction) and high risk (50 per cent reduction) (GBRMPA 2001b) (table 3.1).

Table 3.1 **Current discharges and targets proposed by GBRMPA[a]**

	Sediment		*Nitrogen*		*Phosphorous*	
	Current	*2011 target*	*Current*	*2011 target*	*Current*	*2011 target*
	tonnes/year	%	tonnes/year	%	tonnes/year	%
Baffle	103 376	-50	844	-33	185	-33
Barron	145 877	-33	321	-33	34	-33
Black	82 887	nc	411	-33	90	-33
Boyne	16 974	-33	314	-33	69	-33
Burdekin	2 443 232	-50	11 134	-33	2 438	-50
Burnett	728 607	-50	1 244	-33	272	-50
Calliope	60 772	-50	325	-33	71	-33
Daintree	94 132	nc	499	-33	53	-33
Don	509 528	-33	812	-33	178	-50
Endeavour	486 871	nc	721	-33	76	-33
Fitzroy	2 635 482	-50	6 579	-33	1 440	-50
Haughton	172 454	-33	801	-50	175	-50
Herbert	664 787	-33	1 588	-50	168	-33
Johnstone	305 142	-50	1 849	-50	196	-50
Kolan	61 589	-50	444	-33	97	-50
Mossman	15 131	nc	234	-50	25	-33
Mulgrave-Russell	222 425	-33	1 441	-50	153	-33
Murray	17 098	-33	420	-50	45	-33
Normanby	1 620 279	nc	1 960	nc	208	nc
O'Connell	366 309	-50	1 666	-50	365	-50
Pioneer	288 343	-50	471	-50	50	-50
Plane	114 860	-50	1 612	-50	353	-50
Proserpine	227 314	-50	1 169	-50	256	-50
Ross	58 383	nc	530	-33	116	-33
Styx	136 011	-50	642	-33	140	na
Tully	88 084	-33	1 303	-50	138	-33
Total	**11 665 944**	**-37**	**39 334**	**-38**	**7 391**	**-47**

[a] Current sediment discharges are based on estimates by the National Land and Water Resources Audit. Current Nitrogen and Phosphorous discharges are based on data from the Australian Institute of Marine Science. **nc** No change.

Source: GBRMPA (2001b).

GBRMPA (2001b) argued that its water quality targets should be incorporated into relevant plans under the National Action Plan for Salinity and Water Quality (NAP) and through other catchment management plans. However, there are several concerns that would need to be addressed if this was to occur. One concern, as noted by the Queensland Government’s Science Panel (2003), is that the risk categories and reduction percentages used to develop the water quality targets appear to be arbitrarily set and lack transparency. A second issue is that the GBRMPA Plan does not discuss how implementation would be achieved. Various parties have expressed concerns to the Commission about the use of end-of-river targets, as proposed in the GBRMPA Plan. For example, the Johnstone Ecological Society (sub. 4, p. 2) argued that:

> End of river targets are totally useless as a managerial tool. If the objective is to improve water quality then it follows that it is essential to know the sources of pollution so that remedial action can be taken. What on earth is supposed to happen if it is decided that quality of water at the river mouth is unsatisfactory? Shut everything down? Fine everybody irrespective of their 'guilt'?

The GBRMPA Plan does not specify how the reduction targets are to be linked to pollution sources or how monitoring and enforcement of targets is to occur.

Environment Protection and Biodiversity Conservation Act 1999

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) prohibits actions that have, or are likely to have, a significant impact on the environmental values associated with Commonwealth land, and/or on a matter of National Environmental Significance (NES). Included in areas of NES are World Heritage Areas, such as the GBR and Wet Tropics.

Environment Australia (EA) administers the EPBC Act under the direction of the Commonwealth Minister for Environment and Heritage. Upon receiving referrals from either local authorities responsible for development approvals or from third parties, including any member of the public or community group, the Minister must decide whether the referred action requires assessment under the Act (EA 2002a).

Since the commencement of the EPBC Act in July 2000, several referrals for actions directly relevant to water quality entering the GBR lagoon have been assessed. For example, the Minister recently issued an airport development proposal near Proserpine with notice that it must submit a management plan that addresses, among other things, impacts on the World Heritage values of the GBR, as a condition of approval. The determination includes references to erosion control, sediment loads, turbidity levels, quality of surface water and potential impacts on adjacent seagrass beds, as prerequisite issues for inclusion in the plan (EA 2002b).

3.2 Managing water quality in Queensland catchments and coastal waters

State government

The Queensland Government has jurisdiction over virtually all land-based activities in the GBR catchment that lead to discharges into rivers and ultimately the GBR lagoon. However, Queensland policies relevant to water quality are directed at issues in catchments and coastal waters, rather than the GBR lagoon itself. These policies consist mainly of statutory instruments (table 3.2) but also include several non-statutory programs and initiatives. The EPA, Department of Natural Resources and Mines (DNRM) and Department of Primary Industries (DPI), under the direction of the respective Ministers, have primary responsibility for administering these policies (box 3.1).

Box 3.1 **Agencies that administer Queensland water quality policies**

The **Environmental Protection Agency (EPA)** is Queensland's principal agency for environmental management and incorporates the Queensland Parks and Wildlife Service.

The **Department of Natural Resources and Mines (DNRM)** is responsible for the management of Queensland's land, water, mineral, petroleum and vegetation resources.

The **Department of Primary Industries (DPI)** is concerned with the performance of Queensland's rural and agriculture-based industries.

Sources: EPA (2001a); DNRM (2001a); DPI (2001a).

The *Environmental Protection Act 1994* (EP Act) is the primary item of legislation for the regulation and protection of the environment in Queensland. The Act contains provisions for the regulation of Environmentally Relevant Activities (ERAs). These are activities that will, or have the potential to, release contaminants into the environment and those contaminants may cause environmental harm (EPA 2002). Any activities meeting this definition may be prescribed as an ERA (refer to s. 19 of the EP Act).

Table 3.2 Queensland legislation and policy instruments relevant to GBR water quality

Legislation	*Objective*[a]	*Instrument*	*Administering agency*[b]
Environmental Protection Act 1994	To protect Queensland's environment while allowing for development consistent with maintaining ecological processes	Point source discharge licensing and development approvals for Environmentally Relevant Activities (ERAs)	EPA, DPI, and local governments
Coastal Protection and Management Act 1995	The protection and management of Queensland's coastal zone including coastal ecosystems	Coastal management plans	EPA
Water Act 2000	Multiple objectives including sustainable management and efficient use of water and riverine protection	Water resource management and use plans	DNRM
Vegetation Management Act 1999	The protection and management of vegetation on freehold land	Regional Vegetation Management Plans and vegetation clearing permits	DNRM
Land Act 1994	Multiple objectives including the sustainable management of non-freehold land	Lease conditions (for example, land management and use conditions)	DNRM
Fisheries Act 1994	The management, use, development and protection of fisheries resources and fish habitats and the management of aquaculture activities	Permit system to control aquaculture facilities and the clearing of marine plants, such as seagrasses and mangroves	DPI
Integrated Planning Act 1997	Framework to integrate planning and development assessment so that development and its effects are ecologically sustainable	Integrated Development Assessment System (includes ERA assessments and local government planning)	State and local governments
River Improvement Trust Act 1940	The protection of rivers including the improvement of condition, repair and prevention of damage, and flood prevention	River trusts (provide and maintain flood management and river stabilisation infrastructure)	DNRM

[a] Summarised from Act 'object' and/or 'long title'. [b] Acronyms for administering agencies are EPA (Environmental Protection Agency), DNRM (Department of Natural Resources and Mines), and DPI (Department of Primary Industries).

Sources: NLWRA (2002a), AustLII (2002).

ERAs are regulated through a command-and-control system of development approvals and discharge licences. The EPA maintains a list of ERAs that specifies the requirements for each separate activity (EPA 2002). Several ERAs are relevant to GBR water quality, with responsibility for assessment and approval divided between the EPA, other government agencies and local government:

- EPA has responsibility for aquaculture, chemical storage facilities, milk processing, sewage treatment, sugar milling and refining, and mineral processing;
- DPI has responsibility for cattle feedlotting and pig farming; and
- local governments have responsibility for marinas, poultry farming, and crude oil and petroleum product storage.

The current ERA list is limited to activities that are relatively easy to measure and control (end-of-pipe point source discharges like sewage treatment plants and aquaculture farms). There are few agricultural activities listed as ERAs even though these appear to account for the majority of discharges into the GBR lagoon (chapter 2). This raises concerns about the cost-effectiveness of current policies.

One example of this concern comes from APFA (sub. 45), which observed that prawn farming is strictly regulated and accounts for less than 0.2 per cent of suspended solids, nitrogen and phosphorous entering the GBR lagoon from land uses (see table 2.3 in chapter 2). Nevertheless, the EPA (2000) proposed new discharge limits from prawn farms that in some cases would exceed the quality of water entering those farms (APFA, sub. 45, p. 13). APFA claims that existing regulations have come at the cost of discouraging the growth of prawn farming (and hence employment) in the GBR catchment. This is supported by the Bowen Collinsville Enterprise (2002), which observed that existing regulatory arrangements for aquaculture have stifled employment growth in the Bowen shire.

There would appear to be significant scope for re-examining the current ERA list to include other activities responsible for diffuse source discharges, and to ensure that the level of regulation and control was consistent with the level of threat posed by each activity. Further, there may be more equitable and cost-effective approaches than the current system of controls.

The EPA also administers the *Environmental Protection (Water) Policy 1997* (subordinate legislation to the EP Act). This provides a framework for setting and formalising water quality objectives for all Queensland waterways. The policy requires local government to develop and implement environmental plans for sewage management, trade waste management, urban stormwater quality management, and water conservation.

Another relevant policy is the *State Coastal Management Plan* released in August 2001. This will guide the development of regional coastal plans for seven coastal regions adjacent to the GBR lagoon (EPA 2001c). A core objective for the regional plans will be coastal zone water quality management. As one component of this objective, GBRMPA (sub. 27, p. 25) notes that the:

> … State Coastal Management Plan requires sewage discharges into Queensland coastal waters to achieve appropriate nutrient removal by 2010, for islands by 2005 …

The regional plans are also to address other factors that impact upon water quality, including the 'further loss or degradation of coastal wetlands' (EPA 2001c, p. 43). However, World Wide Fund for Nature (WWF, sub. 28, p. 5) noted that:

> … agricultural activities are not listed as Environmentally Relevant Activities under the Queensland *Environment Protection Act 1994* (other than intensive feedlotting and aquaculture) and therefore the loss of wetlands due to agricultural development does not trigger the provisions of the State Coastal Management Plan.

The *Water Act 2000* is the primary act in Queensland governing the allocation of water between different uses. The Act uses several statutory planning instruments to specify the allocation and use of water (box 3.2).

Box 3.2 **Plans implemented under the Queensland *Water Act 2000***

Water Resource Plans (WRPs) are the central water planning and management instrument under the Act. They are determined on a catchment by catchment basis by the Minister for Natural Resources and Mines (DNRM coordinates the process) in consultation with stakeholders. In addition to determining water allocations within each catchment, WRPs must also address issues related to water volume and quality (s. 47). WRPs have been finalised for the Fitzroy, Burnett and Boyne catchments, with others nearing completion.

Resource Operation Plans (ROPs) specify the operational rules for WRPs including the water and natural ecosystem monitoring practices that will apply in a plan area (s. 72).

Water Use Plans (WUPs) may be prepared for areas where the Minister is satisfied that there are risks that water allocations and use (as determined under a WRP) will cause negative effects on land and water resources including salinity, deteriorating water quality and increasing erosion. Water use plans must specify several factors including the objectives for water use efficiency and monitoring requirements and responsibilities (s. 60).

To be able to use a water allocation for irrigation purposes (as determined under a WRP), individual property managers must prepare **Land and Water Management Plans** (LWMPs) which may include requirements for water quality management.

Source: Water Act 2000, Commonwealth of Australia and State of Queensland (2002).

A key concern with current policies is the large number of disconnected, and not necessarily consistent plans. This led Queensland Fruit and Vegetable Growers

(QFVG, sub. 49, p. 3), the peak body representing the horticulture industry in Queensland, to comment that:

> … QFVG is seeking the development of an integrated sustainability strategy for rural industries in Queensland that overhauls the current approach in which single issues are being tackled through a series of disjointed planning processes.

In addition to statutory regulation and planning, there are several non-statutory water quality programs relevant to water quality entering the GBR lagoon. These include:

- Rural Water Use Efficiency Initiative — a joint DNRM–industry program designed to improve the use and management of available irrigation water for industries such as sugar, dairy, cotton and horticulture;
- grazing land management education — DPI workshops tailored for specific catchments, such as the Fitzroy and Burdekin, to improve awareness of resource management issues and how these relate to property level decision making; and
- State Leasehold Land Strategy — DNRM is in the preliminary stages of reviewing the administration and management of pastoral leases (under the *Land Act 1994*). The strategy is to consider options for improved land management on pastoral leases, such as requiring the use of Property Management Plans as a condition of operating a lease (DNRM 2001c).

Local government

There are 21 local governments with coastal boundaries adjacent to the GBR World Heritage Area and more than twice that number are located further inland, within the catchments from which watercourses flow into the GBR lagoon (GBRMPA 1999).

Local governments are to prepare environmental plans under the *Environmental Protection (Water) Policy 1997* and also have responsibility for development approvals and licensing of several ERAs relevant to water quality (including marinas and poultry farming).

Local governments may also address water quality issues through local council planning and development schemes. For example, the Douglas Shire in North Queensland, in its strategic plan, has placed a strong emphasis on maintaining ecological values, including a cap on urban growth and the further development of tourist and other facilities (River 2000). Similarly, the Hinchinbrook Shire, also in North Queensland, specifies the importance of maintaining ecological values in assessing development applications (Hinchinbrook Shire Council 1997).

Catchment Management Associations

Each catchment in Queensland has at least one Catchment Management Association (CMA). These associations were first developed in 1991 for the policy of Integrated Catchment Management — a community and local government based approach to catchment management. They provide planning, coordination and advisory functions to develop strategies to achieve integrated management of natural resources within a river catchment (Queensland Government 1999).

The associations have direct input to the drafting of WRPs and ROPs (box 3.2) through representation on Community Reference Panels. As such, they are involved in issues such as water quality, sustainable commercial use of river systems, water allocation processes, and environmental flows.

Unlike in other jurisdictions, such as Victoria and South Australia, there is no basis in legislation for catchment management associations in Queensland — they have no statutory powers or support.

River Improvement Trusts

River Improvement Trusts (RITs) were first developed under the *River Improvement Trust Act 1940*. They are based on local government areas and have statutory responsibilities for the provision and maintenance of public flood management and river stabilisation infrastructure, including requiring land users to undertake action for the protection of riparian vegetation. Within the GBR catchment, there are nine trusts located between Port Douglas and Mackay.

North Queensland River Trusts' Association Inc. (NQRTA, sub 47, p. 1) noted that the work of RITs, such as riparian area revegetation, has reduced sediment discharges into the GBR lagoon. The role of RITs in the management of diffuse pollution in the GBR catchment, together with other bodies such as CMAs, is discussed further in chapter 10.

3.3 Policies with unintended water quality impacts

Policies may not always adequately account for their environmental impacts. Perverse incentives and unintended outcomes can reduce the benefits from policy, and in some cases make the community worse off overall (PC 2001a).

In the GBR lagoon and adjacent catchments and coastal areas, some policies may unintentionally provide incentives to reduce water quality. For example, various parties (such as the Nature Conservation Council of New South Wales, sub. 52, p. 6) expressed concerns about the Sugar Industry Infrastructure Package. This is a joint Commonwealth–Queensland initiative which subsidises irrigation, water management, and transport infrastructure used to expand cane growing areas. WWF (2002, p. 1) claimed that:

> The industry expanded rapidly in the 1990s due to the government funded Sugar Industry Infrastructure Package that subsidised the cost of irrigation and drainage schemes. By the year 2000, 400 000 hectares of low-lying coastal land had been converted to cane production.
>
> The expansion of this industry saw the large-scale loss of wetlands, riparian (streambank) vegetation and forests and woodlands in low-lying areas.

As far as possible, such impacts should be considered and accounted for in the process of policy development.

Some graziers in the upper Burdekin catchment expressed concerns to the Commission (pers. comm., 9 September 2002) that drought relief assistance may reduce the incentive for some property managers to conservatively stock their properties during periods of extreme climatic variability. Overstocking can contribute to increased soil erosion and sediment discharges into rivers and eventually into the GBR lagoon.

Certain tax provisions for primary producers may also unintentionally contribute to declining water quality. For example, Landcare tax deductions may be claimed by rural businesses for some types of expenditure to prevent and combat land degradation, including for 'destroying plant growth detrimental to the land' (*Income Tax Assessment Act 1997*). This provision may unintentionally create an incentive for land clearing and the removal of regrowth (Douglas 2002).

3.4 Funding vehicles for MOU actions

The MOU between the Commonwealth and Queensland Governments states that assistance to implement low cost measures to improve water quality will be given via the NAP and the Natural Heritage Trust (NHT).

National Action Plan for Salinity and Water Quality

The NAP is a joint initiative of the Commonwealth, State and Territory governments. It involves a funding package of $700 million over 7 years (2000-01 to 2006-07) from the Commonwealth, matched by States and Territories. In March 2002, the Queensland and Commonwealth Governments signed a bilateral agreement for implementation of the NAP, with each to invest up to $81 million (Commonwealth of Australia and State of Queensland 2002).

The NAP, by targeting water quality in the catchments adjacent to the GBR lagoon, will influence the quality of water entering the lagoon. Among the four investment priority regions identified for the NAP in Queensland, one region is within the GBR catchment — Burdekin-Fitzroy. This region includes the Burdekin, Burnett, Boyne, Fitzroy and Mary catchments (Commonwealth of Australia and State of Queensland 2002).

Delivery of funding to programs in NAP priority regions is to occur through regional natural resource management (NRM) bodies, which are to develop NAP accredited NRM plans. Regional bodies are to have:

> … majority community membership, balancing production and conservation interests, include local government and seek effective participation by all relevant stakeholders including indigenous interests. (Commonwealth of Australia and State of Queensland 2002, p. 10)

The Queensland Government has recognised two existing bodies for the delivery of NRM planning in the Burdekin-Fitzroy region. These are the Fitzroy Basin Association and the Burdekin Dry Tropics Group (Commonwealth of Australia and State of Queensland 2002) (box 3.3).

Regional plans are to address catchment water quality through several actions including the setting of targets for water quality and by developing measures for improving stream and terrestrial biodiversity. Plans must specify how these actions are to be achieved and monitored. Funding to implement an accredited NRM plan 'will be determined on the basis of a Regional Investment Strategy to be developed by the relevant NRM body' (Commonwealth of Australia and State of Queensland 2002, p. 13).

Natural Heritage Trust

The NHT was set up in 1997 as a Commonwealth funding vehicle to help restore and conserve Australia's environment and natural resources (NHT 2002). In 2001, the Commonwealth committed $1 billion to extend the NHT for a further five years from 2002-2003, including $350 million to improve water quality.

Under the delivery programs of Coastcare, Rivercare, Bushcare and Landcare, there are likely to be several activities relevant to water quality in the GBR catchment. For example, the Coastcare Program is to invest in activities that contribute to protecting coastal catchments, ecosystems and the marine environment. Funding for these programs is to occur primarily through accredited, integrated NRM plans that 'will follow, where appropriate, the model developed for the NAP' (AFFA, sub. 53, p. 20).

Box 3.3 Queensland regional bodies for delivery of the NAP

The **Fitzroy Basin Association** is a community based natural resource management organisation (based on a Catchment Management Association) with the role of promoting sustainable development and management in the Fitzroy Basin through Integrated Catchment Management processes. It consists of a Stakeholder Council (responsible for policy setting and overall direction), a Management Committee (responsible for task setting and operational decisions) and general members. Membership of the Stakeholder Council includes representatives from: industry; local government; State government; indigenous; conservation; education and research; and other subregional NRM bodies within the Fitzroy basin.

The **Burdekin Dry Tropics Group** is one of 13 Regional Strategy Groups that were formed in 1999 (in conjunction with the Queensland Government) to allow an interface between government and community to participate in the development of strategic regional approaches to NRM. A membership board is responsible for deciding policy direction. There are nine voting members on the board, comprising primary producers, local government and community interest groups. There are four non-voting members representing the Commonwealth Government, the Queensland Government, the Aboriginal and Torres Strait Islander Commission, and the Great Barrier Reef Marine Park Authority.

Sources: Burdekin Dry Tropics Group (2003); Fitzroy Basin Association (2002).

The regional NRM bodies formed under the NAP and NHT will play a key role in delivering the objectives of the *Reef Water Quality Protection Plan*. These bodies are to prepare regional NRM plans and investment strategies that include setting end-of-river water quality targets aimed at protecting the GBR World Heritage Area (Reef Protection Steering Committee 2002).

3.5 Summing up

This chapter has found that:

- Commonwealth policies target water quality in the GBR lagoon, with limited jurisdiction outside this area;
- Queensland policies target water quality in the catchments and coastal areas adjacent to the GBR lagoon, with limited recognition of links to the lagoon;

- water quality policies currently focus on managing point source discharges, with little control of diffuse source discharges;
- a large number of plans (not necessarily well integrated) are used by governments to manage land and water use; and
- some policies with industry development/assistance objectives could have the unintended effect of reducing water quality in the GBR lagoon.

4 Economic and social importance of the main industries

This chapter outlines the current economic and social importance of the main industries in the GBR lagoon and adjacent catchment at the national, state, regional and local levels. It also contains projections of the future economic importance of the main industries in 2010 and 2020. The statistical boundaries of the lagoon and the catchment are defined in section 4.1. This is followed by a discussion of the key indicators used in the analysis in section 4.2. Section 4.3 reports on the importance of industries in the GBR lagoon and catchment at the state and national levels. The relative importance of individual industries to the whole GBR lagoon and catchment is investigated in section 4.4. This is followed by regional and local analyses in section 4.5. The future importance of industries is discussed in section 4.6 and the key conclusions of the chapter are summarised in section 4.7. Appendix E provides more detail on data sources, industry definitions, and the importance of industries within regions.

4.1 Defining the GBR lagoon and catchment regions

For the purposes of this chapter, the GBR catchment is defined as the five statistical divisions of Far North, Northern, Mackay, Fitzroy and Wide Bay-Burnett specified in the Australian Standard Geographical Classification (ASGC) (ABS 2001a). This broadly corresponds to the GBR catchment (figure 4.1)[1]. Note, however, that the catchment area within the statistical divisions of Darling Downs and South West is excluded from the analysis. Where feasible, statistical division data have been edited to only incorporate activity occurring within the GBR catchment. For the Far North region, mining industry data exclude Weipa and commercial fishing data exclude fisheries in the Gulf of Carpentaria.

[1] The Great Barrier Reef Marine Park Authority (GBRMPA) is not the custodian of the original industry data used to create the maps in this chapter and does not accept any liability for the accuracy or currency of the data (figures 4.1, 4.6, 4.7 and 4.8). The locations of mines and mineral processing, agricultural land use and aquaculture farms in the GBR catchment were provided by relevant Queensland Government agencies.

Source: GBRMPA.

For commercial fishing, the GBR lagoon is divided into five regions according to lines of latitude extending easterly from where statistical division boundaries intersect the coastline.

4.2 Indicators of economic and social importance

There are several indicators which could be used to describe the economic and social importance of industries. However, not all of these are available. The main indicators which are used in this report are defined briefly in box 4.1.

Box 4.1 **Indicators of economic and social importance**

Gross value added is the value of the output produced by an industry, less the value of the inputs the industry used.

Gross value of production is the value of output produced by an industry. This is calculated by multiplying the quantity of output by an average market price.

Employment is the number of persons employed in an industry.

Index of relative socioeconomic disadvantage is an ordinal index calculated by the Australian Bureau of Statistics which measures the socioeconomic disadvantage of geographic areas by considering variables such as income, unemployment and skills.

Economic importance

In this report, the economic importance of an industry is described as that industry's contribution to the total economic activity occurring in the nation, state, region or local area. Two elements of economic activity are reported: the level of production and employment.

The economic importance of an industry can be determined from its *gross value added* (GVA). Broadly speaking, this is the value of outputs produced by an industry less the value of its inputs. In essence, this surplus equates to the sum of incomes earned directly from an industry's production process, including returns to labour and capital.

GVA provides a meaningful basis for the comparison of economic importance across industries, because the sum of the GVA figures for different industries operating in a region represents the total economic activity which occurs in that region. That is, GVA figures can be directly compared with gross domestic product (GDP), to evaluate the proportion of GDP attributable to an individual industry. However, GVA understates the economic importance of an industry to a region, because it excludes the value of inputs produced within the region. Furthermore, GVA figures are not widely available for geographical areas smaller than the state level.

An alternative measure of economic activity, which is available for smaller geographical units, is *gross value of production* (GVP). Broadly speaking, this is the quantity of output produced, multiplied by an average market price. GVP will tend to overstate the economic importance of an industry to a region, because it includes the value of inputs produced outside the region. The problem is most pronounced when analysing a small geographic area which obtains many of its inputs from other regions. Consequently, caution must be exercised when using GVP to compare industries with very different ratios of inputs to outputs. Unlike GVA, the sum of GVP figures for industries in a region does not represent the total economic activity which occurs.

Furthermore, it was not possible to calculate GVP using a consistent pricing methodology for all industries. In particular:

- wholesale prices are used to calculate GVP for sugar, horticulture and beef industries;
- landed prices are used to calculate GVP for commercial fishing and aquaculture industries;
- mine site prices are used to calculate GVP for the mining industry;
- turnover, which is equivalent to sales plus operating revenue, is used to approximate GVP for the mineral processing industry;
- expenditure by tourists is used to approximate GVP for the tourism industry; and
- expenditure by recreational fishers is used to approximate GVP for the recreational fishing industry.

In general, the retail price of a commodity is greater than the price received by the producer (wholesale, landed or mine site prices). Consequently, the reported GVP figures may overstate the economic importance of the tourism, recreational fishing and mineral processing industries (because of the use of retail and retail-equivalent prices) relative to other industries.

Finally, the *number of persons employed* in an industry is also used as an indicator of that industry's economic importance. However, casual and part time employment can be a feature of some industries in the GBR catchment; for example, workers in the hospitality and tourism industry. Similarly, seasonal workers are a feature in agricultural industries such as sugar and horticulture. Consequently, the number of persons employed needs to be interpreted with caution.

Social importance

Many indicators could be used to consider the social importance of an industry. One approach is to consider the definition of wellbeing from the Australian Bureau of Statistics (ABS) system of social statistics. This concept, which is derived from OECD (2001) definitions, is based on aspects of life contributing to wellbeing, such as realisation of personal potential through education, personal safety and protection from crime. Each of these aspects corresponds with a generalised area of concern, which can be measured by various indicators (table 4.1).

Table 4.1 **Concepts of social wellbeing**

Aspects of life contributing to wellbeing	*Areas of concern*	*Indicators of wellbeing*
Support and nurture through family and community	**Family and community**	Social attachment, suicide rate
Freedom from disability and illness	**Health**	Life expectancy, prenatal mortality rate, short and long term disability
Realisation of personal potential through education	**Education and training**	Regular and adult education experience
Satisfying and rewarding work, both economic and non-economic	**Work**	Unemployment, working hours, earnings, leave
Command over economic resources, enabling consumption	**Economic resources**	Income, income distribution, socioeconomic disadvantage
Shelter, security and privacy, through housing	**Housing**	Homelessness, home ownership
Personal safety and protection from crime	**Crime and justice**	Fatal and serious injuries, crime rates
Time for and access to cultural and leisure activities	**Culture and leisure**	Leisure time, participation in leisure time activities

Sources: ABS (2001d); Horn (1993).

The indicators of wellbeing listed in table 4.1 are not, per se, representative of an industry’s social importance in a region. Rather, they enable the measurement of the social wellbeing of a region as a whole. Indicators which could represent an industry’s social importance would measure that industry’s influence on the areas of concern, such as how that industry influences the economic resources of a region.

Examples of industry indicators of social importance, and their relevant areas of social concern, are listed in table 4.2. Indicators have not been identified which relate specifically to the culture and leisure aspect of social wellbeing. However, it should be noted that recreational fishing, by definition, contributes to these aspects of social wellbeing. Similarly, the tourism industry contributes to social wellbeing because local residents, as well as tourists, benefit from the recreational and leisure infrastructure and services associated with that industry.

Table 4.2 **Possible indicators of industry social importance**

Indicator	*Areas of concern*	*Explanation*
Employment by industry, and as proportion of total regional employment	Economic resources; Work; Family and community	An industry is socially important to a region if it accounts for a significant proportion of employment in the region, by providing economic resources, work satisfaction and community linkages.
Average duration of employment in an industry, or employee experience in other industries	Economic resources; Work; Family and community	Employees and residents may have a strong attachment to an industry if people have a long history of employment in that industry. They may also find it more difficult to adjust to industry restructuring.
Median age, by industry	Economic resources; Work; Education and training	Employees may have less capacity to adjust to change by undergoing training if the median age of workers in an industry is high.
Education level attained by those employed in an industry	Economic resources; Education and training; Family and community	Employees may have less capacity to find employment in alternative industries if they have lower education levels or industry-specific skills.
Median household income, by industry	Economic resources; Education and training; Health; Housing	Income enables consumption, including the consumption of education, health and housing goods.
Years of residence, by industry	Economic resources; Family and community	Employees and communities may have less capacity to adjust to change by relocating, if they have been resident in a region for many years.

Unfortunately, a comprehensive data set of the social indicators listed in table 4.2 cannot be obtained from the surveys conducted by the ABS and other organisations. However, where available, these indicators have been used to provide some guidance on the social importance of industries at the regional and local levels. One measure consistently available is the ABS (1998) *Index of Relative Socioeconomic Disadvantage*, which is based on attributes of socioeconomic disadvantage including incomes, unemployment and skills.

Nonmarket values

A limitation of the economic indicators used in this chapter is that they only reflect the value of marketed goods and services produced by the main industries in the GBR lagoon and catchment. The indicators may not fully reflect the relative importance of industries because they do not account for all the values that can accrue to society from the GBR lagoon and catchment — particularly when resources are not used. Nor do they reflect all the social costs that can be associated with industry activity (Driml 1994). These unpriced values are termed nonmarket values — often markets simply do not exist for some values to be priced (box 4.2). Nonmarket values are difficult to quantify and there are considerable variations between estimation techniques, and indeed, estimates. It has not been feasible to estimate the nonmarket values for the GBR lagoon and catchment within the short timetable for this study.

The nonmarket values associated with the use of the GBR lagoon and catchment by Indigenous communities are important. Commission discussions with Indigenous groups highlighted the links between the subsistence and cultural values of GBR coastal resources. For example, North Queensland Land Council (sub. DR60, p. 4) noted that:

> In all coastal regions of Australia, Aboriginal people continue to engage in significant subsistence hunting, fishing and gathering activities in the rivers, seas and on land. For these people, subsistence resources form an important part of the domestic economy. In addition these activities are culturally important and life sustaining.

Box 4.2 **Nonmarket values**

Sources of nonmarket value potentially include:

- use values from ecosystem services — such as the water filtering provided by wetlands and the habitat provided to native species; and
- nonuse values such as existence, option and bequest values.
  - existence values can arise from knowledge that the area is retained in its natural state; and
  - option and bequest values include the future value society may place on the resource.

4.3 National and state importance

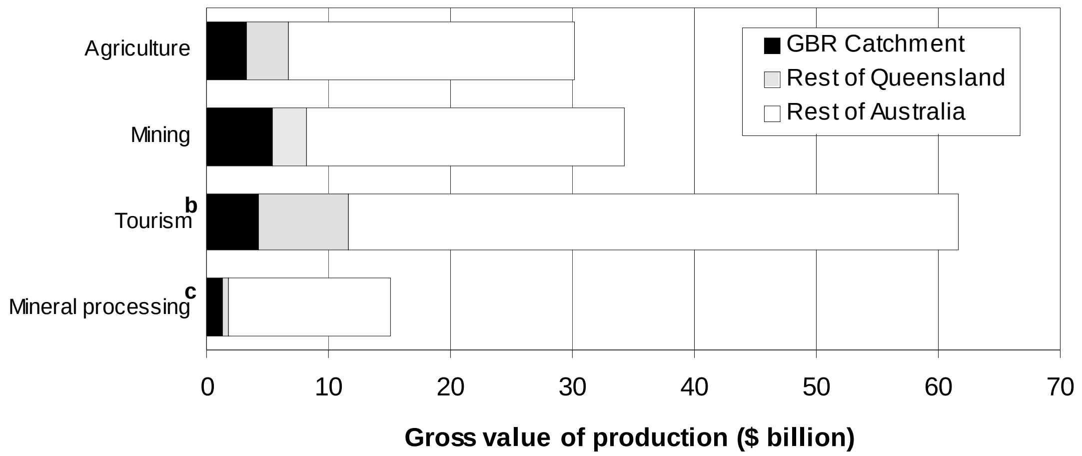
A substantial proportion of the GVP of mining, agriculture and tourism in Queensland and, to a lesser extent, Australia as a whole, is generated within the GBR lagoon and catchment (figure 4.2).

The industries with the highest GVP in the GBR catchment, relative to that for Queensland as a whole, are the mining and mineral processing industries (67 per cent and 76 per cent respectively). The share is lower for agriculture

(47 per cent) and for tourism (36 per cent). Similarly, a high proportion of national mining and mineral processing GVP occurs within the GBR catchment. Mining and mineral processing in the GBR catchment contribute 16 per cent and 12 per cent respectively to the national GVP. Agriculture and tourism in the GBR lagoon and adjacent catchment contribute 11 per cent and 5 per cent respectively to the gross value of national industry production.

Figure 4.1 **Gross value of production by agriculture, mining, tourism and selected processing industries[a]**

1999-00, unless otherwise specified



[a] Gross value of production calculated using wholesale prices (agriculture) and mine site prices (mining); approximated by visitor expenditure (tourism); and turnover (processing). 1996-97 data were used for processing industries. [b] Tourism expenditure for Queensland and the GBR catchment as defined in OESR (2001a) for 1999. Tourism expenditure for Australia as defined in ABS *Australian National Accounts: Tourism Satellite Account*, Cat. No. 5249.0. [c] Refers to ANZSIC industries 2711 (Basic iron and steel manufacturing); 2721 (Alumina production); and 2722 (Aluminium smelting). ANZSIC industry 2723 (Copper, silver, lead and zinc smelting and refining) excluded due to confidentiality restrictions.

Data sources: ABS (unpublished data; *Mining Operations Australia: 1999-2000*, Cat. No. 8415.0; *Manufacturing Companion Data*, Cat. No. 8221.0; *Australian National Accounts: Tourism Satellite Account*, Cat. No. 5249.0); OESR (2001a, c).

As noted previously, value added is a better measure of the economic importance of an industry than GVP. However, value added data are unavailable for most industries below the national level. Comparing the ratio of value added to GVP for different industries at a national level gives some idea of how the GVP overstates the relative contribution of some industries to the economy (table 4.3). Value added estimates for mineral and food processing are less than a quarter of their respective GVP estimates. In contrast, value added for the mining industry is much closer to its GVP — the Queensland Mining Council (sub. 13, p. 3) noted that ‘a very large percentage of the value of mineral production in Queensland is value added’.

However, caution is required in interpreting GVP data since the prices used to estimate the GVP values are not consistent across industries.

Table 4.3 **Ratio of value added to gross value of production**

1999-00, unless otherwise specified

Industry	*Australia*
Agriculture	0.40[a]
Mining	0.70[a]
Mineral processing[b]	0.22[c]
Selected food processing[d]	0.23[c]
Tourism	0.40[e]

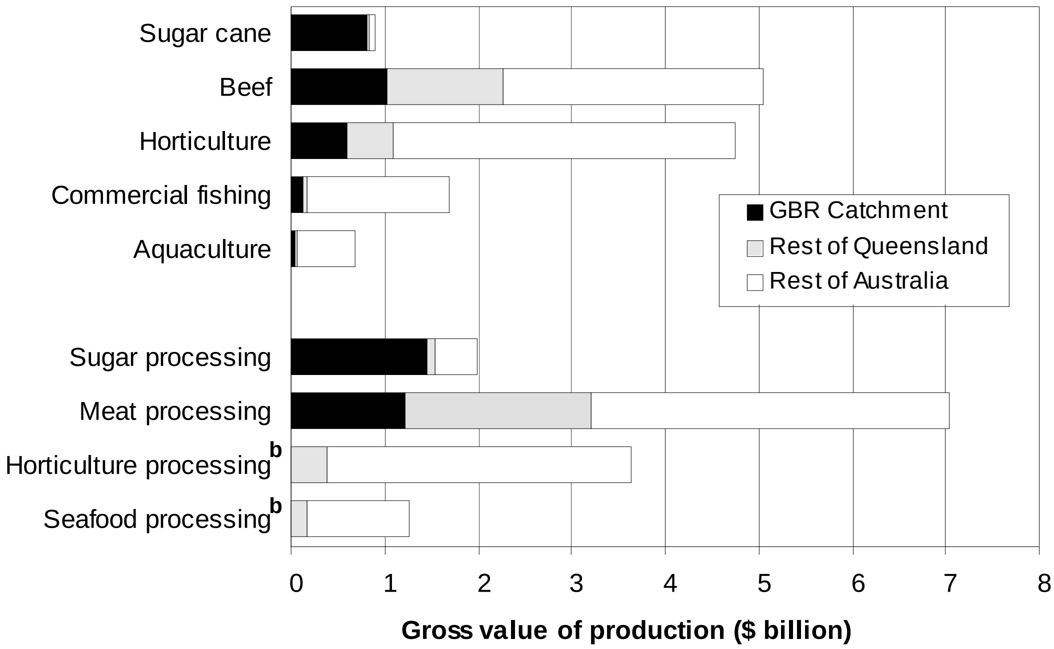
[a] Ratio of industry value added to GVP. [b] Comprises ANZSIC industries 2711 (Basic iron and steel manufacturing); 2721 (Alumina production); and 2722 (Aluminium smelting). [c] Ratio of industry value added to turnover. [d] Comprises ANZSIC industries 2130 (Fruit and vegetable processing); 2111 (Meat processing); 2171 (Sugar manufacturing); and 2173 (Seafood processing). [e] Ratio of Tourism GDP at basic prices to tourism consumption.

Data sources: ABS (unpublished data; *Mining Operations Australia 1999-2000*, Cat. No. 8415.0; *Australian National Accounts: Tourism Satellite Account*, Cat. No. 5249.0; *Manufacturing Industry Australia*, Cat. No. 8221.0 Companion Data); OESR (2001a, b).

In figure 4.3, GVP for agricultural and food processing industries are disaggregated into separate industries. It is evident that the GBR lagoon and catchment account for sizeable proportions of the GVP for most food industries at the state and national level. Nearly all the GVP of both national and state (90 and 97 per cent respectively) sugar cane production occurs in the GBR catchment. The GBR catchment accounts for 45 per cent of the GVP of the Queensland beef industry and 20 per cent of the national industry. Consequently, sugar processing and meat processing in the GBR catchment are also important contributors to the turnover for those industries at the state and national level. Although GBR commercial fishing and aquaculture are important to the GVP of those industries at the state level (68 per cent and 70 per cent respectively), they are much less significant at a national level (7 per cent and 6 per cent respectively).

Figure 4.2 **Gross value of production by food industries**[a]

1999-00, unless otherwise specified



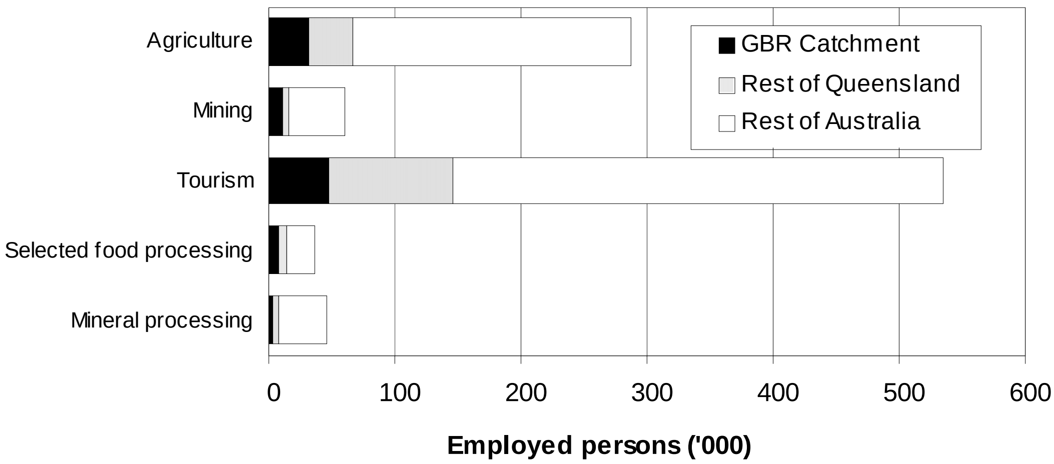
[a] Gross value of production calculated using farm gate prices (sugar cane, beef and horticulture) and landed prices (commercial fishing and aquaculture). Sugar and meat processing data for the GBR catchment was extrapolated from 1996-97 data, by assuming catchment shares of Queensland turnover by processing industries were constant since 1996-97. [b] GBR catchment data for horticulture and seafood processing are included in 'Rest of Queensland' due to confidentiality restrictions.

Data sources: ABS (unpublished data); QFS (unpublished data).

Industries in the GBR catchment are important employers from both a state and national perspective (figure 4.4). For example, people employed in selected food processing industries in the GBR catchment account for 56 per cent of Queensland's and more than 20 per cent of Australia's employment in those industries. People employed in mining in the GBR catchment comprise 66 per cent of Queensland's and 17 per cent of Australia's employment in mining. People employed in the tourism industry in the GBR lagoon and catchment represent 33 per cent of Queensland's and 9 per cent of Australia's employment in tourism.

Figure 4.3 **Employment in agriculture, mining, tourism and selected processing industries[a]**

1999-00, unless otherwise specified

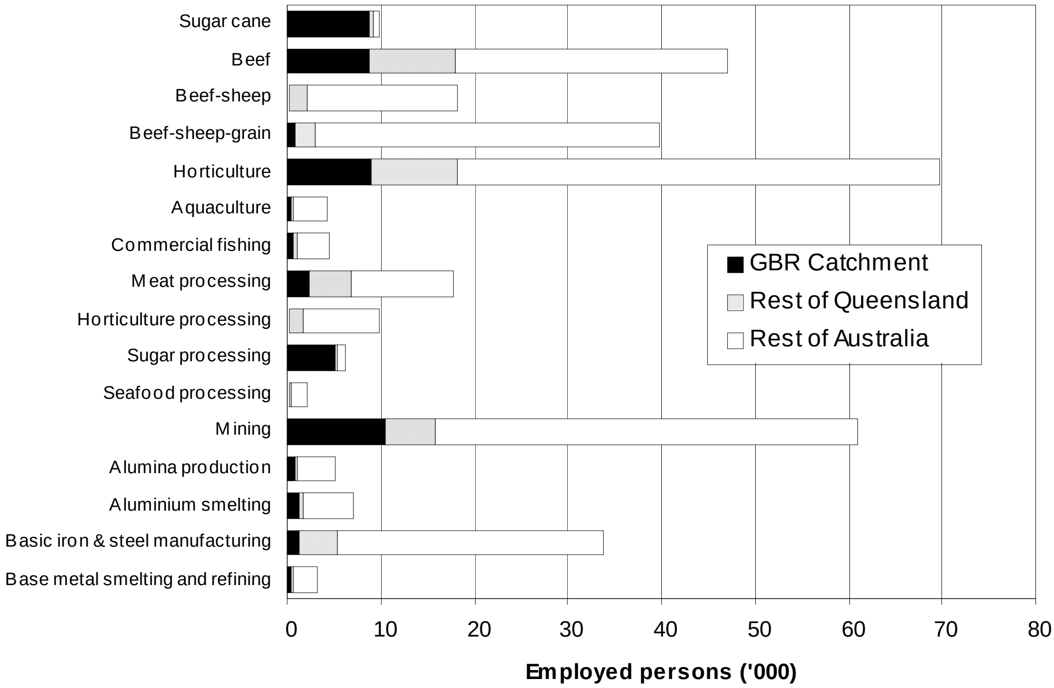


a ‘Selected food processing industries’ refers to ANZSIC industries 2111 (Meat processing); 2130 (Fruit and vegetable processing); 2171 (Sugar manufacturing); and 2173 (Seafood processing). Mineral processing industries refers to ANZSIC industries 2711 (Basic iron and steel manufacturing); 2721 (Alumina production); and 2722 (Aluminium smelting).

Data sources: ABS (unpublished data 2001 Census; *Tourism Satellite Account 2000-01,* Cat. No. 5249.0); OESR (2001a, 2002a).

Similarly, the GBR lagoon and catchment account for a large proportion of Queensland and national employment for the disaggregated industries in figure 4.5. For most of these industries, employment in the GBR catchment represents more than half of total Queensland employment. Most notably, sugar industry (cane growing and processing) employment in the GBR catchment represents almost all that industry’s state and national employment. However, for most of the main industries reported, employment in the GBR lagoon and catchment represents between 10 and 20 per cent of national industry employment.

Figure 4.4 **Employment by industry and region**[a]
Week prior to 7 August 2001



[a] The industries reported in this figure are classified according to ANZSIC (1993). For further information on industry classification refer to appendix E.

Data source: ABS (unpublished data 2001 Census).

4.4 Importance of individual industries to the GBR lagoon and catchment

Gross value of production

Based on estimates in table 4.4, the mining, tourism and agricultural industries have the highest GVP in the catchment. The gross value of minerals produced ($7052 million), in particular coal production ($5969 million), dominates the GVP from the catchment. The Queensland Mining Council (sub. 13, p. 3) noted that:

> The largest single commodity produced in terms of value is black coal, which contributed $6.2 billion or 57 per cent of the total value of minerals. With the exception of the relatively small tonnage produced west of Brisbane this coal is produced from within the Great Barrier Reef catchment area and 118 million tonnes (86% of production) was exported, 98% of which was exported through the ports of Gladstone, Hay Point and Abbott Point, which are also located within the GBR catchment.

Table 4.4 **Economic importance of industries in the GBR catchment**
1999-00, unless otherwise stated

Industry	Gross value of production[a]	*Employed persons*[b] Total	Employees	Employers	Own account workers	Family
	$m	no.	%	%	%	%
Primary production						
Sugar cane	803	8 736	37	25	35	3
Beef[c]	1 017	8 728	34	18	44	4
Horticulture[d]	708	9 006	66	15	17	2
Total agriculture	3 203	32 253	45	19	33	3
Commercial fishing	119	641[e]	39	34	24	3
Aquaculture	38	378	64	13	20	3
Mining[f]	7 052	10 380				
Coal	5 969	7 233	99	0	1	0
Metal ore	na[g]	2 337	97	1	2	0
Oil & gas	na[g]	124	98	2	0	0
Other minerals	1 083[h]	686	92	4	4	0
Processing [i]						
Sugar processing	1 929	5 110	98	1	1	0
Meat processing	765[j]	2 350	97	1	2	0
Horticulture processing	27[k]	307	85	8	6	1
Seafood processing	33[l]	180	84	11	5	0
Mineral processing	1 392[m]	3 918[n]	na	na	na	na
Alumina production	789	940	99	0	1	0
Aluminium smelting	535	1 265	98	1	1	0
Basic iron and steel mfg	68	1 248	83	9	7	1
Base metals	na[g]	465	98	1	1	0
Other						
Recreational fishing	240	na	na	na	na	na
Tourism	4 269[o]	47 660[p]	na	na	na	na
All industries[q]	na	396 581	81	8	10	1

(Continued next page)

[a] Calculated using wholesale prices (beef, horticulture and sugar cane); landed prices (commercial fishing and aquaculture); and mine site prices (mining). Approximated with turnover (processing); expenditure by recreational fishers (recreational fishing); and expenditure by tourists (tourism). [b] Week prior to 7 August 2001. Due to rounding, figures might not sum to 100 per cent. [c] Gross value of production data refer to the commodity-based industry (beef cattle farming). Employment data refer to the ANZSIC industry 0125 (Beef cattle farming). A further 800 employed persons in the GBR catchment are classified under ANZSIC industry 0122 (Grain-sheep and sheep-beef cattle farming) and 129 workers to ANZSIC industry 0123 (Sheep-beef cattle farming). For further information on industry classification refer to appendix E. [d] Comprises fruit-growing and vegetable-growing. [e] Employment data refer to ANZSIC industry 041 (Marine fishing). [f] Gross value of production data refer to 2000-01. [g] Not available due to confidentiality restrictions. [h] Comprises metals, oil and gas, and other mining. [i] Gross value of production data refer to 1996-97. [j] Due to confidentiality restrictions, GVP for the catchment cannot be reported. This figure refers to production in the catchment, plus production by an additional two meat processing locations in the North West statistical division. [k] Due to confidentiality restrictions, GVP for the catchment cannot be reported. This figure refers to production in the catchment, plus production by an additional two fruit and vegetable processing locations in the Darling Downs statistical division. [l] Due to confidentiality restrictions, GVP for the catchment cannot be reported. This figure refers to production in the catchment, plus production by an additional seafood processing location in the Moreton statistical division. [m] Comprises ANZSIC industries 2711 (Basic iron and steel manufacturing); 2721 (Aluminium production); and 2722 (Alumina smelting). [n] Comprises ANZSIC industries 2711 (Basic iron and steel manufacturing); 2721 (Aluminium production); 2722 (Alumina smelting); and 2723 (Copper, silver, lead and zinc smelting and refining). [o] Expenditure by all visitors in 1999. [p] 1998-99. [q] Refers to all workers in the catchment, not only those classified to the industries outlined in the table. **na** Not available.

Data sources: ABARE (2001); ABS (unpublished data 2001 Census); DNRM (unpublished data); QFS (unpublished data).

In 1999-2000, tourism expenditure ($4.3 billion) exceeded the GVP of agriculture ($3.2 billion). Within the agricultural sector, the GVP of beef ($1 billion) exceeded sugar and horticulture. The sugar processing and mineral processing sectors are also significant; each industry had an annual turnover of more than $1 billion.

Fisheries (aquaculture, and commercial and recreational fishing) are among the smaller industries shown in table 4.4. Expenditure by recreational fishers of the GBR lagoon and catchment ($240 million) was estimated to exceed the GVP of both commercial fishing and aquaculture combined ($157 million). In contrast, Fenton and Marshall (2001) estimated the GVP by commercial fishing vessels from GBR ports at more than double the QFS estimate shown in table 4.4. However, there are significant problems with the methodology used by Fenton and Marshall (see appendix E for details).

The downstream processing industries associated with mining and agriculture are also important in terms of GVP. While turnover is likely to overstate the seafood processing industry's significance, it is an important source of employment locally. As noted earlier, care is required interpreting GVP data, due to the potential for double counting and overestimating the importance of industries. This is particularly the case for agricultural and food processing industries. For example, Canegrowers (sub. 34, p. 4) commented that:

> Sugar cane as a stand-alone crop has no commercial value. It is only of value to a sugar mill and must be processed within sixteen hours of being cut. Sugar mills are located in

> the centre of cane growing areas and all sugarcane is therefore processed in the locality where it is grown. The value of the industry should therefore be considered as the gross value of production of the sugar rather than the sugar cane… Sugar mills and sugarcane growing go hand in hand; neither would exist without one another.

The data in table 4.4 for meat, horticulture and seafood processing overstate their relative GVP due to the inclusion of plants outside the GBR catchment.

As noted earlier, value added provides the best measure of the relative economic contribution of an industry. However, given the limited data on food processing industries, the GVP of both the primary and manufacturing sectors are reported where available.

Industry assistance

A limitation of measures such as GVP and GVA is that they can include assistance provided by governments and thereby distort the relative importance of industries. For example, some participants commented that the GVP estimates may overstate an industry's contribution to the economy because of the effect of government assistance (Queensland Seafood Industry Association, sub. 31, p. 10; and Australian Democrats, Senator Andrew Bartlett, sub. 44, p. 4).

The Commission has considerable experience in estimating assistance to industry. Its estimates cover assistance delivered through direct subsidies, budgetary programs, tax concessions, tariffs and statutory marketing arrangements (SMAs). However, they exclude some items such as certain forms of drought relief and the underpricing of infrastructure services. They also focus on assistance that selectively benefits particular industries or activities, rather than covering assistance that applies to all industries or activities.

For this report, the Commission has drawn on its estimates of assistance from tariffs, Commonwealth budgetary outlays and tax concessions, and state SMAs of national significance. This has been combined with information on the size and composition of industries in the GBR catchment, to develop estimates of assistance to the main industries in the catchment. The Commission's methodology is set out in appendix F, and the estimates are summarised in table 4.5. The estimates are 'net' figures in that, as well as counting the assistance that industries receive on their outputs, they also subtract the penalties that assistance to other industries impose on their inputs.

The sugar industry receives the highest level of assistance relative to its GVP from tariffs, Commonwealth budgetary outlays and tax concessions, and state SMAs of national significance (3 per cent in 1999-00, 6.1 per cent in 2000-01 and

4.5 per cent in 2001-02) (table 4.5). Most other industries in the GBR catchment attract measured assistance of less than 2 per cent of their GVP. Both mining and tourism attract negligible rates of assistance.

The Commission also examined budgetary assistance provided by the Queensland Government. However, data limitations prevented the calculation of detailed estimates. Nevertheless, it appears that Queensland budgetary assistance is significant for industries in the GBR catchment, especially for the primary production sector.

Table 4.5 **Measured assistance to selected industries in the GBR catchment**

1999-00 to 2001-02

Commodity/Industry	*NSE*[a]			*NSE*[a] */ GVP*[b]		
	1999-00	*2000-01*	*2001-02*	*1999-00*	*2000-01*	*2001-02*
	$m	$m	$m	%	%	%
Primary production						
Sugar cane	24.0	48.6	36.1	3.0	6.1	4.5
Beef	9.4	9.6	10.5	0.9	0.9	1.0
Horticulture[c]	11.7	12.7	14.7	1.7	1.8	2.1
Total agriculture[d]	79.5	88.3	84.5	2.5	2.8	2.6
Fisheries[e]	2.5	2.5	2.6	1.6	1.6	1.6
Mining[f]	31.7	23.4	19.9	0.4	0.3	0.3
Processing						
Food processing	28.2	21.6	21.8	1.0	0.8	0.8
Mineral processing[g]	10.2	9.8	8.9	0.7	0.7	0.6
Other						
Tourism[h]	7.7	7.9	11.6	0.2	0.2	0.3
All industries	**ne**	**ne**	**ne**	**0.9**	**0.8**	**0.8**

a Net Subsidy Equivalent. NSE estimates in the GBR catchment (for each commodity/industry group other than tourism and other agriculture) are derived by multiplying national NSE estimates by a constant ratio of GVP in the GBR catchment to national GVP. For agriculture and fisheries, mining, and processing commodities/industries, these ratios are based on 1996-97, 1999-00 and 2000-01 production values, respectively. Agriculture has been adjusted to reflect regional characteristics. **b** Gross Value of Production. **c** Comprises fruit-growing and vegetable-growing. **d** Total agriculture estimates have been adjusted to reflect regional characteristics in relation to dairy. **e** Comprises commercial fishing and aquaculture. **f** Comprises coal and other minerals. **g** Comprises ANZSIC industries 2721 (Alumina production), 2722 (Aluminium smelting) and 2711 (Basic iron and steel manufacturing). **h** Preliminary estimates. **ne** Not estimated.

Data source: Commission estimates.

Employment

The tourism industry is the largest source of employment in the GBR catchment (almost 48 000 employed persons) (table 4.4). Collectively, the agricultural industries are also important employers, with around 32 000 employed persons. Although mining is the largest contributor to GVP, it is a relatively small employer compared to tourism and agriculture with about 10 000 employed persons.

A feature of the agricultural and fishing industries is the relatively high proportion of ‘own account’ workers (people who operate their own business or engage in a profession but do not hire employees) compared to other industries. The agricultural and fishing industries also have the highest percentage of family members working for the family business. In the mining and processing industries, employed persons are primarily employees.

Historical trends

The GVP data presented in table 4.4 do not represent the economic importance of the industries over time. The measures are a snapshot of the industry in 1999-2000 and consequently do not show variability that can occur from year to year or the relative growth of particular industries over time. Appendix E provides detailed times series of GVP for the major industries in the GBR catchment. The data highlight that the GVP of particular agricultural industries can be more variable than other industries. For example, the beef industry in the GBR catchment experienced relatively poor years in 1996, 1997 and 1998. Sugar cane GVP peaked between 1995 and 1998 and more recently has dropped back to early 1990s levels. In contrast, the gross value of mining industry production has increased substantially since 1997, although in percentage terms its growth has been moderate since the late 1990s. Similarly, the importance of the tourism industry in the GBR catchment has increased. Tourism expenditure has grown consistently faster over the last decade than other industries.

Age and education

In the GBR catchment, the median age of persons employed is highest in the agricultural industries (particularly sugar cane and beef, at 47 years) (table 4.6). Canegrowers (sub. 34, p. 6) noted:

> Anecdotal information points to an ageing if not old cane growing population. Canegrowers has undertaken a number of grower surveys since 1991 and in each case, the ‘decision maker’ was asked to respond to a phone survey. The average age of these decision makers has been between 49 and 52 over six years to 1999.

> It does appear that ownership is a separate issue, with the ability or willingness of the 'older' owner to sell or pass over the property limited by a number of factors. These may include willingness to sell, availability of finance for the younger grower, and the ability of the property to support the level of debt necessary to acquire the property. Anecdotal reports indicate that there is an absence of younger persons prepared to assume farming responsibilities.

The median ages in the mining and mineral processing industries are among the lowest. In general, processing industries tend to have employed persons with the lowest median ages. For meat processing, in 1996, 51 per cent of employed persons were less than 35 years of age (PC 1998). Meat processing employed persons were also likely to be male, not educated above secondary school level but with some accredited industry competency, and slightly more mobile than in other industries (PC 1998).

Education levels of employed persons vary considerably across industries in the GBR lagoon and catchment. Most employees in agricultural, commercial fishing and food processing industries are educated to between Year 9 and Year 11. In comparison, the proportion of employed persons in the mining industry holding a certificate or diploma is much higher. Aquaculture and some industries associated with mining have more tertiary educated employed persons than other industries.

Data are limited on the characteristics of people employed in tourism in the GBR lagoon and catchment. However, at the national level, the Industry Commission (1996) found that the tourism workforce had a relatively high proportion of young and female employees; a high proportion of part time (casual) employment; relatively low levels of formal education; and high labour mobility.

Table 4.6 **Age and education characteristics of employed persons in the GBR catchment**

7 August 2001, unless otherwise stated

		Level of education completed[a]				
Industry	*Median age*	*Year 8 or below*	*Year 9, 10 or 11*	*Year 12*	*Certificate or Diploma*[b]	*Tertiary*[c]
	years	%	%	%	%	%
Primary production						
Sugar cane	47	20	46	11	21	2
Beef[d]	47	19	46	14	17	5
Horticulture	41	13	48	16	19	4
Total agriculture	45	17	47	14	19	4
Commercial fishing[e]	41	9	43	11	35	2
Aquaculture	38	6	28	20	29	17
Mining						
Coal	40	7	30	11	44	8
Metal ore	38	4	29	12	40	15
Oil & gas	40	5	17	15	51	12
Other minerals	40	9	39	12	33	7
Processing						
Sugar processing	42	8	28	15	44	5
Meat processing	33	8	47	17	25	2
Horticulture processing	39	8	51	17	21	3
Seafood processing	41	12	50	20	17	2
Mineral processing						
Alumina production	41	4	24	8	49	15
Aluminium smelting	37	2	30	14	45	8
Basic iron & steel mfg	37	3	26	14	55	2
Base metals	31	4	16	25	43	11
Other						
Recreational fishing	na	na	na	na	na	na
Tourism	na	na	na	na	na	na
All employed persons[f]	**39**	**6**	**34**	**18**	**30**	**12**

[a] Excludes employed persons still studying, or who did not clearly answer relevant questions on Census paper. Due to rounding, figures might not sum to 100 per cent. [b] Employed persons who have completed diploma, advanced diploma or certificate studies. [c] Employed persons who have completed bachelor, graduate diploma, graduate certificate, masters or postgraduate studies. [d] Employed persons categorised to ANZSIC industry 0125 (Beef cattle farming). Excludes employed persons categorised to ANZSIC industries 0122 (Grain-sheep and grain-beef cattle farming) and 0123 (Sheep-beef cattle farming). [e] Employed persons categorised to ANZSIC industry 041 (Marine fishing). [f] Refers to all employed persons in region, not only those classified to the industries detailed in this table. **na** Not available.

Source: ABS (unpublished data 2001 Census).

Income and household characteristics

For each industry, median income levels of individuals and their households are summarised in table 4.7. People working in mining and mineral processing have the highest median individual and household incomes, with employed persons in the coal industry earning $78 000 per annum in August 2001. Employed persons in agriculture have the lowest median individual and household incomes, with horticulture employed persons earning an average of $20 623 per annum. Employed persons in the commercial fishing, aquaculture and food processing industries tend to have median individual and household incomes that range between those in the mining and agricultural industries.

Reflecting the more mobile nature of workers in the industry, a higher proportion (around 30 per cent) of employed persons in the mining industry (particularly oil and gas) in the GBR catchment had moved region in the five years up to August 2001. In contrast, more than 90 per cent of employed persons in the sugar industry (both sugar cane growing and processing) resided in the same statistical division as in 1996.

Working hours

People employed in mining and some mineral processing industries, followed by those in the beef and sugar industries, generally worked longer hours than people in the other main industries (table 4.8). In contrast, people employed in commercial fishing and seafood processing were more likely to work less than 15 hours per week. People employed in the processing industries were more likely to work between 35 to 40 hours per week, but also had a wider distribution of working hours than other industries.

Caution is required in interpreting these data, because they are only for a certain point in time (the date of the 2001 Census — 7 August). The snapshot nature of the data does not demonstrate the likely short term, seasonal and/or annual variation within individual industries. For example, sugar processing employment is subject to seasonality, with more casual employees engaged during peak harvest in the dry season.

Table 4.7 **Income and household characteristics of employed persons in the GBR catchment**

7 August 2001, unless otherwise stated

Industry	*Median annual income*		*Same Statistical Division of residence in 1996*[a]
	Individual	*Household*	
	$	$	%
Primary production			
Sugar cane	21 947	37 218	96
Beef[b]	22 669	38 339	86
Horticulture	20 623	35 332	82
Total agriculture	21 598	37 111	88
Commercial fishing[c]	28 087	50 513	85
Aquaculture	26 856	45 240	69
Mining			
Coal	78 000	91 369	77
Metal ore	62 100	72 065	68
Oil & gas	65 565	76 266	56
Other minerals	38 487	54 122	79
Processing			
Sugar processing	33 659	49 208	93
Meat processing	31 759	49 229	77
Horticulture processing	22 731	41 339	80
Seafood processing	23 183	40 039	83
Mineral processing			
Alumina production	58 747	71 328	86
Aluminium smelting	51 718	65 447	74
Basic iron & steel mfg	32 487	52 404	85
Base metals	43 008	60 258	74
Other			
Recreational fishing	na	na	na
Tourism	na	na	na
All industries[d]	**27 623**	**49 920**	**80**

a Excludes employed persons who did not state place of residence five years previously. **b** Employed persons categorised to ANZSIC industry 0125 (Beef cattle farming). Excludes employed persons categorised to ANZSIC industries 0122 (Grain-sheep and grain-beef cattle farming) and 0123 (Sheep-beef cattle farming). **c** Employed persons categorised to ANZSIC industry 041 (Marine fishing). **d** Refers to all employed persons in region, not only those classified to the industries detailed in this table. **na** Not available.

Source: ABS (unpublished data 2001 Census).

Table 4.8 **Distribution of hours worked in the GBR catchment**[a]

Week prior to 7 August 2001, unless otherwise stated

Industry	*Less than 15 hours*	*16-34 hours*	*35-40 hours*	*41 hours or more*
	% of employed persons	% of employed persons	% of employed persons	% of employed persons
Primary production				
Sugar cane	8	8	17	67
Beef[b]	8	9	17	66
Horticulture	10	21	31	38
Total agriculture	9	12	21	58
Commercial fishing[c]	24	16	15	45
Aquaculture	11	10	29	50
Mining				
Coal	5	3	18	74
Metal ore	10	3	11	76
Oil & gas	19	3	12	67
Other minerals	7	6	22	65
Processing				
Sugar processing	2	3	51	45
Meat processing	7	9	54	30
Horticulture processing	13	19	33	35
Seafood processing	29	21	25	25
Mineral processing				
Alumina production	4	2	34	60
Aluminium smelting	5	3	18	74
Basic iron & steel mfg	7	6	44	44
Base metals	7	1	34	58
Other				
Recreational fishing	na	na	na	na
Tourism	na	na	na	na
All industries[d]	14	19	32	35

a Due to rounding, figures might not sum to 100 per cent. **b** Employed persons categorised to ANZSIC industry 0125 (Beef cattle farming). Excludes employed persons categorised to ANZSIC industries 0122 (Grain-sheep and Grain-beef cattle farming) and 0123 (Sheep-beef cattle farming). **c** Employed persons categorised to ANZSIC industry 041 (Marine fishing). **d** Refers to all employed persons in region, not only those classified to the industries detailed in this table. **na** Not available.

Source: ABS (unpublished data 2001 Census).

4.5 Distribution of output and employment across GBR regions

The economic and social importance of the main industries varies across regions within the GBR catchment. Some industries are more concentrated in particular geographical areas — reflecting more suitable climate and natural resource endowments than other areas — whereas others are diffuse. For most industries, regional shares of employment broadly correspond to the regional shares of GVP. Where they diverge, some commentary is provided. Summaries of the regional GVP and employment levels of industries are provided in appendix E.

Mining

The major coal fields of the Bowen Basin dominate mining deposits in the GBR catchment (figure 4.6). Most mines in the basin are concentrated in the Fitzroy and Mackay regions, which collectively produce more than 80 per cent of the GVP of mining in the GBR catchment (table 4.9). Most of the remaining small proportion of coal production is attributable to the Northern region. The other feature of the mining industry in the GBR catchment is the GVP from 'other mining', particularly in the Far North and Northern regions (table 4.9). Most of this is attributable to gold and base metals (such as copper, tin, silver and zinc). These mines are dispersed throughout the upper catchments of the Far North and Northern regions. The Far North region produces 94 per cent of Queensland's gold output (ACIL Consulting 2002).

However, the Queensland Mining Council (sub. 13, p. 4) observed that:

> While much of the mining of other mineral commodities takes place outside the GBR catchment area (eg Mt Isa and Weipa) a very large percentage of these minerals are either transported into the catchment for further processing or for export through Townsville.

As with mining, particular regions, and more especially towns, are associated with certain types of mineral processing (figure 4.6). For example, ACIL Consulting (2002) noted that Townsville has emerged as a major mineral processing centre for the Far North and Northern regions, with Townsville Copper Refinery and Yabulu Nickel Refinery being major processors (also see table 4.9). Alumina and aluminium processing is only located in the Fitzroy region (table 4.9). The Gladstone Alumina Refinery (which transforms bauxite into alumina) and the Boyne Island Aluminium Smelter represent the vast proportion of the gross value of mineral processing in the Fitzroy region (the Parkhurst Magnesia Plant near Rockhampton is nevertheless important). Basic iron and steel manufacturing is important in the Mackay region. Some caution is required in interpreting the value of production for mineral processing because the data are for turnover in 1996-97. Nevertheless, 2001 employment shares broadly match the value of production shares.

The Queensland Mining Council (sub. 13, p. 5) highlighted the importance of mining to regional communities in the GBR catchment:

> A number of communities within the catchment have been established by mine activity, examples being Moranbah, Dysart, Tieri, Middlemount, Glenden. Many other regional communities are underpinned by mining and downstream infrastructure and processing. Charters Towers, Blackwater, Emerald and Gladstone are examples of these.

Tourism

Tourism is the predominant industry in the Far North region which accounts for more than 40 per cent of the value of tourism expenditure in the GBR lagoon and catchment (table 4.9). Cairns, the regional centre of the Far North region, is a major tourist transport hub. The Cairns Port Authority (sub. 43, p. 1) noted that Cairns has the fifth busiest international airport in the country, and with almost 34 000 visiting passengers in 2001 was the second largest cruiseliner port after Sydney. The Authority also observed that 737 000 passengers departed on reef trips from the Cityport area in 2000. Correspondingly, the Far North region also has by far the largest share of tourism employment, with more than 40 per cent of all tourist industry employed persons in the GBR lagoon and catchment (table 4.10). The Mackay region was the next largest location of tourism expenditure, accounting for nearly 20 per cent of expenditure and 16 per cent of employment. The Northern and Wide Bay-Burnett regions account for lower levels of expenditure but similar levels of employment. The Fitzroy region has the lowest share of tourist expenditure (10 per cent) and employment (13 per cent) in the GBR catchment.

Sources: GBRMPA; ACIL Consulting (2002).

Table 4.9 **Distribution of the gross value of production across regions**[a]

1999-00, unless otherwise stated

Industry	*Far North*	*Northern*	*Mackay*	*Fitzroy*	*Wide Bay-Burnett*	*Total*
	%	%	%	%	%	%
Primary production						
Sugar cane	20	37	27	0	16	100
Beef	11	10	12	43	23	100
Horticulture[b]	40	27	0	5	28	100
Other agriculture	19	3	8	43	27	100
Commercial fishing	46	16	17	15	6	100
Aquaculture	32	41	10	1	16	100
Mining[c]	6	11	41	40	2	100
Coal	0	7	46	45	2	100
Other mining	43	36	0	16	5	100
Processing[d]						
Sugar processing	17	na[e]	34	0	na[e]	100
Meat processing	na[e]	na[e]	na[e]	45	22	100
Horticulture processing	na[e]	na[e]	na[e]	na[e]	na[e]	
Seafood processing	na[e]	na[e]	na[e]	na[e]	na[e]	
Mineral processing						
Alumina production	0	0	0	100	0	100
Aluminium smelting	0	0	0	100	0	100
Basic iron & steel mfg	na	na	24	17	na	100
Base metals	0	100	0	0	0	100
Other						
Recreational fishing	30	23	15	9	23	100
Tourism	43	15	19	10	13	100

a Gross values of production were calculated using wholesale prices (agriculture, beef, horticulture and sugar cane); landed prices (commercial fishing and aquaculture); and mine site prices (mining). Gross values of production were approximated with expenditure by visitors (tourism); expenditure by recreational fishers (recreational fishing); and turnover (processing industries). Due to rounding, figures might not sum to 100 per cent. **b** Due to high standard errors, calculations excluded value of fruit in the Mackay region. **c** 2000-01. **d** 1996-97. **e** Suppressed due to confidentiality restrictions. **na** Not available.

Data sources: ABS (unpublished data); DNRM (unpublished data); QFS (unpublished data); OESR (2001c).

Table 4.10 **Distribution of employment across regions**

7 August 2001, unless otherwise stated

	Far North	*Northern*	*Mackay*	*Fitzroy*	*Wide Bay-Burnett*	*Total*[a]
	%	%	%	%	%	%
Primary production						
Sugar cane	21	30	30	0	18	100
Beef[b]	10	9	16	36	29	100
Horticulture	36	6	13	6	39	100
Other agriculture	22	13	18	17	30	100
Commercial fishing	36	13	7	13	30	100
Aquaculture	52	12	8	5	23	100
Mining	10	13	41	31	5	100
Coal	1	1	56	40	3	100
Metal ore	36	48	3	4	9	100
Oil & gas	13	0	16	50	21	100
Other minerals	22	22	10	34	12	100
Processing						
Sugar processing	22	29	28	0	21	100
Meat processing	7	11	10	54	18	100
Horticulture processing	26	16	13	6	38	100
Seafood processing	27	8	6	19	40	100
Mineral processing	7	20	5	61	7	100
Alumina production	2	0	0	97	1	100
Aluminium smelting	2	2	1	91	4	100
Basic iron & steel mfg	24	21	15	26	17	100
Base metals	2	96	0	1	1	100
Other						
Recreational fishing						
Tourism[c]	41	15	16	13	16	100
All employed persons[d]	**24**	**21**	**15**	**19**	**20**	**100**

[a] Due to rounding, figures might not sum to 100 per cent. [b] ANZSIC industry 0125 (Beef cattle farming). [c] 1998-99. [d] Refers to all employed persons in regions, not only those classified to industries specified in this table. **na** Not available.

Source: ABS (unpublished data 2001 Census).

Sugar cane and processing

Sugar production is primarily located on the narrow coastal plains and the rich river flats of many of the lower catchments of the GBR. Canegrowers (sub. 34, p. 2) observed that the industry 'was historically the main driver of settlement along the coast of Queensland'. It is found from Mossman in the north to Maryborough in the south, but is absent from Plane Creek to almost Bundaberg (figure 4.7). There are 24 sugar mills in the GBR catchment, with seven in the Far North region, six in the Northern region, six in the Mackay region, and five in the Wide Bay-Burnett region (Canegrowers 2001).

Most of the GVP from sugar cane growing is concentrated in the Northern (37 per cent) and Mackay (27 per cent) regions, with the Far North and Wide Bay-Burnett regions contributing the remaining 36 per cent (table 4.9). The industry is absent in the Fitzroy region. The distribution of employed persons also broadly corresponds to the distribution of GVP (table 4.10). Reflecting the concentration of sugar cane growing and processing in particular geographical areas within the catchment, Canegrowers (sub. 34, p. 7) highlighted the importance of the sugar industry to local towns, such as Innisfail, Tully, Ingham, Ayr and Home Hill, Proserpine and Mackay.

Beef

The beef industry is widespread across the GBR catchment. In general, beef grazing occurs inland of the coastal plains that are dominated by sugar cane and horticulture, and often in the upper catchment areas. The industry is most concentrated in the open plains and valleys of the Fitzroy basin. Over 40 per cent of the GBR catchment's beef GVP and 36 per cent of beef employment is attributable to the Fitzroy region (tables 4.9 and 4.10). Rockhampton — the regional centre — is widely known as the 'Beef Capital of Australia'. Several major abattoirs are located in the Fitzroy region. For example, Australia Meat Holdings Limited (sub. 21, p. 1) highlighted its major export facility in Rockhampton. Wide Bay-Burnett is also an important beef producing region, with around 20 per cent of beef industry GVP. The Mackay, Northern and Far North regions have similar GVPs, and account for the remainder of the industry. However, estimates for the Far North region are likely to overstate significantly the GVP in the Far North region of the GBR catchment, because they include output from the tropical savanna country in the Gulf region.

Source: GBRMPA.

Horticulture

Horticulture is more geographically concentrated than beef and is generally found in highly localised areas where sufficient labour, fertile and arable soils, and high rainfall or irrigation combine to enable intensive cropping. Table 4.11 summarises the horticulture districts and the types of fruit and vegetables grown. The Far North region generates 40 per cent of the gross value of horticulture production and the Northern and Wide Bay-Burnett regions are important to a lesser extent (table 4.9). Horticulture appears to be largely absent from the Fitzroy and Mackay regions. However, grapes and fruits are grown near Emerald and pineapples and other fruits near Yeppoon. There is some variability between the GVP and employment shares (particularly for the Northern, Mackay and Wide Bay-Burnett regions), with the industry in the Northern region being a substantially less important employer than the GVP share would suggest (table 4.10). This may reflect the types of horticulture included in the two measures (GVP excludes nuts and cut flowers but they are included in the employment data). Variations may also reflect differences in the labour intensities of crops produced in different regions.

Table 4.11 **Fruit and vegetable growing districts in the GBR catchment, by region**

Growing district	*Fruit types*	*Vegetable types*
Far North		
Atherton Tableland	Mangos, avocados, lychees, pawpaw, exotic fruit	Potatoes
Tully-Innisfail	Bananas, lychees, pawpaw, exotic fruit, melons	
Northern and Mackay		
Burdekin-Bowen	Mangos, melons	Tomatoes, capsicums, cucumbers, eggplant
Fitzroy		
Yeppoon	Pineapples, mangos, exotic fruit	
Rockhampton	Grapes, melons, pawpaw, mangos	
Emerald	Citrus, grapes	
Wide Bay-Burnett		
Bundaberg	Melons, lychees, mangos, avocados, pineapples, bananas, citrus	Tomatoes, capsicums, zucchini, cucumbers
Central Burnett	Citrus, stone fruit, grapes	
Gympie	Mangos	Curcurbits, beans

Source: Queensland Fruit & Vegetable Growers (sub. 49, p. 10).

Although many horticulture enterprises are family farms, most rely on seasonal workers to assist with harvesting. The Queensland Fruit & Vegetable Growers (sub. 54, p. 4) note that horticulture has:

> … a symbiotic relationship with the tourism sector as over 3000 holiday makers work in the fruit and vegetable industry each year and spend much of their earnings on tourist activities.

Other agricultural industries

Other agricultural industries are significant in specific regions within the GBR catchment. For example, the Atherton Tableland dairying area is important to the Far North region. In 2000-01, the turnover of the Dairy Farmers Co-operative milk and cheese processing plant at Malanda was $100 million (Dairy Farmers 2002). Similarly, in the Fitzroy region, dryland and irrigated crops and fibres are important. Cotton Australia (sub. 48, p. 2) estimated the gross value of cotton production alone in the Fitzroy region (from the Emerald, Dawson Valley and Biloela growing areas) at $121 million in 2000-01.

Aquaculture

Aquaculture farms are dispersed along the GBR coastal region (figure 4.8) and are generally located in the estuary and coastal lake systems. Most of the major prawn and barramundi farms are located between Cairns and Townsville. GBRMPA (sub. 27, p. 11) noted that:

> The aquaculture industry is a relatively young industry in the GBR catchment and still in an expansion phase. There are currently 40 licensed aquaculture operations adjacent to the Great Barrier Reef World Heritage Area. Operations include pond and tank based aquaculture for finfish and crustaceans as well as hatcheries.

Prawns comprise the vast majority of the gross value of aquaculture production. The Australian Prawn Farmers Association (APFA) (sub. 45, p. 5) observed that:

> In 1999-2000, production of aquaculture in Queensland reached $54 million. Prawn farming has historically been of great significance to the aquaculture industry in Queensland and is presently estimated to contribute approximately 75 per cent of total aquaculture production.

However, with respect to GBRMPA's claim that aquaculture is in an expansion phase, APFA (sub. DR59, p. 1) argued that industry growth has come from 'existing farms using entitlements which were granted many years ago'. APFA also noted that 'there has been only one new prawn farm, approved and operating in the past three years'.

Sources: GBRMPA; QFS (unpublished data).

Species that comprise the remainder of the gross value of aquaculture production include barramundi (10 per cent), with redclaw crayfish, silver perch, oysters, pearl oysters and fish hatcheries having very minor shares. The APFA (sub. 45, p. 6) also highlighted the high GVP achieved per hectare of prawn farming ($104 000 GVP/hectare) compared to other industries such as grazing ($12 GVP/hectare).

According to Queensland Fisheries Service (QFS) estimates, the Far North and Northern regions account for more than 70 per cent of the GVP of the relatively small but growing aquaculture industry (table 4.9). The remainder of the industry is located in the Wide Bay-Burnett (16 per cent) and Mackay (10 per cent) regions. Little aquaculture occurs in the Fitzroy region. Employment shares vary among regions (table 4.10). However, given the small number of people employed in aquaculture in the GBR catchment and lagoon (378 employed persons)(table 4.4), only minor variations in employment levels would result in major share differences.

Commercial and recreational fishing

The Far North accounts for almost half the GVP of commercial fishing in the GBR lagoon. The Northern, Mackay and Fitzroy regions (each with similar shares) together account for most of the remainder of the GVP (table 4.9). Only about 6 per cent of the GVP of commercial fishing in the GBR catchment is derived from the small Wide Bay-Burnett region of the lagoon.

Most commercial fishers are located in the Far North region, followed closely by Wide Bay-Burnett (table 4.10). This broadly corresponds with QFS estimated shares of regional employment based on the port of origin of fishing vessel crews. The high employment in Wide Bay-Burnett relative to the GVP from the Wide Bay-Burnett region of the lagoon reflects the fact that Wide Bay-Burnett commercial fishers operate in other regions of the lagoon and south of the eastern boundary of the GBR World Heritage Area. The 2001 Census estimates of commercial fishing employment are higher than QFS estimates because of the ‘point in time’ nature of the Census (see appendix E).

Recreational fishing is an important lifestyle activity for residents and visitors to the GBR lagoon and catchment. The QFS estimated expenditure on recreational fishing in the GBR lagoon and catchment at $240 million in 1999-2000 (almost half the total spent on recreational fishing in Queensland). The Far North region had the largest share of the expenditure (30 per cent) (table 4.9). The Northern and Wide Bay-Burnett regions had lower but similar shares, of around 23 per cent. The fourth largest expenditure occurred in the Mackay region (15 per cent), while the Fitzroy region had the smallest share, with 9 per cent.

Commission discussions with Indigenous groups highlighted the cultural and economic importance of the GBR fishery to local Indigenous communities. The North Queensland Land Council (sub. DR60, p. 4) observed that: ‘the sea, like the land, is integral to the identity of each Aboriginal persons and Aboriginal people have a kin relationship to important animals, plants, tides and currents’. For example, the hunting of sea turtle and dugong have been an important part of the traditional lifestyle of many communities in the Far North region. The North Queensland Land Council (sub. DR60, pp. 3–4) noted:

> Aboriginal people do not distinguish between natural and cultural resources. Dugong, mullet, shellfish, crabs, turtle, along with fish, crustaceans and reptiles are killed for food, and are part of a continuum of Aboriginal culture that binds the life of humans, animals, earth, sea, past and present. …
>
> Modern dependence on subsistence resources involving traditional activities such as hunting for turtle and dugong are widely practiced. This food is shared among the extended families of the community and represents a continuation of a true subsistence economy. The use of traditional food sources is very important to the maintenance of health, life and culture of Aboriginal communities.

There are few data on the extent of use of the fishery by Indigenous individuals and groups.

Unemployment and relative socioeconomic disadvantage

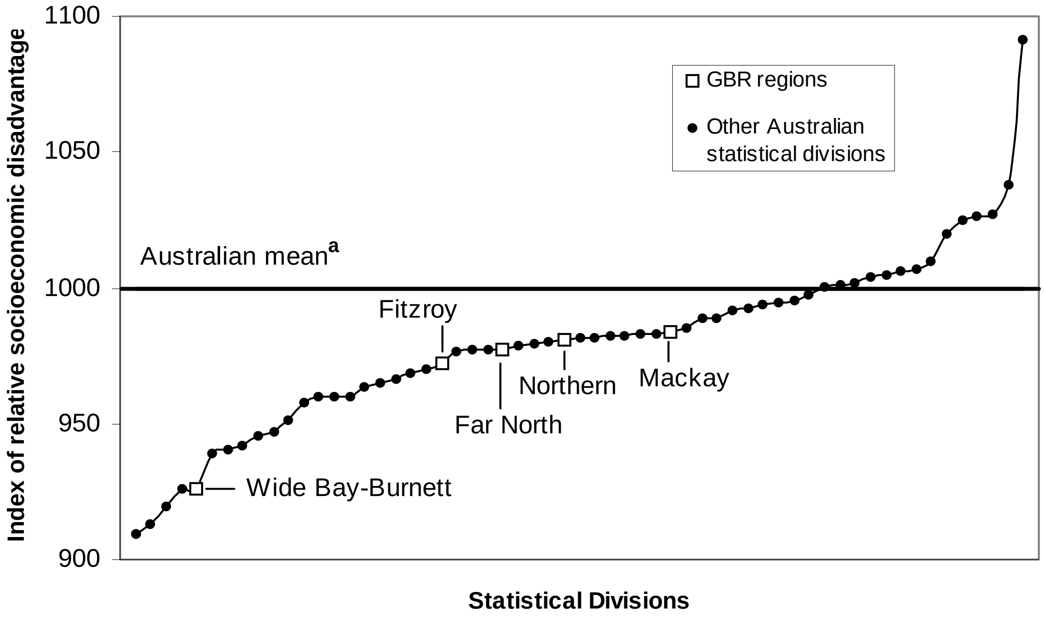
In the week before the 2001 Census, the unemployment rate in Wide Bay-Burnett (11.7 per cent) was higher than in the GBR catchment as a whole (8.6 per cent), Queensland (8.6 per cent) and Australia (7.4 per cent) (ABS unpublished data). In comparison, the Mackay region had the lowest unemployment rate (7.3 per cent) in the GBR catchment. The Fitzroy and Northern regions had the highest levels of annual household and individual income in the catchment.

According to the ABS (1998) based on the index of relative socioeconomic disadvantage, all five regions in the GBR catchment had a lower level of socioeconomic wellbeing than the average (1000) (figure 4.9). The index is disaggregated to local government areas in appendix E and highlights pockets of relative disadvantage within the five regions.

The Wide Bay-Burnett region (926) was the most disadvantaged region in the GBR catchment according to the index. Only four of the other 58 statistical divisions in Australia had a lower level of socioeconomic wellbeing. In comparison, the Mackay region (984) was the least disadvantaged region in the GBR catchment, with 23 statistical divisions in Australia having a higher index. Indices for the other regions were Northern (980), the Far North (978) and Fitzroy (972).

Figure 4.5 **Socioeconomic disadvantage in GBR regions relative to other Australian statistical divisions**

Based on 1996 Census



[a] Averaged over all collection districts in Australia. A collection district is roughly equivalent to a small group of suburban blocks in urban areas. In urban areas it comprises on average about 250 dwellings, while in rural areas it usually contains fewer. In 1996, there were 34 500 collection districts throughout Australia.

Data source: ABS (unpublished data).

4.6 Future economic importance of industries

This section contains projections of the future economic importance of the main industries in the GBR catchment. The projections were supplied by the Australian Bureau of Agricultural and Resource Economics (ABARE). Three sets of projections (base case, high and low) were produced for each main industry to reflect different possible scenarios for future economic growth. This section focuses on the base case projections — detailed information on the projections is provided in appendix G.

The projections should be interpreted with caution, since they depend on assumptions that are subject to considerable uncertainty. While they provide useful background, the projections are not the basis for developing or assessing policy options in this study. This is because an industry's projected economic importance is not an appropriate criterion for deciding which land users should or should not abate diffuse pollution entering the GBR lagoon. As noted in later chapters, abatement options should be selected on the basis of their effectiveness in reducing threats to reefs and associated ecosystems, and their cost per unit reduction of those threats. These criteria are not necessarily related to industry size.

As with any projection exercise, the estimates depend on underlying assumptions that are subject to considerable uncertainty. For example, the key macroeconomic variables (including world and Australian economic growth and exchange rates) may alter considerably over the period. Similarly, although the estimates assume that producers continue current management practices, and consumers' tastes and preferences follow current patterns, these factors may also change over time.

ABARE's projections were derived by modelling each industry separately, rather than considering industry growth within the economy-wide framework of a dynamic computable general equilibrium (CGE) model. The main advantage of a CGE approach is that it can take account of interactions between industries over time. However, the sectoral approach was selected because no 'off the shelf' CGE model was readily available with the required sectoral and regional detail. While some existing CGE models could be modified to include the required industries and regions, it is very unlikely that this could have been done within the short timetable for this study. For example, it would be a major task to overcome the lack of consistent industry data at a sufficiently disaggregated geographic level. In contrast, since many of the main industries are concentrated regionally, an advantage of the sectoral approach is that detailed local sectoral insights could be incorporated.

The Commission hosted a workshop attended by interested parties in Brisbane in late November 2002 to receive feedback on the projections. Two consultants (Dr Peter Chudleigh of Agtrans Research and Mr Bill Cummings of Cummings Economics) were engaged to present critical reviews of ABARE's methodologies and results. Both discussants broadly supported ABARE's methodologies, and agreed with the direction and magnitude of the growth forecasts.

Given the general agreement by discussants and participants with ABARE's approach, only a limited number of changes were made to the projections published in this study's draft report. Most notably, tourism forecasts were revised in response to international events which are likely to significantly affect the tourism industry. In addition, improvements were made to the transparency of the forecast methodologies by describing ABARE's models.

Gross value of production

The mining industry in the GBR catchment is projected to remain a substantial industry, even though its GVP is projected to fall slightly (figure 4.10, table 4.12

and table 4.14). The GVP of the mineral processing industry — currently the second largest industry — is projected to increase by 36 per cent from 2001 to 2020. The already significant tourism industry is projected to become relatively more important, as its GVP increases by more than 50 per cent by 2020.

The GVP of the major agricultural industries in total (sugar, beef and horticulture) is projected to remain substantial — GVP in each industry is projected to grow by between 1 and 2 per cent per annum over the forecast period. The GVP growth rates of the sugar and horticulture industries are projected to exceed that of the beef industry, but the GVP of the beef industry is projected to remain the largest, in absolute terms.

Commercial and recreational fishing and aquaculture are projected to remain relatively small compared to other major industries. The GVP of commercial fishing is projected to fall, while expenditure by recreational fishers is projected to increase marginally. The GVP of the aquaculture industry is expected to almost quadruple by 2020, by which time the industry is projected to be double the size of commercial fishing.

Employment

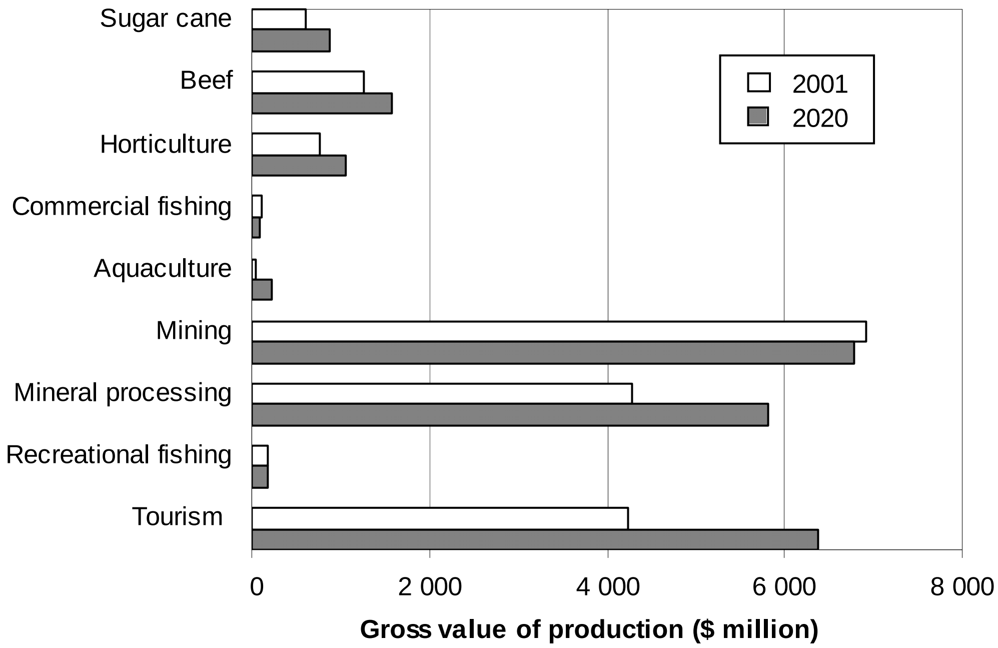
The projected patterns of change differ for employment.

Employment is projected to decline in most industries as labour productivity increases more rapidly than output (figure 4.11, table 4.13 and table 4.14). Exceptions are aquaculture, horticulture production and processing, and mineral processing. Note also that tourism employment is not projected because of data limitations. Nevertheless, tourism is likely to remain a major employer, given the projected increase in tourist expenditure of more than 50 per cent from 2001 to 2020.

The horticulture industry is projected to increase in importance as a major employer (outstripping mining) as its employment grows by 33 per cent, while employment in most other industries contracts. Nevertheless, the mining and mineral processing industries are projected to remain important employers, even though mining employment is projected to decline by almost 20 per cent with mineral processing employment projected to expand by more than 40 per cent. Both commercial fishing and aquaculture are projected to remain relatively small employers.

Figure 4.6 **Projected gross value of production in GBR catchment and lagoon[a]**

2001 and 2020



[a] Base case. In constant 2000-01 prices. Calculated using wholesale prices (sugar, beef and horticulture); landed prices (commercial fishing and aquaculture); mine site prices (mining); turnover (mineral processing); expenditure by recreational fishers (recreational fishing); and expenditure by visitors (tourism).

Source: ABARE projections.

Figure 4.7 **Projected employment in the GBR catchment and lagoon**[a]
2001 and 2020

a Base case.

Source: ABARE projections.

Table 4.12 **Projected gross value of production by industries in the GBR catchment[a]**

Industry	Low		Base case		High	
	2010	2020	2010	2020	2010	2020
	$m	$m	$m	$m	$m	$m
Primary production						
Sugar cane	575	594	816	883	1 053	1 140
Beef	1 394	1 544	1 401	1 571	1 409	1 600
Horticulture	787	814	888	1 060	981	1 350
Commercial fishing	87	69	111	93	138	122
Aquaculture	82	194	98	225	118	279
Mining	6 814	6 392	6 928	6 777	7 194	7 571
Other						
Mineral processing	3 919	4 113	5 208	5 813	6 474	6 835
Recreational fishing	224	207	189	189	209	228
Tourism	4 667	5 803	4 878	6 367	5 098	6 983

a In constant 2000-01 prices; rounded to the nearest whole number. Calculated using wholesale prices (sugar, beef and horticulture); landed prices (commercial fishing and aquaculture); mine site prices (mining); turnover (mineral processing); expenditure by recreational fishers (recreational fishing); and expenditure by visitors (tourism).

Source: ABARE projections.

Table 4.13 **Projected employment by industries in the GBR catchment**

Industry	Low		Base case		High	
	2010	2020	2010	2020	2010	2020
	no.	no.	no.	no.	no.	no.
Primary production						
Sugar cane	6 743	5 641	7 754	6 769	8 607	7 514
Beef	na	na	7 097	6 560	na	na
Horticulture	11 225	11 784	12 282	14 250	13 159	16 853
Commercial fishing	1 280	965	1 400	1 100	1 382	1 129
Aquaculture	1 071	2 396	1 098	2 518	1 126	2 645
Mining	10 321	9 230	10 496	9 783	10 665	10 392
Processing						
Sugar processing	3 946	3 301	4 538	3 962	5 037	4 397
Meat processing	na	na	na	na	na	na
Horticulture processing	82	98	89	119	102	163
Mineral processing	3 817	4 205	5 072	5 944	6 305	6 988

na Not available.

Source: ABARE projections.

Table 4.14 **Projected industry output and employment growth rates for the GBR catchment[a]**

Industry	2001 to 2010 Output	2001 to 2010 Emp.	2010 to 2020 Output	2010 to 2020 Emp.	2001 to 2020 Output	2001 to 2020 Emp.
	%	%	%	%	%	%
Primary production						
Sugar cane	32	-11	8	-13	43	-23
Beef	12	-5	12	-8	25	-12
Horticulture	16	14	19	16	38	33
Commercial fishing	-6	-17	-16	-21	-21	-35
Aquaculture	139	160	130	129	449	495
Mining	0	-12	-2	-7	-2	-18
Processing						
Sugar processing	na	-11	na	-13	na	-23
Meat processing	na	na	na	na	na	na
Horticulture processing	na	29	na	34	na	72
Seafood processing	na	na	na	na	na	na
Mineral processing	21	25	12	17	36	46
Other						
Recreational fishing	1	na	0	na	1	na
Tourism	15	na	31	na	51	na

a Base case. In constant 2000-01 prices; rounded to the nearest whole percentage value. **na** Not available.

Source: ABARE projections.

4.7 Summing up

Mining, tourism and agriculture are the most significant of the main industries in the GBR catchment. However, all the main industries investigated are individually important to particular regions and local economies within the catchment. This importance can vary in terms of GVP and employment.

The mining and mineral processing industries are concentrated in the Northern, Mackay and Fitzroy regions. These industries have very large GVPs but relatively small numbers of employees, who are generally young, well educated and well paid.

Tourist expenditure within the GBR catchment is relatively large, particularly in the Far North region, compared to the value of output of most industries. The tourist industry is a major employer in coastal areas of many regions. In general, people employed in tourism are relatively young, more mobile, are part time and have relatively low levels of education and pay compared to other industries.

The main agricultural industries (sugar cane, beef and horticulture) are very significant locally in terms of GVP and employment. Sugar cane is important in all the regions except the Fitzroy region, while beef is important in all the regions but most important in the Fitzroy region. Horticulture is important in the Far North, Northern and Wide Bay-Burnett regions. In general, people employed in agricultural industries in the GBR catchment are older, and have lower levels of education and income than most other industries.

Similarly, food processing industries (sugar, beef, horticulture and seafood) are very important locally (particularly in towns where major processing plants operate) in terms of GVP and employment. People employed in the food processing industries are generally younger, more mobile and better paid than people employed in the associated primary industries.

The commercial fishing and aquaculture industries are relatively small in terms of GVP and employment but are nonetheless important, particularly to the major coastal towns with port access to the GBR lagoon. People engaged in commercial fishing are generally older and have lower levels of education and income than the small number of people engaged in aquaculture. Recreational fishing expenditure is also relatively small but is recognised as an important lifestyle activity for residents and visitors to the GBR lagoon and catchment. The GBR fishery also has significant cultural and economic importance to local Indigenous communities.

Projections prepared for this report indicate that tourism and mineral processing could be expected to increase substantially in the GBR catchment between 2001 and 2020. Base case projections indicate that tourism expenditure would be likely to increase by around $2.1 billion (growth of over 50 per cent), and the gross value of production by the mineral processing industry could rise by about $1.5 billion (growth of 36 per cent). In contrast, little growth is in prospect for the value of mining production in the GBR catchment. The gross values of production of sugar cane, beef, horticulture, commercial fishing and aquaculture (combined increase of $1 billion) are expected to remain much smaller than that of tourism, mining and mineral processing. Nevertheless, the gross values of production of beef and sugar cane — two of the most significant sources of discharges into the GBR lagoon — are projected to expand by 25 and 43 per cent respectively between 2001 and 2020.

5 Current management practices

In this chapter, the current management practices of several industries that may influence water quality entering the GBR lagoon are discussed. Industries covered are beef, sugar cane, horticulture and, to a lesser extent, cotton and dairy. These industries can have significant impacts on water quality entering the GBR lagoon (chapter 2), but are subject to few policies to control or discourage discharges (chapter 3). Other industries and activities that may impact on water quality, but which contribute less to overall pollution loads and are typically quite heavily regulated, are discussed in appendix H.

The aim of this chapter is to highlight key management practices currently used and how these can impact on water quality. Because quantitative information on the water quality impact of different practices is scarce, this discussion is generally qualitative. Where possible, comments are made on how extensively particular practices are adopted, and the rationale for their adoption. A summary of water quality concerns, possible causes and management practices is provided at the end of the chapter (drawing on information in appendix H as well as this chapter).

5.1 Beef

The grazing of cattle for beef production is the largest single use of land in the GBR catchment, with approximately 4.5 million cattle grazed (GBRMPA 2001c). GBR catchments with significant cattle numbers include the Burdekin, Fitzroy, Burnett, Burrum and Kolan basins.

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Most beef production in the GBR catchment occurs in what is referred to as the 'northern cattle region' of Australia, where cattle are grazed primarily on native grasses and plants on large stations (DPI 2001b; NLWRA 2001a). Some cattle, however, are grazed on improved pastures (sown or oversown with preferred grasses or legumes). In a few areas, particularly coastal regions, cattle are also grazed on improved pastures produced under shallow water retained behind low earth walls (referred to as ponded pastures). In addition to grazing systems, some beef cattle are placed in feedlots where they are hand or machine fed (particularly to 'finish off' cattle before slaughter). The management practices for feedlot systems are distinct from those of grazing and are discussed separately in Appendix H. A significant amount of beef also comes from the dairy industry (section 5.4).

Potential water quality impacts

Beef production can affect water quality in a number of ways, including through:

- woodland removal and vegetation clearing, particularly in riparian areas;
- overgrazing and soil disturbance by cattle;
- cattle access to waterways; and
- applying fertilisers and herbicides to pastures.

Current management practices

Management practices for the grazing of beef cattle across the GBR catchment vary significantly. Most obviously, management practices vary between grazing on unimproved and improved pastures. Significant variations also exist within systems. In native pasture based grazing systems, for example, variations can reflect regional differences in soils, pasture species, topography and climate. Although these differences may be most clearly seen across catchments, significant differences can occur within catchments and within individual properties. Management practices can also vary depending on the scale of operation, and the different philosophies, resources and skills of the property manager.

Land clearing

Land clearing for grazing activities is often seen as a possible contributor to sediment and nutrient runoff. It has been estimated that the average clearing rate for Queensland was 577 000 hectares (or 0.33 per cent of Queensland's land area) per year between 1999–2000 and 2000–2001, with approximately 94 per cent of woody vegetation change attributed to clearing for pasture (DNRM 2003). These figures include the clearing of native vegetation, disturbed areas of native vegetation, regrowth, plantations of native and exotic species, and domestic woody vegetation. Although approximately half the land clearing in Queensland between 1999–2000 and 2000–2001 occurred in the Murray Darling Basin, considerable clearing was located within the GBR catchment. In particular, 16 per cent of the total clearing in Queensland occurred in the Fitzroy catchment, with another 16 per cent in the Burdekin catchment (DNRM 2003).

The impact on water quality of land clearing for grazing, however, is unclear because increased grass and herbage cover can compensate for the loss of tree cover. Some studies, for example, have shown that native woodlands generate higher runoff and soil movement than areas of well maintained pasture (McIvor et al. 1995). There is evidence, however, that the removal of trees can disturb local hydrological regimes, and that this may result in increased salinity (DNR 2000).

Another potential effect of land clearing may be on soil acidification as cleared woody vegetation decomposes or is burnt (DNR 2000). Some graziers try to manage these potential impacts by allowing woody vegetation to remain or regrow in certain areas (which can also provide shade for cattle), along with maintaining good pasture cover (Allingham, T., grazier, Charters Towers, pers. comm., 8 September 2002).

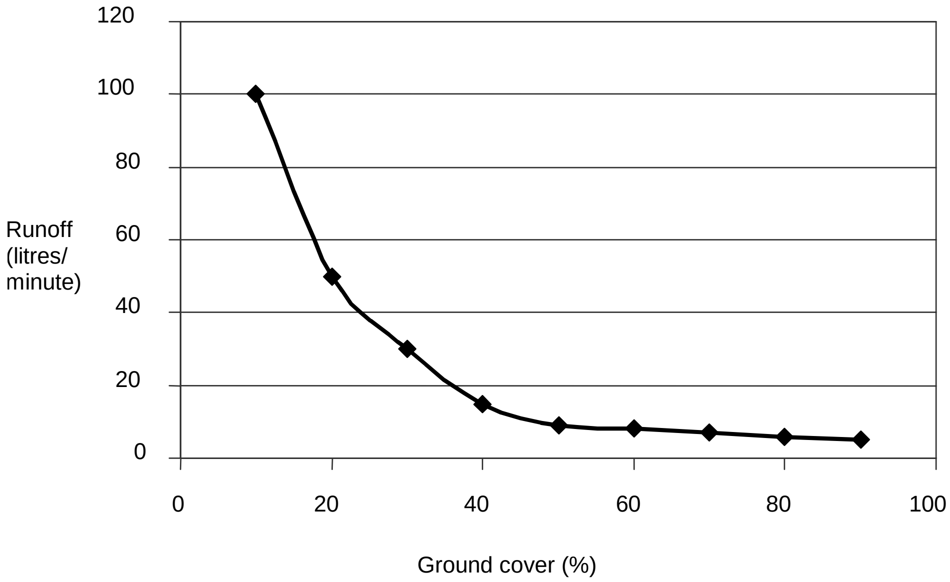
Methods of clearing can influence the consequences of land clearing. Killing trees by stem injections of herbicides, for example, can result in understorey populations of seedlings and multi-stemmed suckers being left untouched. The establishment of introduced grasses, however, often means soils are cultivated after initial clearing to remove competition from existing vegetation. This can restrict natural regrowth and the build up of woody vegetation. (DNR 2000)

The clearing of native vegetation is currently regulated under the *Land Act 1994* (Qld) for most leasehold tenures, and the *Vegetation Management Act 1999* (Qld) for freehold land. Both Acts require approval for land clearing (except in the case of regrowth vegetation or sustainable forest harvesting) (DNR 2000). Other controls exist, such as those provided under the *Water Act 2000* which covers the clearing of beds and banks of watercourses.

Ground cover

Managing ground cover (through trees and/or pasture) has been identified on many occasions as critical in influencing erosion levels, sediment and nutrient runoff, and salinisation (CSIRO 2002a; AgForce, sub. 33, p. 4). Plant cover can intercept and absorb the energy of falling rain drops, impede the flow of runoff water and thereby increase infiltration, and resist the erosive force of flowing water (McIvor et al. 1995). Research in the Burdekin catchment, for example, has found that suspended sediment losses are low if at least 60 per cent of grass cover is maintained, but increase dramatically when cover drops below 60 per cent (AgForce, sub. 33, p. 4). McIvor et al. (1995) and Ash and Quirk (2001) also report that runoff can increase at an accelerating rate as ground cover declines (figure 5.1).

Figure 5.1 **The relationship between ground cover and runoff**
An example from north-east Queensland grazing lands



Source: Ash and Quirk (2001).

Managing ground cover is not an easy task, and needs to take account of spatial and temporal variations in land condition and type, as well as climate (Ash and Quirk 2001). Management activities include:

- conservative grazing pressure on pastures to maintain healthy pasture;
- adequate distribution of water, food and shelter for cattle;
- control of weeds and pests through integrated pest management; and
- reclamation of degraded land and maintenance of riparian zones and conservation areas.

Rotating paddocks or 'spelling', such that paddocks are rested to allow pasture to recover after being grazed, can be an important part of managing healthy pastures and keeping good ground cover (Tropical Savannas CRC 2002). Although spelling is often done in the wet season (when grass regrowth is high), some graziers spell a portion of their paddocks all year round (Landsberg 2002); often for use as a fodder bank or for dry season burning to control woody weeds and regrowth.

Spelling can be used to alter the species composition of pastures and allow preferred vegetation to build up. In some areas, spelling in the wet season combined with heavier grazing in the autumn period can prevent young grass from being overgrazed. Spelling can also offer graziers flexibility during a drought by giving cattle access to rested land. Some graziers are also adopting cell grazing where grazing patterns are managed to mimic nature, with heavy grazing for a short period followed by a long recovery period.

The ability of land owners to spell a paddock depends in part on their fencing network, watering points, and climatic and economic circumstances. In north-east Queensland, most properties have their borders fenced, but internal fencing is limited (Tropical Savannas CRC 2002). However, Natural Heritage Trust (NHT) funding for fencing appears to be improving pasture management (Three Rivers Landcare Group, Ewan, pers. comm., 9 September 2002).

Managing pasture utilisation rates (the proportion of forage grown each year that is consumed by livestock) is another key factor in maintaining pasture cover. This depends in large part on stocking rates (area per animal). 'Sustainable' stocking rates vary across landscape and pasture type, and from year to year reflecting weather conditions. In the Coastal Burnett region, rates have been given as 1.6 to 2.0 hectares per adult for well maintained sown pastures, while for native black speargrass they are between 2.8 and 4.0 hectares per adult (DPI 2000). However, DPI (2000) noted that actual stocking rates for both sown and native pastures were generally above recommended sustainable rates. In areas around Charters Towers in the Burdekin catchment, conservative stocking rates are estimated at around 6 hectares per adult on good pasture and soils, or closer to 10 for more moderate quality areas (O'Reagain, P., DPI, Charters Towers, pers. comm., 9 September 2002).

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Conservative stocking combined with spelling, for example, can allow paddocks to maintain good pasture cover even in drought conditions (Allingham, T., grazier, pers. comm., 8 September 2002). Providing for flexibility in stocking levels (through destocking, buying or agisting, for example), and the judicious use of supplementary feeding practices, can also help manage grazing pressure, particularly in highly variable climates.

A study undertaken in north-east Queensland (titled Ecograze) found two grazing strategies that were effective in maintaining perennial grasses in pastures that were in good condition:

- continuous grazing at a 25 per cent utilisation rate; and
- spelling pasture for the first six to eight weeks of the wet season and then utilising up to 50 per cent of the pasture (Ash and Quirk 2001).

Beef producers need to provide cattle with adequate access to water and shelter. Having a good spread of watering points can help distribute cattle and achieve more even grazing across paddocks. Spreading supplementary feeding points can have a similar effect. Stock also need shelter, such as shade camps during hot weather and timbered areas in cold weather. Providing cattle with access to riparian zones as a source of water may, however, increase soil and vegetation disturbance, erosion and compaction, which can increase sediment and nutrient runoff. It may also directly increase nutrient concentrations from cattle urine and faeces. Management practices to address these concerns include providing off–stream watering points, fencing and/or revegetating riparian zones, laying rocks or gravel down at key access points to minimise erosion, and conservative stocking rates.

The management of pasture composition, weeds, pests and degraded land may also have implications for water quality. Fertiliser application in intensively managed areas, for example, may be washed or leached into waterways or groundwater. Fertiliser application may also change plant species compositions, with commensurate effects on both ground and surface water quality. On the other hand, thicker pasture from fertiliser application may lead to less soil erosion.

While the application of fertilisers may give rise to water quality concerns, very little fertiliser is applied to beef pastures in North Queensland (Fertilizer Industry Federation of Australia (FIFA), sub. 32, p. 5). Sown pastures are more likely to receive fertiliser application than native pastures (DPI 2000). Optimising fertiliser applications through monitoring pasture and soil condition can help minimise nutrient runoff and leaching to groundwater.

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Native pastures can also be managed by the use of fire. This can remove old and low quality growth, make new growth more accessible to stock, as well as control woody and herbaceous weeds. In addition, fire can reduce the effects of patch grazing by encouraging the use of the whole pasture, and helps prevent wild bush fires. The net efficacy of burning has been questioned, however, at least for some areas:

> Since we stopped burning, areas of bare ground are reducing dramatically … We (also) have more variety of grasses etc co-existing in our paddocks. (Atkinson, K., sub. 11, pp. 2-4)

Burning can also leave land more vulnerable to erosion, at least during large rainfall events (McIvor et al. 1995).

Pastures may be renovated through mechanical disturbance, such as with a plough. This can mobilise nitrogen and other nutrients in the soil humus, improve water infiltration, and provide a rough seed bed for grass and legume seedlings to establish (DPI 2000). Renovation can also provide some short-term benefits to

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problems of soil compaction. In addition, graziers may restore slumping or eroding river or creek banks through revegetation and/or restricting cattle access.

Managing pests, such as wild donkeys, pigs or rabbits, may also be undertaken. Wild pigs, for example, can play havoc with riparian areas, digging holes and reducing land cover. Fencing cattle off from riparian zones under these circumstances may not provide the benefits sought if pig disturbance is not tackled.

Graziers may also directly manage riparian zones by building sediment trapping wetlands (NLWRA 2001a) or conservation areas. These zones may provide the additional benefit of a reserve of fodder in times of severe drought, easing pressure on other areas. Graziers may also exclude stock from degraded areas.

Other management activities

Other management activities undertaken by graziers include planning, monitoring and training. Planning activities can include developing property plans which address water, vegetation and land management issues. Monitoring activities include the monitoring of pasture composition and ground cover to determine stocking rates, paddock rotations, pasture spelling, weed control and land reclamation requirements. 'GRASS Check' is a tool that is increasingly being used by graziers to help monitor pastures (DNRM 2001b).

Mapping land condition and use is underway in several areas. The Tropical Savannas CRC and National Land and Water Resources Audit (NLWRA) in the Burdekin catchment, for example, are mapping to identify areas that require particular management practices (AgForce, sub. 33, p. 4). In addition, the Tropical Savannas CRC is developing remote and ground based methods for monitoring land condition for producers to use at paddock and property levels to manage stocking rates (AgForce, sub. 33, p. 4).

While the adoption rates of various management approaches are not comprehensively documented, national estimates provided by ABARE (cited in NLWRA 2001a) show that:

- over 40 per cent of beef producers maintained areas of conservation value;
- over 20 per cent adopted formal monitoring of vegetation and pasture condition;
- almost 70 per cent maintained vegetation cover along drainage lines; and
- almost 40 per cent excluded stock from degraded areas.

In addition, a 1999 survey of beef producers in central Queensland found around two–thirds practised 'pasture monitoring or in-field checking', or used some form of ‘strategic spelling, cell grazing or time control grazing’. Industry extension officers in central Queensland have also reported an increase in pasture monitoring. Further, over one-third of the surveyed beef producers took part in activities such as property management planning, FutureProfit workshops and GRASS Check between 1996 and 1999. Over the same period, around half had taken part in Landcare/catchment field days or similar (NLWRA 2002b).

The variable (although perhaps improving) adoption of sustainable grazing practices appears to be supported by the Commission’s experience on site visits, and from submissions received as part of this study:

> Grazing systems are not always based on practices to improve and retain a good perennial base, nor are they as flexible as they might be to accommodate annual droughts and more exceptional events. (NLWRA, sub. 3, p. 3)

To date, the adoption of management practices in grazing systems to help improve water quality appears to be driven largely by land managers’ own economic incentives not to lose too much top soil, and (perhaps to a lesser extent) to demonstrate clean and green production (Shepherd, B., DPI, Charters Towers, pers. comm., 9 September 2002). Some graziers definitely hold the view that healthy ecosystems (grasses, soils, water and nutrients) can make a property more profitable.

Economies of scale may, however, impact on some graziers’ ability both physically and financially to graze conservatively and adopt other environmentally beneficial practices (Matthews, E., grazier, pers. comm., 9 September 2002). Management skills have also been seen as impacting on management practices adopted, with more informed and skilled graziers likely to adopt practices more consistent with the long term sustainability of the land (Allingham, T., grazier, pers. comm., 8 September 2002). Further, some participants argued that research which discovers and demonstrates productivity benefits from sustainable practices are important in the adoption of management practices (for example, Matthews, E., grazier, pers. comm., 9 September 2002). Extension officers from DPI, and local Landcare and industry groups, may similarly influence adoption.

As noted above, the Vegetation Management Act and Land Act can influence land clearing practices. The Land Act also contains provisions to allow DNRM to intervene if significant degradation is being caused and lessees fail to take remedial action (although these provisions have not been used to date).

5.2 Horticulture

The horticulture industry in Queensland produces over 120 types of fruit and vegetables along with cut flowers and nursery products. Around 3700 farms grow horticultural products across the state. In general, the average size of land holdings is relatively small, with many farms growing a range of crops. Horticulture production is seasonal in nature and requires more intensive use of farm inputs, such as fertilisers, water and labour, compared to other agricultural industries.

Much of Queensland's horticulture production occurs in the GBR catchment, due to favourable coastal climates, fertile soils, and access to irrigation and markets. The main crops grown in the catchment include bananas, pineapples, mangos, lychees, and tomatoes (GBRMPA 2001c). Considerable production is clustered in the south-east between Gympie and Rockhampton, and further north between Gumlu Bowen and Mossman (QFVG 2002a).

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Potential water quality impacts

Despite important product and regional differences in production processes, a number of core activities are common to growing horticultural produce. These include the preparation of land, drainage, irrigation (with around 95 per cent of the industry using irrigation), application of fertilisers, and weed and pest management control. Horticulture production may therefore impact on water quality through:

- clearing vegetation, including the thinning of riparian vegetation which can make waterways vulnerable to weed infestation, bank erosion and greater exposure to the natural elements such as heat from the sun;
- soil erosion and soil structure decline from soil cultivation, including potential cultivation of acid sulphate soils;
- irrigation which can lead to the runoff of sediments, nutrients and pesticides; possible soil salinity, rising water tables and water logging; and saltwater intrusion in coastal aquifers. Drainage from acid sulphate soils can induce the movement of sulphuric acid, iron and aluminium into streams and rivers;
- off-site movement of fertilisers, pesticides and herbicides during heavy rainfall and/or if poorly applied; and
- inappropriate storage or disposal of chemicals and their containers.

There are, however, differences in the nature and extent to which the production of different horticulture products may affect water quality. Banana production, for example, often involves using relatively large amounts of nitrogen fertiliser per hectare, and frequently occurs on steep slopes in elevated areas. Similarly, some crops form better ground cover than others, which can assist in minimising runoff during flood events.

Current management practices

Production practices for growing horticulture produce can vary considerably. Most obviously, there are differences between the production of annual crops, such as lettuce and potatoes, and perennial crops, such as bananas, berry fruits and nuts. There are also differences depending on the scale of operation, and the management approach, resources and skill levels of producers. Guidelines and 'best practice' recommendations exist for a range of crops, including an overarching code titled *Farmcare Code of Practice for Sustainable Fruit and Vegetable Production in Queensland* (QFVG 1998).

Key management practices currently adopted by some horticultural growers that can reduce harm to water quality include:

- land use planning, including consideration of land use suitability and farm layout;
- reduced tillage, and the use of cover crops and mulching to reduce the exposure of soils to wind and water;
- more efficient irrigation, including the use of new technologies, reuse of tailwater and improved drainage;
- improved fertiliser and pesticide use through improved scheduling, application techniques and drainage arrangements, and greater use of more benign types of inputs;
- protecting riparian zones, including maintaining buffer strips of vegetation along watercourses and major gullies leading into watercourses;
- use of soil erosion control structures, such as contour drains, shortening slope lengths and wind breaks; and
- rehabilitation of degraded land.

Land use planning

Assessing land suitability and layout can assist with soil erosion and other potential water quality impacts by considering soil types, geology, hydrology, topography and climate. Orientating rows in particular directions, for example, can minimise soil erosion and nutrient loss during heavy rainfall events. DNRM has published guides on these issues, such as Land Management Manuals (QFVG 1998). In its best practice guidelines, the Johnstone River Catchment Coordinating Committee (1995) has recommended that farmers phase out or refrain from cropping land where slopes and soil type would result in annual soil losses exceeding 20 tonnes per hectare.

Cover crops and reduced tillage

Because of the risk of soil erosion and nutrient losses, some farmers have been implementing reduced tillage practices (particularly on sloping land with high erosion risk). Using herbicides to kill spent summer crops, for example, is sometimes used to reduce tillage by requiring ploughing only at the time of planting. This practice is adopted for around 50 per cent of the beans produced in the Gympie district (QFVG 1998). Tilling when soils are a certain moisture content and depth can also reduce erosion, as tilling when water content is high can smear and compact soils (QFVG 1998).

Some farmers also undertake management practices to reduce the exposure of bare ground to natural elements and thereby reduce erosion. QFVG (1998) suggested that ground cover of over 30 per cent can increase water infiltration and significantly reduce erosion. Because many horticultural operations involve a fallow period where ground can be bare, some farmers grow fodder crops, such as sorghum, oats or pasture to maintain cover. In the case of bananas, for example, the need for soil protection is greatest in the first six months of the plant's life before debris from deleafing and harvesting offers cover. Grasses are therefore sometimes planted in the rows between banana plants.

Irrigation

An increasing number of farmers are using more efficient irrigation delivery mechanisms and scheduling to time water applications to meet crop demand. Micro application systems are seen as most efficient, reflecting their ability to minimise evaporation losses, inaccurate application and soil compaction, while also enabling more accurate and timely fertigation (by which fertiliser is applied through irrigation). In some cases, scheduling methods rely considerably on grower experience, while in others more advanced technologies are used to indicate soil condition. Growers sometimes use more than one method of irrigation, such as overhead irrigation in conjunction with trickle irrigation.

An audit of the irrigation efficiencies of horticultural producers in 1999 found that of those surveyed:

- 62 per cent used micro application systems such as drip, trickle or micro spray;

- 31 per cent used low pressure systems of centre pivot, lateral move, boom, hand shift or solid set;
- 6 per cent used high pressure systems of soft or hard hose winches or travelling irrigators;
- 1 per cent used furrow or flood based systems; and
- 31 per cent used irrigation advisors (Barraclough and Co 1999).

The survey also found that annual crops were irrigated mainly by low-pressure sprays (47 per cent), while most perennial crops were irrigated using microsystems (84 per cent). A higher percentage of growers of perennial crops used technology to support scheduling than growers of annual crops (37 per cent compared to 25 per cent). However, only 7 per cent of growers calculated their water use efficiency. Approximately 16 per cent had attended irrigation training courses (Barraclough and Co 1999). In addition, surveys reported by HRDC and NLWRA (2001a) found that 47 per cent of annual crop growers and 43 per cent of perennial crop growers used moisture probes to determine the timing and volume of water application.

In some cases, economies of scale may limit the adoption of more efficient irrigation. In banana production, for example, overhead or travelling irrigation systems are still often used on small scale farms (QFVG 1998).

Capturing (or harvesting) water runoff in dams and reusing it later as irrigation water is another practice being adopted by horticultural producers. This can avoid nutrient enriched water moving off-farm and capturing sediments.

In terms of water sources, the audit by Barraclough and Co (1999) reported that 43 per cent of horticultural producers surveyed used water from unregulated sources, such as unregulated streams, bores and on-farm water harvesting, with 22 per cent using on-farm storage to support their system. Many growers used more than one source of water for irrigation purposes.

An important program to encourage efficient water use has been the Water for Profit program funded by DNRM as part of its Rural Water Use Efficiency (RWUE) Initiative. QFVG (sub. 49, p. 31) commented that:

- over 50 per cent of horticultural growers have made changes to increase the efficiency of their irrigation systems during the past two years, with around two thirds of these influenced by the RWUE Initiative;
- grower self-assessments suggest that changes made under the program have led to water savings and productivity gains of approximately 10 per cent; and
- almost 30 per cent of horticultural growers have been granted subsidies to improve the efficiency of their irrigation systems.

More efficient water use is also becoming evident in the nursery and garden sector. While uptake is slow and the industry acknowledges the adoption of best practice is at its early stages, a number of nurseries are now changing to more efficient water use systems, including computer controlled irrigation. Monitoring plant needs, and improving the growing conditions of plants such that less water, fertiliser and pesticide input is necessary, is similarly being more widely adopted, especially for new nurseries. To support these practices, Nursery and Garden Industry Queensland has developed several documents, including *Nursery Industry Water Management — Best Practice Guidelines* and *Managing Water in Plant Nurseries — Irrigation, Drainage and Recycling*. Much of the motivation for change has come from the growing realisation by nurseries that inputs are being wasted and that money can be saved by more efficient practices. (Scotts, D., Nursery and Garden Industry Queensland, pers. comm., 3 October 2002)

Fertiliser and chemical use

Management practices for fertiliser and chemical use continue to evolve, and more commonly now include:

- fertiliser and pesticide use based on technical advice and soil tests, with nitrogen fertiliser inputs more closely matching crop demand;
- using alternatives to chemicals (including biological control techniques) or the use of a combination of control methods (Integrated Pest Management (IPM));
- using more environmentally benign chemicals; and
- improving application technologies, such as the use of fertigation.

QFVG (sub. 49, p. 34) noted that the use of IPM techniques is growing, and is quite high for some commodities, particularly bananas and citrus. QFVG claimed that there has been a 93 per cent reduction in pesticide use in the banana industry since 1985 by using ‘bell injections’ of a highly targeted pesticide (where small amounts of pesticide are applied to an emerging banana bunch). The adoption of targeted pesticide applications, and use of consultants to monitor pests and advise on specific treatments, has changed pesticide use in the industry, with moves away from blanket aerial or mister applications (QFVG, sub. 49, p. 57). Rates of adoption of IPM, however, have depended on access to suitable pesticides, as well as availability of specialist services and advice (QFVG, sub. 49, p. 35).

QFVG (sub. 49, p. 36) argued that the ChemCert, ChemCollect and DrumMuster programs have all been successful in improving the handling of chemicals and chemical containers. It noted that ChemCert has been a major driver of best practice handling, application and storage of farm chemicals, and that ChemCollect and

DrumMuster have helped facilitate the safer disposal of agricultural chemicals and containers.

Riparian zone protection, soil erosion control and land rehabilitation

The protection of riparian zones has been widely advocated by industry and catchment groups (see, for example, QFVG, sub. 49, p. 37; Johnstone River Catchment Coordinating Committee 1995). This reflects concerns that in many areas farmers have sought to maximise production by clearing and cultivating right up to stream banks, leaving little riparian vegetation (Johnstone River Catchment Coordinating Committee 1995).

Some horticultural producers are now allowing for buffer zones between cultivated areas and stream banks, or directly revegetating bank areas where erosion is occurring, to protect riparian zones. Other examples of soil erosion control and rehabilitation include the use of wind breaks, applications of lime to counter acidification, growing deep-rooted perennial species, and reshaping gullies. The extent to which these practices occur, however, is unknown (Muller, J., QFVG, Brisbane, pers. comm., 3 October 2002).

QFVG (2002b) noted that in many cases landholders do not have access to the salinity and water quality data required to enhance remediation or preventative land management systems. They argued that the Natural Resource Sciences division of DNRM, responsible for completing and analysing this data, is 'seriously under-resourced'.

Other management practices

Some horticultural producers are moving to adopt system based approaches which can help manage water quality issues, such as farm plans and Environmental Management Systems (EMSs). Farm plans, for example, are increasingly used, although there is little evidence to date of their impact on water quality (Muller, J., QFVG, Brisbane, pers. comm., 4 September 2002). While case studies and trials for EMSs are underway — including a QFVG and EPA trial for the North Queensland banana industry which commenced in 2001 — EMS adoption has been very low (as for other agricultural industries).

QFVG (sub. 49, p. 1) noted that a number of initiatives are currently underway to support improved management practices, including the *Water for Profit* scheme and IPM programs. QFVG (1998) also released its *Farmcare Cultivating a Better Future Code of Practice for Sustainable Fruit and Vegetable Production in Queensland* in 1998. It outlines management options for minimising adverse environmental impacts from horticultural activities, and aims to help growers meet their general environmental duty under the EP Act. A 'checklist' to help growers assess their management practices was distributed by QFVG in 1999. Adoption rates for the Code and its recommended practices are unknown, however. On adoption rates, QFVG (sub. 49, p. 29) commented that:

> Levels of adoption of the Farmcare Code of Practice, however, are difficult to quantify, as formal reporting processes have not been established.

QFVG (sub 49, p. 30) did note, however, that:

> The impact of the code has been significant, with anecdotal evidence gathered from discussions with growers, suggesting that Farmcare is highly valued as a resource book and guideline.

In discussing the general adoption of management practices by horticultural producers, HRDC and NLWRA (2001, p. 95) noted that:

> …horticultural industry organisations recommend good management practices (GMP) but opinions vary on adoption rates among growers.

Further, several submissions suggested that while examples of good practice exist, adoption rates are generally poor across agricultural industries, including horticulture:

> Although there are excellent examples of 'best practice' at a property level within each of the major agricultural industries (grazing, sugar, horticulture), the decline in water quality is due to the low level of uptake of these practices throughout these sectors. (WWF, sub. 28, p. 4)

Variation in practice was also highlighted in submissions:

> We also know of banana farms that are well managed but others that are dreadful — gross over use of water, bananas growing to the top of steep banks etc. (Johnstone Ecological Society, sub. 4, p. 3)

NLWRA (2001a), however, reported that improvements in environmental performance Australia-wide are under way across all horticultural crop groups, although not all crop groups and regions are progressing at the same rate. Larger, more professionally managed groups are reported as typically being more advanced than others, and perennial crop sectors are generally better prepared for improved environmental performance than annual crop sectors.

NLWRA (2001a) argued that changes in the horticultural industry are being driven by several factors, including:

- new and revised codes of practice;

- increasing focus on integrated solutions to pest and disease management, and improvements in the structure, management and planning of organisations;
- greater investment in environmental research and development at the enterprise and regional level; and
- greater industry awareness of available programs.

However, NLWRA (2001a, p. v) also noted that:

> There are few strong signals for improved environmental management coming from the market place or from legislation.

Weaknesses in environmental performance were seen by NLWRA (2001a) as relating to poor linkages between programs (particularly research and development and codes of practice); generally poor and inadequate industry databases to monitor environmental and economic performances; and inadequate resources and skills in some crop groups to adopt better practices (especially small crop groups). NLWRA (2001a) also noted that the fragmented and multi-commodity nature of horticulture creates barriers for introducing environmental initiatives.

5.3 Sugar cane

Queensland produces approximately 95 per cent of Australia's sugar, with around 5890 cane farming enterprises operating in the state (5635 in the GBR catchment). Approximately 545 100 hectares of cane production occurred across Australia in 2001, including 509 485 in the GBR catchment (representing one per cent of the catchment land area). Most cane farms are family owned, with an average farm size of 80 hectares in 1999 (up from 33 in 1960) (CSIRO 2002b). Sugar milling and refining are discussed in appendix H.

Potential water quality impacts

Growing sugar cane involves a number of processes including land preparation, planting, fertiliser application, pest and disease management, irrigation, managing water quality and quantity for crops (including drainage activities), and harvesting. These production processes can exert pressure on water quality entering the GBR lagoon. These pressures can come from:

- land clearing, including the past removal of coastal wetlands which had previously trapped sediment and nutrients and slowed the rate of discharges, and clearing of riparian vegetation which can make waterways vulnerable to weed infestation, bank erosion and greater exposure to the natural elements, such as heat from the sun;

- tillage and other soil disturbance (particularly during planting) which can contribute to soil erosion and subsequently reduce soil health including nutrient holding capacity;
- application of fertilisers, fungicides and pesticides which can result in pesticide and fertiliser residues reaching waterways and leaching into groundwater;
- irrigation and drainage, which can lead to the runoff of sediments, nutrients, pesticides and sugars (lost to the soil during harvesting); possible soil salinity, rising water tables and water logging; and saltwater intrusion in coastal aquifers. Drainage from acid sulphate soils can induce the movement of sulphuric acid, iron and aluminium into streams and rivers; and
- harvesting, which can release cane juices and sugars into waterways (depleting oxygen in these waters), and leave bare ground if trash is burnt or removed rather than left in the field (increasing the chances of soil erosion).

A conceptual model of the farm-level potential impacts on aquatic systems from growing sugar cane and related management system components prepared by Canegrowers (sub. 34, p. 8) is provided in figure 5.2. CRC Sugar (2002) notes that nitrogen from cane lands is the cause of most concern from sugar production, above that of sediments and other nutrients.

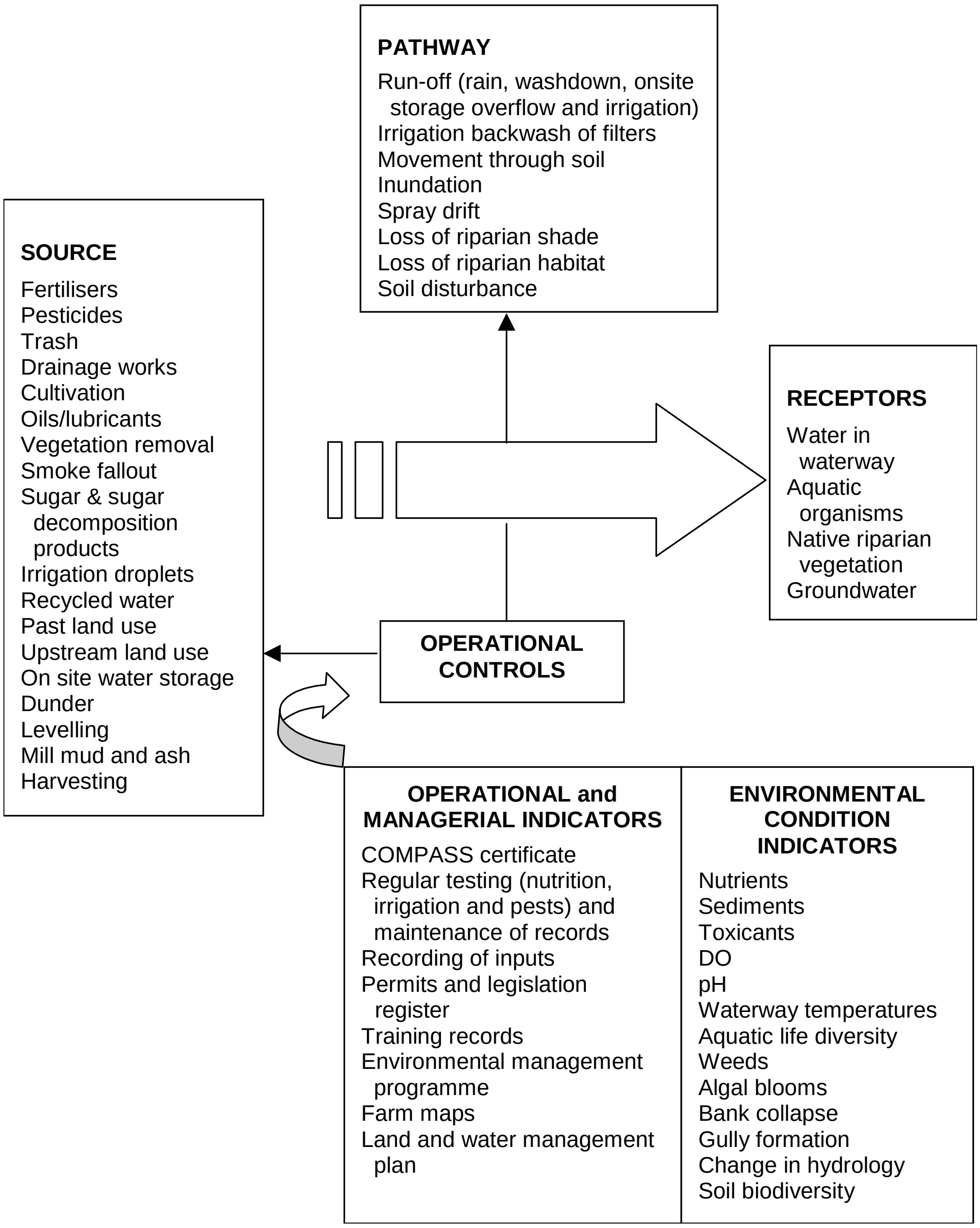
Current management practices

Management practices vary across cane farms, depending on local conditions (such as soil, climate and topography), scale of operation and variety of cane grown. Irrigation is widespread in the Burdekin, for example, but not in the wet tropics. Different practices are also likely to reflect cane growers' different financial status, scales of operation, expectations of future earnings, education and training, and attitudes to the environment.

Table 5.1 provides information on the adoption rates of different management practices, as reported in a survey by CRC Sugar (2000). It shows significant variation in adoption rates across practices. Table 5.2 shows the regional variability in some of the practices adopted.

In general, the industry has made some significant improvements in its environmental management (particularly in relation to soil erosion), although scope for improving management practices remains. The discussion below describes current management practices and reasons for their adoption.

Figure 5.2 **Conceptual model of farm-level potential impacts on aquatic systems from growing of sugar cane and related management system components**



Source: Canegrowers (sub. 34, p. 8).

Table 5.1 **Adoption of environmentally sound farm practices, 1998**
(% of respondents)[a]

Adoption of farm practices	*Yes*	*No, but plan to in the near future*	*No, do not intend to implement this practice*	*Practice is not applicable in the area*
Do you carry out soil tests to help match fertiliser to crop needs?	90	6	3	2
Do you fallow land between crop cycles?	88	6	4	2
Do you use minimum cultivation techniques?	86	5	6	3
Have you adopted an Integrated Pest Management (IPM) strategy to reduce weeds, pests and diseases in sugar cane?	69	14	12	5
Do you maintain areas of remnant vegetation on your farm?	67	2	10	21
Do you use mill by-products such as mill mud or dunder for fertiliser	58	10	20	12
Do you alternate sugar cane with crops such as soybeans or other legumes?	44	24	21	11
Do you have an environmental management plan on your farm?	40	27	22	13
Have you established artificial wetlands on your farm?	21	6	23	49
Do you engage in tailwater recycling?	19	10	13	58
Do you use methods such as mini-pans to maximise water use efficiency?	16	10	24	50
Have you planted substantial areas of native vegetation on your property?	13	17	25	44

[a] Number of respondents for each question varied between 955 and 990.

Source: CRC Sugar (2000).

Preparing land for planting

Preparing land for planting can involve land clearing, leveling, draining and ploughing. One planting generally leads to four or five harvests, with the stubble remaining after the first harvest putting out new shoots which grow into what are called ‘ratoon crops’. This means that bare ground during the establishment of plant crops (which is when soils are most susceptible to erosion) only occurs every four or five years.

Table 5.2 **Adoption of environmentally sound practices by cane growing region, 1998**

(% adopters)

Adoption of farm practices	*North Qld*	*Central Qld*	*South Qld*	*Burdekin*	*New South Wales*
Soil test to help match fertiliser to crop needs	91	95	86	92	88
Fallow land between crop cycles	87	94	89	93	86
Use minimum cultivation techniques	97	95	84	63	78
Adopted IPM strategy	73	80	52	71	66
Use mill by-products (mill mud or dunder)	54	79	44	45	73
Alternate sugar cane with legume crops	58	57	43	34	76
Established artificial wetlands	35	50	41	56	39
Engage in tailwater recycling	11	35	41	43	**nr**
Planted substantial areas of native vegetation on your property	30	29	11	24	18
Adopted green cane trash blanketing	96	93	71	17	20

nr Not reported**.**

Source: Adapted from CRC Sugar (2000).

Land clearing by cane growers has been identified as a major environmental issue in the past and may be again if the industry expands further. There has been concern, for example, that the loss of wetlands in coastal environments is likely to have exacerbated sediment and nutrient delivery through reduced filter functions (CSIRO 2002b).

Minimum tillage and other erosion minimising systems, such as the use of contour and diversion banks, have been adopted by many farmers to reduce the risks of soil erosion (Canegrowers 1996) (table 5.1). Glyphosate herbicide to remove old cane and weeds, for example, is sometimes used to reduce tillage. The use of laser grading to level fields and reduce runoff can also decrease the potential for soil erosion.

Other soil conservation measures include cross slope rows and better fallow management. Fallow management can include growing legume cover crops to reduce erosion risks, given fallow periods often involve little or no ground cover and no rows to divert runoff water (Canegrowers 1999). Growing fallow crops such as soybeans, for example, is practised in many regions to improve the health and biological functions of soils (table 5.2). Initiatives are underway to expand the use of such crops through the development of animal feed industries in Townsville and the Burdekin catchment (CSIRO 2002b). The use of more ratoon crops can also reduce soil disturbance and erosion. Improved drainage design (including wide spoon type drains) can also be used to trap eroded soil (BSES, sub. DR97, p. 3).

Fertilisers and chemicals

Fertilisers are used by cane growers to maintain soil fertility and assist the growth of cane plants. Indeed, sugar cane accounts for most of the fertiliser used in the GBR catchment, even though some crops, such as bananas, are fertilised at higher rates (FIFA, sub. 32, p. 5). ABARE data from 1996 suggest fertilisers account for about 20 per cent of the average cost of cane production (Canegrowers, sub. 34, p. 6). Fertilisers are applied at planting, during fallow and to existing crops, depending on the type of fertiliser and drainage characteristics of the land (Canegrowers 1996). As noted by BSES (sub. DR79, p. v), sugar cane produces a significant amount of biomass compared to other crops, which requires considerable fertiliser inputs.

The total use of fertilisers on cane land in Queensland has increased considerably in recent years — increasing over 35 per cent for nitrogen and 100 per cent for phosphorus between 1994 and 2000 (Rayment, G., DNRM, Indooroopilly, pers. comm., 18 October 2002). In 2000, approximately 75 000 tonnes of nitrogen and 11 000 tonnes of phosphorus were applied (averaging around 180 kg and 26 kg of nitrogen and phosphorus per hectare). Considerable amounts of this are considered to be lost from the root zone (although not necessarily directly to water), with estimated losses of 50–75 kg of nitrogen per hectare (CRC Sugar 2002). In addition, over 345 kg of nitrogen per hectare is considered to be 'held' in subsoils in the Johnstone and Tully catchments (CRC Sugar 2002). There are concerns that this 'sink' cannot accumulate indefinitely, and that although much cane land now contains more phosphorus than crops require for maximum yield, growers continue to add more (Rayment, G., DNRM, Indooroopilly, pers. comm., 18 October 2002). That said, recent analysis by the fertiliser industry indicates that nitrogen use rates per hectare in sugar production are declining, at a rate of at least 10 per cent per year (FIFA, sub. 32, p. 10). FIFA suggests this may reflect greater use of green cane trash blanketing (see 'harvesting section' below), awareness of environmental issues, and efforts to reduce production costs.

A number of practices can be used to reduce the environmental effects of added nutrients. Several of these are outlined in table 5.3. Taking soil samples prior to planting to determine crop nutrient requirements is one example. A 1998 survey by CRC Sugar found that most of the cane growers surveyed had carried out soil tests to help match fertiliser use to crop needs (table 5.1). However, FIFA (sub. 32, p. 12) suggested that growers have been slow in embracing soil and leaf testing services, and decision support tools that it claimed would dramatically alter current practices. It argued that farmers often 'err a little on the high side' when faced with the tradeoff between small incremental fertiliser costs (with nitrogen urea costing around $0.75/kg of nitrogen) and potentially significant yield reductions. This appears to reflect, in part, risk aversion by growers (Schroeder et al. 1998; Mallawaarachchi et al. 2002).

BSES (sub. DR79, p. 18) highlights the difficulties faced by farmers in determining the optimal rate of nitrogen to apply, noting that because increasing nitrogen use increases yield it is visually difficult to judge the optimal application rate. It suggests this has tended to encourage farmers to apply nitrogen in excess of recommended rates. Farmers are currently being educated in the use of gross margins analysis ($/hectare) to determine optimal nitrogen application rates. BSES research has shown that while increasing nitrogen application increases yield, the maximum cash return from trialed crops was obtained at the recommended application rate of 150 kg per hectare.

Studies by Schroeder et al. (1998) and Schroeder and Wood (2001) suggest that fertiliser application is often based on 'average' recommended rates which do not take sufficient account of varying soil properties between and within regions. This can result in too much fertiliser being applied in a number of areas (which can be undesirable for profitability and water quality).

FIFA (sub. 32, p. 9) have pointed to the industry's assignment system as creating incentives for the high use of fertilisers by cane growers:

> Importantly, the sugar industry's assignment system, in operation for many years, has ensured that the area planted to sugar cane is tightly controlled. This has encouraged growers to apply high rates of fertilizer to maximise yields and farm income because they have not had the option of planting additional land to sugar cane.
>
> …[it has also] allowed those farmers who consistently grow over-quota cane to share in the allocation of new assigned land and quotas when the industry has expanded.

In addition to fertiliser use or rates, many cane farmers also manage the timing and type of chemical applications. NLWRA (2001b), for example, identified that over 90 per cent of sugar producers consider the possibility of rain in applying chemicals (which can avoid chemicals being washed away). The use of fallow periods is another example where nitrogen and potassium fertiliser needs are reduced by allowing natural nutrient levels to build up in the soils. In addition, FIFA (sub. 32, p. 3) has developed a *Nutrient Management Code of Practice* to help farming industries (including sugar) achieve an efficient use of nutrients in their system to both minimise environmental impacts and increase production efficiency.

Table 5.3 **Practices that can reduce loss of fertilisers and chemicals to the environment**

Ways to minimise loss	*Type of practice*	*Examples, and how they can mitigate loss*
Maximise crop nutrient uptake	• Application technique	• Good germination in well-prepared moist seedbed with sterilised equipment and a planter that is set up correctly.
	• Application location and timing	• Encourage nutrient uptake by placing fertiliser close to the root system during active growth.
	• Planning and monitoring	• Pest management — development of a pest management plan before weeds or insects cause problems.
	• Other production practices	• Drainage — to help fix growth constraints. • Soil and leaf tests — to help develop balanced fertiliser program. • Crop selection — select varieties suited to region (soil and climate), and free of disease and insects. • Irrigation — scheduling helps to overcome lack of moisture that can stress crop and limit growth.
Reduce denitrification loss	• Application quantities	• Avoid high nitrate concentrations by not applying excessive fertiliser.
	• Application location	• Place fertiliser on well-drained, raised rows, not low, poorly drained interspaces.
	• Application timing	• Avoid fertiliser application during periods of excessive rainfall.
	• Other production practices	• Alternate crops — use cover crops over wet-season fallow periods to trap nitrate for later crop use. • Laser levelling of fields to avoid ponding.
Reduce nitrogen volatilisation loss	• Application technique	• Liming products and urea should not be applied together. • Mixtures of ammonium sulphate and urea can reduce volatilisation losses due to sulphate acidification.
	• Application quantities	• Do not exceed recommended fertiliser rates.
	• Application location	• Apply below the ground.
	• Application timing	• If urea applied to surface of ratoons, delay application until the crop is 50 cm high (allows direct absorbing of ammonia by crop canopy, and reduces mixing of air near the soil surface). • Apply fertiliser when irrigation or rainfall moderate and during rapid crop growth, to improve fertiliser entry to soil and promotes crop uptake.
	• Fertiliser type	• Consider ammonium nitrate, sulphate of ammonia, calcium ammonium nitrate and polymer coated or urease-inhibited urea.

(Continued next page)

Table 5.3 (continued)

Ways to minimise loss	Type of practice	Examples, and how they can mitigate loss
Reduce leaching loss	• Application technique	• Apply nitrogen in a narrow band.
	• Application quantities	• Use recommended application rates. • Smaller, more frequent fertiliser application may be beneficial for certain soils.
	• Application location	• Do not apply near waterways.
	• Application timing	• Time fertiliser application to avoid periods of high infiltration.
	• Other production practices	• Hilling to reduce water leaching through the row. Also improves early nitrogen uptake. • Crop rotation, reduce soil compaction, increase soil organic matter and control root pests and diseases, to foster extensive and healthy root systems. • Irrigation — adjust amount to avoid deep drainage. • Buffer zones between activity and waterways.
	• Vegetation management	• Artificial wetlands. • Native vegetation plantation.
Correct management, handling, application and movement of chemicals	• Application technique	• Avoid off-target drift by paying attention to climatic conditions and using appropriate pressures and nozzle types.
	• Application timing	• Do not apply pesticides when heavy rain is imminent, to reduce surface runoff and erosion loss. • Do not treat large areas during times of high rainfall risk. • Allow time for pesticide to 'bind' to soil or foliage (freshly applied chemicals often are more mobile).
	• Chemical type	• Use less mobile chemicals on highly porous soils or in areas with shallow water tables, to minimise contamination of groundwater or stream baseflow.
	• Other production practices	• Chemical storage, use and cleaning of equipment. • Equipment maintenance — check accuracy of measuring equipment, calibrate equipment combinations. • Irrigation — avoid if significant rainfall occurs shortly after application (because it could carry to groundwater). • Recycle surface irrigation tail water which may contain high pesticide residues.

Source: Adapted from Reghenzani et al. (2001).

Several submissions have also pointed to the potential benefits to water quality of growers using particular types of fertiliser, with NutriSmart being one example (Professor Pang, sub. 39; J D Cambridge Corporate Services Pty Ltd (sub. 40), Rovira and Associates (sub. 41) and CK Life Sciences (sub. 42)). The BSES is currently undertaking field trials to investigate leaching and crop nutrient uptake claims relating to NutriSmart (BSES, sub. DR97, p. 21).

BSES (sub. DR79, p. 9) suggests that to reduce the loss of nutrients to the environment, all the different pathways of loss of nutrients to the environment have to be reduced simultaneously, uptake of nutrients by plants maximised and inputs matched to crop requirements. It argues that concentrating on reducing one pathway of loss may result in increased losses in other pathways.

Pests and diseases also need managing, such as pineapple disease and soldier fly larvae that feed on cane roots. Chemicals are often used to manage pests and diseases, along with suitable farm hygiene or the use of pest and disease resistant varieties (Canegrowers 1999). Surveys have reported that IPM strategies have been adopted by almost 70 per cent of cane growers (table 5.1), and BSES (sub. DR79, p. v) has noted that the use of green cane harvesting has reduced herbicide use. Using controlled release insecticide formulations in a targeted way may also reduce the potential for environmental damage (BSES, sub. DR79, p.v).

Irrigation

Irrigation water is used on approximately 60 per cent of Australian cane crops, with cane growers the largest users of irrigation water in Queensland (Bonanno 2000). Irrigation is seen as essential for crop growth in the Burdekin and Tableland districts. Other areas use it on a supplementary basis. Cane growers also need to manage on-farm water quality. This can, for example, involve growers applying lime or gypsum to help address alkaline waters.

Irrigation methods include furrow irrigation (which involves distributing water through ditches), spray irrigation (normally using high pressure water winches, but also hand spraylines and automated centre pivot and lateral move spraylines), and trickle irrigation (which uses trickle tubing beside or underneath each crop row). Water usage is generally highest with furrow irrigation, followed by spray and then trickle irrigation methods, although this ranking depends on soil type, topography and scale of operation. In many cases, a mix of irrigation methods is applied (Canegrowers 1996). Some cane growers have been moving towards more efficient irrigation systems. Tailwater recycling is also being used, with surveys indicating around 20 per cent of cane growers adopt this practice, particularly in dryer regions (table 5.1 and 5.2). This management practice can reduce demand for fresh irrigation water, and mitigate against extremes in climate (providing water traps during floods and sources during droughts). In some areas (including Hervey Bay), cane farmers reuse urban wastewater (Canegrowers, sub. 34, p. 13). This not only reduces cane growers' demand for fresh irrigation water, but also reduces the polluting impacts of other human activities.

More efficient irrigation has also resulted from soil moisture monitoring and irrigation scheduling, which can improve the timing and extent of irrigation to better meet plant demands (HRIC 2002). The use of irrigation scheduling using evaporation mini pans, for example, has been found to reduce water usage by 10 to 47 per cent in some areas in the Burdekin catchment (Shannon et al. 1996). Approximately 16 per cent of surveyed cane growers indicated they used methods such as mini pans to maximise water use efficiency (CRC Sugar 2000).

However, an audit of cane grower practices in 1995 reported that only two per cent of audited irrigating growers used some form of objective irrigation scheduling (GHD Pty Ltd. 1996). A more recent survey in 2000 also found that scheduling irrigation was uncommon, although about one quarter of farms had structures to trap surplus water from their land, including tailwater dams, retention basins and artificial lagoons (Christiansen et al. 2001).

That said, approximately 84 per cent of cane growers in Queensland who irrigate had taken part in the RWUE program by 2002 (DNRM 2002c). In addition, around 350 cane growers (or roughly 6 per cent of growers) have attended training sessions on *A Fish Habitat Code of Practice* relating to the maintenance of drainage areas. This code was developed (at least in part) to help cane growers meet their legal obligations under the *Fisheries Act 1994* (Azzopardi et al. 2001).

Harvesting

Cane can be harvested after being burnt or without burning and leaving trash on the ground (which is referred to as green cane trash blanketing). Changing harvesting practices, and in particular the adoption of green cane harvesting and trash blanketing, have been found to reduce significantly the extent of soil erosion (CSIRO 2002b). Green cane harvesting in conjunction with minimum tillage was found in one study to reduce soil erosion by tenfold (Johnson and Bellamy 1998). Other benefits include improved water use efficiency and reduced weeds (with the trash protecting soil moisture and inhibiting weed growth). That said, CSIRO (2002b) pointed out that uncertainties remain as to whether green cane harvesting may have negative impacts in terms of deep drainage and leaching of nutrients.

The adoption of green cane harvesting and trash blanketing has increased substantially over the last decade or so, with the BSES (sub. DR79, p. 2) reporting a doubling in adoption throughout Queensland between 1989 and 1997. Adoption has been reasonably stable since 1997, however, at around 65 per cent (BSES, sub. DR79, p. 2). That said, adoption has not been uniform across regions. In 2000, for example, more than 95 per cent of the cane crop was harvested green in areas north of Mackay, but much lower rates applied in the Burdekin catchment where large, high yielding crops and the use of flood irrigation are seen as making such practices unsuitable (Azzopardi et al. 2001). Regional variation in the adoption of green cane trash blanketing is highlighted in table 5.2.

Canegrowers (1999) suggested that a mix of profitability and environmental benefits have been the driving forces behind the adoption of green cane harvesting and trash blanketing. In addition, an audit of cane grower practices in 1995 reported that 25 per cent of farmers who had adopted green cane harvesting claimed that community pressure had been the main reason for doing so (GHD Pty Ltd. 1996).

Revegetation

Some cane growers have revegetated sugar cane lands and land adjacent to sugar cane areas, with potential benefits for water quality. For example, over one million trees were planted on cane farms or in cane growing regions during 1997–1999. CRC Sugar (2000) reported that 13 per cent of surveyed cane growers indicated they had planted substantial areas of native vegetation on their property (table 5.1).

Some farmers also maintain riparian corridors, which can potentially reduce runoff, capture sediments and nutrients, and reduce the erosion of river banks. The construction of artificial wetlands in some areas may similarly benefit water quality, as wetlands can act as silt traps and nutrient sinks, as well as habitat for fish, birds and water plants (Canegrowers 1998) (table 5.2). CRC Sugar (2000) found that 21 per cent of surveyed cane growers in 1998 had established artificial wetlands on their farms (table 5.1).

Planning, monitoring and training

Cane growers undertake a number of planning activities, such as developing farm plans, land and water management plans, mapping activities and, to a limited extent, EMSs and Environmental Impact Assessments (EIAs). Farm plans, for example, have been used to include information on soil types, topography, natural watercourses, proposed revegetation sites, water control structures and location of drains, and can assist producers in operating in an environmentally friendly manner (Canegrowers 1998). Farm management plans have been developed for approximately 62 per cent of cane growers in Queensland and New South Wales (Christiansen et al. 2001). In addition, surveys by CRC Sugar (2000) found 40 per cent of cane growers in 1998 had an environmental management plan for their farm (table 5.1). These estimates are substantially higher than those in an earlier audit, which found that only 5 per cent of audited growers had property management plans (GHD Pty Ltd 1996).

The mapping and identification of potential trouble spots, in terms of acid sulphate soils, is also underway (HRIC 2002). That said, EMSs have not been commonly adopted. This is typical across agricultural industries. EIAs have also rarely been used, and have generally only been prepared when required by the *Environment Protection and Biodiversity Conservation Act 1999*.

Some sugar cane growers undertake monitoring activities, such as the use of biological indicators to gauge water quality impacts and in-stream health. Examples include the monitoring of macroinvertebrates (CRC Sugar 2002), and measurement of nutrient movement in irrigation runoff and groundwater (HRIC 2002). An audit of cane grower practices in 1995, however, reported that only 'a very small percentage of growers had any documented history of environmental conditions, i.e. changes in soils, watertable levels, salinity, pest numbers' (GHD Pty Ltd 1996).

Many of the planning and monitoring activities that could be used by cane growers are outlined in the *Canegrowers Code of Practice for Sustainable Cane Growing in Queensland 1998*. Adoption rates for most recommended practices are unknown, although some relevant data have been collected by CRC Sugar (tables 5.1 and 5.2). In 2000, it was estimated that 79 per cent of cane growers were aware of the Code, around 62 per cent had a copy, and about 53 per cent found it useful in making farm management decisions (Dawson, D., Canegrowers, Brisbane, pers. comm., 4 September 2002). Concerns have been expressed, however, that adoption is low due to the voluntary nature of the Code (Wildlife Preservation Society of Queensland (Cairns Branch), sub. 35, p. 6).

Concern about low adoption of the Code prompted the industry to develop a self-assessment workbook and workshop titled COMPASS. Canegrowers (sub. DR67, p.11) claimed that COMPASS now forms the 'cornerstone of the sugar cane growing industry's best management practice program'. The COMPASS program aims to help cane growers identify areas where they might improve farming practices, minimise offsite impacts and become more sustainable. It also aims to demonstrate to the public the industry's commitment to sustainable sugar growing practices (Azzopardi 2001). COMPASS provides a workbook through which growers self assess their performance by ranking their current farming practices across areas such as nutrition and fertiliser use, irrigation and pest management. On completion of the workbook, growers are encouraged to complete action plans prioritising tasks requiring attention.

To date, 700 growers (equivalent to approximately 13 per cent of cane grower enterprises) have received certificates from the workshop (Canegrowers, sub. 34, p. 7). Little information is available on how the program has changed farming practices, although anecdotal information and satisfaction surveys suggest the program is being well received (Dawson, D., Canegrowers, Brisbane, pers. comm., 25 November 2002). Around three quarters of those who completed workshop evaluation sheets indicated they would recommend the program to a neighbour, and 65 per cent said they would be interested in attending a follow-up workshop (Dawson, D., Canegrowers, Brisbane, pers. comm., 4 September 2002).

Regional and catchment initiatives are also being developed. In the Johnstone catchment, for example, cane growers are currently developing their own Best Management Practice guidelines (Johnstone River Catchment Management Association, sub. 5, p. 3), building on initiatives in the early 1990s.

In addition, various training programs have been undertaken by farmers to help them discover and adopt practices most appropriate for their farms. For example:

- approximately 70 per cent of Queensland cane growers have completed a voluntary one-day course in the use of farm chemicals (HRIC 2002);
- about 350 growers (around 6 per cent) attended training sessions relating to drainage practices in 2000 (Azzopardi et al. 2001); and
- CRC Sugar has run four short courses on soils and nutrition, four *Environmental Short Courses on Sustainable Sugar Production*, one course on *Managing Soils, Nutrients and the Environment for Sustainable Sugar Production*, and another course on the *Irrigation of Sugarcane*.

Overall, CSIRO (2002b) claimed that the sugar industry has been giving increasing prominence to sustainable cane growing practices in recent years, and has been improving its environmental performance. D. Dawson (Canegrowers, Brisbane, pers. comm., 4 September 2000) suggested that this reflects the introduction of the EP Act, the personal desires of farmers to protect cane growing regions, and increasing pressure from environmental activists. BSES (sub. DR97, p. vii) argues that where uptake of particular practices has been poor, this is most likely to be because they are not economically viable.

5.4 Other agricultural industries

Other agricultural industries and activities can also have potentially significant impacts on water quality entering the GBR lagoon. This section briefly discusses the management practices that relate to cotton and dairy production.

Cotton

Cotton is grown in three regions of central Queensland within the GBR catchment (Emerald, Dawson Valley and Biloela). In 2001-02, these regions grew approximately 22 000, 5500 and 610 hectares of cotton respectively (Cotton Australia, sub. 48, p. 3). At least 95 per cent of cotton production in Central Queensland is irrigated, with furrow irrigation the principal method (although some growers also irrigate with drip systems and centre pivots) (Cotton Australia, sub. 48, p. 3). Pest and weed management, including the use of pesticides and herbicides, is also important in growing cotton.

The main water quality concerns regarding cotton production include the use of pesticides (for controlling budworms, *Helicoverpa* app.), which can pollute waterways; and the use of water and fertilisers, which can affect the quantity and quality of downstream water (NLWRA 2001a).

Management practices that can be adopted by cotton growers to maintain water quality include the efficient use of water, use of IPM, and the management of chemicals and chemical containers. Cotton growers, for example, have been involved with Queensland's RWUE initiative. Cotton Australia (sub. 48, p. 15) argued that the Financial Incentives Scheme (part of the RWUE initiative) has been 'exceedingly successful in initiating change for growers, as well as accelerating the rate of change across industries'. Cotton Australia (sub. 48, p. 15) also reported that grower awareness and participation in the RWUE initiative had exceeded 75 per cent by August 2001, with a number of irrigators achieving irrigation efficiencies above the benchmarks set for the state at the beginning of the program. An example of more efficient practice is the greater use of tailwater recycling, which can reduce demand on water supplies and increase control of runoff.

In relation to pest management, Cotton Australia (2002) reported that sprays for heliothis pests were reduced by 50 per cent nationally in the 1999-2000 season due to the growing of Ingard cotton (a genetically modified variety of cotton). Using Ingard cotton near waterways is another management practice that farmers may use, although it is unknown how widely this is undertaken. Sound management of chemicals and their containers has been assisted by DrumMuster and ChemCollect programs (Cotton Australia, sub. 48, p. 14).

Cotton Australia (sub. 48, p. 13) claimed that environmental management in the cotton industry has been significantly influenced by the industry's voluntary BMP program, released in 1997. Cotton Australia stated that approximately 90 per cent of Australian cotton growers had changed their farming practices to better manage their farm and the environment as a result of the program. NLWRA (2001a) also commended the program, reporting that improved resource management is occurring on a broad scale as a result.

The BMP program encourages growers to develop plans for improving their farm management and environmental performance. The program covers farm design and management, application of pesticides, chemical storage and handling, IPM, and farm hygiene. Practices related to farm design, for example, include maintaining ground cover for erosion and runoff control and the use of buffer zones. Pesticide management in the program includes the development of a Pesticide Application Management Plan, and practices such as developing farm maps (including neighbouring farms and sensitive areas). Growers' progress in adopting BMPs is assessed through an independent audit.

In the central Queensland regions of Emerald, Dawson Valley and Biloela, BMP activities have been audited for 42, 87 and 30 per cent of cotton growers respectively. Examples of changes arising from the program include reduced pesticide use (by almost half in some cases), adoption of variable fertiliser application technology, and use of 'area-wide management groups' to coordinate spray data (Cotton Australia, sub. 48, p. 13). Detailed results from audits are not publicly available. C. Ross (Cotton Australia, Brisbane, pers. comm., 25 October 2002) noted that meeting community expectations for improved environmental performance was a significant motivator for developing the BMP program.

Dairy

Dairy farming in Queensland occurs predominantly in the south-east of the state, including GBR catchments such as the Burnett and Mary. Considerable dairy production also occurs in the Fitzroy catchment and further north on the Atherton Tablelands in the Johnstone and Barron catchments.

Dairy cows are predominantly fed through grazing, so many of the potential water quality and management practices relating to beef cattle also apply to dairy (section 5.1). However, because dairy production involves more intensive grazing and management, it uses more fertilisers, irrigation and pasture improvement activities than beef grazing. For example, about 60 per cent of dairy farms in the sub-tropical zone (where all of Queensland's dairy farms are located) use irrigation (NLWRA 2001a). In addition, effluent from cattle is more concentrated (especially around dairy sheds) and so requires greater management. The twice daily herding of cows from paddocks to dairy sheds also means that waterways are often crossed, and roads and paths are needed and compacted (with potential runoff implications). Potential water quality impacts can therefore come from grazing, cattle movement and access to waterways, and concentrated effluent discharges around dairy sheds.

Management practices adopted by the dairy industry to reduce water quality impacts include maintaining good pasture cover through appropriate utilisation and stocking rates (especially in the wet season and along waterways), erosion control, fencing riparian areas and areas of remnant vegetation, draining and gravelling roads and paths, and scheduling the timing of irrigation and fertiliser applications. Significantly, NLWRA (2001a) reported that dairy farms which irrigate in the sub-tropical zone all use spray irrigation systems, with only 2 per cent also using flood irrigation. Survey data indicate that water use efficiency for the dairy industry in Queensland increased by around 8.7 per cent between 2001 and 2002 (DNRM 2002a).

Dairy farmers can manage cattle movements to achieve more even pasture grazing, and more dispersed trampling and effluent impacts. Some farmers have deliberately grown trees for shade, and developed alternative water and supplementary feeding sources, to spread cattle across properties (Chapman, R., dairy farmer, Malanda, pers. comm., 11 September 2002).

Other management activities include effluent management, farm planning and site selection, and on-farm carcass and waste disposal. Effluent management is widely seen as important in controlling water quality impacts from dairy farms and for farmers to meet their environmental duty under the EP Act (Silver, B., DPI, Malanda, pers. comm., 11 September 2002). Effluent is captured using effluent ponds and often reused through irrigation systems or by direct application (via mobile pumps or containers). Good management includes avoiding effluent application to pastures near watercourses. Effluent management guidelines for dairy sheds have been developed under the National Water Quality Management Strategy launched by the Australian Water Resources Council and ANZECC (AFFA, sub. 53, p. 13). These guidelines need to be followed to meet the requirements of dairy processors under their quality assurance programs.

The dairy industry has a *Queensland Dairy Farming Environmental Code of Practice* to help producers and local authorities manage farms in an ‘ecologically sustainable manner’, and to help producers meet their general environmental duty under the EP Act (DPI 2002). To date, there has been no formal assessment of the adoption or effectiveness of the code.

While the use of environmentally beneficial practices appears to be influenced by the EP Act, in many cases adoption is motivated by profitability and asset protection, with farmers believing such actions contribute to good farm management as well as the environment (Chapman, R., dairy farmer, Malanda, pers. comm., 11 September 2002). Fencing, for example, can keep cattle clear of waterways and help with mustering. Maintaining healthy pasture, sometimes through the use of sown or exotic pasture, may also contribute to maintaining soil stability as well as dairy production. Some management practices may also be driven by catchment based programs, such as revegetation activities at the property and regional level (such as the Upper Johnstone Revegetation Project).

5.5 Concluding comments

The management practices of the main industries in the GBR catchment can have important impacts on water quality (as discussed in this chapter and appendix H). Some can harm water quality (such as overgrazing which can lead to soil erosion and sedimentation in waterways), while others can reduce potential negative impacts (such as more precise fertiliser application). Water quality can also be degraded by destroying the filtration functions of riparian zones; conversely, filtration can be enhanced by revegetation and appropriate management. In many areas, improvements in management practices are being made, but progress is varied and adoption rates often unknown.

In considering the adoption or otherwise of beneficial or harmful practices (in terms of water quality), it is clear that no industry can be stereotyped as 'good' or 'bad'. As expressed by the Johnstone Ecological Society (sub. 4, p. 3):

> It is a fact and one that is beyond argument, that there is enormous variation between the practices of farmers even within the same industry. JES [Johnstone Ecological Society] could easily take you to cane farms that are sustainable in all senses, and to others that are deplorable, shockingly bad.

Table 5.4 provides a summary of some of the major water quality concerns, their possible causes, and the main management practices that may impact on them. Practices considered to have the greatest impact on water quality in the GBR lagoon are highlighted (shaded) in the table.

From reviewing management practices in this chapter and appendix H, important messages emerge which can have implications for policy options. Key messages are:

1. Management practices vary significantly across:
   - (a) regions, catchments and even properties;
   - (b) type and variety of product or service;
   - (c) scale of operations; and
   - (d) skill, experience and resources of the operator.

Table 5.4 **Examples of current management practices relevant to GBR water quality**

Water quality concerns and possible causes	*Main industries/ activities*[a]	*Potentially harmful practices*	*Potentially beneficial practices*
Sediments			
Loss of groundcover	• Beef • Sugar • Horticulture	• Overstocking • Land clearing • Frequent and intensive crop cultivation • Leaving ground bare during fallow	• Spelling • Spreading cattle via feed and watering points • Keeping or planting natural vegetation • Minimum tillage • Cover crops between rows and during fallow periods • Harvesting leaving debris (eg green cane trash harvesting) • Buffer zones between activity and waterways • Alternative watering points
Streambank erosion	• Beef • Dairy • Sugar • Horticulture	• Excessive cattle access to waterways • Cultivation close to waterways	• Fence riparian strips • Moderate riparian grazing pressure • Erosion control structures • River bank restoration and revegetation • Buffer zones between activity and waterways
Large-scale earth works	• Coastal development	• Poor site selection and timing of works	• Minimise wet season works • Build erosion control structures during and after construction
Nutrients[b]			
Overuse or misapplication of fertilisers	• Sugar cane • Horticulture • Cotton	• Application beyond plant needs • Application near waterways	• Precision methods and scheduling application (eg soil tests, account for weather and irrigation timing) • Use of more benign fertilisers
Loss of riparian filters	• Beef • Dairy • Sugar cane • Horticulture	• Activity close to waterways (eg cropping, grazing)	• Moderate grazing pressure near riparian zones • Buffer zones between activity and waterways
Urban sewage and stormwater	• Coastal development	• Discharge into rivers or directly into the GBR World Heritage Area • Leakage from septic tanks or overflow of sewage system	• Secondary and tertiary treatment of sewage • Use of gross pollutant traps and artificial and natural wetlands

(Continued next page)

Table 5.4 (continued)

Water quality concerns and possible causes	*Main industries/ activities*[a]	*Potentially harmful practices*	*Potentially beneficial practices*
Effluent discharge from aquaculture	• Aquaculture	• Direct discharge • Poorly designed prawn ponds	• Revegetating pond walls • Sediment and bioremediation ponds
Other pollutants[c]			
Overuse or misapplication of herbicides and pesticides	• Sugar cane • Horticulture • Cotton	• Over application of chemicals	• Weed and pest monitoring • Integrated Pest Management • Use of more benign chemicals • Coordinating application with irrigation activities
Disturbing acid sulphate soils	• Sugar cane • Horticulture • Coastal development • Aquaculture	• Poor site selection	• Planning site selection • Maintaining vegetation and ground cover
Loss of filter functions in coastal areas[d]			
Clearing and drainage of wetlands	• Sugar cane • Coastal development	• Poor site selection	• Withdrawing activity and rehabilitating wetlands • Effective site selection (eg away from sensitive areas) • Protecting remaining filters (eg buffer zones)
Other			
Irrigation	• Sugar cane • Horticulture • Cotton	• Over irrigating	• Irrigation scheduling • Use of more efficient irrigation systems (eg drip irrigation and use of tailwater)
Increased impermeable surfaces and fresh water runoff	• Coastal development	• Poor urban planning	• Effective stormwater systems (eg gross pollutant traps, artificial wetlands)
Leaching of chemicals from mines	• Mining and mineral processing	• Poor mining and mine closure practices	• Retention ponds and concrete walls • Use of lime to neutralise acid

[a] The industries highlighted are believed to be the major current sources, in aggregate terms, considering extent, location and predominant management practices. These industries and activities are discussed in either this chapter or appendix H. [b] The main nutrients of concern are nitrogen and phosphorus. Elevated nutrients may also be caused by sediment runoff that mobilises 'natural' nutrients existing in the landscape. [c] Include herbicides, pesticides, heavy metals, acidic runoff from acid sulphate soils, and storm water runoff. [d]Examples include loss of mangroves and other wetlands.

Examples of excellent management practices have been cited in all industries, as have poor practices. What makes good practice in one area may not in another, with local conditions and proximity to sensitive areas important. The effectiveness of particular practices can also depend on other practices (such as managing feral pigs in addition to cattle access to riparian zones).

It is unlikely that there will be many practices that should be made mandatory, or prohibited, everywhere in the GBR catchment. Policy effort should focus on practices that make the biggest environmental difference for a given cost.

2. Management practices, and how and when implemented, can play a large role in determining environmental outcomes. While other factors outside an operator's control, such as weather, can be important, good management allows for these.

A major issue for managing water quality is likely to be how to upgrade the managerial expertise and knowledge of operators to move further towards best practice and continuous improvement.

3. Many industry and catchment groups have developed codes of practice to improve management practices (to either a minimal level of performance or to 'best practice'). The existence of such codes does not necessarily indicate actual practice. In most cases adoption rates are unknown.

The effectiveness and impacts of voluntary codes have not yet been rigorously evaluated, although there are signs they can improve resource decisions.

4. Motivations for adopting management practices beneficial to water quality are many and varied:
   (a) Adoption is likely to be greatest when practices increase profitability or help protect operators' capital assets.
   (b) Regulation, or the threat of regulatory action, has also played a role, encouraging the implementation of some specific actions as well as the development of codes of practice.
   (c) Cost sharing programs between governments and operators have provided strong incentives for action, as in the case of fencing. Programs, such as the RWUE Initiative, have also had some success in changing practices.
   (d) Community expectations of environmental performance can also motivate change, as in cotton production and improved sewage treatment. However, market signals for improved environmental practices have not been strong.

Understanding motivations for the use of different management practices will be important in moving to new and improved practices.

5. There are gaps in industry and government knowledge about what management practices are actually adopted, the variation between best and worst practice, and

what forms ‘average’ practice. There are also considerable knowledge gaps in how management practices impact on water quality, with monitoring often poor.

Knowledge gaps on current practices and their water quality impacts can limit government’s and industry’s ability to identify where management practices are poorest (across industries and regions), and where the potential benefits from the wider adoption of particular practices would be greatest.

Further research on adoption rates and the impacts of particular management practices would improve the basis upon which policy is made and reviewed.

PART II – POLICY OPTIONS

6 Analytical approach

The first part of this report provided the context for an analysis of options to abate diffuse pollution entering the GBR lagoon. The purpose of this chapter is to outline the approach used to analyse abatement options in the second part of the report. Key aspects of the water quality problem are summarised first. The approach used in light of those aspects is then specified.

6.1 Nature of the problem

The information presented in preceding chapters indicated that, since European settlement, there has been an increase in pollutants entering the GBR lagoon that have the potential to harm the Reef and associated ecosystems. It also appears that diffuse sources of pollution, particularly agriculture, are now the most significant sources of these pollutants. However, evidence that declining water quality entering the GBR lagoon has adversely affected the health of the Reef and associated ecosystems is not yet conclusive, partly because of limited prior research and monitoring. Therefore, the policy problem is to address an indeterminate potential threat to these natural assets of very high (but unknown) value.

A major constraint for policy makers is that information about this threat, and how various actions could mitigate it, is very limited. What is known is that:

- the link between runoff in the GBR catchment and the health of the Reef and associated ecosystems is complex;
- often significant distances and time lags separate cause and effect;
- most of the pollutant discharges into the GBR lagoon tend to be linked to irregular events (floods), but some do occur on a continuous basis (the relative importance of these to the GBR and associated ecosystems is unclear); and
- risks (and the consequential losses) are likely to vary between different regions of the GBR lagoon.

Policy making is also constrained by the limited information on the distribution of current management practices within each industry and the runoff caused by those practices. Thus, it is unclear how much the widespread adoption of Best

Management Practices would reduce the threat to the GBR and associated ecosystems.

6.2 Existing policy approaches

As noted in chapter 3, existing policies are not well-suited to addressing the issue of declining water quality entering the GBR lagoon.

There are few policies that explicitly target water quality in the GBR lagoon. Where such policies do exist, they are largely confined to activities that occur within or directly adjacent to the GBR lagoon, and focus on point sources of pollution.

The Queensland Government has jurisdiction over virtually all land-based activities that lead to discharges into rivers and ultimately the GBR lagoon. However, Queensland policies relevant to water quality tend to be directed at issues in catchments and coastal waters, rather than the GBR lagoon itself. Existing policies have also tended to focus on what is relatively easy to control (point sources like sewage plants and aquaculture farms) rather than on what accounts for the majority of discharges into the GBR lagoon (diffuse sources like grazing and cropping). The Queensland Environmental Protection Agency has not been given a mandate to control diffuse source discharges from agricultural activities that appear to constitute a major threat to the GBR and associated ecosystems.

Governments devote considerable effort to controlling activities which are relatively low threat and have high costs (including opportunity costs) of abatement, while it may be possible to manage higher threat activities at lower cost. For example, considerable effort is devoted to regulating aquaculture, which accounts for less than 0.2 per cent of pollutants discharged into the GBR lagoon (chapter 2). This has probably come at the cost of lower income and employment growth in prawn farming (Australian Prawn Farmers Association, sub. 45, p. 13; Bowen Collinsville Enterprise 2002). There would appear to be significant scope for re-examining the current approach to include other activities responsible for diffuse source discharges, and to ensure that the level of control is consistent with the threat posed by each activity.

Another issue is that governments have developed a large number of disconnected, and not necessarily consistent, environmental plans that are not yet well integrated and some of which may be redundant. The main instruments have been licensing and permits, plans, and development approvals. But there are many other approaches that can complement, or partly replace, command-and-control measures, including education and voluntary, and industry-based or market-based, approaches.

Different policy instruments are likely to be effective for different people, as well as different industries and locations.

In addition, some existing policies may unintentionally provide incentives to reduce water quality in the GBR lagoon. For example, various parties expressed concerns that the Sugar Industry Infrastructure Package has led to the extensive clearing and drainage of wetlands and riparian vegetation; and that the Queensland drought relief scheme unintentionally penalises those who destock early in a drought, while rewarding those who overgraze.

6.3 Assessing abatement options

The costs and benefits of particular management practices can vary markedly between different properties, depending on factors such as their proximity to a water course, soil type, and topography. This geographic variability, combined with the short timetable for this study, made it impractical to undertake a detailed financial analysis of management practices that could improve water quality. That is a role for in-depth case studies of individual properties or sub-catchments.

Undertaking detailed case studies on a large scale would also be premature until the previously mentioned problems with the existing policy framework are addressed. Of particular concern are:

- the absence of well-developed processes to ensure that the regulatory effort devoted to specific land uses or regions is consistent with the threat they pose to ecosystems in the GBR lagoon; and
- the current emphasis on policy instruments that involve prescriptive regulation, which is probably ill-suited to controlling diffuse pollution because of the limited information held by policy makers on abatement costs.

Given the above concerns, the remainder of this report places emphasis on developing an appropriate policy framework. The proposed framework has the following five steps:

1. clarify objective;
2. prioritise threats;
3. understand the relevant land users;
4. short list and rank pollution abatement options; and
5. identify suitable institutional arrangements to implement the options chosen.

These steps are outlined briefly below and then detailed further in subsequent chapters.

Clarify objective

Ideally, the objective would be to reduce pollutants entering the GBR lagoon until the cost of further abatement outweighs the additional benefits. However, such an objective is impractical because the benefits of improved water quality are difficult to measure in dollar terms. In practice, a more useful objective is cost-effectiveness. This is where the aim is to achieve a measurable goal — such as a certain level of water quality or the adoption of particular management practices — at least cost. This is broadly the approach that has been proposed by the Commonwealth and Queensland Governments.

The objective of the *Reef Water Quality Protection Plan* is to halt and reverse the decline in water quality entering the GBR lagoon as soon as practicable (appendix C). More specifically, the public consultation paper for the Plan mentioned the goal of progressively reducing water-borne sediments, nutrients and pesticides from diffuse sources entering the GBR lagoon (Reef Protection Steering Committee 2002). However, this does not answer the question of 'by how much, where and when?'.

Regional Natural Resource Management (NRM) bodies are expected to clarify the Plan's objective by setting targets for the quantity and timing of discharge reductions in particular regions. At the time of writing this report, the criteria used to set these targets had not been determined. However, if a target is to be effective and achievable, then it will be necessary to consider:

- the expected reduction in threat to reefs and associated ecosystems; and
- the likely cost in broad terms.

Hence, there is an interdependence between the choice of targets and their effectiveness and cost. An assessment of which land uses in which areas pose the greatest threat to reefs and associated ecosystems would be a useful starting point in setting targets (discussed in chapter 7). This prioritisation of threats could then be followed by an evaluation of the likely effectiveness and cost of different water quality targets.

In setting a water quality target, it is also desirable to take account of the irregular nature of the problem. In particular, the threat to reefs and associated ecosystems is linked to irregular floods, which deliver diffuse pollution into the GBR lagoon. One way to address this issue is to state the objective in terms of the *probability* of achieving a certain level of water quality. This is preferable to simply stating the objective as an *average* level of water quality over time, since some policy options could raise average water quality but also increase its variability.

It should be noted that the objective does not necessarily have to be specified in terms of a water quality target. Given the measurement problem in attributing diffuse pollution to individual land users, it may be more useful to state the objective as the adoption of specific management practices by land users. The Commission understands that the *Reef Water Quality Protection Plan* will give regional NRM bodies the flexibility to follow such an approach in the short term. In the longer term, new monitoring technologies — such as remote sensing — may make it more practical to state the objective in terms of a water quality target.

Prioritise threats

Data presented in earlier chapters suggest that the threat posed to reefs and associated ecosystems from declining water quality is not uniform across (or within) different land uses and regions in the GBR catchment. Prioritising threats from different regions and land uses could therefore be an important step in determining where pollution abatement is likely to be most effective. It could also be useful in setting water quality targets, as noted previously.

The Commonwealth and Queensland Governments have indicated that a risk-based approach will be used in the *Reef Water Quality Protection Plan* (appendix C). To this end, the Governments have hired a group of scientists to produce detailed estimates of sediment and nutrient discharges that can be used to identify priority regions within the GBR catchment. It is expected that the results will be available in mid-2003, which is after the completion of this study.

Chapter 7 discusses how threats could be prioritised and summarises the preliminary evidence on such threats.

Understand the people involved

While there are many parties with an interest in land uses in the GBR catchment and/or water quality in the GBR lagoon, it is individual land users whose decisions and behaviours will have to change if management practices that cause diffuse pollution are to be altered. Past research has shown that the capacity and willingness of land users to adopt more sustainable management practices varies with socioeconomic characteristics, such as their income, debt, education and participation in a community land care group (Cary et al. 2002). If a proposed pollution abatement option ignores such characteristics among the land users it is targeting, then it is more likely to fail. Thus, before formulating abatement options, policy makers should ensure that they have sought advice and suggestions from the land users whose behaviour they seek to change, and are well informed about land users' socioeconomic characteristics. The issue of socioeconomic characteristics is discussed further in chapter 8.

Short list and rank pollution abatement options

The next stage is to short list possible land use changes and associated policy instruments that are likely to be effective in addressing threats at reasonable cost. Each proposed change in land use must be considered in combination with the policy instrument(s) expected to implement it. One example is a reduction in the excessive application of fertilisers, that might be achieved by a tax on fertilisers and/or an education program on more efficient fertiliser application methods.

Some land use changes that raise water quality entering the GBR lagoon could also deliver benefits to individual land users and others within a particular catchment. For example, farm practices that reduce sediment runoff help farmers to retain their topsoil and diminish the loss of nutrients attached to that soil, while reducing adverse impacts on downstream users of a catchment. This suggests that well-designed policies to address environmental concerns at the property and catchment level would go a long way to removing the threat to the Reef from declining water quality coming from the catchments. It also suggests that benefits beyond those in the GBR lagoon should be considered in assessing different abatement options.

Ideally, an assessment of abatement options would involve a formal benefit–cost analysis, where tradeoffs are taken into consideration (including over time, using discount rates). However, this approach is impractical when a large proportion of the benefits of different actions cannot be measured in dollar terms. This is likely to be the case for the GBR, where nonmarket values are significant. Therefore, the strategy should be to rank short listed abatement options according to their cost-effectiveness, taking note of additional benefits outside the GBR World Heritage Area.

As noted above, this study was completed before detailed information was available from the Commonwealth and Queensland Governments' assessment of priority discharge sources. Therefore, the Commission did not have access to crucial information on which land uses in which areas pose the greatest threat to reefs and associated ecosystems. This, combined with the geographic variability in abatement costs and the short timetable for this study, meant that the costs and benefits of different abatement options could not be quantified. Even if information on which properties warrant consideration in an assessment of abatement options was available, it is possible that detailed case studies of many individual properties would have been required to obtain an accurate estimate of total abatement costs. Nevertheless, it was possible to provide a qualitative assessment of various abatement options. This is done in chapter 9, using examples for the control of soil erosion and the overuse/misuse of fertilisers and chemicals.

Identify suitable institutional arrangements

An important determinant of the success of abatement options will be the roles and responsibilities assigned to different parties. For example, if the selection and implementation of abatement options requires detailed knowledge of local conditions, then there may be a strong case for devolution to local organisations. This is the approach being proposed for the *Reef Water Quality Protection Plan*. If this is to occur, then the local organisations would need to be given sufficient resources and powers to implement selected abatement options. There would also need to be a mechanism for ensuring that the actions of local organisations were consistent with catchment-wide objectives, as well as those at a state and national level.

Another important issue is to ensure that there are arrangements in place for ongoing monitoring and review (Adaptive Management). This is important because of the scientific uncertainty associated with water quality entering the GBR lagoon. It is likely that new information will become available in the future and that this will require the fine tuning of existing policy approaches.

A detailed discussion of institutional arrangements is provided in chapter 10.

In summary, this chapter has outlined a framework for policy options. This involves clarifying the objective; prioritising threats; understanding the relevant land users; short listing and ranking abatement options; and identifying suitable institutional arrangements. The remaining chapters of this report elaborate on aspects of the framework, beginning with how threats could be prioritised and the preliminary evidence on such threats.

7 Prioritising threats

The information presented in earlier chapters indicated that the threats that terrestrial runoff poses to the Great Barrier Reef (GBR) and associated ecosystems vary between areas and over time. Therefore, ranking the physical threats that declining water quality poses to reefs and associated ecosystems could provide an indication of what land use changes warrant consideration in an assessment of cost-effectiveness. It should be noted that the selection of abatement options needs to also take account of costs, and so may not correspond to a ranking based solely on physical threats. The selection of abatement options is discussed in chapter 9. This chapter focuses on how physical threats from terrestrial runoff could be prioritised and summarises the preliminary evidence on threats.

As noted earlier in this report, terrestrial runoff is not the only threat to reefs and associated ecosystems. Other pressures include marine accidents and oil spills, overfishing, outbreaks of crown-of-thorns starfish (which feed on coral), global atmospheric changes (which can influence water temperatures, sea levels, and climatic patterns such as the frequency and size of cyclones), and coral bleaching. While these other threats are beyond the scope of this study, they should be considered by policy makers when formulating abatement options.

7.1 Approach used to prioritise threats

Prioritising threats on the basis of a single criterion — such as the level of discharges or their increase since European settlement — has the advantage of being relatively straightforward. Such an approach was used by GBRMPA (2001b) in its *Great Barrier Reef Catchment Water Quality Action Plan*, which gave rivers a risk rating (low, medium or high) based on the growth of discharges since 1850 (see chapter 3). However, using a single criterion is unlikely to be sufficient to prioritise threats with a reasonable degree of accuracy.

In broad terms, threats are a function of both the magnitude of possible damage and the probability that it will occur. With respect to the GBR and associated ecosystems, numerous factors could influence the magnitude and probability of damage from declining water quality. Many of these factors can move independently of each other. They include:

- variations in the amount, types, timing and variability of discharges across regions;
- proximity of river mouths to reefs;
- the direction and extent of flood plumes;
- concurrence with other threats (which may make reefs in some areas particularly vulnerable to water quality threats); and
- concurrence with high economic, cultural and environmental values (such that the consequences of water quality problems are potentially more severe).

Thus, there is a strong case for using a multi-criteria approach to prioritise threats. Implementing such an approach will require judgements to be made about which criteria to include and what weights to give them relative to other selected criteria. This is largely a role for scientists with relevant expertise. Nevertheless, the criteria used will need to cover relevant characteristics of both the hazard (discharges from land use) and receiving areas (rivers and the GBR lagoon).

An example of how a multi-criteria approach might be implemented is provided by Devlin et al. (2001a). They developed an Ecosystem Risk Index based on estimates of discharges from particular rivers, the movement of flood plumes from those rivers, and proximity of the river mouths to individual reefs (box 7.1).

Several research projects are currently being conducted or planned that will improve the capacity to prioritise threats. For example, the Commonwealth and Queensland Governments have commissioned a group of scientists to produce detailed estimates of sediment and nutrient discharges that can be used to identify priority regions within the GBR catchment. Another project will expand the analysis by Devlin et al. (2001a) to assess the risk faced by a larger number of reefs in the GBR World Heritage Area. Both projects are expected to be completed by mid 2003.

7.2 Preliminary evidence

While a thorough prioritisation of threats to reefs and associated ecosystems has yet to be undertaken, some of the data that would be utilised in such an assessment are available in a preliminary form. Such data are used here to illustrate why prioritising threats is likely to be an important step in addressing declining water quality entering the GBR lagoon.

Box 7.1 **Quantifying differences in the threat to individual reefs**

Devlin et al. (2001a) developed a methodology for quantifying differences in the threat that terrestrial runoff poses to different reefs. Their technique involves a two-step procedure.

The first step is to calculate a *river pollution index* for individual rivers, which increases with the size of:

- average annual discharges from the river;
- the variability of river flows (number of days when flows exceed the daily mean);
- the flow of suspended solids (based on model estimates from the National Land and Water Resources Audit);
- dissolved inorganic nitrogen flow (based on nitrogen fertiliser use per hectare in the relevant catchment);
- diuron flow (based on diuron use per hectare); and
- urban discharge (based on catchment population).

The second step is to calculate an *ecosystem risk index* for individual reefs. This is based on:

- pollution coming from nearby rivers (as measured by the river pollution indices from step one);
- the proximity of those rivers from the relevant reef; and
- the direction of each river in relation to the reef.

The proximity of each river is relevant because pollution concentrations decline with distance from a river mouth. The direction of each river in relation to a reef is also relevant because flood plumes most often (but not always) move north of a river mouth, due to south-east winds and the Coriolos effect.

Source: Devlin et al. (2001a).

Differences in discharges across the GBR catchment

Data presented in chapter 2 showed that discharges of sediments and nutrients entering the GBR lagoon vary significantly between different rivers/catchments. This variability includes the level of discharges, their year-to-year variation, and the type of materials being discharged.

Catchments generating the highest level of discharges of sediment, nitrogen and phosphorus are the Burdekin and Fitzroy. Significant discharges of sediment also come from the Herbert, Burnett, and Normanby rivers (Furnas 2002; NLWRA 2002b). In terms of nutrients, high levels of nitrogen and phosphorus are discharged from the Mary, Normanby, Johnstone and Herbert rivers (Furnas 2002; NLWRA 2002b).

Combining data on river flows, the variability of those flows, and the pollutants they carry, Devlin et al. (2001a) generated pollution indices for rivers draining into the GBR lagoon. Their results — summarised in table 7.1 — provide an insight into how different factors lead to a high pollution rating for different rivers. For example, a high pollution index is estimated for both the Burdekin and Fitzroy rivers due to their substantial average annual flows and the large amount of suspended solids carried in those flows. Other rivers — such as the Johnstone, Tully and Russell-Mulgrave — have smaller average annual flows but still receive a high pollution rating due to greater discharges of nutrients from fertiliser use.

Published estimates indicate that there are also significant differences in the *rate* of discharges (tonnes per hectare) across the GBR catchment. This is illustrated in figure 7.1 for sediment discharges. Based on similar estimates to those used in the figure, Prosser et al. (2001) concluded that 80 per cent of sediment exported to the GBR lagoon is generated from less than 30 per cent of the catchment area. This suggests that a large proportion of the effort to reduce sediment discharges could be concentrated in a relatively small part of the GBR catchment.

The prioritisation of different regions should extend to the sub-catchment level. This is illustrated by estimates from Prosser et al. (2002), which indicate that 95 per cent of the sediment discharged into the GBR lagoon from the Burdekin catchment comes from only 13 per cent of the catchment area. Areas closer to the coast were estimated to be more likely to contribute to sediment discharges from the Burdekin catchment (figure 7.2). This is largely due to the limited possibilities for sediment to be deposited prior to reaching the coast. Another important factor is the Burdekin Falls Dam, which limits the amount of sediment reaching the GBR lagoon from upstream areas of the Burdekin catchment (Prosser et al. 2002). However, the Dam is more likely to trap coarser silts and sands than fine sediments, especially during floods.

Sediment discharges are largely due to various types of soil erosion. NLWRA (2001a) estimated that in the North East Coast Drainage Division (which largely comprises the GBR catchment), 64 per cent of sediment delivered to streams is from hillslope erosion, 22 per cent from streambank erosion, and 14 per cent from gully erosion. Developing similar estimates for smaller regions within the GBR catchment could be useful for determining priorities.

Table 7.1 River pollution indices

River	*Discharge index*[a]	*Frequency index*[b]	*Suspended solids index*[c]	*Fertiliser index*[d]	*Diuron index*[e]	*Urban index*[f]	***River pollution index***
Nth and Sth Johnstone	4.6	9.1	1.0	10.0	3.6	3.0	**31.2**
Pioneer	1.2	3.7	3.6	7.5	7.3	3.0	**26.2**
Plane Ck	1.5	3.2	1.1	6.8	10.0	3.0	**25.6**
Tully	3.2	10.0	0.4	5.4	0.8	3.0	**22.8**
Burdekin	10.0	4.3	3.5	0.1	0.0	3.0	**20.9**
Fitzroy	5.8	4.1	6.4	0.1	0.0	4.0	**20.4**
Russell-Mulgrave	3.5	8.7	0.9	3.7	1.2	2.0	**19.9**
Burnett	1.1	4.6	9.3	0.3	0.1	4.0	**19.4**
Herbert	3.9	6.0	2.4	2.7	0.8	3.0	**18.8**
O’Connell	1.5	3.8	3.5	3.3	4.9	1.0	**18.0**
Mossman	0.6	8.4	0.4	3.9	3.4	1.0	**17.6**
Haughton	0.7	3.1	3.4	8.7	0.5	1.0	**17.5**
Murray	1.1	8.4	0.2	6.0	0.6	1.0	**17.3**
Don	0.7	3.5	10.0	0.7	0.1	2.0	**17.0**
Proserpine	1.1	2.7	3.1	3.3	1.8	3.0	**15.0**
Barron	0.8	5.1	2.7	2.0	0.1	4.0	**14.6**
Normanby	4.8	4.5	4.8	0.0	0.0	0.0	**14.1**
Daintree	1.2	7.2	1.1	0.4	0.5	0.5	**10.9**
Black	0.4	3.3	3.2	0.0	0.0	4.0	**10.9**
Calliope	0.3	2.9	3.0	0.1	0.0	3.0	**9.2**
Endeavour	1.7	2.0	3.9	0.0	0.0	1.0	**8.7**
Ross	0.5	2.4	1.7	0.0	0.0	4.0	**8.7**
Kolan	0.4	3.6	2.2	1.1	0.3	1.0	**8.5**
Baffle Ck	0.8	4.0	1.9	0.2	0.0	1.0	**8.0**
Boyne	0.3	3.2	0.9	0.0	0.0	2.0	**6.4**

a Index of average annual discharges from the relevant river, ranging from 0 to 10. **b** Index of the variability of a river’s flow (based on the number of days when flows exceed the daily mean), ranging from 0 to 10. **c** Index of the flow of suspended solids, including nitrogen and phosphorus (based on model estimates from the National Land and Water Resources Audit), ranging from 0 to 10. **d** Index of dissolved inorganic nitrogen flow (based on nitrogen fertiliser use per hectare in the relevant catchment), ranging from 0 to 10. **e** Index of diuron flow (based on diuron use per hectare), ranging from 0 to 10. **f** Index of urban discharges (based on catchment population), ranging from 0 to 4.

Data source: Devlin et al. (2001a).

Figure 7.1 **Predicted rate of sediment discharges to the coast from different regions of the GBR catchment**

tonnes/hectare per year

Source: Adapted from Prosser et al. (2001).

Figure 7.2 **Predicted rate of suspended sediment discharges to the coast from different regions of the Burdekin catchment**

tonnes/hectare per year

Source: Adapted from Prosser et al. (2002).

In examining nutrient discharges, it is important to distinguish between those entering the GBR lagoon attached to sediment particles, and those which are in a dissolved form. There is considerable concern with dissolved inorganic forms of nitrogen and phosphorus because they are completely 'biologically available' to plants and bacteria. Nitrate is one form of dissolved inorganic nitrogen, with fertilisers a common source. Dissolved forms of nutrients like nitrate also tend to travel greater distances in river plumes than particulate nutrients (Devlin et al. 2001b). Thus, discharged dissolved nutrients (often from fertilisers) are more of a threat to inner-shelf coral reefs than are particulate nutrients. As noted in chapter 2, most nitrogen exported from the wet catchments is in dissolved form. This suggests that reducing nutrient discharges from the wet catchments is likely to be of greater priority than that from the dry catchments.

Land uses in high discharge areas

Once high discharge areas have been identified, it will be more straightforward to identify the main land uses contributing to discharges. In many cases, there will be a limited range of land uses in a particular area.

As noted in chapter 2, available estimates indicate that nonpoint sources, particularly cattle grazing and crop production, are now the most significant activities contributing to pollutant discharges into the GBR lagoon (given the controls on urban, industrial and other point sources). Cattle grazing is a significant source of sediment discharges, particularly in the dry catchments, such as the Burdekin and Fitzroy. Cropping is a major source of dissolved nitrogen, particularly in the wet catchments. However, this information is of limited usefulness without an understanding of the management practices used in the relevant industries. There are a range of management practices that can aggravate runoff problems, along with a range of practices that can minimise pollution risks (chapter 5). The mix of management practices used is likely to vary between properties, depending on management expertise, soil and vegetation types, climate, and topography. Identifying management practices that have the most negative or positive impact on pollution will reveal more about where priorities might occur in an area than ‘naming and blaming’ a particular industry.

Other factors that can influence the discharge of sediment and nutrients into the GBR lagoon are the loss of wetlands and changes in water flows. Wetlands have been altered for the purposes of flood mitigation and flow improvement works, and reclamation (by draining and filling) for agricultural, industrial and residential developments. Unfortunately, evidence on the relative role wetlands can play in trapping sediments and filtering nutrients is limited (chapter 2). Nevertheless, the removal of wetlands in coastal areas and the development of extensive drainage networks appears to have led to a significant loss of floodplain function (which can play a significant role in trapping sediments and nutrients). Changing water flows as a result of human activity can increase concentrations of nutrients and impact on the movement and deposition of sediment. This may occur through the extraction of water for irrigation or urban water supply, development of dams and weirs, and (potentially) impacts on hydrology from grazing activities (Roth, C., CSIRO Land and Water, pers. comm., 12 December 2002).

Times of greatest risk

The threat to reefs and associated ecosystems is the result of events that can vary markedly over time. In particular, floods play a major role in transporting pollutants into the GBR lagoon. Hence, it may be important to give greater priority to certain time periods.

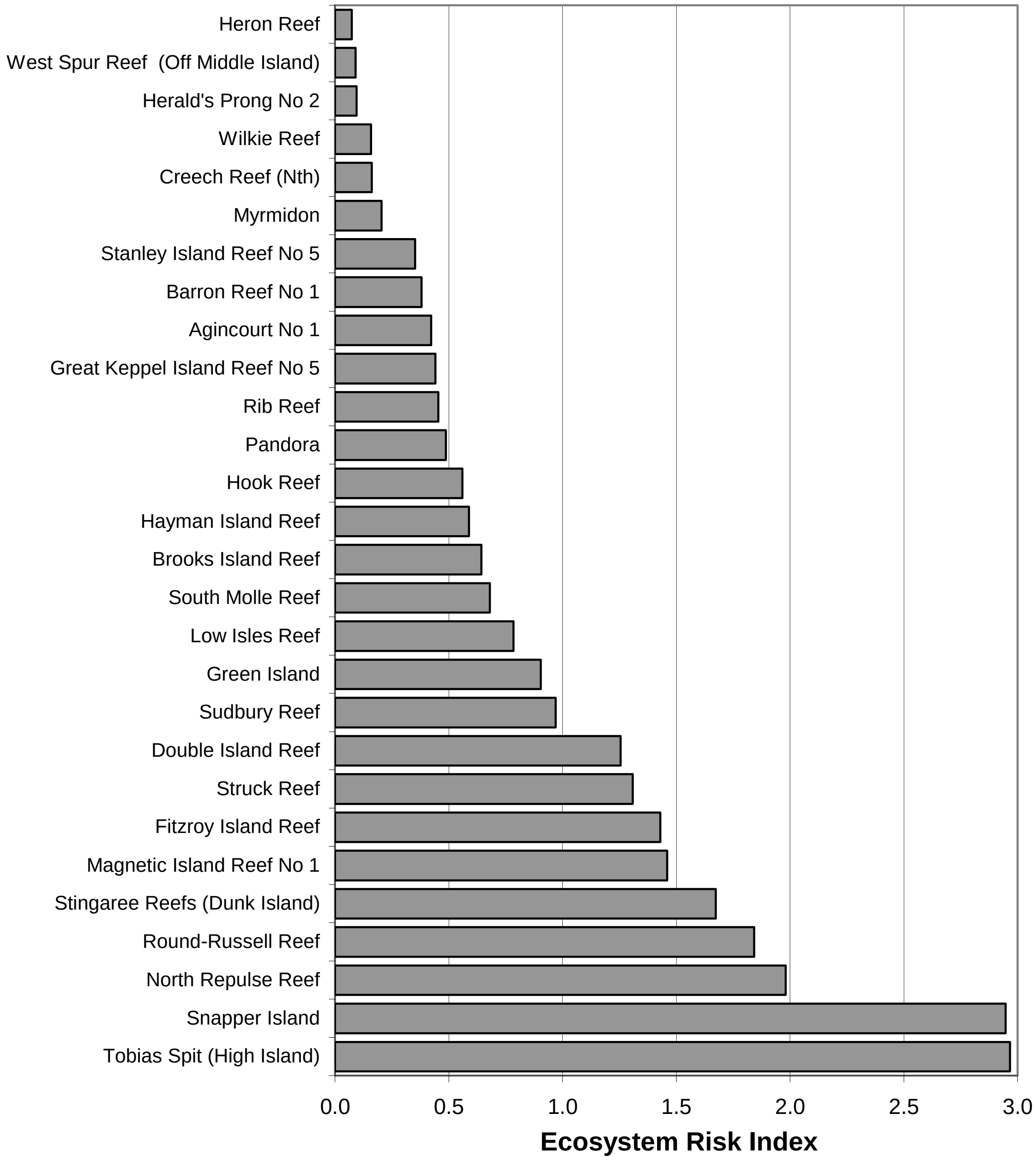
For example, floods that break a long drought can lead to sediment loads several times those of other floods of similar size. This suggests that maintaining ground cover prior to drought breaking floods is a strong candidate for consideration as an abatement option. This is likely to be most relevant in the dry catchments. Sediment loss can vary from one year to the next by a factor of 100 or more in the drier southern catchments, compared to a factor of 5 or more in the Wet Tropics (Moss et al. 1992). In general, runoff from the relatively small Wet Tropics catchments is driven by several flood events per wet season, whereas discharges from the monsoonal catchments of Cape York and the drier areas of the southern GBR catchment are driven by a single major event per year.

Reefs at greatest risk

The process of prioritisation needs to take account of not only high discharge areas, associated land uses, and the timing of discharges, but also the characteristics of receiving areas (rivers and the GBR lagoon). It may be the case that some high discharge land uses have little impact because the relevant river mouth is located far from reefs and associated ecosystems. Conversely, rivers with relatively low levels of pollutant discharges could have significant adverse impacts if they are in close proximity to highly valued reefs and associated ecosystems.

Devlin et al. (2001a) attempted to address some of these issues with their Ecosystem Risk Index, which takes account of the proximity of river mouths to individual reefs and the direction of flood plumes. They calculated risk indices for 28 reefs in the GBR World Heritage Area. Their results show that there are significant differences in the risk faced by individual reefs (figure 7.3). Thus, ranking physical threats could provide useful information about which abatement options warrant consideration. However, the ranking of abatement options needs to take account of both effectiveness and costs, and so may not correspond to a ranking based solely on physical threats.

Figure 7.3 **Risk indices for selected reefs**



Data source: Devlin et al. (2001a).

Devlin et al. (2001a) also used their estimated risk indices to produce a risk assessment map (figure 7.4). They concluded that:

- inner shelf reefs in the Wet Tropics and Whitsundays regions face the greatest risk from terrestrial runoff;
- reefs in inshore and midshelf areas between Cape Upstart and the Daintree River face a moderate risk;

- reefs facing a moderate to low risk are primarily in midshelf areas (along with some inshore reefs within Princess Charlotte Bay); and
- northern reefs and the outer shelf reef area face minimal risk from terrestrial runoff.

In setting priorities, it would be useful to link such a risk assessment for individual reefs back to the contributing discharge areas and land uses.

It should be noted that the methodology used by Devlin et al. (2001a) summarises, in a single index, a wide range of complex factors that influence the threat to individual reefs. Such a methodology inevitably involves making assumptions and relying on estimates. For example, Devlin et al. assumed that all pollutants decline in a linear fashion with distance from a river mouth. They acknowledged that this may be the case for some pollutants, such as nitrate, but not for suspended solids. They also acknowledged that they did not take account of the fact that some catchments are actually basins and consist of many small streams discharging into the GBR lagoon separately in different locations. Furthermore, Devlin et al. assumed that there is a linear tradeoff between different pollutants; that each reef is identical; and all the components of their river pollution index (see table 7.1) are independent and have equal weight. It may be possible to address some of these issues by further refinement of the methodology.

Ideally, an assessment of the risk faced by individual reefs should also take account of factors that affect the probability of damage occurring; the current condition of the reef; stresses from factors other than declining water quality; and whether the reef is of particularly high economic or cultural (including Indigenous) value.

The current condition of a reef provides an indication of what potentially could be lost. However, information on the extent to which reefs are currently in poor condition and sensitive to further stresses is incomplete (Roth, C., CSIRO Land and Water, pers. comm., 12 December 2002). As noted in chapter 2, most monitoring and research has been conducted on outer reefs, which are not subject to as great a threat from land-based activities as are the inner reefs.

There are also limited data on the value of the different reefs and associated ecosystems that make up the GBR World Heritage Area. Nevertheless, it is apparent that areas of high tourist value include those around the Whitsundays region, Cairns, and Port Douglas. Areas of high importance to Indigenous communities and for commercial and recreational fishing may also raise the priority assigned to some reefs.

Given the above, there appears to be a strong case for governments to fund further research on the condition of inner reefs, and their economic and cultural value.

Figure 7.4 **Risk assessment map**

Source: Devlin et al. (2001a).

In conclusion, the information presented in this chapter indicates that there is a strong case for prioritising threats using a multi-criteria approach. While a thorough prioritisation of threats to reefs and associated ecosystems has yet to be undertaken, preliminary evidence suggests that a large proportion of the threats can be attributed to a relatively small proportion of the GBR catchment, land uses, and time periods. This is evident from the work of Prosser et al. (2001), who estimated that 80 per cent of sediment entering the GBR lagoon comes from less than 30 per cent of the GBR catchment. It is also evident from the risk indices calculated by Devlin et al. (2001a) for 28 reefs in the GBR World Heritage Area. Their results indicate that the threats caused by terrestrial runoff vary markedly between individual reefs.

8 Understanding land users' capacity for change

While there are many parties with an interest in land uses in the GBR catchment and/or water quality in the GBR lagoon, it is individual land users whose decisions and behaviours will have to change if management practices that cause diffuse pollution are to be altered. Past research has shown that the capacity and willingness of land users to adopt more sustainable management practices varies with socioeconomic characteristics, such as their income, debt, education, and participation in a community land care group. If a proposed pollution abatement option ignores such characteristics among the land users it is targeting, then it is more likely to fail. Thus, before formulating abatement options, policy makers should ensure that they have sought advice and suggestions from, and are well informed about the socioeconomic characteristics of, the land users whose behaviour they seek to change.

This chapter discusses factors that could influence the capacity and willingness of land users to adopt practices that abate diffuse pollution in the GBR catchment. This is done by highlighting the diversity of land users; considering decision processes of land users; and reviewing aspects of diffusion research. It is concluded that important factors are likely to be the characteristics of land users (including their decision processes) and the practices that abate diffuse pollution. These insights may help inform the design of cost-effective abatement options.

8.1 The diversity of land users and properties

The adoption of practices that improve natural resource management outcomes involves land users understanding the natural resource management issue and having the motivation, as well as the capacity, to adopt the practice (CIE 2001). Drivers of this process will include, among other things: an individual's personal attributes (values; goals; knowledge; information; communication; desire to remain on the land); security of tenure; costs of the practice; peer pressure; financial constraints; and skills. Of course, within this framework, there will be considerable variability between land users. Barr and Cary (2000) argue it is necessary to understand this diversity of land users and rural communities before policies can be developed to change their behaviour.

It would clearly be wrong to assume that land users are homogeneous, with the same skills, values, preferences and resources. As one workshop participant noted, ‘farmers are not an amorphous mass’. Land users are very heterogenous and come from diverse cultural, economic, social and biophysical environments. While many land users may be driven by maximising profits, other factors — such as a desire for lifestyle and minimising risk — are also likely to be important.

Another factor to consider is diversity of the biophysical resources managed by farmers. Just as land users are heterogeneous, so too are the properties they manage. This can result in concentrated and diffuse hazard areas both across and within catchments, and across and within properties. It can mean that specific practices to abate diffuse pollution are not suitable for all farming situations. In addition, what is considered suitable for one farming enterprise could be unsuitable for another or might need to be specially tailored. Ideally, policy instruments should be sufficiently flexible to address this diversity and enable land users to match or tailor the most suitable practice to their particular circumstances.

8.2 Understanding land users’ decision processes

An individual’s decision process is one means of understanding the voluntary adoption of practices that abate diffuse pollution (Barr and Cary 2000). Stages in the decision process are: anticipation of degradation; seeing degradation; seeking information; weighing the alternatives and risks; making a decision; undertaking a trial; making a change and reaffirming the decision.

Reaching the early critical phases of this decision process may be particularly challenging for land users whose practices are contributing to declines in off-site water quality. Anticipation of the problem may be confronting. Barr and Cary (2000, p. 14) observed that it is ‘natural to resist a proposition that one is the culprit in the degradation of soil and water beyond the farm boundary’. Seeing the problem may also be difficult. For example, the loss of nitrogen fertilizer through runoff and soil leaching is not observable to the naked eye. Similarly, while minor soil erosion over time on a large scale may have significant off-site impacts, at the farm level it can be difficult to assess:

> The limited research into perception of land degradation problems in Australia has demonstrated a tendency for individuals to underestimate the extent of the soil degradation on their own farm. This tendency is often manifest in what is now called the proximity effect where land holders will describe the resource problem in their own

region as serious, their neighbourhood as a moderate problem and on their own farm as being no problem. (Barr and Cary 2000, p. 3)

It is likely that an information asymmetry exists between governments and land users. Governments tend to be better informed about hazard areas, while land users would be better informed about abatement costs. It is possible to design instruments to address such an information asymmetry. For example, auction schemes like the BushTender program in Victoria can highlight community preferences to land users and reveal a land user's estimate of abatement costs. In such a scheme, land users bid for funds to set aside and to manage areas according to agreed practices. Such policy instruments address impediments to land users implementing practices that abate diffuse pollution. Nevertheless, the instruments need to be designed in ways to ensure that the desired environmental outcomes are achieved. Poorer quality environmental outcomes may occur if land users are not fully committed to particular practices or if there is insufficient flexibility in the scheme to allow land users to chose and tailor practices that suit their properties.

Another important consideration is a farmer's perception of risk. First, attitudes to risk could be an important factor in the emergence of the water quality problem. For example, the Fertilizer Industry Federation of Australia (FIFA) (sub. 14) argued that sugar cane growers apply higher nitrogen levels than recommended as an 'insurance' against fertiliser losses by heavy rains and because of a lack of confidence in diagnostic tools to test for nitrogen levels in the soil. Second, risk and uncertainty are also relevant considerations when considering management change. Cary et al. (2002) concluded that a lack of information and uncertainty in assessing the worth of practices to improve environmental outcomes were important explanators of the low adoption of the practices by land users. In addition, the CIE (2001) concluded that climatic variability makes the identification of the benefits of such practices difficult. The GBR catchment's disposition to climatic extremes, suggests challenges for land users in estimating the benefits of particular practices. In the case of conservative stocking rates, uncertainty about its economic benefits may be compounded by lags in observing longer term improvements in pasture productivity.

8.3 Characteristics of sustainable farming practices

The characteristics of practices that abate diffuse pollution can affect their adoption. Rogers (1983, p. 233) concluded that the key characteristics of an innovation that affect its rate of adoption are:

- relative advantage — the superiority of the idea relative to the one it supersedes;

- compatibility — the consistency of the idea with existing values;
- complexity — how difficult the idea is to understand and use;
- trialability — extent to which it can be experimented with; and
- observability — the visibility of the results to others.

Relative advantage

From an economic perspective, profitability can demonstrate the superiority of an innovation. A profitable farming practice is more likely to be adopted than an unprofitable one. For example, Griliches (1957), in the groundbreaking study on agricultural technology diffusion, found profitability was the primary explanator of adoption rates of hybrid corn by mid west land users in the United States of America. In contrast, relying on land users' notions of altruism to increase the adoption of practices to improve natural resource management outcomes is unlikely to be successful (Barr and Cary 2000). Abatement options centred on voluntary actions are more likely to be successful where land users are already inclined toward the particular practice.

Given differing natural resource endowments, cost structures and management skills, particular practices to abate diffuse pollution are unlikely to be uniformly profitable across farming enterprises. Although some practices (such as green trash blanketing) have been widely adopted in the GBR catchment, others (such as conservative stocking of pastoral properties) have not, despite being available for many years. This suggests that the net benefits of particular practices to the land user may be weak or uncertain.

Cary et al. (2002) reviewed, across various farming systems, a range of farming practices that improve environmental outcomes and found many were characterised by low profitability. Some practices relevant to water quality in the GBR lagoon are likely to be relatively costly compared to their potential private benefits. For example, minimising soil disturbance in riparian zones could be very costly. For large grazing properties, the cost of fencing creeks and minor watercourses is likely to be substantial; widening crop buffer zones on small sugar cane farms could reduce returns and in some cases affect viability. Given these practices are likely to generate public benefits, abatement options should focus on aligning private incentives with societal water quality objectives.

In some cases, the net benefits of a practice to a land user may be unclear, have high information or management costs, or have long lags before tangible benefits are realised. Cary et al. (2002) found that many practices which improve environmental outcomes can be risky, complex and require more time and management skills of the land user. For example, while anecdotal evidence suggests conservative stocking rates can be profitable, calculating the short run *and* long run ecological *and* economic stocking rates for a particular property could be difficult without sophisticated computer simulation models (such as GRASP — see Ash et al. 2001) or substantial trialing. The Burnett Mary Regional Group for NRM (sub. DR66, p. 1) observed:

> … the adoption of better farming systems will only take place with economic security for the farming practice. Reduced stocking rates to reduce soil and subsequent erosion requires an overall and long term assessment of the whole system.

Similarly, given limited trialing, the net benefits of some new generation fertilisers and precision applications to land users does not yet appear to be firmly established.

Various submissions have suggested altering incentive structures to increase the profitability of adopting particular practices and thereby increase their rate of adoption. Where appropriate, changing incentives structures could be achieved in different ways (box 8.1). The choice of combination by policy makers will depend on the characteristics of the environmental problem, the land use practice, and the land users themselves.

Compatibility

A land use practice that is consistent with the existing values and experiences of land users is more likely to be adopted.

For example, green trash blanketing is widely adopted by sugar cane growers in the wet tropics. FIFA (sub. 14) notes that 90 per cent of sugar cane growers in North Queensland use green trash blanketing to protect the soil from raindrop impact, slow down the velocity of surface runoff, reduce the loss of phosphorus via soil loss and suppress weeds. However, green trash blanketing is less widely adopted on irrigated sugar cane farms in the Burdekin delta. For example, BSES (sub. 47, p. 3) estimate less than 10 per cent of sugar cane growers in the Burdekin region green cane harvest. This appears to be simply the result of compatibility, as a heavy green trash blanket inhibits flood irrigation water dispersing easily across the cropping area.

Structural factors within an industry may also influence compatibility and adoption of some practices. For example, FIFA (sub. 14) claimed:

> Importantly, the sugar industry's assignment system, in operation for many years, has ensured that the area planted to sugar cane is tightly controlled. This has encouraged growers to apply high rates of fertilizer to maximise yields and farm income because they have not had the option of planting additional land to sugar cane.

Box 8.1 Alternative methods to encourage the adoption of particular practices

- Adopter versus diffuser — One approach to reducing the costs of encouraging an innovation involves careful selection of who to target with an incentive. For example, given that demand for nitrogen fertiliser is relatively price inelastic, taxes or subsidies to change sugar cane growers' usage may be relatively ineffective. Alternatively, an incentive to fertiliser companies to trial new eco-friendly technologies might be more appropriate, since the companies are a major source of extension services to sugar cane growers. This approach might also be more cost-effective because it reduces administrative costs and alleviates the problem of monitoring on-farm use.
- Individual versus system — Policies could be directed to land users or to the social system they belong to, such as catchment management, industry policy councils or (cooperative) processors. Examples might include providing resources to regional NRM groups to fund prevention strategies or using processors to facilitate change via a requirement for suppliers to follow an EMS. When designing group schemes, care is needed to avoid the emergence of free rider behaviour.
- Positive versus negative — Incentives can be used to reward or punish behaviour. Responsiveness of land users to incentives may vary according to the price elasticity of the technology. For example, an incremental subsidy could be granted as ground cover exceeds a certain threshold and land users taxed on an incremental basis as ground cover falls below the threshold.
- Monetary versus non-monetary — Policies do not necessarily have to involve a financial exchange. They could involve a commodity or an intangible desired by land users. For example, greater security of tenure could be granted on pastoral leases in return for meeting agreed codes of conduct.
- Immediate versus delayed — Incentives could be granted when practices are adopted or at a later date. Some practices, such as those related to the prevention of soil erosion, can have upfront costs and long lead times before a return on the investment is achieved. While immediate incentives may fund establishment costs, a delayed incentive might also be useful to ensure longer term implementation. Nevertheless, compliance monitoring is likely to be an important component of a delayed incentive scheme.

Source: Adapted from Rogers (1983).

In addition, Barr and Cary (2000) argue that some practices to enhance environmental outcomes are perceived by land users as 'productivity reducing' and consequently they may not be consistent with a pervasive culture among land users of increasing farm output to increase profits.

Complexity

A complex land use practice is less likely to be adopted, since complexity increases the risk that implementation will not be successful. Although on first inspection some practices appear to be relatively simple, their application to individual farms could be complex and require significantly more management time and expertise of land users. ABS (2002b) found a lack of time was a major barrier to changing land management practices to address salinity — 21 per cent of all land users reported it as a very limiting factor.

Cary et al. (2002, p. 14) pointed out that complexity has constrained the adoption of integrated pest management (IPM). This complexity was highlighted by the Queensland Fruit and Vegetable Growers (QFVG) (sub. DR68):

> The IPM approach involves using a wide range of pest control methods in such a manner as to minimise pesticide use. It includes the use of monitoring for pest threshold levels that crops can withstand before significant economic damage is caused, the judicious use of pesticides and the use of biological and cultural control options where available.

The regular monitoring of crops for pests and diseases and the timely recognition of infestations can be difficult even with suitable scientific training. Nevertheless, QFVG (sub. DR68) claimed that there has been a 93 per cent reduction in pesticide use in the banana industry since 1985, when IPM was first introduced. However, progress in adopting IPM appears to be much slower for minor fruit and vegetable crops, which appear to rely on older, less targeted chemicals.

Similarly, the estimation of grazing capacity and grazing rotation based on cattle feed requirements and pasture forage supplies can be complex. For example, Ash and Quirk (2002) noted that:

> In NE Queensland where the average property sizes are in the order of 30 000 hectares (Hinton 1993) considerable landscape diversity can occur within the paddocks so the estimation of carrying capacity requires detailed property maps and a good understanding of the pasture communities. … Decision tools for safe carrying capacity in the Upper Burdekin have been developed through the use of a grass production model called GRASP to assist in the process. This model allows limited site specific data to be extrapolated sensibly across time and space and in conjunction with digital property maps using geographic information systems, the estimation of carrying capacity is becoming more achievable.

In the case of sugar cane, soil nitrogen testing is straightforward when planting sugar cane crops after fallow. However, FIFA (sub. 14) noted the complexity of accurately diagnosing nitrogen requirements for ratoon sugar cane crops.

Trialability

Trialing a new management practice enables land users to test it on a small scale before deciding to apply the practice more extensively. This approach can make the choice of adoption less risky for land users. Trialing can also enable practices to be tailored to the particular biophysical conditions of the farm and management skills of the land user. JD Cambridge Corporate Services (sub. 12, p.3) noted the importance of trials to land users:

> … the farming industry cannot afford to implement new production methods without being assured they work effectively.

Most of the practices mentioned in chapter 5 that abate diffuse pollution appear to be amenable to trialing. For example, green trash blanketing was easily trialed by sugar cane growers as crops were successively harvested over time. Contract harvesting also facilitated the change as growers were not required to purchase expensive machinery to test the practice. Similarly, where properties have sufficient internal fencing, spelling of beef grazing paddocks at the start of the wet season is also relatively easy for individual land users to trial.

Several submissions highlighted the importance of trialing for emerging technologies linked to particular practices to abate diffuse pollution. For example, Dr Alberta Rovira (sub. DR41) claimed that the new fertiliser NutriSmart 'now requires extensive field trials … to compare its performance with conventional fertilizer…'. Similarly, FIFA (sub. 14) observed that Near Infra Red (NIR) spectrophotometry is being used to estimate nitrogen levels in harvested sugar cane, and that further trialing is occurring to determine its reliability as a diagnostic tool to assess the adequacy of existing fertiliser practices.

However, the cost of trialing can be high. For example, QFVG (sub. 68) claimed that rates of adoption of IPM for minor crops will depend on the availability of suitable 'soft' chemicals. However, the high costs of residue trials may be discouraging the development of these chemicals.

Observability

A new management practice is more likely to be adopted if the advantages of the practice are observable.

Observability is likely to vary across industries and across land use practices. Rogers (1983) noted that the outcomes of preventative innovations can be more difficult to observe than innovations which enhance existing outcomes. Land users may be less likely to observe the benefits of practices that are directed at prevention of long term and often off-site environmental problems rather than at increasing existing farm production. For example, the benefits of establishing micro artificial wetlands on sugar cane farms to act as nutrient filters might not be easily observed without the aid of complex, long term, scientific monitoring.

The geographic concentration of industries and farm size could be important for observation of particular practices. For example, the smaller size of sugar cane farms and their concentrated geographical nature make the observance of management changes by peers far more feasible compared to large grazing properties that are widely dispersed across the GBR catchment. Possibly in response to this, many Landcare programs have attempted to locate demonstrations along major roads to enhance visibility (Cary et al. 2002, p.15).

8.4 Characteristics of land users

There is great diversity in land users' socioeconomic characteristics. A common approach used in previous research to evaluate this heterogeneity was to classify individuals according to their willingness to adopt land use practices (see box 8.2).

This section, however, does not attempt to categorise individuals, but rather highlights some of the links between land users' socioeconomic characteristics and their capacity and willingness to adopt practices that abate diffuse pollution. Several studies have explored which socioeconomic characteristics of Australian land users have most influence on their management decisions (see, for example, Cary et al. 2001; Fenton et al. 2000; CIE 2001). This section focuses on the following broad categories:

- age;
- education and training;
- farm business characteristics; and
- geographic location and farming networks.

Age

Sugar cane growers and beef producers tend to have higher median ages than the general workforce (box 8.3). The evidence on the relation between age and capacity to change land use practices is mixed.

Younger land users tend to have higher levels of formal education (ABARE 1999) and may have greater abilities to obtain and use information about improving land management (Cary et al. 2002). Research has suggested that younger land users are more likely to participate in Landcare groups (Curtis and Van Nouhuys 1999) and more likely to recognise land degradation and the need for conservation (Fenton et al. 2000) than are older farmers. Data from the 1998 ABARE Resource Management Survey of Australian broadacre and dairy farmers indicate that younger land users were more likely to exclude stock from degraded areas and use conservation tillage than were older land users. While some younger land users could be more open to change, it is likely that some older individuals possess skills and experience which assist them in adopting more sustainable practices (Cary et al. 2001).

Box 8.2 **Individuals' willingness to adopt land use practices**

The classification of individuals according to their willingness to adopt innovations was, until recently, a common approach to explaining the adoption of sustainable resource management practices. The approach arose from US studies of the adoption of hybrid corn varieties in the 1950s, and was based on the model that innovations are developed on research stations and then promoted to land users.

The system of classification frequently cited in the adoption literature is based on work by Rogers (1962), who categorised individuals as innovators, early adopters, early majority adopters, late majority adopters or laggards. Early research attempted to profile the social characteristics, such as age or income, of each of these adopter categories.

More recently, rural sociologists have expressed concern that this 'universal' approach of classification restricts the design of policies to encourage particular land use practices. Dunn (1997) noted:

> The assumption [is that] research results and information can be transferred from source to receiver using skilful communication … there is a strong notion that non-adoption of scientific results is irrational behaviour which can be rectified by rationally communicated argument and explanation. Failure to adopt is seen as … aberrant behaviour for which someone has to take the blame — usually extension workers and farmers.

Current research increasingly acknowledges that the identification of the goals and values which drive land users' management decisions is important to understanding individuals' decisions — land users preferences are heterogeneous. Policy development will be assisted by understanding the situations in which a farmer's objectives, such as long-term security of at least a minimum standard of living for their family, may conflict with the goals of the practice.

Sources: Barr and Cary 2000; Dunn 1997; Cary et al. 2002.

The reduction in family farm succession — evident in regions characterised by ageing rural populations, declining numbers of younger people entering farming, and increasing migration out of rural areas — may discourage adoption of sustainable management practices which have longer-term benefits to the farmer.

However, on the other hand, older land users may wish to pass on a viable property to their children and thus could be more conscious of longer-term sustainable management practices.

Box 8.3 **Age trends in sugar cane and beef industries**

ABS 2001 Census data indicate that sugar cane growers and beef producers in the GBR catchment have a median age of 47 years, 8 years older than workers in general. ABARE (1999) data indicate that 59 per cent of Australian beef producers in 1997-98 were 55 years or older.

While the average age of sugar cane growers is increasing (Canegrowers, sub. 34, p. 6), ABARE farm survey data indicate that the average age of Queensland beef producers has remained constant throughout the 1990s. ABARE survey results also indicate that between 1997-98 and 2001-02, the average age of broadacre operators/managers in the Burdekin catchment decreased.

Source: ABARE (1999, 2002, unpublished).

Education and training

Workers employed in the sugar, beef and horticulture industries in the GBR lagoon and catchment are less likely to have post-school education than workers in other industries, such as aquaculture or mining (see chapter 4). It is widely believed that land users with higher levels of formal education have greater ability to obtain and process information, to understand and apply new technologies, to analyse the benefits and risks involved, and to be more willing to seek further education and training as required (Cary et al. 2001, 2002). However, empirical studies suggest that the relationship between formal education and adoption of alternative land use practices is weak.

Land use practices to abate diffuse pollution may be complex and require greater time and management skills. A land user who has undergone training and is better equipped in terms of managerial and technical skills *may* have greater capacity to adopt new management practices (Fenton et al. 2000). For example, training in design and monitoring strategies is likely to be particularly important to successful adoption of integrated pest management (IPM), because the method relies on a combination of techniques which must be tailored to individual situations (Environment ACT 2000).

ABARE (unpublished) data indicates that, in 2001-02, 62 per cent of sugar cane farms in the Burdekin catchment used irrigation scheduling tools to plan irrigation timing, and 33 per cent of farms re-used drainage water. Training in the design and implementation of efficient irrigation techniques is likely to be important to further encourage adoption of these practices.

Information on participation rates in training programs on land use practices to abate diffuse pollution in the GBR catchment and their impact on management practices is limited. There is some evidence on the participation of sugar cane growers in voluntary programs such as COMPASS — 700 growers (approximately 13 per cent of sugar cane enterprises) have to date completed the self-assessment workbook. However, little specific information is available on the extent to which training programs have actually changed farming practices.

Farm business characteristics

Financial circumstances

The financial pressures on land users to ensure a reasonable standard of living for their families may impact on their capacity to adopt practices to abate diffuse pollution.

Lower profitability is generally associated with less available financial capital to invest in sustainable practices. Particular practices can require initially significant investments in capital and training, but are perceived to deliver uncertain benefits over a longer time frame. Land users who face short-term financial constraints — such as debt servicing requirements, combined with variable or low levels of income — may lack the financial resources to invest in practices that may yield productivity gains only in the long term. For example, in 1997-98, 63 per cent of Queensland specialist beef producers cited financial constraints as the most important barrier to the adoption of potentially attractive innovations (ABARE 1999).

Moreover, since the 1950s, the continuing trend of declining terms of trade have significantly reduced primary producers' per unit production margins (Cary et al. 2001), although this has in some situations been offset by increases in productivity. For example, between 1977-78 and 1998-99, the terms of trade for broadacre beef producers declined by an average of 2.1 per cent per annum, but productivity increased 2.1 per cent (ABARE 2000). Beal (1997), in a review of the economic pressures affecting the depletion of natural resources on farms in Australia, suggested that many producers, in response to declining terms of trade:

> … have sought to make their land produce more so that a minimum net income and standard of living may be maintained. More often, however, degradation of the

> resource base has occurred, because more than sustainable use has been made of resources. (Beal 1997, p. 213)

Conversely, in some circumstances, the financial pressures on land users could intensify if existing unsustainable land management practices continued. Consequently, there is anecdotal evidence of some land users swiftly adopting 'seachange' land use practices in order to circumvent what they see as an inexorable economic and ecological decline.

Off-farm income

Off-farm income may improve a farmer's capacity to adopt land use practices that abate diffuse pollution.

Supplementary income could enable individuals to invest in management practices, such as precision fertiliser use, which has high initial costs (Cary et al. 2001). The contribution of off-farm income to total farm income has been increasing for many farms (Cary et al. 2001). However, for some of these land users, off-farm income may instead reflect poor farm returns and hence the need to supplement farm income (CIE 2001). Furthermore, the time required to earn off-farm income could also reduce the time available for adopting new practices or participating in training (Cary et al. 2001). On the other hand, off farm employment may also enable the land user to gain new skills and insights that could improve their farm management skills.

Off-farm income may also encourage the adoption of practices that abate diffuse pollution because at least part of the total farm income will be independent of production levels. Canegrowers (sub. 34, p. 6) noted:

> It is apparent that the income derived from many small farms is supplemented by off farm employment or investment income. That additional income could be regarded as sound diversification that underwrites farming operations during periods of poor production or very low prices.

Income which is not linked to farm production may enable land users to hedge against the financial risks — which are particularly great in variable climate conditions — posed by activities such as destocking during drought and reducing fertiliser application rates (Cary et al. 2001).

Opportunities for farm household members to earn off-farm income are likely to be greater when farms are in close proximity to sources of off-farm employment.

Enterprise mix

Diversification of farming activities could provide greater income security, and thus increase capacity for management change, by reducing dependence on commodities which are subject to large price fluctuations (CIE 2001). Farm diversity may also be related to management skills (CIE 2001) and the willingness to experiment with new techniques (Fenton et al. 2000). However, in other cases, a mixed enterprise farm might have less resources than would otherwise be available to support improved management practices. In the case of beef grazing, diversification opportunities are generally limited by pastoral lease conditions (PC 2002a).

Diversification may also comprise part of a change in land use practices. For example, some sugar cane growers are introducing fallow crops such as legumes to increase returns, reduce tillage and improve soil nutrients. ABARE (unpublished) data indicate that 13 per cent of irrigated sugar cane farms in the Burdekin delta grow a cover crop on fallow land. This is similar to unpublished estimates for the wet tropics (Sing, N., QDPI, pers. comm., 7 January 2003).

Farm size

Farm size may have a variety of influences on the adoption of practices to abate diffuse pollution. For example, small property sizes, combined with pressures to generate higher farm incomes, might be linked to land degradation (Cary et al. 2002). Chudleigh (2002, p. 5) noted:

> There is some evidence that economies of size in cane farming exist … Small farms without off-farm income are likely to be currently struggling to provide living expenses for their families, more so than larger farms, as any margins above essential production costs are likely to be lower.

A commonly suggested practice is the establishment of riparian buffer zones on sugar cane farms. However, cane farms with a smaller scale of operation may not have the financial capacity to remove this land from production. Alternatively, as on irrigated properties in the Burdekin catchment, non-cultivated riparian strips may be used largely for roads and tracks rather than vegetation (ABARE unpublished data). Similarly, the Mary Burnett Region Group for NRM (sub. DR66, p. 1) observed:

> Economic pressures on farmers include the need to have a cash flow to keep the bank manager happy; the area of land which they farm may be too small to be economic thus forcing them to continually crop when the land/soil needs improvement such as green manure crops etc.

Cary et al. (2002) suggested that larger properties may be easier to manage profitably and may have more resources available for improving land management.

For example, the scope for trialing and implementing particular practices, such as spelling and reducing stocking rates, may be greater on a large grazing property than a smaller farm. However, in regions such as the Burdekin catchment, the relatively large size (approximately 30 000 hectares on average) and varied land conditions of grazing properties may make it more difficult for land users to recognise and monitor localised areas of soil erosion.

Geographic location and farming networks

Exposure to new ideas and the uptake of innovations is enhanced by land users' social and industry networks and, conversely, can be retarded by the geographic remoteness of individual land users. The rate of adoption of new techniques is likely to be higher for land users who can readily access services and information, including education and training. Land users who have greater contact with neighbours and friends are more likely to obtain direct information and observe demonstrated benefits about management practices relevant to their situation. For example, 64 per cent of specialist beef producers who responded to the ABARE 1997-98 beef industry survey cited other land users/family as one of the two most valuable sources of technical information in the management of their property (ABARE 1999).

The adoption of new telecommunication technologies, such as the Internet, may assist the distribution of information. ABARE (unpublished) data indicate that 61 per cent of sugar cane growers in the Burdekin catchment used the Internet in 2001-02 to obtain farm production or management information. However, services will need to be available and sufficiently reliable to facilitate use.

The potential for land management information to be distributed through social and industry networks, such as workshops and field days, depends on the industry's structure and geographic location. Some industries, such as sugar, have stronger links between primary production and processing sectors than other industries, such as beef cattle production. Because sugar must be milled within 16 hours of harvesting to prevent deterioration, coordination networks exist between cane growers and mill owners to maximise returns (BCG 1996).

ABARE (unpublished) data indicate that 90 per cent of sugar cane growers in the Burdekin catchment obtain farm production and management information from the Bureau of Sugar Experiment Stations (BSES). The BSES (sub. 47, p.1) highlighted that it is the principal provider of research, development and extension services to the Australian sugar industry.

The financial interdependency and close geographic proximity between sugar cane growers and millers could assist the adoption of improved management practices. For example, Hildebrand (2002) suggests that adoption of the sugar industry code of practice could be increased by requiring mill acceptance of all cane to depend on signed farmer agreement to adhere to the code.

The existence of farming networks and the participation in social groups and movements is also likely to have longer-term impacts on social attitudes and norms — the "social capital" of the community (PC forthcoming). Participation in community groups, such as Landcare initiatives may, in the longer-term, result in incremental shifts in individual values (Cary et al. 2002). However, the link between geographic location and participation in community groups is not clear. Remoteness may limit the opportunities for joining and participating in Landcare initiatives, but may increase the significance of social contacts provided by Landcare membership (Cary et al. 2001). Furthermore, the effectiveness of Landcare to bring about short-term change in management practices is limited by its focus on longer-run, incremental cultural change.

8.5 Conclusions

The diversity of land users and their properties makes it unlikely that particular practices to abate diffuse pollution will be universally applicable.

The characteristics of particular practices to abate diffuse pollution will influence the capacity of land users to adopt them. Practices that are profitable, compatible with existing practices, not too complex, easily tested by land users, and whose results can be easily observed, are more likely to be adopted rapidly. For example, green trash blanketing, which has many of these characteristics, has been widely adopted by the sugar industry and is providing significant environmental and productivity benefits.

The way in which the socioeconomic characteristics of land users influence their management decisions depends on the situation and goals of individuals. There is mixed evidence about the relations between different characteristics and the capacity to change. However, some links are stronger than others. In some cases, ageing and less educated land users can find the adoption of particular practices more challenging. Yet in other cases, the experience of older farmers and their desire for the next generation to receive the farm in the same state as they received it, or better, can provide a catalyst for introducing innovative land use practices.

The business characteristics of the enterprise can also drive the uptake of practices to abate diffuse pollution. Large, diverse and profitable properties can often provide a land user with the flexibility to introduce management change and absorb potential costs and risks. Nevertheless, for some land users where existing unsustainable practices are leading to long term financial pressures, alternative land use practices can provide a ‘short circuit’ and the means to attaining long term viability.

Finally, the role of farming communities’ social and industry networks in the spread of new land use practices should not be overlooked. This is particularly important for the GBR catchment, which is characterised by both highly concentrated sugar cane and horticulture industries and a highly dispersed beef industry. Instruments which tap the strengths of close knit communities and address some of the communication challenges of isolated communities will be critical.

The above factors are particularly important when considering the design of policies to improve water quality in the GBR lagoon. This and previous chapters have highlighted the diversity of the region, the land users, the enterprises and the land management practices themselves. This diversity is accentuated by the differing nature of land uses in potential hazard areas — by extensive beef grazing in dry tropic catchments and intensive cropping in the coastal wet tropics. Careful policy design may enable the development of instruments that can harness or countervail particular characteristics and so increase the adoption of desirable land use practices.

9 Abatement options

As noted in earlier chapters, the Commonwealth and Queensland Governments have made a commitment to reverse the decline in water quality entering the GBR lagoon and are currently formulating a *Reef Water Quality Protection Plan* for this purpose. This chapter examines various options to abate diffuse pollution that comes from land uses in the GBR catchment and is adversely affecting water quality entering the GBR lagoon. Each abatement option is a combination of proposed land use changes and the policy instruments to achieve those changes.

The terms of reference for this study required an analysis of the likely costs and benefits of abatement options. A qualitative assessment of costs and benefits is provided, but it was not feasible to quantify the size of costs and benefits. As noted in chapter 6, the benefits of improved water quality are extremely difficult to measure in dollar terms. Abatement costs are also very difficult to quantify because they can vary markedly between different properties, depending on factors such as soil type, topography, rainfall, and income forgone by changing management practices. At the time of writing this report, the Commonwealth and Queensland Governments were still undertaking an assessment of which regions, land uses, and time periods pose the greatest threats to reefs and associated ecosystems. Thus, it was unclear which properties warranted consideration in an assessment of abatement options. Even if this information had been available, it is possible that detailed case studies of many individual properties would have been required to obtain an accurate estimate of total abatement costs, and of the effectiveness of each possible measure.

While a thorough ranking of threats to reefs and associated ecosystems has yet to be completed, it does appear that the most significant sources of diffuse pollution entering the GBR lagoon are:

- soil erosion on grazing properties; and
- overuse/misuse of fertilisers and chemicals by cropping industries.

Therefore, this report provides a qualitative assessment of abatement options to control these problems. The options examined here may not be those short listed when more information is available from a prioritisation of threats, but they do provide a useful illustration of the issues that need to be considered in assessing options.

The next section provides a framework for formulating abatement options, with an emphasis on policy instruments. Following sections then assess specific abatement options for soil erosion and the overuse/misuse of fertilisers and chemicals.

9.1 Developing abatement options

The process of developing abatement options for diffuse pollution can be characterised as having three components (Shortle and Horan 2001):

- what to target;
- who to target; and
- what instruments to use.

What to target

It is impractical to target actual emissions, due to the inability to meter diffuse pollution regularly at reasonable cost with existing technologies. Instead, it is necessary to use an alternative target that is correlated with emissions. The literature on diffuse pollution control focuses on three possible targets (Shortle and Horan 2001):

1. *inputs or practices known to lead to pollution* — such as the quantity of fertiliser and pesticides used, or practices that affect their movement into the environment;
2. *emission proxies or other site-specific environmental indicators* — such as estimates of field losses of fertiliser residuals to surface water, and the excess of nutrient inputs over the nutrients contained in farm products; and
3. *ambient pollution* — concentrations of pollutants in the environment, such as the quantity of dissolved inorganic nitrogen in an estuary.

Targeting inputs or practices has the advantage that land users readily understand what policy makers are seeking to change. However, it may be difficult for policy makers to find inputs or practices that have a clear relationship to pollution.

Targeting emission proxies or other site-specific environmental indicators provides a stronger link to actual pollution, but requires the development of accurate models of how different actions affect emissions. There could also be a high ongoing cost in regularly collecting site-specific data for such models. Furthermore, land users would need to understand how their actions affect predicted emissions. It should also be noted that the target would be *expected* emissions, since the actual level of pollution will depend on rainfall, which land users cannot control.

The targeting of ambient pollution — such as an end-of-river target — was originally proposed in a pathbreaking study by Segersen (1988). The idea is to link actual pollution to policy instruments at the property level. For example, a tax could be imposed on all land users in a catchment if water quality at the relevant river mouth falls below a particular level. However, an ambient target is only cost-effective under very restrictive assumptions about how land users anticipate each other's behaviour (Ribaudo et al. 1999). It is also less likely to be cost-effective in cases where there are multiple pollutants, as is the case for water quality entering the GBR lagoon (Shortle and Horan 2001).

It appears that targeting inputs or practices is the only practical option at present, given the limitations of existing emission models and the restrictive conditions under which an ambient target would be cost-effective. Therefore, the abatement options examined in later sections of this chapter target inputs or practices, such as the amount of fertiliser applied to a crop. In the longer term, new monitoring technologies — such as remote sensing — may make it feasible to target emission proxies or other site-specific environmental indicators.

Who to target

Abatement options do not necessarily have to target land users, even though diffuse pollution is caused by the actions of some land users. For example, restrictions could be placed on the chemicals and fertilisers that input suppliers sell to farmers. Alternatively, industry associations could be required to develop and publicise codes of practice for chemical and fertiliser use. When there are many land users contributing to diffuse pollution, these approaches may be more cost-effective than targeting individual land users. Hence, the most cost-effective group to target will have to be determined on a case-by-case basis.

What instruments to use

Policy instruments — such as regulations and taxes — are the means used to achieve a desired change in behaviour. There is a well-developed literature on policy instruments that can be used to control point sources of pollution, such as sewage treatment plants. In contrast, the application of policy instruments to diffuse pollution, such as that entering the GBR lagoon, is a relatively new and evolving phenomenon. The range of possible policy instruments can be grouped into the following broad categories:

- *regulations and standards*, which mandate or proscribe certain types of behaviour or outcomes;
- *taxes and subsidies*, which change the financial incentives faced by land users;
- *markets*, which enable land users to trade property rights in order to meet society's environmental objectives;
- *contracts and bonds*, which commit land users to undertake certain actions;
- *liability rules*, which are enforced after environmental damage has occurred;
- *education and information provision* to land users about new technologies or the better use of old technologies; and
- *guidelines*, such as codes of practice.

Table 9.1 provides examples of policy instruments that could be applied under the three different options for what to target.

It is not possible to say that a particular policy instrument will be the most cost-effective in all circumstances. Policy makers have to make an assessment on a case-by-case basis. In most circumstances, it will probably be more cost-effective to use several instruments simultaneously.

Market-based instruments (taxes, subsidies, and markets) are often seen as being superior to other approaches because they can give land users an incentive to minimise abatement costs. However, there may be barriers to the adoption of market-based instruments (discussed below). Thus, other instruments — such as regulation — cannot be ruled out as being more cost-effective in some cases. In addition, there has been little research on the efficiency or effectiveness of voluntary measures (OECD 1999; Weersink et al. 2001).

Regulations and standards

Regulations and standards typically involve command-and-control measures prescribing actions that must or must not be undertaken. This gives policy makers a degree of certainty about what will be done by each land user, but effectiveness depends on monitoring and enforcement, which can be costly. In addition, land users may be given little flexibility to adapt abatement actions to their unique site-specific conditions and to changing conditions over time. This reduces the likelihood of getting the most cost-effective outcome. Regulations and standards appear to be best suited to situations where land users and their properties are similar; the 'cause and effect' relationships are well understood; there is a high probability of serious environmental damage; and this damage can clearly be linked to the land use being controlled.

Table 9.1 **Examples of policy instruments to control diffuse pollution**

	What to target		
Category	*Inputs or practices*	*Emission proxies*	*Ambient pollution*
Regulations and standards	Pesticides registration Restrictions on fertiliser application rates Mandatory use of property management plans that include approved pollution control practices	Restrictions on modelled nutrient loads Regulations on fertiliser applications in excess of estimated crop needs	
Taxes and subsidies	Charges on pesticide purchases Taxes on fertiliser applications Subsidies for inputs or practices that reduce pollution Rate rebates for adopting approved pollution control practices	Taxes on modelled net soil loss Penalties for fertiliser applications in excess of estimated crop needs	Taxes imposed on all land users within a catchment when its water quality falls below a threshold level
Markets	Tradeable permits to use inputs such as fertilisers Land users compete in an auction to maintain riparian vegetation in return for a subsidy	Tradeable permits for predicted emissions	
Contracts and bonds	Land retirement contracts Contracts to adopt particular land management practices		
Liability rules	Negligence liability rules for failure to meet duty of care	Strict liability rules based on modelled emissions	Joint liability rules based on ambient pollution
Education and information provision	Best Management Practice (BMP) training Extension services Peer group learning		
Guidelines	Voluntary codes of practice		

Source: Adapted from Shortle and Horan (2001).

Taxes and subsidies

Environmental taxes and subsidies, if set appropriately, can change the incentives land users face so that they reflect the costs and benefits to society of different actions by land users. For example, a tax could be imposed on fertiliser applications in excess of plant requirements so that land users bear the cost of any adverse impacts they cause. Alternatively, a subsidy for abatement actions could reward land users for their contribution to protecting the environment. In theory, land users acting in their own private interest would then achieve an outcome that is optimal from society's perspective. However, governments need to be well informed in order to set taxes or subsidies at the appropriate level. This problem is compounded by the prospect that the benefits of abating diffuse pollution will vary between properties, providing a case for site-specific taxes or subsidies. Monitoring and enforcement costs could therefore be high. A further problem is that diffuse pollution is partly determined by rainfall (chapter 2).

Markets

The rationale for creating markets is that environmental problems are due to the absence of markets for things that people care about. In the case of the GBR lagoon, there is no market to reward land users for the benefits they provide to others by abating pollution.

A common form of market creation is a tradeable permit market to control point source pollution. This involves a limit on aggregate emissions and a market in which parties can trade the right to pollute within that limit. A market for emission permits can be very cost-effective because parties with the lowest abatement cost have an incentive to reduce pollution and sell their emission permits to polluters with higher abatement costs. Applying this approach to diffuse pollution faces a major, but possibly not insurmountable, hurdle because emissions cannot be regularly metered. In the future, it may be possible to establish a permit market for *expected* emissions if there are sufficient advances in remote sensing techniques and emission modelling. However, the possibility of legal challenges to the accuracy of predicted emissions would need to be considered. In the near term, a more feasible option is to target inputs. For example, tradeable permits to use fertilisers within an aggregate limit could be introduced for a particular catchment.

A more recent development in market-creation schemes has been to invite land users to compete in an auction to supply ecosystem services — such as the maintenance of riparian vegetation — in return for a subsidy. Such a scheme, termed BushTender, is currently being trialed in Victoria. The advantage of auctions is that they can overcome an information asymmetry between governments (better informed about hazard areas) and land users (better informed about abatement costs) that may otherwise lead to inefficient outcomes. If a government simply were to ask individual land users to enter into a contract to adopt a certain practice (such as land retirement), then its ignorance of abatement costs could lead it to pay far more than in an auction. However, offering individual contracts may be more cost-effective when there are a limited number of land users in a hazard area and hence few potential bidders for an auction.

Liability rules

Liability rules are unlikely to be an effective instrument, particularly if used in isolation. This is because the probability of a successful prosecution is low, given that it is difficult to conclusively prove the source of diffuse emissions. Hence, the deterrent effect of liability rules is limited. It would also be necessary for land users to be able to understand how their actions affect emissions.

Education, information provision and guidelines

In isolation, education, information provision and guidelines will be most effective when the desired land use change increases profits. Thus, these instruments are best-suited to cases where profitable pollution abatement does not occur because land users are not well informed or lack the necessary skills.

Multiple instruments and land use changes

An emerging theme in the literature on controlling diffuse pollution is that combining instruments can be more cost-effective than using them in isolation (Ribaudo et al. 1999). This issue was also mentioned in several submissions (box 9.1). An example of how combining instruments could be useful is provided by education, which in isolation will be ineffective when the desired land use change is unprofitable. However, education could be very effective when combined with another instrument, such as a subsidy for the land use change. Similarly, the development of guidelines for pollution control practices could be used in combination with rate rebates for adopting such practices.

A related theme is the sequencing of multiple instruments. When there is significant uncertainty about the cost-effectiveness of different instruments, it may be appropriate to begin with an information campaign and the development of guidelines. If these instruments are not sufficiently effective, then more costly or coercive instruments — such as taxes and regulations — can be considered. Furthermore, the use of instruments like taxes and regulations may be more effective if preceded by an information campaign and the development of guidelines.

Box 9.1 **Combining instruments**

Several submissions suggested that a combination of instruments would be needed to reduce diffuse pollution in the GBR lagoon (for example, Department of Primary Industries, Queensland, sub. DR63; and Tully and District Wildlife Preservation Society, sub. DR65).

The Queensland Seafood Industry Association (sub. DR62) detailed a 'step approach' to encouraging best practice. Providing incentives (that are low cost to government) was the first plank of the approach, supported by other measures, such as plans and research. Regulation was suggested as necessary only if time and support was first given to incentives, and these had not been sufficiently effective. Suggested incentives included:

- providing incentives to farmers, such as:
  - improved access to natural resources and markets;
  - discounts on future natural resource cost increases; and
  - preferred access to government programs and extension services;
- defining BMPs on an industry-by-industry basis, such that they are:
  - voluntary, but binding once incentives flow;
  - guided by industry codes;
  - exceed minimum duty of care;
  - independently accredited; and
  - continuously improving; and
- defining BMP plans as enforceable contracts with individual land users which are reviewed every three years.

Sources: Department of Primary Industries, Queensland (sub. DR63); Queensland Seafood Industry Association (sub. DR62); Tully and District Wildlife Preservation Society (sub. DR65).

It is possible that policy makers will seek to achieve several land use changes simultaneously or at least provide land users with a range of options to reduce emissions. For example, diffuse pollution from grazing properties could be reduced by fencing off vulnerable riparian areas and/or more conservative stocking rates. One way to provide a framework for multiple land use changes is to require the use of a:

- *property management plan* (PMP), which documents resources and management practices on a property; or
- *environmental management system* (EMS), which is a system used to manage environmental impacts on a methodical and continuous basis.

PMPs can be one component of an EMS, and be used to record information that demonstrates compliance with a duty of care (Caltabiano 2002). An EMS documents the overall approach of a business to environmental management and can range from informal to externally-accredited documents.

The use of an EMS or PMP has the advantage that land users could be given some flexibility about which land use changes they utilise to abate pollution. Another possible advantage of using an EMS or PMP is that they could take account of all environmental issues, not only those relating to water quality entering the GBR lagoon. However, it may be administratively complex to address multiple environmental issues via an EMS or PMP, since more than one government agency and/or jurisdiction is likely to be involved. Hence, certification could require a lengthy assessment process by several different organisations and/or more than one jurisdiction.

Check list for assessing options

To aid the assessment of abatement options in the following sections, a check list of five issues was developed (table 9.2).

The first of these issues is whether relevant parties have sufficient information to implement an abatement option. This is relevant because of possible uncertainty about how different actions affect emissions. There could also be difficulties due to an information asymmetry between governments (more knowledgeable about hazard areas) and land users (more knowledgeable about abatement costs).

The next issue is whether an abatement option is technically and legally feasible. This will be particularly important when using instruments where it is assumed that there is an ability to enforce, such as with a regulation or tax. For example, there may be constitutional difficulties with applying a tax to specific geographic regions.

The size and timing of costs is a major consideration. There are different possible costs to consider, as noted in table 9.2. This should include the cost of production opportunities forgone by abating pollution.

Flexibility is an issue because abatement options that can provide cost-effective solutions under a variety of conditions will outperform those that are not self-adjusting. This is likely to be important because of the diversity of land users and their properties across the GBR catchment, and the possibility that new technologies for estimating and abating emissions will emerge in the future.

Finally, the distribution of costs and benefits between parties and over time will have some bearing on whether an abatement option receives community acceptance.

Answers to the above-mentioned five issues are then used to make a qualitative assessment about the likelihood that the desired land use change will occur.

Table 9.2 **Check list for assessing abatement options**

Issue	*Comments*
1. Informational requirements	Do land users and other parties possess the necessary information to implement the abatement option? If not, can they obtain the needed information at reasonable cost?
2. Feasibility	Are there technical or legal impediments to implementation?
3. Costs	What are the costs and when do they occur? This includes the costs of: • administration; • monitoring; • enforcement; • compliance; and • opportunities forgone.
4. Flexibility	Is the abatement option flexible enough to adapt to the different economic and site-specific conditions of different properties? Or is it a one-size-fits-all approach? Will the abatement option have to be continually adjusted in response to changing economic and environmental conditions? Or is it sufficiently flexible to adapt to such changes? In the longer term, do land users have an incentive to seek out and adopt new lower cost abatement technologies?
5. Distribution of costs and benefits	What is the distribution of costs and benefits between parties and over time?
6. Likelihood of achieving desired change in land use	Given the above, what is the likelihood that the desired change in land use will occur?

9.2 Soil erosion

This section examines several options to reduce soil erosion on grazing properties in the dry tropic areas of the GBR catchment.

Inputs or practices to target

The widespread use of land management practices which maintain ground cover on grazing properties, particularly at the end of the dry season, could be a cost-effective approach to reducing soil erosion. While these practices may be profitable or unprofitable to individual land users, they can have clear public benefits.

Several practices to influence pasture growth and composition have been suggested, including conservative stocking rates and spelling. In areas prone to extreme climate variability, these practices have been found to improve long term ground cover. The focus of the practices is to stock and rotationally graze in ways that 'buffer' forage supplies against extended dry periods (Ash et al. 2001). Other management practices may address streambank rather than hillslope erosion. These include maintaining riparian vegetation — possibly by fencing to regulate the timing, duration and intensity of grazing along highly susceptible waterways — and identifying alternative watering points for stock.

Rotational grazing and conservative stocking are likely to reduce soil loss on many properties. However, the design of the most appropriate scheme will vary from property to property due to diversity in the physical characteristics of grazing enterprises. It is likely to be more cost-effective to provide land users with the flexibility to choose between a range of abatement options so that they can use their site-specific knowledge to select the least cost abatement options.

Barriers to change

Insufficient ground cover on beef grazing properties, particularly at the end of the dry season, can result in soil erosion that has off-site impacts which are borne by the public and not by the land user. In some cases, land users may have little incentive to abate soil erosion because it would be unprofitable (box 9.2). For example, the costs of fencing off riparian areas or destocking areas vulnerable to erosion are likely to be high, with few resulting benefits for the land user. It is also possible that the high short term establishment costs of some new practices may outweigh their longer term benefits. For example, spelling on a particular property may require more internal fencing than on another and this can make the practice unviable for an individual beef producer. In such cases, abatement options need to be designed to change the incentives faced by beef producers so that they can benefit from adopting land use changes that generate public benefits. The extent to which particular land management practices are profitable or unprofitable will vary across land users and properties.

Past research has demonstrated that some practices, such as spelling and conservative stocking rates, can be profitable (Ash et al. 2001). However, in some cases the large size and geographic remoteness of individual grazing properties can make it difficult for land users to observe and physically assess the longer term incremental benefits of practices implemented on other properties in their district. On the other hand, the potentially small number of properties in individual hazard areas may facilitate observation and information exchange and so partially offset that impediment. Climate variability is another factor which creates complexities in assessing the risks and benefits of different management practices. The variations in physical characteristics of properties can mean that the costs faced by land users differ. For example, spelling regimes may be complex to design on all large properties, but more so where there is considerable landscape and soil type variability. The current level of a land user's management skills and knowledge will also influence uptake of what could be profitable practices.

Box 9.2 **Possible impediments to adopting more sustainable practices**

Spelling

Rotational grazing and sequentially destocking paddocks for wet season recuperation may increase profitability by improving pasture productivity in the long term, and reduce the risk of pasture deterioration. However, it may be difficult to realise the private benefits (which are likely to be longer term and uncertain due to climate variability) because of the high upfront and ongoing costs (for fencing and rotating cattle).

Spelling may not be immediately compatible with existing practices because many grazing properties have insufficient internal fencing. On large properties, spelling may also be constrained by the time and labour required to move cattle. The estimation of grazing capacity and rotation regimes may be complex, particularly on large properties with considerable landscape diversity. Given the longer term incremental nature of spelling, it may be difficult for land users (in the short term) to visually assess the benefits of the practice where it has been introduced by peers.

Conservative stocking

Like spelling, conservative stocking may increase profitability by improving long term pasture productivity and reduce the risk of pasture deterioration. However, the financial benefits are likely to be medium to longer term and pose a degree of risk due to climate variability. Conservative stocking, particularly during the dry season, may not be compatible with some land users' practices as it could be perceived to be productivity-reducing.

Maintaining riparian vegetation

While the public benefits of this practice may be high (if it significantly reduces streambank erosion), the private costs are likely to be high because it excludes productive land from beef cattle production. Maintaining riparian vegetation poses up-front costs such as fencing (to prevent cattle access). However, the practice could benefit land users by improving the quality of on-site waterways.

Maintaining riparian vegetation appears relatively straightforward, but it may not effectively address soil erosion if feral animals enter fenced waterways. Preventing cattle access to waterways may also lead to additional costs to provide alternative watering points for stock.

It is therefore likely that a range of policy instruments, targeted at different barriers, is required to increase the adoption of practices to address soil erosion. For example, addressing the unprofitability of spelling for some land users could be important. This could be done by providing funding for trials and extension services to demonstrate how the practice may be introduced.

Abatement options selected for analysis

Interested parties suggested a range of possible options to address soil erosion (some of these are listed in box 9.3).

Box 9.3 **Possible policy instruments to address soil erosion**

Extension, education and information provision.

Financial support for demonstration of Best Management Practices (BMPs).

Access to subsidies conditional on improved practice.

Reward good land management with lease extension, renewal or increased security of tenure.

Tax concessions for expenditure on fencing and stock water infrastructure.

Tax incentives for marginal sized properties to increase their holdings or sell out.

Simplify process to review and change tax year to better suit seasonal patterns.

Review the Queensland Drought Relief Assistance Scheme.

Encourage diversification at a commercial scale on leasehold land.

Environmental levy in conjunction with farm management deposits.

Environmental tender scheme.

Modification of the FarmBis program to encourage adoption of BMPs.

Environmental (eg wetland) banking.

Rate rebates for conservation practices on private land.

Five abatement options are assessed in this section to illustrate the potential of a range of approaches to address the loss of ground cover on grazing properties in the GBR catchment:

1. subsidise the erection of internal and riparian fencing and watering points to facilitate the spelling of stock between paddocks;
2. change drought assistance arrangements to discourage the retention of non-breeding stock as prolonged drought develops;

3. hold an auction where graziers can bid for public funds to retire land or adopt certain practices;
4. provide more generous pastoral lease conditions in return for adopting approved land management practices; and
5. education, extension and trialing of conservative stocking practices.

Assessment of abatement options

A factor inhibiting the wider adoption of spelling on beef grazing properties is that many properties in potential hazard areas are relatively large and can lack sufficient paddocks to adequately to spell areas of the property over successive wet seasons (Shepherd, B., DPI, pers. comm., 31 January 2003). An impediment for some beef producers may be that the practice is unprofitable because the high cost of establishing sufficient internal fencing and watering points outweighs the longer term productivity gains from improved pasture management. A subsidy could overcome this barrier to adoption (table 9.3).

The cost to taxpayers of subsidies for internal and riparian fencing and associated watering points is likely to be relatively high, given the size of the properties and the scale of the hazard areas. The budgetary costs could be reduced by only providing subsidies in priority hazard areas, and to graziers for whom spelling is not otherwise profitable. A recent example of such cost sharing is the use of subsidies for riparian fencing in the upper Burdekin catchment (box 9.4). However, it would be extremely challenging for governments to target the appropriate properties and select the level of subsidy that is just sufficient to encourage the required level of spelling. A subsidy should also be sufficiently flexible to allow land users to use their site-specific knowledge to establish internal fencing in locations that could optimise the benefits of a spelling regime for their property.

Table 9.3 **Assessment of subsidies for internal and riparian fencing and associated watering points**

Issue	*Assessment*
1. Informational requirements	Moderate. Land users could require some new information. For example, to design the internal fencing and grazing system (managing stock movement, ongoing monitoring of pasture productivity gains, and adaptive change to design of system). Information requirements on governments could be high, especially if they need to identify hazard areas for subsidy eligibility and to assess the appropriate level of subsidy.
2. Feasibility	Feasible. No constitutional constraints and pastoral leases allow for infrastructure development of properties.
3. Costs	High. Reflects large size of properties, the number of internal fences required to effectively spell and the potential extent of hazard areas. Subsidies may create perverse incentives. For example, internal fencing may encourage more intensive grazing but not result in spelling.
4. Flexibility	Moderate. Land users could use their site-specific knowledge to establish fencing and watering points in the most appropriate locations, and to design stock rotations to suit property characteristics, such as soils and topography. It could encourage better stock and pasture management beyond spelling and reduce overall grazing pressures across the property. Easier stock handling could encourage short term stocking levels that are more responsive to climatic conditions. Subsidies could be adjusted to reflect the costs of fencing and the priorities placed on different hazard areas.
5. Distribution of costs and benefits	Cost could be borne entirely by government or shared with land users. The size of the subsidy is likely to be important. May only need to fund a proportion of the fencing cost to encourage land users to erect fencing and establish water points.
6. Likelihood of achieving desired change in land use	Moderate. Depends on supporting instruments such as education and extension programs or lease provision arrangements. Internal fencing and associated watering points for new paddocks are necessary but not sufficient for spelling. It is possible that internal fencing may be used for more intensive grazing and not spelling. Costs could be prohibitively high but this would depend on the price responsiveness of land users.

Box 9.4 Subsidisation of riparian fencing in the upper Burdekin catchment

The Cape River catchment in the upper Burdekin comprises around 80 commercial beef properties covering 2.2 million hectares of grazing land. Fifty-six (70 per cent) of the properties participated in a project in which five landcare groups obtained NHT-1 funding with the aim of regulating the timing, intensity and duration of grazing in riparian areas.

Over five years, participants erected 1180 kilometres of fencing, 112 off-stream watering points and installed 36 pasture monitoring sites. On most properties, fences were located on alluvial soils at the edge of flooded areas to reduce the risk of flood damage. The fencing allows graziers to stock the riparian and frontage areas from the end of the wet season until ground cover levels approach a critical level (40 to 50 per cent).

The NHT funding covered the cost of steel pickets and barbed wire ($770 per kilometre). The balance of the fencing costs ($1800 per kilometre) was borne by the graziers and included strainer assemblies, gates, droppers, flood crossings, and labour costs for line clearing and erecting the fences. The cost of the additional watering points (estimated at $10 000 each) was also borne by graziers. In total, the Commonwealth Government provided $0.9 million in subsidies and participating graziers invested $3.3 million.

Source: Shepherd, B., DPI, Charters Towers, pers. comm., 31 January 2003.

Another approach to improving the level of ground cover on grazing properties during times of climatic extremes is to address perverse incentives within the Queensland Drought Assistance Scheme (DRAS) (table 9.4). Currently, the Scheme can reward land users who maintain stock levels during periods of drought. For example, transport rebates are available to land users purchasing fodder after a drought declaration has been made.

Altering the DRAS to encourage land users to turn off non-breeding stock progressively, as extended dry periods persist towards drought, could reduce the incidence of erosion at the end of droughts. It may be possible to design such changes so that they are revenue neutral to government. However, governments may need substantial information to assess the level and nature of incentives required to alter short term stocking levels in the face of uncertainty over the length of drought conditions.

Table 9.4 **Assessment of drought assistance to discourage the retention of non-breeding stock as a prolonged drought develops**

Issue	*Assessment*
1. Informational requirements	High. Governments would require information on the future duration of a drought and the impact of financial incentives on land user behaviour. Land users would require information about conditions necessary to achieve drought-declaration status.
2. Feasibility	Feasible.
3. Costs	Could be designed to be revenue neutral for government and minimise costs to land users.
4. Flexibility	High. Likely to encourage greater land management flexibility but this would depend on the prescriptiveness of the scheme. Prescriptiveness could be minimised through careful design of the suite of approved practices.
5. Distribution of costs and benefits	Could raise land user profitability if it improves pasture productivity. Land users likely to face compliance costs and costs of improved management (such as destocking). However, the instruments could be designed to minimise the costs to land users. May lead to structural adjustment — marginal land users, poor managers, or those facing short-term financial constraints (eg. those reliant on 'drought insurance' to ameliorate climatic risks and remain financially viable) may retire from land management.
6. Likelihood of achieving desired change in land use	Moderate. Depends on extent to which current drought assistance arrangements create perverse incentives for land mismanagement. Depends on impact of Commonwealth drought funding and Exceptional Circumstances assistance.

A government sponsored program to set aside land from grazing or allow only restricted grazing could in theory be implemented using an auction scheme (table 9.5). Under such a scheme, land users could bid for public funds to retire land and/or manage it according to agreed practices.

Auctions can be an efficient mechanism for land users to reveal the private cost of abatement while governments could be well placed to identify hazard areas. Auction schemes can be quite flexible if they are established for particular hazard areas and land users can propose how the land might be used and managed. Potentially, the land user could build the costs of any associated internal fencing into a bid. Under a competitive auction, the long term costs of setting aside land can be minimised and the costs of long term management could be shared with the landholder. Nevertheless the costs of such a scheme are likely to be high reflecting, in part, the productivity losses associated with land retirement. While auctions have been shown to be very effective in revealing land users' costs, an important constraint could be the large size and potentially small number of properties within hazard areas. This may mean that there are insufficient land users to hold a competitive auction. In such cases, government sponsored land retirement could be facilitated by carefully designed agreements with individual land users. On leasehold land, governments may opt to excise fragile areas from conventional grazing practices, or only allow limited use, as part of the lease conditions for particular properties.

Table 9.5 **Assessment of auctions to retire land or adopt certain practices**

Issue	*Assessment*
1. Informational requirements	Low. Auctions can overcome the information asymmetry between governments and land users by getting land users to reveal their cost of abating soil erosion. Governments are better placed to identify hazard areas. Could be moderate informational requirements on governments to design an appropriate scheme.
2. Feasibility	Feasible. Pastoral lease provisions could be altered to recognise areas that have been set aside or are subject to the adoption of practices that abate diffuse pollution.
3. Costs	Could be high administrative, monitoring and enforcement costs associated with selecting land users and ensuring that they deliver what has been promised. Also likely to be high opportunity costs if abatement involves retirement of productive land.
4. Flexibility	High. Governments can grant land users flexibility in what they propose to do with land in return for funding. Can tailor design of the scheme to different hazard areas and constraints faced by land users and government.
5. Distribution of costs and benefits	Costs of abatement can be shared between land users and government. Government bears costs of scheme design, administration, monitoring and enforcement. Land users face productivity losses, tendering, compliance costs, and need to estimate the benefits and costs of reducing grazing levels.
6. Likelihood of achieving desired change in land use	Low. Depends on design of scheme, number of participants and size of hazard areas. Large properties likely to reduce the effectiveness of the auction system because there are few potential bidders. Effectiveness will also depend on: • commitment of land users with poorer management skills; • private valuations of abatement actions — possible that improvements will not be achieved by the ‘bottom half’ managers; and • financial circumstances of land users — possible that tenders will be won by land users who are less financially constrained.

A feature of grazing enterprises in the dry tropics of the GBR catchment is that a major form of land tenure is leasehold rather than freehold. For example, around 85 per cent of the land area in the Burdekin catchment is held under a pastoral lease (figure 9.1). In the Fitzroy catchment, around 42 per cent of the land area is covered by pastoral leases and a high percentage of this appears to be in hillslope areas possibly more prone to erosion. Over the next two decades, almost half the pastoral holdings in Queensland will be due for renewal (DNRM 2001c). Several interested parties have suggested that lease provisions could be linked to the environmental management practices of land users. One approach could be for government to offer more generous lease terms (such as greater land use flexibility) in return for land users implementing approved land management practices (table 9.6). However, prescription is not the answer. Land users should be given the flexibility to select from a range of possible abatement options. This would enable land users to use their unique site-specific knowledge to select abatement practices best suited to their properties. Approved practices could include those linked to other abatement options, such as conservative stocking and establishing covenants for land set aside. A disadvantage of linking lease conditions to management practices could be the monitoring and compliance costs associated with land users demonstrating the appropriate implementation of the practices.

Table 9.6 **Assessment of more generous pastoral lease conditions in return for adopting approved management practices**

Issue	*Assessment*
1. Informational requirements	Moderate. Government needs to know the extent to which particular practices will address soil erosion and what impact lease terms will have on management practices. Land users need to know the private costs and benefits of implementing the practices.
2. Feasibility	May be feasible. But there could be Native Title implications (eg see PC 2002a).
3. Costs	Low for governments but could be sizeable compliance costs for land users.
4. Flexibility	Flexible if land users are able to select from a range of possible management practices that take account of local conditions. Would be desirable to ensure that arrangements are sufficiently flexible to accommodate improvements in methods to demonstrate/monitor application of practices (eg remote sensing) over time.
5. Distribution of costs and benefits	Short term costs to establish scheme could be high with possible ongoing monitoring, enforcement and compliance costs.
6. Likelihood of achieving desired change in land use	High for hazard areas with a high proportion of pastoral leases, since more generous lease conditions are likely to be attractive to land users.

Figure 9.1 **Distribution of land tenure types in the Burdekin catchment**[a]

[a] Compiled from the Digital Cadastral Database extracted on 4 February 2002. While every care was taken to ensure the accuracy of these data, the Queensland Department of Natural Resources and Mines makes no representations or warranties about their accuracy, reliability, completeness or suitability for any particular purposes and disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damage (including indirect or consequential damage) and costs which might be incurred as a result of the data being inaccurate or incomplete in any way or for any reason.

Source: Queensland Department of Natural Resources and Mines.

The expansive and at times remote nature of dryland GBR grazing properties could constrain access to information and demonstration of how to implement particular practices. For many land users, the net economic benefits of conservative stocking may be uncertain because they do not have access to appropriate information or the practice cannot be easily trialed on individual properties. Education and extension services, such as extending and targeting programs like Ecograze to beef producers in particular hazard areas, may address such impediments (table 9.7). An option could be to address the potential transaction costs associated with delivering these programs. The costs to government would be moderate because the abatement option would build on the existing scientific knowledge and extension programs. A series of target schemes could reflect the flexibility of such an approach to address particular hazard area problems, and the goals and socioeconomic characteristics of beef producers in the target areas. Nevertheless, policies aimed at suasion, such as an education and extension program may be insufficient on their own. This is particularly the case when the desired land use change is not immediately profitable. In such cases, using additional instruments, such as a fencing subsidy, may be more effective.

Table 9.7 **Assessment of education, extension and trialing of conservative stocking practices**

Issue	*Assessment*
1. Information requirements	Moderate. Governments require moderate information — which land users to target. Land users likely to require low levels of information as government's aim is to meet information requirements.
2. Feasibility	Feasible.
3. Costs	Moderate. Costs include those for designing, implementing and communicating results of trials. Costs also involved with developing, promoting and implementing education and training programs.
4. Flexibility	Moderate. Extension and education services could be designed and targeted to reflect the goals and aspirations of land users and their socioeconomic characteristics. Extension and education programs could also be designed to reflect differing hazard area pressures, such as streambank and hillslope erosion. Individual property-based solutions could evolve.
5. Distribution of costs and benefits	Governments bear most of the costs of the program, but the cost of implementing practices would be borne by land users.
6. Likelihood of achieving desired change in land use	Low. In isolation, suasion is rarely successful. However, likely to be high when supported by other policy instruments, such as financial assistance for fencing and watering points. May address some information asymmetries and make the profitability of proposed new practices more transparent.

In assessing the above mentioned options it is clear that no single solution should be preferred over others. Each abatement option is likely to have some effect on graziers' management practices and could feasibly be implemented. That said, where it is cost-effective to do so, removing the perverse incentives, such as those created by existing drought relief policy, could be a fundamental first step. Tying management conditions to more favourable lease terms is likely to be relatively more flexible, lower cost and more effective than other options in hazard areas where pastoral leases are the main form of land tenure, but will of course, have negligible influence where hazards arise on freehold land. A tender scheme could also be quite flexible but, given the spatial distribution of graziers, it may not be effective and is likely to be relatively costly and take time to develop and implement. A fencing subsidy is likely to be useful but not sufficient to increase spelling and may be relatively costly to governments unless carefully targeted. While education and extension may not be particularly effective in isolation, they are likely to be fundamental to support the effectiveness of other abatement options and may be less costly than the tender or subsidy options.

Combining abatement options

Although some abatement options may have limited effectiveness when applied in isolation, their power is likely to be increased when combined with other options. Gleeson (sub. 50, p. 3) noted:

> Policy analysis often progresses with the intent of identifying 'superior' options rather than with the intent of identifying alternative and complementary options and the circumstances within which various combinations of options would be most effective.

The advantage of 'bundling' different options arises because it can address situations where management practices are not immediately profitable, as well as situations where barriers prevent the adoption of otherwise profitable activities. For example, spelling may not be adopted by some land users because they lack the financial capacity to fence internal paddocks. However, a fencing subsidy alone — even if it addressed land users' short term financial constraints to fencing — is likely to have limited effectiveness if a barrier to adoption is the information required by land users to design a commercially beneficial spelling regime. The combination of a subsidy and an education and extension service to trial and demonstrate the benefits of spelling is likely to be far more cost-effective than either option in isolation.

Bundling of options may also be an effective way to deal with the diversity of land users and their management skills. For example, some land users may require regulatory approaches to facilitate change whereas others may respond better to incentives.

There are many ways in which abatement options could be bundled to address soil erosion, and more sustainable land management generally, on grazing properties in the dry tropics. If a large proportion of properties in hazard areas are leasehold, the leasehold based incentives are likely to be particularly effective. When combined with other options, more generous lease terms could raise the capacity of land users to invest in management practices with longer term but uncertain benefits. Another advantage of leasehold incentives is their potential flexibility. Land users could implement and tailor abatement practices to suit their particular circumstances. Implementing practices could, in turn, be used as a criterion for eligibility for financial assistance such as fencing subsidies.

Summing up

In summary, it is apparent that there is no single instrument that can be used in isolation to address soil erosion on grazing properties. Each of the options examined is likely to have some effect on graziers' management practices and could feasibly be implemented. But their relative merits will probably vary between land users and properties.

Subsidising internal and riparian fencing and watering points may encourage greater adoption of spelling but the cost to taxpayers could be high, given the size of grazing properties. This cost could be reduced by only providing subsidies in priority hazard areas, and to graziers for whom spelling is not otherwise profitable. It would be extremely challenging, however, to target the appropriate properties and select the level of subsidy that is just sufficient to encourage the required level of spelling.

Modifying drought assistance arrangements, to discourage the retention of non-breeding stock as prolonged drought develops, could be effective. New arrangements could also be designed so that there is no reduction in the total amount of drought assistance provided. However, it may be difficult for governments to determine the incentives required to alter stocking levels when there is uncertainty about the length of a drought.

The advantage of auctions is that they can overcome an information asymmetry between governments (better informed about hazard areas) and land users (better informed about abatement costs) that may otherwise lead to inefficient outcomes. If a government simply were to ask individual land users to enter into a contract to adopt a certain practice, then its ignorance of abatement costs could lead it to pay far more than in an auction. Hence, an auction can increase the cost-effectiveness of subsidies. A drawback of auctions is the administrative, monitoring and enforcement costs associated with selecting land users and ensuring that they deliver what has been promised. In addition, there may be few bidders in a given hazard area because of the large size of grazing properties. An auction could also be costly when it involves land retirement, since it is unlikely to be profitable for graziers and so a large subsidy may be required.

As many properties in hazard areas are leasehold, providing more generous lease terms in return for the adoption of approved practices could be effective. In addition, it should not require a significant increase in government expenditure. But there would be monitoring and enforcement costs, in addition to the costs involved in adopting the practices themselves.

In isolation, education, extension, and trialing of conservative stocking practices could be cost-effective, provided that the relevant practices are profitable for graziers. But there are limits to how much voluntary measures can achieve.

Combining abatement options may be a good way to deal with the diversity of properties and graziers. For example, some land users may require regulatory approaches to facilitate change whereas others respond better to incentives or education. An important first step may be to consider the removal of perverse incentives created by existing policies, such as those that might be created by existing drought assistance. Tying abatement actions to more favourable lease terms is likely to have a lower cost to government and be more flexible and effective than prescriptive options in hazard areas where pastoral leases are the main form of land tenure. This option will, of course, have negligible influence where hazards arise on freehold land. A fencing subsidy is likely to be useful but not sufficient to increase spelling and may be costly to governments unless carefully targeted (targeting may itself also be costly). Education and extension are likely to be important to support the effectiveness of other abatement options.

9.3 Overuse/misuse of fertilisers and chemicals

The application of fertilisers (affecting nutrient exports) and, perhaps to a lesser extent, chemicals such as pesticides and herbicides, are a major concern for water quality entering the GBR lagoon (chapter 2). This section focuses on abatement options to address nutrient and chemical runoff from cropping activities, which are significant users of fertilisers and chemicals, and are subject to limited regulation for environmental outcomes.

In particular, this section:

- discusses cropping inputs, practices and actions that could be targeted to help reduce nutrient and chemical losses to waterways, highlighting barriers that might currently be limiting their adoption; and

- identifies various abatement options, providing a qualitative assessment of a selection of these according to the criteria established in section 9.1.

Inputs, practices or actions to target

Changing management practices in cropping industries has the potential to significantly reduce inputs and discharges of nutrients and chemicals into waterways:

> Large variations in agrochemical discharge from similar landscapes and the result of in-field measurements of nutrient fluxes, suggest that it is possible to minimise losses by the application of appropriate management techniques and new technology. (Reghenzani et al. 2002, p. 7)

Several practices have been suggested to reduce excessive nutrient and chemical losses to the GBR lagoon (chapter 5). These include increasing the nitrogen uptake of crops, improving the location, timing and techniques of fertiliser and chemical application, and improving drainage design and use of buffer zones near water courses. Planning and monitoring, such as through nutrient management plans, farm plans or EMSs, are ways to incorporate several of these practices.

Crop growers in the GBR catchment have made progress in implementing Best Management Practices (BMPs) to reduce nutrient and chemical losses to the environment. However, the extent to which these practices are being adopted varies, both within and across catchments (chapter 5). For example, a survey of cane growers in 1998 found that, among those surveyed, about 90 per cent conducted soil testing (CRC Sugar 2000). On the other hand, alternating the use of different crops across seasons had a lower adoption rate among those surveyed, particularly in the Burdekin catchment (chapter 5). There is also variability in the uptake of various ‘desirable’ practices in horticultural industries (chapter 5). Scope for improving the adoption (and ongoing development) of BMPs, therefore, clearly remains.

Governments may seek to expand or speed up the adoption of environmentally beneficial fertiliser and chemical practices (through a range of policy instruments) if doing so is judged to have clear net public benefits.

The practices governments need to target, however, will vary across regions (and even properties), as well as over time. Abatement options aimed at one particular practice for all areas, and with no in-built mechanism for updating, will therefore have significant weaknesses. Options should therefore be flexible and target a number of practices. Anther reason for targeting several practices is that addressing one cause of nutrient loss through changing a particular practice may lead to an increase in losses elsewhere:

> Management practices can substantially reduce nutrient losses to particular pathways, however to reduce losses overall, practices that target all loss pathways have to be implemented and fertiliser application rates adjusted downwards accordingly. (Bureau of Sugar Experiment Stations, sub. DR79, p. 15)

Governments may also want land users to undertake actions to address fertiliser and chemical pollution that do not relate to management or production practices. Governments, for example, may wish to target the rehabilitation of riparian zones or freshwater wetlands in particular areas. These remedial actions may replace filter functions lost through past human activities that are currently exacerbating nutrient and chemical runoff problems.

Barriers to change

It is important to understand the reasons for the adoption or non-adoption of practices that can reduce fertiliser and chemical pollution. Different environmental circumstances and crop requirements, for example, can influence which practices are adopted (chapter 5). The profitability, availability of information, complexity, compatibility with existing farm systems, and trialability of practices, can also influence adoption (chapter 8). Land user characteristics (such as age, education and training, income and risk aversion) and farm characteristics (such as farm size) may likewise influence adoption (chapter 8). Linked to these influences may be the impacts of past and current legislative arrangements, which may have the effect of inhibiting or discouraging innovation and change (BCG 2003).

Impacts on profitability, and the need to provide incentives to encourage the adoption of more environmentally sustainable fertiliser and chemical practices or maintenance of buffer zones, were raised in a number of submissions (such as by Canegrowers, sub. DR67, p. 12; Queensland Fruit and Vegetable Growers, sub. 49, p. 43; Mulgrave Landcare and Catchment Group Inc., sub. DR71, p. 3). Changing cropping practices may also be seen by growers as risky in terms of yields, input requirements or crop quality. This may lower expected profits and discourage change, even if a private benefit is available (such as using less fertiliser, a costly input in growing crops). Some practices may also only be profitable in the longer term, or when capital for investments is readily available, delaying the adoption of practices which may benefit water quality.

Inadequate information about the size, nature and location of potential nutrient and chemical problems has also been identified in submissions as inhibiting the adoption of BMPs. The Mulgrave Landcare and Catchment Group Inc. (sub. DR71,

p. 3), for example, suggested that a lack of acceptance by some land users that excess nutrients are being transported to the Reef has been an impediment to change.

Abatement options selected for analysis

As discussed in section 9.1, a spectrum of policy instruments, ranging from the prescriptive to the light handed, is available to government. At the regulatory extreme, legislation may be established to ban the use of a fertiliser or chemical that is deemed harmful, as has been done with some pesticides. However, such a response is only likely to be cost-effective in certain restrictive circumstances. Applying a total ban on all fertilisers used by the agricultural sector, for example, would impose enormous costs on farmers (and subsequently the community at large), and would be unnecessary as much of the harm from fertilisers derives from how, when and where they are applied, rather than their use as such.

Examples of policy instruments relating to fertiliser and chemical application that have been suggested to the Commission include:

- the establishment of nutrient sensitive zones, where nutrient management plans are mandated and fertiliser use licensed;
- land use regulation including mandated riparian zones free from cropping;
- fertiliser taxes;
- subsidies for equipment, or for the purchase of more benign chemicals;
- rate rebates, subsidies or in-kind rewards for the adoption of BMPs;
- environmental service tenders (water quality auctions);
- tradeable permits (for inputs or effluent);
- facilitating demand-side responses, aimed either at final consumers or processors or mills;
- development of voluntary codes of practice;
- extension services, and education and training (information provision); and
- incentives for R&D.

Six abatement options are examined in more detail below, using the check list in table 9.2. These options were selected because they have been prominent in policy discussion, offer the prospect of being highly cost-effective, and/or allow for a representative review of the spectrum of policy instruments available to government. The assessments that follow provide an indication of the likely cost-effectiveness or otherwise of each option. They do not represent a 'final' view on their usefulness, as this will depend on local factors that influence their costs and benefits.

The six options assessed were:

1. require mandatory riparian buffer zones between crops and major watercourses on lands where fertilisers and chemicals are used;
2. introduce nutrient sensitive zones where fertiliser users have to be licensed and have a nutrient management plan;
3. impose a fertiliser tax;
4. provide subsidies for pollution abatement practices that are not otherwise profitable;
5. hold an auction where farmers can bid for funds to reduce nutrient and chemical levels in runoff; and
6. sugar mills only accept cane from growers who adopt approved BMPs.

Assessment of abatement options

Mandating riparian buffer zones across the GBR catchment could have the benefit of trapping and absorbing excessive nutrients and chemicals, reducing their entry into waterways (table 9.8). However, mandating buffer zones in all areas is unlikely to be cost-effective. In some areas, such zones would be unnecessary, and the cost of losing large areas of productive land would be considerable (given the extent of creeks and streams in the GBR catchment). Introducing variable zone requirements may improve this situation, but would add to administration costs and remain unlikely to address the variability required for such an approach to be cost-effective.

Table 9.8 **Assessment of mandatory riparian buffers**

Issue	*Assessment*
1. Informational requirements	High. Governments will require property-level information to monitor and enforce regulation. Land users will require information about their responsibility to implement regulation. Information collection could be made easier in the future as remote monitoring technologies improve.
2. Feasibility	Feasible. Queensland Government could implement through land and water legislation.
3. Costs	High. Costs include opportunity cost of areas lost to production, and costs of monitoring and enforcing regulation.
4. Flexibility	Low.
5. Distribution of costs and benefits	Costs to governments include monitoring and enforcement costs, and compensation for loss of land from production (if offered). Depending on the level of government funding, costs to land users will include the opportunity cost of lost production in the zoned area (which may be the most fertile land). It may be possible to lower compliance costs for land users (collectively) by targeting areas of greatest importance to water quality outcomes. But this could add significantly to administration costs.
6. Likelihood of achieving desired change in land use	Moderate. Effectiveness would depend on how governments monitored properties and enforced requirements.

A more targeted and flexible regulatory approach would be to identify nutrient sensitive zones, and then apply licensing requirements which could be flexible in terms of the requirements on crop growers (table 9.9). Licences could require, for example, a government approved nutrient management plan drawing on a number of environmentally beneficial management practices (which may or may not include riparian buffer zones). Such plans could also include offset arrangements whereby fertiliser or chemical use in one area is offset by pollution abatement activities in another. Land users who are not granted licences would be banned from using fertilisers. The use of fertilisers and compliance with license conditions could be monitored by random audits. On its own, however, such an approach may impose substantial costs on farmers, raising questions over its practicality and likely level of compliance. Governments may have to assist with the development of nutrient management plans, and therefore education and training may be important to ensure effectiveness.

Table 9.9 **Assessment of nutrient sensitive zones where fertiliser users must be licensed and have a nutrient management plan**

Issue	*Assessment*
1. Informational requirements	High. Information requirements of government include determining: • the location of nutrient sensitive zones; • an appropriate nutrient management plan for each property; and • the types of fertilisers for which licences are required. Much of the required information will be location-specific. Costs could be lower if plans are based on guidelines developed by industry or regional associations. Information on nutrient sensitive zones may need to be reviewed periodically.
2. Feasibility	Feasible. Queensland Government can regulate land use.
3. Costs	Moderate to high. Initial costs include establishing nutrient management plans and the licensing body/system (which also requires ongoing funding). Monitoring costs would include: • auditing compliance with nutrient management plans (random audits could keep costs down, while encouraging compliance); and • checking that fertilisers are not supplied to unlicensed users — monitoring could involve auditing suppliers and/or properties.
4. Flexibility	Moderate. Depends on how the scheme is implemented. Land users could be given the flexibility to design nutrient management plans that are best suited to their properties. If requirements for plans are very prescriptive, however, flexibility will be limited.
5. Distribution of costs and benefits	Costs to taxpayers include establishment and ongoing administration of the system. Land users incur costs of establishing nutrient management plans, which may involve high upfront costs (financial and in terms of time). Potentially some benefits to land users, if the scheme encourages reduced use of a costly input without significantly decreasing net financial returns (which also depend on the cost of substitute inputs and crop yields). Some administration costs for fertiliser suppliers but could be low if record keeping requirements are kept to a minimum.
6. Likelihood of achieving desired change in land use	High. Focusing regulatory effort on nutrient sensitive zones will make enforcement more manageable and more likely to be effective. Governments may have to assist with the development of nutrient management plans, and therefore education and training may be important to ensure effectiveness.

Another way to change behaviour would be to use price signals to users of fertilisers and chemicals. Imposing taxes on fertilisers, for example, may create an incentive to reduce their use and adopt more efficient application methods (table 9.10).

However, there are questions over how responsive fertiliser use is to price changes, such that a very significant increase in prices may be needed. This is unlikely to gain community acceptance. Also, to the extent that taxes do change fertiliser use, fertilisers may be replaced with other inputs to maintain output, which have their own potentially adverse consequences on water quality. As with mandated riparian zones, this approach focuses on only one aspect of the nutrient and chemical problem, and puts the costs of change largely on land users. Moreover, such a tax does not target key problems with inappropriate fertiliser use, such as when and how it is applied. There are probably also constitutional difficulties in imposing a fertiliser tax on some users and not others, as well as problems in stopping growers purchasing lower cost fertilisers outside the taxed areas.

Financial signals to change behaviour can, however, be positive, and can address a broader set of practices than a fertiliser tax or mandated riparian zones. Subsidies may bridge the gap between private and public benefits from particular practices, and move adoption closer to what is desirable from the community's perspective. Subsidies, for example, may be offered to assist growers to adopt changes in fertiliser and chemical use (such as timing, application method or type of fertiliser used) that would not otherwise be economically viable (table 9.11). As noted by Cotton Australia (sub. 48, p. 15) in relation to water use, the financial incentives scheme attached to the Rural Water Use Efficiency Initiative 'has been exceedingly successful in initiating change for growers, as well as accelerating the rate of change across industries'.

Targeting subsidies at the adoption of a range of practices is likely to be more cost-effective than focusing on a single practice. Such practices should be approved by government agencies (such as the EPA) and updated periodically to ensure that they deliver appropriate public benefits. This approach gives flexibility to land users to seek and implement the most cost-effective practices for their property.

Table 9.10 **Assessment of fertiliser taxes**

Issue	*Assessment*
1. Informational requirements	High. Ideally, tax rates should vary between properties to reflect differences in: • how the overuse of fertilisers on a property affects the level of nutrients entering the GBR lagoon; and • how a land user would change their behaviour in response to a change in the cost of fertilisers. May also require information on the impact of different fertilisers, if different tax rates are to be applied to each type of fertiliser according to the potential harm caused by each. Use of a single uniform tax rate across a region would lower the informational requirement on governments but would probably also reduce the cost-effectiveness of a fertiliser tax.
2. Feasibility	Constitutional restrictions on applying taxes based on geographic area. Also difficult to stop land users purchasing fertiliser from outside the catchment.
3. Costs	Moderate. Administration and monitoring costs relatively high if going to apply a site-specific tax, but these costs would be lower if a uniform tax was used.
4. Flexibility	Low. Most likely to involve an inflexible one-size-fits-all approach, since the cost of developing site-specific taxes would be prohibitive. Thus, possible that some land users will be under-taxed, while those whose fertilisers have little impact are over-taxed. However, taxes do provide an incentive to find less wasteful fertiliser application methods, or use less harmful fertilisers if subject to lower tax rates.
5. Distribution of costs and benefits	Costs are largely borne by land users in the first instance, although tax revenue could be recycled to land users for education programs, subsidies for precision fertiliser equipment etc. May need an extremely high tax if fertiliser demand is not responsive to price increases and therefore fertiliser users could face large cost increases. Costs would be imposed on land users regardless of whether their fertiliser use contributes to water quality concerns or not. Administration and monitoring costs borne by governments.
6. Likelihood of achieving desired change in land use	Low. Taxes target only one aspect of the problem (quantity), may increase the use of other inputs (such as land and water) which can have their own negative impacts on water quality, and can raise cost pressures which may lead to less sustainable practices being adopted. Taxes may have to be set very high to change behaviour. It could also be difficult to stop growers purchasing lower cost fertilisers outside the taxed areas.

Table 9.11 **Assessment of subsidies for pollution abatement practices that are not otherwise profitable**

Issue	*Assessment*
1. Informational requirements	Moderate. Initially, detailed knowledge at the property level is not needed as governments only need to assess and approve guidelines on desirable practices, which would be developed by industry or regional associations. However, information is required: • to determine most appropriate subsidy level(s), how long the subsidy is required, and the number and timing of payments; and • to assess compliance (including property level information).
2. Feasibility	Feasible to implement and enforce (compliance is measurable).
3. Costs	Funding subsidies would involve efficiency and administration costs associated with collecting tax revenue. Financial costs could be kept lower if in-kind benefits were offered (such as streamlined approvals processes or access to other government programs on a preferred basis). Administration and monitoring costs are also potentially high if auditing and certifying each property. Random audits could be used to keep costs down while still providing an incentive for compliance.
4. Flexibility	Moderate. Guidelines would not prescribe one-size-fits-all practices but allow for differing regional, production and weather conditions to help land users seek low-cost actions. The cost of developing site-specific subsidies would be prohibitive, so payments likely to be flat or single rate payments. Thus, some land users would be over subsidised, while those who may face high costs of adopting desired practices would not change behaviour. Governments would need to provide some degree of certainty in making payments and therefore cannot change schemes too quickly. Little incentive to seek new technologies beyond those required to adopt guidelines, although guidelines could be updated over time.
5. Distribution of costs and benefits	Costs largely borne by taxpayers, unless funded through alternative arrangements. No net cost to land users as adoption of subsidised practices is voluntary and they will only adopt if they perceive a net private benefit.
6. Likelihood of achieving desired change in land use	Moderate. Subsidies can overcome profit related concerns with the adoption of practices that reduce diffuse pollution. Subsidies targeted at a range of practices are more likely to be effective than subsidising a single practice, because they give land users the flexibility to implement the most appropriate actions for their property.

In general, direct payments or rebates are favoured over tax deductions on efficiency and equity grounds, as the benefit of tax deductions can be influenced by a land user's financial position, not only the size of the environmental benefit or service. Direct payments can also have advantages in terms of transparency and accountability compared to tax deductions. Direct payments have similar advantages over discounts on government provided services or resources, which may also distort the resource cost of services provided.

However, because the public benefit of particular land use changes and the barriers to their adoption vary across areas, fixed rate subsidies may overcompensate some farmers, and be insufficient to encourage change by others. Moreover, some may be paid for actions they would have undertaken anyway. Asymmetric information between governments and farmers in terms of what governments need to pay to entice particular behaviours can therefore result in significant ‘over’ or ‘under’ payments with associated inefficiencies.

One way to deal with problems of asymmetric information is to conduct auctions for public funds in return for adopting environmentally beneficial actions (table 9.12). Governments may, for example, seek tenders from cropping enterprises outlining the services or actions they (the land users) are prepared to undertake to protect water quality and what price they would need to be paid to do so. Governments can then assess these in terms of both expected environmental benefit and cost, and select those that are considered most cost-effective.

Environmental tenders can be designed to encourage the adoption of a range of environmentally beneficial cropping practices, or other activities not related to production that can influence runoff. For example, land users could include in their tenders the rehabilitation of wetlands and riparian zones to act as filters; commitments to not use fertilisers and chemicals on specific areas of land; or agreements to withdraw from cropping altogether (assuming the environmental benefits justified sufficient payments by government to induce such actions).

Auction processes could also allow for the achievement of other goals, such as the protection of biodiversity and indigenously important food sources. Because there is likely to be a number of growers in any region, there is a reasonable chance governments will be able to choose between a number of bidders. Paying for environmental services via auctions, and facilitating multi-purpose land use, can often be less expensive than taking land out of production altogether through the outright purchase of land. There may also be opportunities to fund the purchase of tendered services through a combination of government and philanthropic investments.

Table 9.12 **Assessment of auctions to reduce nutrients and chemicals in runoff**

Issue	*Assessment*
1. Informational requirements	Low. Auction process can overcome the information asymmetry between governments (better informed about the source and impact of diffuse pollution) and land users (better informed about abatement costs).
2. Feasibility	Feasible to implement and enforce (compliance is measurable).
3. Costs	Moderate to high. Costs would include: • costs of establishing the auction system, specifying objectives, contract design, and assessing the effectiveness of changes to management practices on particular properties; • monitoring compliance with a contract — these costs are lower the more easily the management practices can be measured. Remote sensing technology could lower these costs; and • efficiency and administration costs associated with collecting tax revenue to fund subsidies.
4. Flexibility	High. Allows land users to choose how they will meet the environmental objectives of government. Objectives can be re-specified at the end of a contract period. Incentives exist to adopt lower-cost technologies (the likelihood of making a successful bid increases as the bid price falls). Can tailor the design of the scheme to different hazard areas and the types of constraints faced by land users and government in each area.
5. Distribution of costs and benefits	Funding costs borne by taxpayers. Can be upfront payment, or several payments over the period of the contract. The size of payment required per unit of abatement depends on system design. For example, if the high effectiveness of abatement actions on a particular property is revealed by government, then the relevant land user may increase their bid. Few net costs to land users. If they tender successfully, they are compensated for costs incurred to implement measures. If their tender is not successful, they will pay the costs of developing a tender without compensation.
6. Likelihood of achieving desired change in land use	High. Tender processes can encourage land users to increase awareness of their practices and the types of land use changes that may reduce diffuse pollution, as well as receive enough incentive to undertake the tasks agreed. High administration and monitoring costs could limit the ability of governments to effectively implement an auction scheme. However, the potentially high costs may be justified if auctions are limited to nutrient sensitive zones. There will be multiple land users in each nutrient sensitive zone, and so a lack of competitive bids is less likely to be a problem than for soil erosion on grazing properties.

A drawback of auctions is the administrative and enforcement costs associated with selecting land users with the best tender and ensuring they deliver what has been promised. Specifying what is to be auctioned may also be difficult. Because of these costs, it may be most appropriate to limit auctions to nutrient sensitive zones where the greatest benefits from action can be expected (perhaps the same areas which may require licenses for fertiliser application). Using a mix of regulatory licensing and the opportunity to gain from auction processes in such zones may also improve the community support necessary for implementation. Alternatively, developing long term management contracts or agreements (such as Land for Wildlife agreements) without the use of a formal tendering process may also reduce administration costs to some extent. For example, the Queensland Government's new Sustainable Sugar Partnership Program includes the use of management agreements targeted at areas of high risk or environmental value. However, benefits of reducing the cost to taxpayers through auctions are then lost.

Another approach that may help overcome information asymmetries is for governments to facilitate self-regulation within industries (table 9.13). Self-regulation can have the advantage of industry and grower support (with potential benefits in terms of compliance), as well as efficiency benefits by tapping into the information and relationship base that exists within industries that governments do not have. Providing a range of possible practices as a condition of sale to mills would allow growers to adopt practices most suited to the environmental conditions on their property. Therefore, although growers would in effect be 'forced' to adopt BMPs, mills would not prescribe exactly what practices should be adopted (such as maintaining riparian zones of a certain size). There is a precedent for these types of arrangements in the NSW sugar industry, where contracts between growers and the NSW Sugar Milling Cooperative Limited require growers to comply with BMP guidelines in relation to activities that may disturb acid sulphate soils. Self-regulatory schemes also exist in other agricultural industries, such as the dairy industry, whereby producers receive premium prices if they adopt particular practices.

Table 9.13 **Assessment of sugar mills only accepting cane from growers who adopt BMPs**

Issue	*Assessment*
1. Informational requirements	Moderate. Few information requirements for government, although mills/cooperatives will need to undertake audits to ensure compliance. Land users will require property-level information on how to implement required practices.
2. Feasibility	Feasible. Could be implemented through contracts between millers and growers.
3. Costs	Moderate. Some costs of administering and enforcing compliance. There will also be some opportunity costs where growers have to change practices to meet mill requirements.
4. Flexibility	High. Required practices can take account of local conditions and can be updated over time.
5. Distribution of costs and benefits	While there would be some costs of adopting required practices for all growers, the opportunity cost of areas lost to production or costs due to changed practices (if required) may vary across growers. Costs could be high for some growers if current practices are far removed from required practice. Mills have to meet costs of monitoring and enforcing requirements (similar arrangement in NSW regarding acid sulphate soils estimated to cost around $1 million to set up and between $50 000 and $100 000 per annum to run). These costs are likely to be much lower than if governments were to enforce similar arrangements, due to superior information held by and available to mills. There may be some benefits to mills from growers adopting BMPs, particularly if marketing benefits can be derived. Costs to governments low. However, governments may help with costs of implementing required practices. Governments may also encourage a green label scheme or offer rebates to cover the costs of audits. Requirements for such a scheme in the sugar industry could also be linked to the Commonwealth Government's assistance package to restructure the industry.
6. Likelihood of achieving desired change in land use	High. Potentially very effective as sugar cane growers have limited options in terms of where they can sell their cane. However, governments may need to induce mills to require the adoption by growers of particular practices, as the incentives faced by mills to make such requests of growers is unlikely to otherwise be adequate.

A challenge with self-regulation can be ensuring that land users and processors have sufficient ability to discipline and reward participants to achieve outcomes it is committed to. In the sugar industry, however, such an approach has the potential to be highly effective because sugar growers have few alternatives in selling their cane if mills reject it. Another challenge is ensuring that land users and processors face sufficient incentives to change practices. While mills may gain some production or marketing related benefits from growers changing their fertiliser and chemical behaviours to reduce risks to the environment, in many cases mills would have little to gain. Governments may assist by raising the prospect of direct regulation if parties did not self-regulate and improve performance. This appears to have been a significant motivator for the NSW Sugar Milling Cooperative Limited to include in its contracts with growers the adoption of best practice in relation to acid sulphate soils (Beattie, R., NSW Sugar Milling Cooperative Limited, pers. comm., 7 January 2003). Governments may also offer support by promoting green labelling schemes or rebates to help cover the costs of audits. The Commonwealth Government may be able to generate incentives for such an approach by linking payments under its industry restructuring package to the achievement of such goals. Doing so would be consistent with the principle of mutual obligation.

In comparing these options, it is clear that there is no single solution. Each has a range of advantages and disadvantages, and these can vary depending on where and how they are implemented.

However, in general terms, the most effective and cost-effective options among those examined are likely to be a requirement by sugar mills that cane growers adopt approved BMPs, and licensing and auctions in nutrient sensitive zones. They allow for flexibility in practices adopted, the targeting of responses in high hazard areas, and involve either minimum or efficient allocation of public funds. They are also likely to be highly effective in changing a range of fertiliser and chemical practices which will be needed to manage the various pathways by which fertilisers and chemicals can reach waterways. In the case of auctions, however, pilot schemes may be required given the relative newness of this approach.

Subsidising practices that may not otherwise be profitable could also be effective in changing land user behaviour. This could be designed so that land users have the flexibility to use their site-specific knowledge to adopt the most cost-effective practices to abate pollution on their property. However, subsidising the adoption of certain practices may be less cost-effective than auctions because they are less targeted, may overcompensate in some cases and, as a result, require greater government expenditure for a given land use change. Restricting the availability of subsidies to nutrient sensitive zones may increase their cost-effectiveness.

A fertiliser tax is unlikely to be cost-effective as it only targets one aspect of nutrient management (fertiliser quantity), may increase other inputs, and impose costs on all fertiliser users regardless of their contribution to pollution. Both fixed-rate subsidies and taxes suffer from being one-size-fits-all approaches, with concern also over the potential for non-compliance if not adequately monitored and enforced. Mandating riparian buffer zones would impose significant costs on farmers, and again focus on only one aspect of nutrient management, rather than provide farmers with some flexibility in how they abate diffuse pollution.

In assessing these options, questions also need to be asked about the distribution of the costs and benefits. The extent to which it should be governments (the public) paying for ‘cleaner’ crop production, or land users’ responsibility not to pollute waterways, can influence the desirability of each option (and the appropriate mix of each). How far each option should go in encouraging changes to management practices also requires careful judgement, and account for the likely diminishing net benefits of ongoing abatement. The desirability of an option may also be affected by what other options are implemented, and the order and timing of their implementation.

Combining instruments

Overall, it is likely that a mix of instruments is most desirable to address concerns over fertiliser and chemical use. In doing so, the disadvantages of some policies can be offset by the advantages of others (such as offering financial incentives as well as regulation and licensing in nutrient sensitive zones). There may also be complementarities between options, such that the cost-effectiveness of an option may depend on the implementation of others.

Important complementary policy instruments can include government support of education, extension and R&D. These instruments may help overcome barriers to BMP adoption caused by a poor awareness of problems on farms, as well as providing solutions that benefit the environment and farm profitability. Indeed, demonstration of the dollar cost to farmers of inefficient practices has been identified as critical to the adoption of BMPs for fertiliser and chemical use (Mulgrave Landcare and Catchment Group Inc., sub. DR71, p. 3). Opportunities to improve the adoption of BMPs through improvements to current extension services were also highlighted in a recent report to Canegrowers by BCG (2003). Education and extension can also support auctions, providing a foundation upon which growers can develop tenders. Focusing extension in hazard areas may increase the cost-effectiveness of such activities. Wherever feasible, programs should account for variations in the management practices considered most effective in each region.

A combination of instruments may be necessary to address the range of barriers to the adoption of particular practices that may exist, the diversity of properties, and the number of pathways of nutrient and chemical movement that can require different policy approaches. For example, a lack of private financial incentives to adopt practices (such as maintaining riparian buffer zones) may require public subsidies, particularly if the benefits of such practices exceed the levels required or expected under farmers’ duty of care to the environment (as outlined in Queensland legislation, for example). A lack of awareness of innovations in fertiliser use may suggest support for extension services. Regulatory approaches, however, may be appropriate to provide for minimum accepted practices, with audits and regulatory penalties to respond to particularly ‘poor’ managers who continually fail to meet such standards. As a result of this policy mix, land users face a continuum of incentives as they change their practices to be more environmentally friendly. A mix may also be desirable to achieve the appropriate sharing of the costs of water quality improvement.

The order and timing of implementation may be important when considering packages of policy instruments. For example, it may be appropriate to commence reforms with fertiliser and chemical use education and extension for growers in nutrient sensitive areas (encouraging and demonstrating the use and benefits of BMPs like those in COMPASS and farm plans, including EMSs). Such a program could also target other parties, such as mills, processors, fertiliser companies, supermarket chains, banks and local communities, that may influence the practices of growers, and seek cooperative and voluntary market driven opportunities to encourage BMPs. At the same time, rewards may be offered to farmers for developing and demonstrating innovative practices that can be fed back into industry or regional BMPs. As mentioned in relation to soil erosion, a useful first step could be to remove existing perverse incentives, such as those that may be present in the Sugar Industry Infrastructure Package or current legislative arrangements applying to the sugar industry.

These measures could then be backed up by a second stage involving tender processes to encourage activities beyond BMPs, such as wetland restoration or rehabilitation. Auctions could be linked back to farm plans and property level audits encouraged in earlier education activities. A third stage could involve re-enforcing the basic duty of care with a negative licensing scheme (where cropping businesses without accredited farm or nutrient management plans or conservation agreements require licences to purchase fertilisers and chemicals).

Summing up

As for soil erosion, it is evident from the options examined that there is no single solution to the overuse/misuse of fertilisers and chemicals. Each option has a range of pros and cons, and it is likely that a combination of options will be needed, giving consideration to the order and timing of implementation, and opportunities for complementarities between options. Policy options will also need to be reviewed over time as more information is available on the size, nature and location of nutrient and chemical pollution, and as total cropping area and practices change.

Nevertheless, it appears at present that the most promising options among those assessed are self-regulation through the conditional acceptance of cane by sugar mills, and licensing and auctions in nutrient sensitive zones. These options provide some flexibility in the practices adopted (and hence opportunities for land users to minimise abatement costs), can be targeted to high hazard areas, and involve either a minimal or efficient allocation of public funds.

Overall, mandating riparian zones in all areas is unlikely to be cost-effective. Licences requiring nutrient management plans in nutrient sensitive zones could be cost-effective, however, as they could allow growers to adopt practices suitable to their environments, and provide for easier monitoring and compliance. Regulatory options in general are more likely to be effective and feasible if balanced by positive incentives.

Taxes on fertiliser or chemical use are unlikely to be cost-effective. They target only one aspect of the problem (quantity), may encourage farmers to substitute other inputs for fertilisers, and increase cost pressures which may lead to less sustainable practices.

Subsidies to encourage particular land use changes can help overcome profit related concerns with their adoption. Subsidies targeted at the adoption of a range of practices, are more likely to be effective than subsidies of particular practices, inputs or equipment, because they give flexibility to growers to implement the most cost-effective approaches for their property.

Tendering processes are likely to increase the efficiency of subsidies to growers, as well as provide a useful tool to encourage farmers to go beyond best practice.

Active self-regulation in the sugar industry by mills or processors could be very effective in changing behaviour. Governments may play a role by increasing the incentives, both positive and negative, for such arrangements to work effectively.

9.4 Concluding comments

The formulation of abatement options requires decisions to be made about what to target, who to target, and what instruments to use. Who to target and what instruments to use are best assessed on a case-by-case basis. With respect to what to target, the only practical options at present are inputs or management practices. The abatement options analysed in this chapter targeted inputs or practices related to soil erosion on grazing properties, and the overuse/misuse of fertilisers and chemicals for cropping. These appear to be the most significant sources of diffuse pollution entering the GBR lagoon. While a limited number of abatement options were examined, they were sufficiently diverse to reach a number of general conclusions. These are discussed below.

There is no single land use change and associated policy instrument that will be effective and cost-effective in all cases. Thus, a combination of land use changes and instruments will be required. This is because:

- cost-effective actions to abate one source of diffuse pollution (eg soil erosion) probably have limited relevance to other sources (eg the overuse of fertilisers);
- for a given source of pollution, the most cost-effective options can vary between properties due to site-specific conditions, such as soil type and topography;
- targeting a single practice — such as the timing of fertiliser application — could lead to increased pollution from other practices — such as the quantity of fertiliser used; and
- combining instruments — such as BMP guidelines and rate rebates for adopting BMPs — can be much more effective than using a single instrument in isolation.

Combining instruments may also give governments greater flexibility regarding the distribution of costs and benefits from abating diffuse pollution. This could be important in achieving community acceptance.

There may be a strong case for sequencing the implementation of different abatement options, rather than combining them all at once. For example, significant uncertainty about the cost-effectiveness of different instruments may justify an initial focus on low cost options, such as an information campaign or the development of guidelines. If this is not sufficiently effective in reducing diffuse pollution, then more costly or coercive instruments — such as regulation — can be considered. Furthermore, the use of instruments like regulation may be more effective if preceded by an information campaign and the development of guidelines.

Considering the removal of perverse incentives created by existing policies should be a priority. This is because perverse incentives encourage diffuse pollution and so hinder the effectiveness of actions intended to abate such pollution. However, policy makers should consider all the costs and benefits associated with changing policies that create perverse incentives before initiating such changes. The example used in this chapter was to change drought assistance to discourage the retention of non-breeding stock as prolonged drought develops. Another possible candidate for change is the Sugar Industry Infrastructure Package (chapter 3).

Abatement options that take account of the information asymmetry between governments and land users are likely to outperform those that do not. This is because land users are better informed about abatement costs but governments are better informed about hazard areas. One way to handle this situation is to get land users to reveal their expected abatement costs in an auction. Another approach is to give land users a range of possible BMPs, from which they can select the least cost options using their unique site-specific knowledge. This is in contrast to a prescriptive regulation or subsidy that specifies exactly which practices a land user should adopt.

Instruments that are strongly linked to property rights are more likely to change behaviour. One way to do this is to provide more generous leasehold conditions in return for the adoption of approved BMPs.

Cost-effective abatement options do not necessarily have to be implemented by governments. The example used in this chapter was an arrangement where sugar mills only accept cane from growers who adopt approved BMPs. A similar approach is already used in New South Wales to ensure that cane growers adopt BMPs in relation to activities that may disturb acid sulphate soils.

Taxes and subsidies are unlikely to be cost-effective if they need to be tailored to site-specific conditions and this is costly. For example, a uniform tax on fertilisers would impose a cost on land users who have little or no adverse impact on the GBR World Heritage Area. Similarly, a uniform subsidy would be a blunt and possibly very costly instrument. However, property-specific taxes or subsidies would be very costly to design and administer. There may also be constitutional problems with imposing an input tax based on geographic location. A more feasible approach may be to target subsidies at high hazard regions rather than individual properties.

It is important to consider the timing of costs and benefits. For example, spelling on grazing properties can be profitable over the long term, but involves a high initial cost for erecting new internal fencing and watering points. Land users are less likely to be persuaded by an education campaign to voluntarily adopt spelling, if they have high debt and/or a strong preference for receiving benefits now rather than later. But if spelling generates net benefits from the perspective of society as a whole, there may be a case for combining the education campaign with targeted subsidies for internal fencing and watering points.

10 Roles and responsibilities

Although diffuse sources of pollution are important contributors to water quality concerns (chapter 2), to date there has been relatively little emphasis on controlling them (chapter 3). As discussed earlier, some responses that help to reduce diffuse pollution may arise without government involvement, such as through land-user initiated changes to management practices (chapter 5). However, private incentives may not be sufficient to achieve the natural resource management (NRM) outcomes desired by society as a whole (chapter 8). Potential instruments that governments may use to target diffuse pollution were discussed in chapter 9. The effectiveness of these options, both in terms of outcomes and costs, depends on the institutional arrangements designed to deliver them.

In this chapter, the roles and responsibilities of different parties in developing and implementing abatement options for diffuse pollution are discussed. It begins by briefly outlining why some changes to institutional arrangements may be justified (section 10.1), before discussing issues to consider when adopting a more regionally-focused approach, including the roles and responsibilities of various parties (section 10.2).

10.1 Managing diffuse pollution

Existing policies to address water quality in the GBR lagoon focus heavily on controlling point sources through a prescriptive system of regulation (chapter 3). Such end-of-pipe approaches are unlikely to be appropriate for diffuse pollution in the GBR catchment, for several reasons.

Difficulties in measuring discharges, a lack of information about the link between particular management practices and discharges, and asymmetric information (the government is likely to know more about water quality impacts, and less about abatement costs, than land users), suggest that a prescriptive regulatory approach is unlikely to be effective for diffuse pollution.

Furthermore, the most effective and cost-effective solutions are likely to vary across catchments, and maybe even within catchments and across neighbouring properties. This suggests that policy options that harness local knowledge are likely to have advantages.

As noted by the Industry Commission (IC 1998, p. 389):

> … the management of the environmental impacts associated with land management needs to reflect the large temporal and spatial variation in both the factors that contribute to the problem and the solutions … Even where the impacts are wider than … [catchments or basins], their effective management still has to reflect local circumstances and conditions.

Thus, cost-effective options for diffuse pollution are likely to be those which enable land users to use their unique site-specific knowledge to adopt least-cost abatement actions (chapter 9). The framework that enables this will require participation at all levels — from land users to the Commonwealth Government — with a focus on achieving outcomes at the regional level.

10.2 Issues in developing a new approach

Institutional arrangements for NRM — including for diffuse pollution threats — have developed differently across Australian jurisdictions over time, reflecting factors such as different environmental issues confronting jurisdictions. In more recent times, there has been a general shift in NRM issues towards an approach that is integrated (across both environmental issues and levels of government) and focused at the regional and property level. This shift is reflected in the Memorandum of Understanding (MOU) signed by the Commonwealth and Queensland Governments (appendix C), which specified that the *Reef Water Quality Protection Plan* would include:

> Actions and responsibilities for implementation, including a commitment to work with Regional NRM Bodies through the Regional Natural Resources Management Planning process to develop more detailed actions to meet targets, including by upstream and downstream users …

The shift to an integrated and regional approach reflects in part the potential benefits that can derive from it, such as the potential to:

- encourage greater participation at the local level, which is particularly important where issues have localised causes or solutions;
- allow issues that cross 'official' boundaries (for example, local government areas or States) to be addressed; and
- allow some consistency across regions, by providing an overarching framework within which issues can be addressed.

Although there appears to be merit in such an approach, the extent to which benefits are realised, and outweigh any costs, depends critically on the way it is designed and implemented. The same approach may not be warranted in all circumstances

(HORSCEH 2000; IC 1998). Nonetheless, there are some general features that effective institutional arrangements for NRM (including those to address diffuse pollution in the GBR catchment and lagoon) should incorporate and foster. These include:

- avoidance of regulatory duplication;
- a systematic and outcome-focused approach;
- well-specified (and understood) roles and responsibilities of different parties, recognising the spatial and temporal variation in problems and solutions;
- coordination and communication across Commonwealth, State, and local Governments, and regional bodies;
- transparent processes and funding mechanisms;
- flexibility in responding to different and/or new issues as they arise; and
- monitoring and review mechanisms (Adaptive Management). This is particularly important given the scientific uncertainty associated with water quality entering the GBR lagoon. New information may necessitate fine tuning of policy in the future.

Some problems with current NRM arrangements in Queensland have been acknowledged by the Queensland Government — as cited in Bellamy et al. (2002), for example, and implicitly in the MOU (appendix C). Problems with the current arrangements include overlapping planning and implementation responsibilities that lack coordination and monitoring/review mechanisms (Bellamy et al. 2002; see also chapter 3). Queensland Fruit & Vegetable Growers (sub. 49, p. 41), for example, noted inefficiencies associated with the:

> … diverse and over-lapping range of environmental protection and natural resource management processes which ultimately are all aimed at achieving the same outcomes.

The Science Panel (2003, p. 123) also commented that:

> … coordinating and streamlining arrangements between local, state and federal agencies is a key area requiring attention if water quality outcomes are to be achieved. The current planning system is a complex array of institutional arrangements at federal, state, regional and local level, to manage resource 'planning' and 'management'.

The effectiveness of policy instruments to control diffuse pollution in the GBR catchment will also be affected by interaction with broader Commonwealth and Queensland Government actions. For example, structural adjustment and other assistance packages may create perverse incentives, and potentially undermine actions to address declining water quality (chapter 3). As well as potentially encouraging actions that have deleterious effects on water quality, such assistance can limit the scope for, and/or increase the costs of, abatement options. Such packages need not have detrimental water quality effects, however. For example, they could be made part of the solution by making assistance conditional on certain types of land user behaviour.

Other parties — including regional NRM bodies, local government, industry associations and processors — also have important roles to play in the implementation of policy reforms, once the Commonwealth and Queensland Governments have provided the supportive broader framework. The Science Panel (2003, p. 108) observed that Queensland:

> … is working towards a robust community-based NRM planning system, with NRM Regional Bodies playing a central role. The transition towards robust regional planning systems will require a substantive effort on behalf of Queensland government agencies at both the State and regional level as well as support from federal and local jurisdictions. This move to regional NRM planning represents a fundamental shift in the way the government hopes to resource and support progress towards ESD [ecologically sustainable development].

The rest of this section focuses on the issues to be considered in implementing an 'integrated regional' approach, focusing on the roles and responsibilities of the various parties.

Role of the Commonwealth Government

Primary responsibility for land and water management is generally seen to reside with the states, although the extent to which this is the case is subject to some uncertainty (HORSCEH 2000). In terms of the GBR, the Commonwealth potentially has a more direct role, given the Reef's World Heritage status, and the powers of the Great Barrier Reef Marine Park Authority (GBRMPA). This does not mean that GBRMPA should have greater direct involvement in implementing solutions for diffuse pollution. The recent experience with aquaculture regulation illustrates the potential for regulatory duplication that may result from this approach (chapter 3). In any case, centralised prescriptive regulatory approaches are not well-suited to the diffuse pollution problem, particularly given the detailed site-specific information required to determine and implement cost-effective abatement actions.

Therefore, the Commonwealth Government's role in addressing diffuse pollution in the GBR may involve:

- broad objective setting for the GBR (in cooperation with the Queensland Government), as agreed in the MOU;
- provision of information to other parties, such as regional NRM bodies;
- fostering a cooperative, partnership approach;

- funding (such as through the National Action Plan for Salinity and Water Quality (NAP) and National Heritage Trust (NHT)) through an objective and transparent process; and
- establishing appropriate accountability and review mechanisms (being mindful to minimise overlap with other systems).

GBRMPA is likely to have a crucial role in many of these functions, but particularly in providing information for priority setting, and feedback for performance monitoring.

Where a case for government involvement is identified, the Commonwealth is likely to have a role when there are economies of scale, or issues that cross jurisdictional boundaries. Communication with, and input from, local groups remains important, however. One example of a suitable role for the Commonwealth Government is its funding (in conjunction with the Queensland Government) of major studies to prioritise hazard and receiving areas in the GBR catchment and lagoon (chapter 7).

Queensland Government involvement

The nature of the Queensland Government's involvement, and its relationship with regional bodies, is crucial to the success of an integrated regional approach. Under this approach, its roles could include:

- setting and communicating objectives for the GBR (in the context of NRM generally) that are consistent with Commonwealth objectives, thus helping to promote a common understanding of policy goals and facilitating a focused and consistent approach to policy implementation;
- establishing the broad framework for the arrangements, including additional devolution of responsibilities to regional bodies (discussed further below);
- providing and gathering information;
- funding and administrative support; and
- implementing and managing some instruments/options.

Thus, although a regional approach involves devolution of some powers and responsibilities by the Queensland Government, there may be circumstances in which it has a fairly direct implementation role. For example, one of the abatement options considered in chapter 9 was to link leasehold conditions to the adoption of approved management practices. The Queensland Government would obviously need to take the lead if this option is implemented, given that it is responsible for overseeing the management of leases. Regional bodies could play a supporting role by advising on the most appropriate practices for particular regions or industries.

There may be scope for accreditation of best management practice (BMP) guidelines to be undertaken by the Queensland Government under existing mechanisms — for example, by the Environmental Protection Agency (under the *Environmental Protection Act 1994*) — although other bodies also may be able to perform this role.

Existing Queensland planning mechanisms might be considered a useful vehicle for implementing some policy instruments (see GBRMPA (sub. DR77, p. 8) and Queensland Seafood Industry Association (sub. DR62, attachment 1, p. 4), for example). However, these will need to be integrated with regional processes to be more effective in promoting a regional approach (discussed below). Further, there may be scope to simplify existing arrangements.

Role of regional bodies

As outlined earlier, regional bodies form a potentially important part of the overall policy implementation framework for managing diffuse pollution in the GBR catchment. Their role may include:

- compiling information and undertaking ongoing monitoring of resource condition;
- improving communication and information dissemination between land users and government; and
- using local knowledge and information, together with other bodies such as industry associations (see below), to set priorities and implement actions at the local level, such as guidelines for BMPs.

Under the NAP, regional NRM bodies are to perform such tasks as part of preparing and implementing Regional Investment Strategies (subject to approval and accreditation by Queensland and Commonwealth Governments) (chapter 3).

At a broad level, key factors influencing the effectiveness of regional bodies may include:

- structural issues, such as geographic boundaries and representation; and
- responsibilities and appropriate (legislative) status.

Structure

The ideal boundaries for regional bodies involved in NRM issues are likely to be the geographic boundaries of the area in which environmental outcomes are to be targeted, such as catchment boundaries within the greater GBR catchment. Johnstone Ecological Society (sub. 4, p. 4) noted that one issue with regional bodies such as river improvement trusts (RITs) (chapter 3) is that they are based on shire boundaries, making it difficult for them to take a catchment-wide view of issues when proposing abatement actions (such as the protection and maintenance of riparian buffers).

Achieving a balance of representation on regional bodies is of key importance. This helps to ensure that they are able to achieve their objectives by taking a 'whole of catchment' view and not protecting the interests of any one party (Bellamy et al. 2002, p. 113). Johnstone Ecological Society (sub. 4, p. 4) further noted with respect to RITs that the dominance of Shire Councillors on trust membership (as set out under s. 5 of *River Improvement Trust Act 1940*) makes it difficult for such bodies to deal with issues at 'arm's length', and that this in turn affects NRM outcomes.

The interaction between regional bodies and the Queensland and Commonwealth Governments is also an important issue to be resolved. This may involve considerations such as whether Queensland Government agency staff act as representatives or as support staff for the NRM body, and whether regional NRM bodies act as local advisers to a Queensland Government agency or as decision makers.

The Queensland Government (1999, p. 11) found that 'community capacity' is an important factor in implementing regionally-based catchment management approaches:

> Changing institutional, legislative and structural arrangements is of little benefit if communities and individuals do not have sufficient capacity to participate or to implement and adopt changes in their management of local resources.

Where 'community capacity' is a barrier, there may be a role for government to provide resources, such as for training and reimbursement of operational costs, to improve the level and quality of participation.

A significant challenge for the delivery of the NAP in the Fitzroy–Burdekin priority investment region is the scale of the area. This could make it difficult for the two currently accredited regional NRM bodies (chapter 3) to achieve sufficient representation at the sub-regional level.

Responsibilities and status

An important factor that may influence the effectiveness of regional bodies is the level of responsibility that is devolved from the Queensland Government and the legislative status of this responsibility. Where regional bodies are identified as playing a key role in delivering policy measures, they need to be given sufficient resources and powers to develop, implement and monitor actions. If they were given explicit powers and resources, then they would need to be accountable for their actions.

There are few precedents for how responsibility might be devolved under regional NRM planning processes. Thus, Musgrave (2002, p. 158) noted that it may be necessary for there to be:

> … a process of experiment and adaptation, particularly at the regional and sub-regional levels of resource governance.

Regional bodies in Queensland currently have no statutory responsibilities and power for NRM. For example, catchment management associations (CMAs) do not have any legislative base, and rely upon voluntary participation by both community and government (Rowland and Begbie 1997). As a consequence, CMAs have been 'developing their own structures and linkages to meet their own requirements' (Bellamy et al. 2002, p. 110). CMAs in some areas, such as the Fitzroy Basin Association, have developed into highly organised bodies with large membership networks, whereas in other areas CMAs have remained largely informal with limited input to regional NRM outcomes.

One option may be to combine the type of statutory powers held by RITs with the catchment level focus of CMAs to target regional NRM objectives.

If regional bodies were to be given statutory powers and responsibility for NRM (including water quality issues) in Queensland, they would need to be integrated into the existing legislative framework. This would be a complex task given potential overlap between existing regional bodies and the large number of statutory NRM plans currently in operation, including water resource and coastal management plans (chapter 3).

For initiatives such as the NAP and NHT, regional NRM bodies will require access to information held by other groups, such as Queensland and Commonwealth departments and research agencies, to be able to perform regional NRM planning tasks, such as setting priorities, and monitoring and reviewing actions. With respect to cooperation in the 'capture, storage and distribution' of information, the Science Panel (2003, p. 126) suggested the Herbert Resource Information Centre (HRIC) — a joint venture including State and local Government, science and industry bodies

— as a potential model for other GBR catchments. CSR Sugar (sub. 14, p. 9) also pointed to the 'significant' benefits attributable to the operation of HRIC.

Role of other groups

Other groups, government and non-government, play potentially important roles in measures to address diffuse pollution in the GBR lagoon. These groups include local government, industry associations and processors. A key issue is how they are included in planning and implementation processes. In some cases, their involvement may include representation on boards of regional bodies.

Local government

Local governments can be involved in several ways in the management of diffuse source threats to water quality in the GBR catchment, including through local planning and development schemes (chapter 3), and input to NRM processes.

Several observers have noted that under the existing NRM arrangements in Queensland, there are barriers to the participation of local governments. For example, Bellamy et al. (2002, p. 35) found that:

> … there are institutional barriers to the participation and involvement of local government in catchment management with some evidence that local governments are confused by the actions of various NRM groups and uncertain as to how best to become involved. Moreover ICM [Integrated Catchment Management] is viewed by some as a threat to local government activity.

The tensions between regional bodies and local government is a key issue that partly may be resolved through more balanced representation on regional bodies and clearer articulation of the respective roles of various parties in NRM issues.

Industry associations

Industry associations, such as Canegrowers, have been important in helping to develop, and promote to land users, BMP guidelines and compliance programs, such as COMPASS (chapter 5). Their expertise and links to land users suggest that they will continue to play an important information and interface role in future arrangements. To the extent that a high proportion of land users are members, such associations also provide a more central point of communication with land users. However, variable compliance with voluntary codes (chapter 5) highlights limitations in the extent to which industry groups alone can promote changed practices by land users.

Processors

The nature of the supply chain of some industries in the GBR catchment, such as sugar cane, suggests that processors may be an important potential driver of changed practices by land users. As discussed in chapter 9, sugar processors could specify in their contracts with cane growers that they meet certain standards (adopting BMP guidelines, for example). A similar approach is already used in New South Wales to ensure that cane growers adopt BMPs in relation to activities that may disturb acid sulphate soils.

Direct involvement or regulation by governments may not always be needed to achieve a particular outcome. For example, the incorporation of conditions relating to acid sulphate soils in cane supply contracts in New South Wales occurred without being required by regulation, although the threat of regulation may have been an influencing factor (chapter 9).

10.3 Concluding comments

The effectiveness of abatement options, both in terms of NRM outcomes and cost, will rely on the institutional arrangements that are to deliver them.

This chapter suggests that achieving greater integration and coordination of institutional arrangements will be necessary to implement abatement options. For this to occur, the roles and responsibilities of the various parties in managing diffuse pollution require clarification, with a focus on achieving outcomes at the local level. This process will also help to identify opportunities, across all levels, for reducing institutional overlap and complexity.

If regional bodies are to have a major role, they will need, as far as possible, to be consistently developed along appropriate geographic boundaries, and be given sufficient resources and powers to develop, implement and monitor actions. Regional bodies currently have limited statutory responsibilities and powers. If they are given additional powers, then they will need to be accountable for their actions.

In addition, regional bodies should not create an additional layer of complexity, but instead be part of a simplified approach that is integrated with the actions of other parties, notably the Commonwealth and Queensland Governments.

Finally, it is highly desirable to have ongoing monitoring and review of policies and the roles assigned to different parties (Adaptive Management). This is important for two reasons. First, as noted above, there are few precedents for how responsibilities might be devolved to regional bodies. Thus, a process of trial and adaptation is probably required. Second, future research and experience could be expected to resolve some of the uncertainties about the benefits and costs of abating diffuse pollution entering the GBR lagoon. This could in turn reveal a need for future modification of policies and the roles assigned to different parties.

APPENDIXES

A Submissions received

	Submission number[a]	Date received
Agforce	33	16 Sept 02
Agricultural Research Technologies (N.Q.) Pty. Ltd.	46	25 Sept 02
Alliance for Sustainable Tourism	10	12 Sept 02
Alliance to Save Hinchinbrook Inc	37	17 Sept 02
Association of Marine Park Tourism Operators	29	16 Sept 02
Atkinson, K & A	11	12 Sept 02
Australia Meat Holdings Pty Limited	21	13 Sept 02
Australian Institute of Marine Science	12	12 Sept 02
Australian Prawn Farmers Association	45	24 Sept 02
Australian Prawn Farmers Association	DR59	19 Nov 02
Brodie, Jon	DR75	17 Dec 02
Bureau of Sugar Experiment Stations	DR79	8 Jan 03
Burnett Mary Regional Group for NRM	DR66	13 Dec 02
Cairns City Council	23	13 Sept 02
Cairns Port Authority	43	18 Sept 02
Canegrowers	34	16 Sept 02
Canegrowers	DR67	13 Dec 02
Cape York Marine Advisory Group	22	13 Sept 02
CK Life Sciences Int’l Inc	42	18 Sept 02
Carter, Professor R M	57	28 Oct 02
Clarke, Simon	38	17 Sept 02
Cotton Australia	48	27 Sept 02
CSR Sugar	14	13 Sept 02
Dawson Catchment Coordinating Association	51	1 Oct 02
Dawson, Noel	17	13 Sept 02
Department of Agriculture, Fisheries and Forestry - Australia	53	2 Oct 02

(Continued next page)

	Submission number[a]	*Date received*
Department of the Environment and Heritage	DR58	14 Nov 02
Department of Primary Industries, Queensland	1	26 Aug 02
Department of Primary Industries, Queensland	DR63	11 Dec 02
Ecofish	2	27 Aug 02
Elders Limited	25	13 Sept 02
Fertilizer Industry Federation of Australia Inc.	32	16 Sept 02
Furnas, Dr. Miles	DR68	13 Dec 02
Gladstone Port Authority	6	10 Sept 02
Gleeson, Tony	50	1 Oct 02
Gleeson, Tony	DR81	16 Jan 03
Great Barrier Reef Marine Park Authority	27	13 Sept 02
Great Barrier Reef Marine Park Authority	DR77	19 Dec 02
J D Cambridge Corporate Services Pty Ltd	40	18 Sept 02
Johnstone Ecological Society	4	6 Sept 02
Johnstone River Catchment Management Association	5	9 Sept 02
Johnstone Shire Council	20	13 Sept 02
Lee & Co	18	13 Sept 02
Mackay Port Authority	30	16 Sept 02
Mackay Port Authority	DR78	23 Dec 02
Malanda and Upper Johnstone Landcare	DR64	11 Dec 02
McCook, Dr. Laurence	DR69	16 Dec 02
McCulloch, Professor Malcolm	DR74	17 Dec 02
Mulgrave Landcare & Catchment Group Inc	DR71	16 Dec 02
National Land and Water Resources Audit	3	29 Aug 02
Nature Conservation Council of NSW	52	1 Oct 02
North Johnstone & Lake Eacham Landcare	36	13 Sept 02
North Queensland Land Council	DR60	4 Dec 02
North Queensland River Trusts' Association Inc	47	26 Sept 02
North Queensland River Trusts' Association Inc	DR80	8 Jan 03
Pang, Professor	39	18 Sept 02
Ports Corporation Queensland	26	13 Sept 02

(Continued next page)

	Submission number[a]	Date received
Queensland Fruit & Vegetable Growers	49	27 Sept 02
Queensland Fruit & Vegetable Growers	54	2 Oct 02
Queensland Mining Council	13	12 Sept 02
Queensland Seafood Industry Association	31	16 Sept 02
Queensland Seafood Industry Association	DR62	10 Dec 02
Rayment, Dr. George	DR70	16 Dec 02
Reid, David	DR73	16 Dec 02
Rockhampton City Council	24	13 Sept 02
Rovira & Associates	41	18 Sept 02
Sea Forum Working Group	15	13 Sept 02
Spradbrow, Ian	7	11 Sept 02
Spradbrow, Ian	DR61	9 Dec 02
Sweet, John	55	7 Oct 02
Sweet, John	56	10 Oct 02
Sweet, John	DR76	17 Dec 02
The Australian Democrats, Senator Andrew Bartlett	44	18 Sept 02
The Leucaena Network	9	12 Sept 02
Tully and District Wildlife Preservation Society of Queensland	16	13 Sept 02
Tully and District Wildlife Preservation Society of Queensland	DR65	13 Dec 02
Whitsunday Rivers Integrated Catchment Management Association	19	13 Sept 02
Wildlife Preservation Society of Queensland (Cairns Branch)	35	17 Sept 02
Wildlife Preservation Society of Queensland (Cairns Branch)	DR72	16 Dec 02
World Wide Fund for Nature, Australia	28	16 Sept 02
Wowan Dululu Landcare Group	8	11 Sept 02

[a] A submission number with the prefix DR indicates that the submission was received after the preparation of the interim report.

B Persons and organisations visited

AgForce Queensland

Allingham, Tony and Trish

Association of Marine Park Tourism Operators (AMPTO)

Australian Bureau of Agricultural and Resource Economics (ABARE)

Australian Institute of Marine Science (AIMS)

Atkinson, Keith, Camel Creek

Canegrowers (Queensland Canegrowers Organisation Ltd)

Chapman, Ross

Commonwealth Department of Agriculture, Fisheries and Forestry Australia (AFFA)

Commonwealth Department of Environment and Heritage (Environment Australia)

Commonwealth Department of Industry, Tourism and Resources (DITR)

Commonwealth Department of Transport and Regional Services (DTRS)

Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Cooperative Research Centre for the Great Barrier Reef World Heritage Area (CRC Reef)

Cotton Australia

Coutts, Doug & Lesley

Fitzroy Basin Association (FBA)

Fry, Russell & Cilla

Great Barrier Reef Marine Park Authority (GBRMPA)

Johnstone Ecological Society

Johnstone River Catchment Management Association Inc.

Johnstone Shire River Improvement Trust

Malanda Milk Factory

Matthews, Eugene and Heather

Morris, Richard and Hassle

National Land and Water Resources Audit (NLWRA)

Natural Resource Management Board (Wet Tropics) Inc

North Queensland Land Council

Queensland Department of Local Government and Planning (DLGP)

Queensland Department of Natural Resources and Mines (DNRM)

Queensland Department of Premier and Cabinet (DPC)

Queensland Department of Primary Industries (DPI)

Queensland Department of State Development (DSD)

Queensland Environmental Protection Agency (EPA)

Queensland Farmers' Federation (QFF)

Queensland Fruit and Vegetable Growers (QFVG)

Queensland Mining Council (QMC)

Queensland Seafood Industry Association (QSIA)

Spry, Michael

Sunfish Queensland Inc.

Three Rivers Landcare Group

Tourism Queensland

Townsville City Council

World Wide Fund for Nature (Queensland)

C Memorandum of Understanding

Memorandum of Understanding between the Commonwealth Government and the Government of the State of Queensland on cooperation to protect the Great Barrier Reef from land-sourced pollutants.

PREAMBLE

The Great Barrier Reef World Heritage Area (the Reef) contains the largest system of coral reefs in the world. This diverse ecosystem also contains extensive seagrass beds, mangrove forests, and sponge gardens. The ecosystem of the reef has a complex inter-dependent relationship with the adjacent river catchments. Many marine species rely on coastal freshwater wetlands and estuaries as breeding and nursery areas. The catchments adjacent to the reef have extensive land modification with a focus on developing land and infrastructure for urban centres, agricultural production, tourism and mining. This development has led to increases in pollutant loads in the rivers since European settlement.

GENERAL

1. The governments agree that the Great Barrier Reef is a nationally and internationally significant area with outstanding natural values that plays a significant role in the local, regional and national economy.
2. The governments agree that the values of the area require protection and that a joint and cooperative approach to the Reef's protection is required.
3. The governments agree that the decline in water quality entering the Reef lagoon poses a significant threat to the natural, economic and social values of the Reef.
4. The governments agree that as a first stage in the protection of the Reef a major goal is stabilising and reversing the decline in water quality entering the Reef lagoon as soon as practicable.

5. The governments agree that the precautionary approach needs to be used to protect the values of the Reef, and that a risk management approach should be taken to address matters posed by declining water quality that might impact on the environmental, social and economic values of the Reef.
6. The governments note that the major source of pollutants entering the Reef lagoon emanates from land use activities in the catchments. The addressing of this source through integrated catchment management is the focus of this agreement.
7. The governments also note that there are a range of other sources of pollutants entering the Reef lagoon that are, and will be, the subject of ongoing actions to reduce their impact on water quality in the Reef lagoon. The potential impacts of these other sources and the action to constrain their impacts will need to be considered.
8. The governments further note that a significant amount of work has already been undertaken to develop water quality objectives and identify what actions are needed to protect the Reef. Governments agree that this information should be used in determining a joint way forward.
9. The governments agree that it is important to build upon the existing participation and support of stakeholders in identifying and implementing approaches to protecting the Reef.
10. The governments note the need for the public and stakeholders to be assured that a joint approach by governments is being taken to protecting the Reef.
11. The governments note that there are other threats to the values of the Reef, for example, impacts from fishing and tourism ventures, and that separate processes are underway to address these threats.

OPERATIVE

12. In order to achieve the goal of stabilising and reversing the decline in water quality entering the Reef lagoon as soon as practicable, the governments will undertake the following actions:

    a. Jointly progress the development of a Reef Water Quality Protection Plan, with a target date for agreement of a draft plan by the end of the third quarter of 2002, with a final plan before the end of 2002. The Plan would include;

       - A clear statement of the objectives;
       - Clear statements of risks and priorities that arise from risk assessment, noting that connectivity is of significance in reef environments in assessing risk;

- An analysis of the pressure on the Reef lagoon associated with water quality in the catchments flowing to the Reef, and what responses in these catchments are appropriate to protect the environmental, social and economic values of the Reef;
- An outline of the range of activities currently undertaken in relation to water quality in the Reef catchments;
- Actions and responsibilities for implementation, including a commitment to work with Regional NRM Bodies through the Regional Natural Resources Management Planning process to develop more detailed actions to meet targets, including by upstream and downstream users;
- Consideration of short, medium and long-term responses;
- Costing for 'no regrets' actions and a financial plan;
- Clear auditing and reporting arrangements; and
- Noting that targets will be developed that are achievable and measurable through the regional NRM planning process where the emphasis will be on catchment by catchment approaches

b. Cooperate in an assessment of options for short, medium and long-term actions to stabilise and reverse the decline in water quality, including the environmental, social and economic benefits and costs of those actions and implementation through the regional NRM planning process.

c. In developing the Reef Water Quality Protection Plan consider the role of measures such as: pesticide and fertiliser chemical uses and practices; upstream and downstream industries for all relevant sectors; development, adoption, implementation, auditing and compliance with existing Codes of Practice, Environmental Management Systems and adoption of Property Management Planning; riparian management and re-vegetation requirements; wetlands management and rehabilitation requirements; total grazing pressure management and any other actions that may assist in stabilising and reversing the decline in water quality.

d. Determine, through the Reef Water Quality Protection Plan, the key sub-catchments where actions need to be undertaken, noting that the regional NRM planning processes will be defining specific actions to meet targets.

e. Jointly host a stakeholder consultative forum.

f. Jointly provide information to and engage stakeholders in consultations over particular aspects of the Reef Water Quality Protection Plan relevant to those stakeholders, with an emphasis on regional and industry by industry approaches.

g. Implement as a priority, agreed 'no regrets' actions that:

- provide a framework for prioritising further regional actions;
- build on industry specific initiatives aimed at improving the environmental performance of those industries, particularly reducing the discharge of pollutants to the Reef lagoon;
- implement priority actions cooperatively with regional communities;
- develop the water quality audit framework built upon existing monitoring and evaluation processes being developed through the NRM Ministerial Council.

'No regrets' actions that are agreed should be of relatively low cost and have broad environmental, social and/or economic benefits beyond the benefit of protecting the Reef lagoon. These actions should commence before the third quarter of 2002.

These 'no regrets' actions may include:

- Identifying the major sediment and nutrient sources in the catchments;
- Negotiating eco-efficiency agreement(s) with the fertiliser industry;
- Have the relevant regulatory agencies undertake a review of the current uses of key herbicides/pesticides used in catchments adjoining the Reef;
- Promoting development and adoption of codes of practice and guidelines for agricultural industries within the catchments; and
- Negotiate and implement local water quality improvement actions where catchment communities wish to take early actions.

h. Cooperate in considering what water quality decline has occurred and what improvements are needed at the catchment and sub-catchment level, the science underpinning the analysis of the status of water quality entering the Reef lagoon and the objectives and mechanisms for improvement to water quality in the Reef lagoon. Cooperation will include participation in and supporting consultation on water quality target-setting through the regional NRM planning process.

13. The governments agree to use best endeavours to ensure that public statements related to the implementation of the MOU will be joint or coordinated between governments. Where separate statements are to be made or reports released, the government proposing to make the statement or release the report will consult the other government beforehand.

14. The Reef Water Quality Protection Plan will include the development of water quality improvement objectives and approaches to achieving these objectives, to provide input into regional NRM planning processes, including target-setting.

15. It is expected that the regional natural resource management plans will be the primary vehicle for implementing the Reef Water Quality Protection Plan at the catchment level.

16. In addition to these joint initiatives the governments will also pursue initiatives individually towards the joint goal. Governments will involve the other government in the pursuit of these initiatives.

17. The Commonwealth government will consider supporting a number of initial actions consistent with the Reef Water Quality Protection Plan. Possible actions include:

a. Undertake economic and socio-economic studies of the industries associated with the Reef and adjacent catchments, including information on the values of industries and information enabling the assessment of the benefits and costs of specific actions that are proposed;

b. Have the National Registration Authority undertake a Chemical Review of Diuron;

c. Provide through normal channels assistance and advice to stakeholders from relevant scientific, research agencies and management agencies;

d. Provide financial, policy and project management assistance to implement 'no regret' actions agreed as priority regional actions under the National Action Plan for Salinity and Water Quality or Natural Heritage Trust;

e. Provide as a priority financial, policy and project management assistance to develop and implement regional plans within the agreed NAP and NHT regions adjacent to the Reef.

18. The Queensland government will consider supporting a number of initial actions consistent with the Reef Water Quality Protection Plan. Possible actions include:

a. Provide financial, policy and project management assistance to implement 'no regret' actions agreed as priority regional actions under the NAP or NHT;

b. Provide as a priority financial, policy and project management assistance to develop and implement regional plans within the agreed NAP and NHT regions adjacent to the reef;

c. Establishing and supporting a scientific panel to investigate Reef health and impact issues; and

d. Provide assistance to industry to refine and encourage industry adoption of current recommended practice.

19. To guide the development of the Reef Water Quality Protection Plan the governments will form a Commonwealth/State Steering Committee of senior officials.

20. A joint project team of officials from both jurisdictions will be formed to support the Steering Committee and the development of the Plan.

13 August 2002.

D CRC Reef consensus statement

The following consensus statement from a group of scientists was included in the report of the Independent Assessment of the Sugar Industry (Hildebrand 2002).

The current level of scientific understanding on impacts of terrestrial run-off on the Great Barrier Reef World Heritage Area

David McB. Williams (CRC Reef / AIMS), Christian H. Roth (CSIRO Land and Water), Russell Reichelt (CRC Reef), Peter Ridd (James Cook University), George E. Rayment (Sugar CRC / Qld NR&M), Piers Larcombe (JCU), Jon Brodie (JCU), Richard Pearson (Australian Centre for Tropical Freshwater Research / JCU), Clive Wilkinson (Global Coral Reef Monitoring Network), Frank Talbot, Miles Furnas (AIMS/ CRC Reef), Katharina Fabricius (CRC Reef/ AIMS), Laurence McCook (CRC Reef/ AIMS), Terry Hughes (JCU), Ove Hough-Gulberg (University of Queensland), Terry Done (AIMS/ CRC Reef).

Run-off of sediment and nutrients to the Great Barrier Reef has increased several-fold as a result of past and current land-use practices. There is significant concern that coastal ecosystems in the Great Barrier Reef World Heritage Area (GBRWHA) are being adversely affected as a consequence of this increase.

While improvements have been made in sustainable land use, other adverse practices continue, including: expansion of farming into marginal areas; increases in fertiliser application; overgrazing; and loss of riparian vegetation and wetlands. If more effective action is not taken to reduce run-off of sediment, nutrients and other pollutants, the present threat to the World Heritage Area and adjacent freshwater systems will worsen.

Provision of a credible and a comprehensive science base that reflects the general state of knowledge accepted by the scientific community is critical to the public debate. This statement intends to provide a consolidated view of our current understanding of the impacts of terrestrial run-off on the Great Barrier Reef World Heritage Area (GBRWHA).

Current scientific understanding about terrestrial run-off in the GBRWHA has been documented in detail in a recent review undertaken by David Williams on behalf of the CRC Reef. It represents the outcome of a review of existing published scientific literature, complemented by a robust and broad consultation of experts in the fields of marine and terrestrial sciences and whose expertise is relevant to the GBRWHA. The review document is publicly accessible at www.reef.crc.org.au/aboutreef/coastal/waterqualityreview.shtml. Major conclusions of the review are summarised in the CRC Reef brochure "Land use and the Great Barrier Reef World Heritage Area" (CRC Reef 2001).

These documents clearly outline our present state of knowledge. A key conclusion concerns the area under threat. Areas at risk are near-shore reefs and seagrass beds south of Port Douglas and within 20 km of the coast. The areas of most concern are those between Port Douglas and Hinchinbrook as well as Bowen to Mackay. A major proportion of the GBRWHA (including the outer reef) is not likely to be threatened by terrestrial runoff.

The other key conclusion is that while enhanced runoff has severely damaged coral reefs elsewhere, there is a lot of uncertainty about the processes by which runoff may damage the GBRWHA. This is not surprising given the complexity and interactions between the physical and ecological processes involved. Since compilation of the review, more scientific publications have become available or are in the process of being published, indicating that our state of knowledge is in constant flux and as new and sometimes contrasting views are introduced, healthy scientific debate is stimulated. This is normal and rigorous scientific debate is an essential part of the process of transforming scientific information into knowledge or understanding.

In summary, the assessment of the potentially adverse impacts of terrestrial runoff and delivery of pollutants (sediments and associated nutrients, pesticides, heavy metals) to the GBRWHA from land-based activities is not straightforward and will continue to be so for a while. The main reasons for this are:

- We have little or no baseline data to indicate what the GBRWHA looked like before European settlement. Much of our understanding has only emerged over the past decade or two, so that in many instances we have to infer from other reef systems with longer records and from the interpretation of "records" embodied within coral cores.
- Against the backdrop of strong disturbance from natural processes (e.g. cyclones, inherent climatic variability, natural biological cycles), many of which have "recovery" periods of decades, it is very difficult to distinguish or even quantify the relative contribution of anthropogenic disturbances. It is likely that adverse human impacts from enhanced runoff will be first observed in the

reduced capability, or failure, of coral reefs or seagrass beds to recover from natural disturbance rather than as direct impacts.

- We are dealing with complex ecological processes, where inherent ecosystem buffering capacity makes it difficult to identify clear human-induced trends in change from relatively short-term studies. However, in many ecosystems, apparent resistance to change due to high buffering capacities can be followed by an abrupt ecosystem collapse once critical disturbance thresholds have been overstepped. Predicting these thresholds is extremely difficult, yet they are absolutely critical, as an overstepping can often lead to irreversible changes or to very slow rates of recovery when the "pressure" abates.

All three reasons are important enough to adhere to the precautionary principle in managing the land-based sources of impacts on the GBRWHA until we achieve more certainty in our understanding of impacts. The very real risk is that by not undertaking any significant action now to reduce delivery of elevated levels of nutrients and pollutants to the GBRWHA, we may overstep some thresholds leading to irreversible loss of near-shore reef systems and sea grass beds. Moreover, post-European land use has very significantly altered and in many cases caused significant damage to rivers or loss of wetlands in the majority of the catchment area of the GBRWHA. The direct and indirect impacts of the changes to or loss of freshwater biodiversity and food chain links to the GBRWHA have yet to be fully assessed.

In conclusion, on the basis that:

- available evidence indicates that post-European land use has significantly increased runoff and sediment associated nutrient and contaminant delivery to near-shore regions of the GBRHWA;
- runoff has had clear detrimental impacts on freshwater aquatic systems; and
- there is significant risk that this impact is currently or may in future damage areas of high exposure along the wet tropical and central Queensland coasts of the GBRWHA,

there is a continued urgency to work towards a reduction in the runoff of sediments, nutrients, herbicides and other pollutants into the Great Barrier Reef World Heritage Area.

E Industry data

E.1 Data sources

Data in sections 4.1 to 4.5 of chapter 4 were sourced from the following agencies:

- Australian Bureau of Statistics (ABS);
- Australian Bureau of Agricultural and Resource Economics (ABARE);
- Office of Economic and Statistical Research (OESR), within the Queensland Treasury;
- Queensland Department of Natural Resources and Mines (DNRM); and
- Queensland Fisheries Service (QFS), within the Queensland Department of Primary Industries.

In addition, data were sourced from industry visits and submissions.

Australian Bureau of Statistics

ABS data included:

- value of production and value added by the sugar, horticulture, beef, agriculture, food processing, mining, mineral processing and tourism industries; and
- social indicators for all industries except recreational fishing and tourism.

Gross value of production (GVP) data were derived from Agricultural Commodity Survey/Census (1991-92 to 1999-2000). Industry value added data for the agriculture, sugar, horticulture and beef industries were derived from the Agricultural Finance Survey (1991-92 to 1999-2000).

Mining GVP and industry value added data for Queensland and Australia were sourced from two ABS publications: *Australian Mining Industry 1998-99*, Cat. No. 8414.0; and *Mining Operations, Australia 1999-2000*, Cat. No. 8415.0.

Turnover and industry value added data for the food and mineral processing industries were obtained from ABS published and unpublished data. Australia and Queensland data were obtained from the ABS companion data *Manufacturing*

Industry, Australia 1999-2000, Cat. No. 8221.0. Regional data were obtained from the 1996-97 Manufacturing Survey.

National tourist expenditure and employment data were obtained from the publication *Australian National Accounts: Tourism Satellite Account 2000-01*, Cat. No. 5249.0.

Employment and social indicator data were derived from unpublished *2001 Census of Population and Housing* data.

Other sources

Commercial fishing and aquaculture GVP data for Queensland and Australia were obtained from the ABARE publication *Australian Fisheries Statistics* (various years).

The QFS provided unpublished regional GVP and employment data for the commercial fishing and aquaculture industries. It also provided estimates of recreational fishing expenditure.

State and regional data on visitor expenditure, tourism generated employment and tourism contribution to gross state product/gross regional product were sourced from OESR (2001a, b, c, 2002a).

DNRM provided unpublished regional GVP and employment data for the mining industry.

E.2 Industry definitions

The Australian and New Zealand Standard Industrial Classification (ANZSIC 1993), which classifies industries according to the goods and services they produce, was used where possible to define industries (table E.1). In general, industry definitions used by the various data sources were consistent with the ANZSIC system.

One exception is that the ABS classifies agricultural industries on a commodity basis when measuring GVP. While the sugar and horticulture industry classifications are equivalent to ANZSIC, this is not the case for the beef industry. GVP data were obtained for cattle and calves slaughtered, but value added and employment data were obtained for ANZSIC industries 0122 (Grain-sheep-beef), 0123 (Sheep-beef) and 0125 (Beef). The GVP of cattle and calves slaughtered is greater than the value of output of industry 0125, as beef cattle are also farmed on properties classified to industries 0122 and 0123. However, the majority of properties in the GBR catchment which farm beef cattle are classified to industry 0125.

Another exception is that the tourism and recreational fishing industries are not ANZSIC industries and cannot be classified according to the goods and services they produce. Rather, these industries are defined by the status of the customer. Consequently, the economic importance of the tourism industry is described by the expenditure of visitors, where visitors are defined as:

> Persons travelling to and staying in places outside their usual environment for not more than one consecutive year for leisure, business and other purposes not related to the exercise of an activity remunerated from within the place visited. (ABS 2002c, p. 41)

Similarly, the importance of the recreational fishing industry is described by the expenditure of recreational fishers. Consequently, care is required in comparing the economic and social importance of recreational fishing and tourism to that of production-defined industries, such as mining and agriculture.

Table E.1 ANZSIC industries

Group or Class	*Name*	*Activities*
	Sugar industry	
0161	Sugar Cane Growing	Growing sugar cane.
	Beef industry	
0122	Grain-Sheep and Grain-Beef Cattle Farming	Growing cereal grains mixed with sheep farming or cereal grains mixed with beef cattle farming.
0123	Sheep-Beef Cattle Farming	Farming both sheep and beef cattle.
0125	Beef Cattle Farming	Farming beef cattle or operating beef cattle feedlots.
	Horticulture industry	
0113	Vegetable Growing	Growing vegetables (except field peas, beans or soybeans) for human consumption.
0114-0119	Fruit Growing	Growing or sun-drying fruits.
	Commercial fishing	
041	Marine Fishing	Catching fish, including prawns and finfish, from ocean or coastal waters.
	Aquaculture industry	
042	Aquaculture	Farming of fish, crustaceans or molluscs, and commercial inland or freshwater fishing.
	Selected food processing industries	
2111	Meat Processing	Slaughtering animals and manufacturing meat (except for poultry, bacon, ham and small goods).
2130	Fruit and Vegetable Processing	Manufacturing canned, bottled, preserved, quick frozen or dried fruit and vegetable products.
2171	Sugar Manufacturing	Manufacturing raw or refined sugar, or molasses.
2173	Seafood Processing	Processing fish or other seafoods.
	Mining	
110	Coal Mining	Mining black coal or brown coal.
120	Oil and Gas Extraction	Producing or treating on-site crude oil, natural gas or condensate.
131	Metal Ore Mining	Mining metal ores including iron ore or iron sands, bauxite, copper ore and gold ore.
	Selected mineral processing industries	
2711	Basic Iron and Steel Manufacturing	Manufacturing iron or steel, ferro-alloys or electro-metallurgical products.
2721	Alumina Production	Refining bauxite to form alumina.
2722	Aluminium Smelting	Smelting alumina to produce aluminium, the recovery of aluminium from scrap, or alloying aluminium.
2723	Copper, Silver, Lead and Zinc Smelting or Refining	Primary smelting or refining of copper silver, lead or zinc, or in the recovery of these metals from waste or scrap.

Source: ABS and NZDOS (1993).

E.3 Fishing data

QFS estimates of commercial fishing GVP were calculated from catch location volumes (based on a census of vessel log book records) and estimates of landed prices of catches. The QFS landed price method is analogous to the farm gate price method used to estimate the GVP of agricultural commodities. Employing this method enables more valid comparisons with the GVP of other industries.

A line of latitude from catch location to the GBR coastline was used to apportion the catch value to a statistical division within the GBR catchment. It is recognised that this latitude method may not represent the processing location of the catch nor the home port of vessels.

Several industry visits and submissions drew attention to a study by Fenton and Marshall (2001) that estimated the GVP of commercial fishing for the GBR catchment at $259 million — well over double the QFS estimate. In addition, Fenton and Marshall's employment estimates were substantially higher than ABS Census or QFS licence and crew data (table E.2).

Table E.2 **Number of employed persons in the commercial fishing industry**

Source	*Far North*	*Northern*	*Mackay*	*Fitzroy*	*Wide Bay-Burnett*	*GBR Catchment*	*Qld*
ABS 2001 Census[a]	232	84	48	82	195	641	1043
QFS[b]	691	294	363	322	432	2 102	na
Switala and Taylor-Moore (1999)[c]	634	238	343	379	465	2 059	2 919
Fenton and Marshall (2001) (peak)[d]	1 293	740	499	568	1 206	4 306	6 759
Fenton and Marshall (2001) (off peak)[d]	1 080	598	467	525	1 092	3 762	5 832

a Main job held in week prior to 7 August 2001. **b** 1999-00. **c** 1996-97. **d** Full-time equivalents. **na** Not available.

Sources: ABS (unpublished data); QFS (unpublished data); Fenton and Marshall (2001); Switala and Taylor-Moore (1999).

Potential discrepancies between the QFS and Fenton and Marshall's estimates may have occurred for a variety of reasons.

Whereas QFS data are a census of licences, log books and crew data for 2000-01, Fenton and Marshall's data were drawn from a telephone survey of 1008 fishers (representing 41 per cent of the industry). Some 9 per cent of those surveyed were considered to have not been actively engaged in commercial fishing. The survey was conducted over an 8 month period (August 1999 to April 2000), and fishers were asked to recall catch quantities and values over the previous 12 months. Consequently, the data collected from different fishers are not for a consistent period of time. In addition, the data may be subject to ‘recall bias’, due to the telephone survey approach.

QFS landed prices (which were averages across the fleet) are consistent with price estimates used by other state agencies. Fenton and Marshall’s approach was to provide fishers with five value ranges from which to estimate catch values. The GVP for a specified geographical area was then estimated by multiplying median catch values by the number of businesses in the area. (Note that this method will only provide an accurate measure of an area’s GVP if all producers have catches that are close to the median. Also note that Fenton and Marshall’s estimates of business numbers were higher than QFS estimates.)

Fenton and Marshall’s estimates of the value of production from the ports of Cairns, Innisfail and Townsville include production from prawn trawlers (approximately 50) fishing in the Gulf of Carpentaria. Similarly, vessels from the southern ports of Bundaberg, Hervey Bay, Tin Can Bay and Maryborough fish below the eastern boundary of the GBR lagoon. Consequently, Fenton and Marshall’s estimates of the value of production of fleets from ports within the GBR catchment overstate the value of the production from fisheries within the GBR lagoon. QFS estimates of the value of production only represent log book catches from vessels fishing within the GBR lagoon.

E.4 Index of relative socioeconomic disadvantage

The Index of Relative Socioeconomic Disadvantage is derived from attributes such as low income, low educational attainment, high unemployment and jobs in relatively unskilled occupations (ABS 1998). Table E.3 lists the index values for statistical divisions, statistical subdivisions and statistical local areas in the GBR catchment. An index of 1000 represents the average level of socioeconomic disadvantage. The lower the index, the more disadvantaged that area is compared with other areas. For example, the Bundaberg statistical subdivision with an index of 932 was more disadvantaged than the Cairns City Part A statistical subdivision with an index of 1012.

Table E.3 **Index of relative socioeconomic disadvantage**

Based on 1996 Census of Population and Housing

Area[a]	*Index of relative socioeconomic disadvantage*
QUEENSLAND	**988**
Wide Bay-Burnett (SD)	**926**
Bundaberg (SSD)	932
Bundaberg (C)	926
Burnett (S) — Part A	953
Wide Bay-Burnett SD Balance (SSD)	924
Biggenden (S)	905
Burnett (S) — Part B	943
Cooloola (S) — excludes Gympie	933
Cooloola (S) — Gympie only	936
Eidsvold (S)	880
Gayndah (S)	942
Hervey Bay (C)	917
Isis (S)	914
Kilkivan (S)	927
Kingaroy (S)	979
Kolan (S)	882
Maryborough (C)	938
Miriam Vale (S)	878
Monto (S)	962
Mundubbera (S)	921
Murgon (S)	859
Nanango (S)	879
Perry (S)	872
Tiaro (S)	893
Wondai (S)	904
Woocoo (S)	967
Fitzroy (SD)	**972**
Rockhampton (SSD)	967
Fitzroy (S) — Part A	973
Rockhampton (C)	966
Gladstone (SSD)	984
Calliope (S) — Part A	1005
Gladstone (C)	976
Fitzroy SD Balance (SSD)	970
Banana (S)	965
Bauhinia (S)	992
Calliope (S) — Part B	937
Duaringa (S)	946
Emerald (S)	1003
Fitzroy (S) — Part B	975
Jericho (S)	931
Livingstone (S)	979
Mount Morgan (S)	821
Peak Downs (S)	1012

(Continued next page)

Table E.3 (continued)

Area[a]	*Index of relative socioeconomic disadvantage*
Far North (SD)	**978**
Cairns City Part A (SSD)[b]	1012
Far North SD Balance (SSD)	942
Atherton (S)	979
Aurukun (S)[c]	626
Cairns (C) — Part B	904
Cardwell (S)	967
Cook (S) — excludes Weipa	855
Cook (S) — Weipa only[c]	1074
Croydon (S)[c]	789
Douglas (S)	1012
Eacham (S)	980
Etheridge (S)[c]	940
Herberton (S)	896
Johnstone (S)	959
Mareeba (S)[c]	954
Torres (S)	797
Northern (SD)	**981**
Townsville City Part A (SSD)[b]	998
Thuringowa City Part A (SSD)[b]	996
Northern SD Balance (SSD)	953
Bowen (SD)	905
Burdekin (S)	982
Charters Towers (C)	966
Dalrymple (S)	943
Hinchinbrook (S)	933
Thuringowa (C) — Part B	988
Townsville (C) — Part B	1008
Mackay (SD)	**984**
Mackay City Part A (SSD)	980
Mackay (C) — Part A	980
Mackay SD Balance (SSD)	988
Belyando (S)	986
Broadsound (S)	999
Mackay (C) — Part B	990
Mirani (S)	978
Nebo (S)	992
Sarina (S)	942
Whitsunday (S)	1014

[a] Statistical local areas (shires and counties) are indented. SD – Statistical Division. SSD – Statistical Subdivision. S – Shire. C – County. [b] Comprises several statistical local areas. [c] Not in GBR catchment.

Source: ABS (1996, *Australia in Profile A Regional Analysis*, Cat. No. 2032.0).

E.5 Importance of industries within regions

Far North region

The major industries in the Far North region are tourism, horticulture and sugar, and sugar processing (table E.4).

In 1999, expenditure by tourists in the region ($1856 million) was almost three times the GVP of agriculture ($682 million). Within the agricultural sector, the GVP for horticulture ($280 million) far exceeded that for sugar cane ($160 million) and beef cattle farming ($113 million). The sugar processing industry is also important, with a turnover of $334 million in 1996-97. Mining is a relatively minor industry in the Far North region.

The tourism industry, with 19 500 employed persons, accounts for around 20 per cent of employment in the Far North region (table E.4). Other important employers are the horticulture industry, with around 3200 employed persons, and the sugar and sugar processing industries, with a total of around 3000 employed persons. Canegrowers (2001) estimated there are 1707 sugar cane growers in the region. Meat, horticulture and seafood processing industries, and the mining industry and mineral processing industries, are not major employers in the Far North region.

Section E.6 provides detailed time series data on the GVP for the main industries in the GBR catchment, highlighting trends and variability in GVP. GVP of agriculture in the Far North region has been subject to the same patterns of variability as agricultural production across the GBR catchment. However, the beef cattle industry in the Far North region nearly doubled its GVP between 1991-92 and 1999-2000.

Both the aquaculture and tourism industries have experienced recent growth in the Far North region. Although aquaculture is a relatively small industry, its GVP tripled between 1996-97 and 2000-01. From 1985 to 1992, tourism expenditure in the Far North region grew from 15 per cent ($341 million) to 46 per cent ($1190 million) of all tourism expenditure in the GBR catchment. Tourism expenditure grew at a slower rate throughout the 1990s, reaching $1860 million in 1999.

In general, employed persons in the Far North region have broadly the same characteristics (including proportions of employers and employees, median age, education level, income, and mobility) as other employed persons in corresponding industries across the GBR catchment (section E.7). Overall, employed persons in the Far North region have slightly lower individual and household incomes, and are slightly less likely to work more than 41 hours per week, than the average employed person in the GBR catchment. However, larger variations were:

- sugar cane growers in the Far North region had a higher median age and a higher percentage had not completed schooling beyond year 8 than the industry average; and
- commercial fishers had higher median household incomes than the industry average and a lower percentage worked more than 35 hours per week.

Table E.4 **Production and employment in the Far North region**

1999-00, unless otherwise stated

Industry	Gross value of production[a]	Employed persons[b] Total	Employees	Employers	Own account workers	Family
	$m	no.	%	%	%	%
Primary production						
Sugar cane	160	1 854	36	23	37	4
Beef[c]	113	863	42	14	39	4
Horticulture[d]	280	3 234	60	18	19	3
Total agriculture	682	7 033	49	19	29	3
Commercial fishing[e]	55	232	41	37	18	4
Aquaculture	12	198	75	11	13	2
Mining[f]	21[g]	1 048[h]				
Coal	0	39	72	9	19	0
Metal ore	na[i]	840[h]	96	0.7	2	0.7
Oil & gas	na[i]	16	100	0	0	0
Other minerals	21[g]	153	94	6	0	0
Processing[j]						
Sugar processing	334	1 124	98	1	1	0
Meat processing	na[i]	162	92	4	4	0
Horticulture processing	na[i]	81	85	7	7	0
Seafood processing	na[i]	48	93	7	0	0
Mineral processing	na[i]	286[k]				
Alumina production	0	22	100	0	0	0
Aluminium smelting	0	26	100	0	0	0
Basic iron & steel mfg	na[i]	228	76	11	11	3
Base metals	0	10	84	16	0	0
Other						
Recreational fishing	72	na	na	na	na	na
Tourism	1 856[l]	19 500[m]	na	na	na	na
All employed persons[n]		96 182	80	8	11	1

(Continued next page)

[a] Calculated using wholesale prices (beef, horticulture and sugar); landed prices (commercial fishing and aquaculture); and mine-site prices (mining). Approximated with turnover (processing); expenditure by recreational fishers (recreational fishing); and expenditure by tourists (tourism). [b] Week prior to 7 August 2001. Due to rounding, figures might not sum to 100 per cent. [c] GVP data refer to the commodity-based industry (beef cattle farming). Employment data refer to the ANZSIC industry 0125 (Beef cattle farming). A further 18 employed persons in the Far North region are classified to ANZSIC industry 0122 (Grain-sheep and sheep-beef cattle farming) and 11 employed persons to ANZSIC industry 0123 (Sheep-beef cattle farming). [d] Comprises fruit-growing and vegetable-growing. [e] Refers to ANZSIC industry 041 (Marine fishing). [f] GVP data refer to 2000-01. [g] Excludes approximate value of minerals produced in the Far North region but external to the GBR catchment. [h] Includes persons employed in the mining of bauxite, which does not occur in the catchment. [i] Not available due to confidentiality restrictions. [j] GVP data refer to 1996-97. [k] Comprises ANZSIC industries 2711 (Basic iron and steel manufacturing); 2721 (Alumina production); 2722 (Aluminium smelting); and 2723 (Copper, silver, lead and zinc smelting and refining). [l] Expenditure by visitors in 1999. [m] Averaged over 1998 and 1999. [n] Refers to all employed persons who live in the catchment, not only those classified to the industries outlined in the table. **na** Not available.

Sources: ABARE (2001); ABS (unpublished data); DNRM (unpublished data); QFS (unpublished data).

Northern region

Mining, tourism and agriculture are large industries in the Northern region (table E.5).

In 1999-2000, the GVP of mining ($754 million) exceeded the GVP of agriculture ($610 million) and 1999 tourist expenditure ($621 million). Sugar cane ($298 million) accounted for approximately half agricultural GVP and nearly two-thirds of agricultural sector employment in the region. The sugar processing industry, with 1507 employed persons, is also a major employer in the region. Together, sugar cane production and processing account for approximately 5 per cent of employment in the Northern region.

The tourism industry, with over 7000 employed persons, is the largest source of employment in the Northern region (table E.5). Mining, with 1339 employed persons, is also a major employer. According to the 2001 Census, there were only 70 employed persons in coal mining resident in the Northern region. However, as the majority of coal mines are located near the border of the Mackay region, it is likely that most people employed in coal mining in the Northern region reside in the Mackay region.

Since 1998, the GVP of sugar has declined substantially (section E.6). In contrast, the GVP of aquaculture tripled from 1996-97 to 2000-01, but the industry remains small in terms of GVP and employment. Tourism expenditure in the Northern region has grown since 1985 (figure E.8). Throughout the 1990s, tourism in the Northern region accounted for approximately 14 per cent of total GBR catchment tourism expenditure.

Table E.5 **Production and employment in the Northern region**
1999-00, unless otherwise stated

Industry	*Gross value of production*[a]	*Employed persons*[b]				
		Total	*Employees*	*Employers*	*Own account workers*	*Family*
	$m	no.	%	%	%	%
Primary production						
Sugar cane	298	2 637	38	23	36	3
Beef[c]	107	804	48	23	26	3
Horticulture[d]	194	584	58	18	22	1
Total agriculture	610	4 246	44	22	31	3
Commercial fishing[e]	19	84	40	32	28	0
Aquaculture	16	45	71	6	17	6
Mining[f]	754	1 339[g]				
Coal	413	70	96	0	4	0
Metal ore	na[h]	1 121	99	0.3	1	0
Oil & gas	0	0	-	-	-	-
Other minerals	342	148	95	3	2	0
Processing [i]						
Sugar processing	na[h]	1 507	99	1	1	0
Meat processing	na[h]	254	95	2	2	0
Horticulture processing	na[h]	50	88	6	6	0
Seafood processing	na[h]	15	100	0	0	0
Mineral processing	na[h]	773[j]				
Alumina production	0	3	100	0	0	0
Aluminium smelting	0	25	67	33	0	0
Basic iron & steel mfg	na[h]	299	88	5	7	0
Base metals	na[h]	446	99	0.7	0.7	0
Other						
Recreational fishing	54	na	na	na	na	na
Tourism	621[k]	7 090	na	na	na	na
All employed persons[l]		83 741	84	7	8	1

(Continued next page)

[a] Calculated using wholesale prices (beef, horticulture and sugar); landed prices (commercial fishing and aquaculture); and mine-site prices (mining). Approximated with turnover (processing); expenditure by recreational fishers (recreational fishing); and expenditure by tourists (tourism). [b] Week prior to 7 August 2001. Due to rounding, percentage values might not add to 100 per cent. [c] GVP data refer to the commodity-based industry (beef cattle farming). Employment data refer to the ANZSIC industry 0125 (Beef cattle farming). A further 15 employed persons in the Northern region were classified to ANZSIC industry 0122 (Grain-sheep and sheep-beef cattle farming) and 17 employed persons to ANZSIC industry 0123 (Sheep-beef cattle farming). [d] Comprises fruit-growing and vegetable-growing. [e] Refers to ANZSIC industry 041 (Marine fishing). [f] GVP data refer to 2000-01. **g** Comprises metals, oil and gas, and other mining. [h] Not available due to confidentiality restrictions. [i] GVP data refers to 1996-97. [j] Comprises ANZSIC industries 2711 (Basic iron and steel manufacturing), 2721 (Alumina production), 2722 (Aluminium smelting) and 2723 (Copper, silver, lead and zinc smelting and refining). [k] Expenditure by all visitors in 1999. [l] Refers to all employed persons in the catchment, not only those classified to the industries outlined in the table. **na** Not available.

Sources: ABARE (2001); ABS (unpublished data); DNRM (unpublished data); QFS (unpublished data).

People employed (particularly in sugar and beef industries) in the Northern region had slightly higher median annual individual and household incomes, and were more likely to have completed year 12, certificate, diploma or tertiary education, than the average employed person in the GBR catchment (section E.7). In contrast to the Far North, employed persons in the sugar cane industry in the Northern region had a lower median age than the industry average and a higher proportion had completed year 12. Commercial fishers in the Northern region had a lower median age and fewer worked more than 35 hours per week than the industry average.

Mackay region

Coal mining, tourism and sugar processing are large industries in the Mackay region (table E.6).

In 1999-2000, the GVP of coal ($2871 million) substantially exceeded the GVP of other industries in the region. Tourist expenditure by visitors totalled $831 million. The GVP of agriculture was $402 million and turnover by the sugar processing industry reached $666 million in 1996-97. The GVP and employment for horticulture, fishing and mineral processing industries are relatively low in the Mackay region.

The tourism industry, with more than 7500 employed persons, is the largest source of employment in the region (table E.6). The coal mining industry, with 4050 employed persons, is also a major employer, accounting for nearly 7 per cent of employment in the region. Although the GVP of sugar cane is small relative to the GVP of coal, sugar cane growing and sugar processing are major employers in the region, with a total of 4075 employed persons.

The gross value of mineral production increased by approximately 50 per cent in the Mackay region from 1996-97 to 2000-01 (section E.6, but as in other regions has declined substantially since 1998. Although tourist expenditure in the Mackay region has increased steadily since 1985, it has been at a slower rate than most other regions.

Employed persons in the beef industry in the Mackay region had a lower median age than employed persons in the industry in the rest of the GBR catchment (section E.7). Employed persons in seafood processing had a higher median age. Sugar cane growers had lower median individual and household incomes. In contrast, employed persons in the beef and horticulture industries in the Mackay region had higher individual and household incomes than the industry average for the GBR catchment.

Table E.6 **Production and employment in the Mackay region**

1999-00, unless otherwise stated

Industry	*Gross value of production*[a]	*Employed persons*[b] *Total*	*Employees*	*Employers*	*Own account workers*	*Family*
	$m	No.	%	%	%	%
Primary production						
Sugar cane	221	2 660	36	30	31	4
Beef[c]	125	1 388	47	21	28	4
Horticulture[d]	0.2	1 150	76	14	10	1
Total agriculture	402	5 770	48	24	25	3
Commercial fishing[e]	21	48	33	47	14	6
Aquaculture	4	31	62	13	19	6
Mining[f]	2 871	4 218[g]	na	na	na	na
Coal	2 871	4 050	99	0.3	0.7	0.1
Metal ore	na	78	88	0	8	3
Oil & gas	na	20	100	0	0	0
Other minerals	0.1	70	91	0	9	0
Processing [h]						
Sugar processing	666	1415	98	1	1	0
Meat processing	na[i]	239	97	1	1	0
Horticulture processing	na[i]	41	83	17	0	0
Seafood processing	na[i]	10	20	40	40	0
Mineral processing	21[j]	200[k]	na	na	na	na
Alumina production	0	0	-	-	-	-
Aluminium smelting	0	14	54	0	23	23
Basic iron & steel mfg	21	186	86	11	4	0
Base metals	0	0	-	-	-	-
Other						
Recreational fishing	36	na	na	na	na	na
Tourism	831[l]	7 580[j]	na	na	na	na
All employed persons[m]		59 604	76	9	14	1

(Continued next page)

[a] Calculated using wholesale prices (beef, horticulture and sugar); landed prices (commercial fishing and aquaculture); and mine-site prices (mining). Approximated with turnover (processing); expenditure by recreational fishers (recreational fishing); and expenditure by tourists (tourism). [b] Week prior to 7 August 2001. Due to rounding, figures might not sum to 100 per cent. [c] GVP data refer to the commodity-based industry (beef cattle farming). Employment data refer to the ANZSIC industry 0125 (Beef cattle farming). A further 132 employed persons in the Mackay region were classified to ANZSIC industry 0122 (Grain-sheep and sheep-beef cattle farming) and 34 employed persons to ANZSIC industry 0123 (Sheep-beef cattle farming). [d] Comprises vegetable-growing; fruit-growing data not available. [e] Refers to ANZSIC industry 041 (Marine fishing). [f] GVP data refer to 2000-01. [g] Comprises coal, metals, oil and gas, and other mining. [h] GVP data refer to 1996-97. [i] Not available due to confidentiality restrictions. [j] 1998-99. [k] Comprises ANZSIC industries 2711 (Basic iron and steel manufacturing); 2721 (Alumina production); 2722 (Aluminium smelting); and 2723 (Copper, silver, lead and zinc smelting and refining). [l] Expenditure by all visitors in 1999. [m] Refers to all employed persons in the catchment, not only those classified to the industries outlined in the table. **na** Not available.

Sources: ABARE (2001); ABS (unpublished data); DNRM (unpublished data); QFS (unpublished data).

Fitzroy region

Coal mining, beef cattle farming, alumina production and aluminium smelting are the major industries in the Fitzroy region (table E.7).

Like the Mackay region, in 1999-2000, the GVP of coal ($2687 million) substantially exceeded the GVP of agriculture ($767 million). Beef cattle farming ($442 million) is the most important agricultural industry in terms of GVP. Meat processing, with a turnover of $344 million in 1996-97, is also an important industry in the Fitzroy region. Horticulture and fishing are relatively minor industries and sugar cane is not grown.

Tourism, with over 6000 employed persons in 1998-99, is the largest employer in the Fitzroy region. Beef cattle farming and mining each account for over 4 per cent of total employment in the region (table E.7). Other important employers are the meat processing industry, with over 1260 employed persons, and the alumina production and aluminium smelting industries, which employed around 2000 people.

The GVP of beef in the Fitzroy region has been subject to the same patterns of variability as beef production across the GBR catchment (section E.6). However, from 1991-92 to 1999-2000, the GVP of beef in the Fitzroy region increased by more than 70 per cent, which represents the fastest growth rate of the industry in the GBR catchment. From 1996-97 to 2000-01, the mining industry also grew more rapidly in the Fitzroy region than elsewhere in the catchment. In comparison, growth in tourism expenditure has slowed considerably since 1992.

Employed persons in the Fitzroy region had similar age, education and hours of work patterns to industry averages for the GBR catchment (section E.7). However, persons employed in the beef industry had higher median individual and household incomes than the GBR catchment average, while for persons employed in the horticulture industry the Fitzroy average was lower. The median income for persons employed in agriculture as a whole in the Fitzroy region was higher than the GBR catchment average. People employed in horticulture in the region had a higher incidence of working 41 hours or more.

Table E.7 **Production and employment in the Fitzroy region**
1999-00, unless otherwise stated

		Employed persons[b]				
Industry	*Gross value of production*[a]	*Total*	*Employees*	*Employers*	*Own account workers*	*Family*
	$m	no.	%	%	%	%
Primary production						
Sugar cane	0	6	100	0	0	0
Beef[c]	442	3 171	35	20	42	3
Horticulture[d]	33	557	60	13	24	2
Total agriculture	767	5 368	38	20	38	3
Commercial fishing[e]	18	82	37	25	30	7
Aquaculture	0.4	18	21	36	43	0
Mining[f]	2 840	3 254[g]				
Coal	2 687	2 868	98	0.8	0.8	0
Metal ore	na[h]	93	86	0	14	0
Oil & gas	na[h]	62	100	0	0	0
Other minerals	153	231	90	3	5	1
Processing [i]						
Sugar processing	0	6	100	0	0	0
Meat processing	344	1 265	98	1	1	0.3
Horticulture processing	na[h]	17	73	0	27	0
Seafood processing	na[h]	35	100	0	0	0
Mineral processing	na[h]	2 391[j]				
Alumina production	789	909	99	0.3	0.7	0
Aluminium smelting	na[h]	1 154	99	0.3	0.5	0
Basic iron & steel mfg	15	325	87	8	5	0
Base metals	0	3	100	0	0	0
Other						
Recreational fishing	21	na	na	na	na	na
Tourism	425[k]	6 040[l]	na	na	na	na
All employed persons[m]		76 513	83	7	9	0.8

(Continued next page)

[a] Calculated using wholesale prices (beef, horticulture and sugar); landed prices (commercial fishing and aquaculture); and mine-site prices (mining). Approximated with turnover (processing); expenditure by recreational fishers (recreational fishing); and expenditure by tourists (tourism). [b] Week prior to 7 August 2001. Due to rounding, figures might not sum to 100 per cent. [c] GVP data refer to the commodity-based industry (beef cattle farming). Employment data refers to the ANZSIC industry 0125 (Beef cattle farming). A further 472 employed persons in the Fitzroy region are classified to ANZSIC industry 0122 (Grain-sheep and sheep-beef cattle farming) and 29 employed persons to ANZSIC industry 0123 (Sheep-beef cattle farming). [d] Comprises fruit-growing and vegetable-growing. [e] Refers to ANZSIC industry 041 (Marine fishing). [f] GVP data refer to 2000-01. [g] Comprises metals, oil and gas, and other mining. [h] Not available due to confidentiality restrictions. [i] GVP data refer to 1996-97. [j] Comprises ANZSIC industries 2711 (Basic iron and steel manufacturing); 2721 (Alumina production); 2722 (Aluminium smelting); and 2723 (Copper, silver, lead and zinc smelting and refining). [k] Expenditure by all visitors in 1999. [l] 1998-99. [m] Refers to all employed persons in the catchment, not only those classified to the industries outlined in the table. **na** Not available.

Sources: ABARE (2001); ABS (unpublished data); DNRM (unpublished data); QFS (unpublished data).

Wide Bay-Burnett region

Agricultural industries are important to the Wide Bay-Burnett region (table E.8).

In 1999-2000, the GVP of the beef industry ($232 million) exceeded the GVPs for horticulture ($199 million), mining ($173 million) and sugar cane ($125 million). In comparison, the fishing, aquaculture and mineral processing industries are relatively minor.

The agricultural sector, with over 9800 employed persons in August 2001, is the major source of employment in the region. Most of these employed persons are in horticulture, beef and sugar cane industries. The sugar processing industry, with over 1000 employed persons in August 2001, is also a major employer. The tourism industry employed over 7400 people in the Wide Bay-Burnett region in 1998-99.

The GVP of agriculture in the Wide Bay-Burnett region has been subject to the same patterns of variability as agricultural production across the GBR catchment (section E.6). However, aquaculture production, which has increased in value elsewhere, has declined in value in the Wide Bay-Burnett region between 1996-97 and 2000-01.

Worker characteristics in Wide Bay-Burnett broadly correspond to industry averages for the GBR catchment (section E.7). However, employed persons in beef have a much higher median age (54 years) than the average for the GBR catchment (47 years), and also tended to have a lower incidence of higher education. In addition, employed persons in the beef and horticulture industries in the region had lower median individual and household incomes.

Table E.8 **Production and employment in the Wide Bay-Burnett region**

1999-00, unless otherwise stated

Industry	*Gross value of production*[a]	*Employed persons*[b]				
		Total	*Employees*	*Employers*	*Own account workers*	*Family*
	$m	no.	%	%	%	%
Primary production						
Sugar cane	125	1 579	40	23	36	2
Beef[c]	232	2 502	19	13	63	5
Horticulture[d]	199	3 481	71	12	15	1
Total agriculture	742	9 836	45	15	37	3
Commercial fishing[e]	7	195	39	32	28	2
Aquaculture	6	86	46	18	32	3
Mining[f]	173	521[g]				
Coal	129	206	99	0	1	0
Metal ore	na	205	96	3	1	0
Oil & gas	na	26	90	10	0	0
Other minerals	44	84	92	4	5	0
Processing[h]						
Sugar processing	na[i]	1 058	98	0.3	1	0.3
Meat processing	167	430	95	2	2	0.7
Horticulture processing	na[i]	118	86	7	5	2
Seafood processing	15	72	81	15	4	0
Mineral processing	na[i]	268[j]				
Alumina production	0	6	100	0	0	0
Aluminium smelting	0	46	100	0	0	0
Basic iron & steel mfg	na[i]	210	77	14	7	1
Base metals	0	6	100	0	0	0
Other						
Recreational fishing	56	na	na	na	na	na
Tourism	536[k]	7 450[l]	na	na	na	na
All employed persons[m]		80 541	76	9	14	1

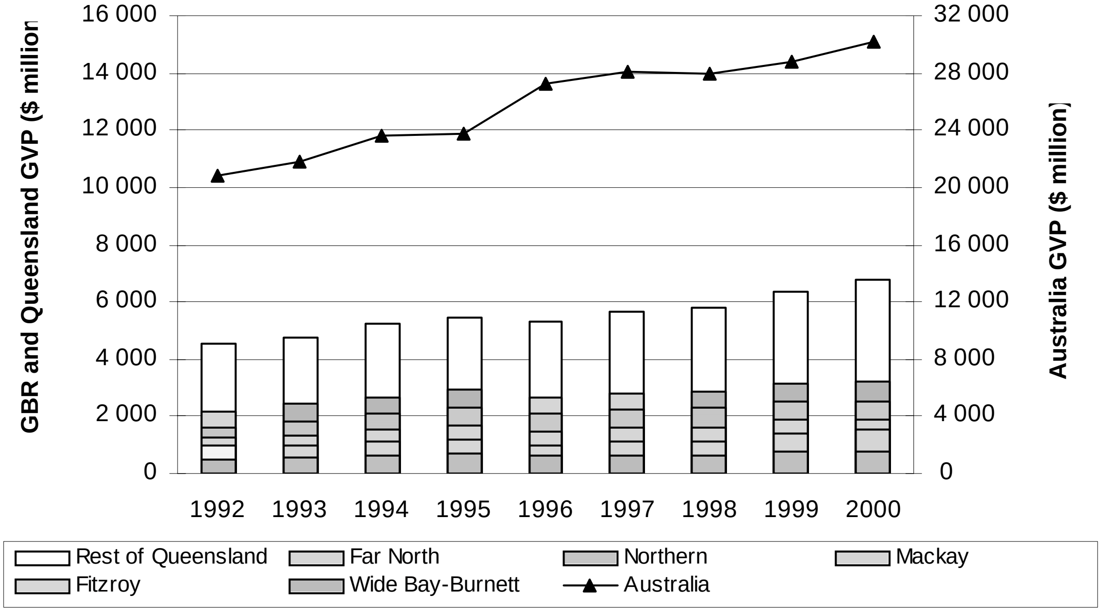
(Continued next page)

[a] Calculated using wholesale prices (beef, horticulture and sugar); landed prices (commercial fishing and aquaculture); and mine-site prices (mining). Approximated with turnover (processing); expenditure by recreational fishers (recreational fishing); and expenditure by tourists (tourism). [b] Week prior to 7 August 2001. Due to rounding, figures might not sum to 100 per cent. [c] GVP data refer to the commodity-based industry (beef cattle farming). Employment data refers to the ANZSIC industry 0125 (Beef Cattle Farming). A further 163 employed persons in the Wide Bay-Burnett region were classified to ANZSIC industry 0122 (Grain-sheep and sheep-beef cattle farming) and 38 employed persons to ANZSIC industry 0123 (Sheep-beef cattle farming). [d] Comprises fruit-growing and vegetable-growing. [e] Refers to ANZSIC industry 041 (Marine fishing). [f] GVP data for 2000-01. [g] Comprises metals, oil and gas, and other mining. [h] GVP data refer to 1996-97. [i] Not available due to confidentiality restrictions. [j] Comprises ANZSIC industries 2711 (Basic iron and steel manufacturing); 2721 (Alumina production); 2722 (Aluminium smelting); and 2723 (Copper, silver, lead and zinc smelting and refining). [k] Expenditure by all visitors in 1999. [l] 1998-99. [m] Refers to all employed persons in the catchment, not only those classified to the industries outlined in the table. **na** Not available.

Sources: ABARE (2001); ABS (unpublished data); DNRM (unpublished data); QFS (unpublished data).

E.6 Time series data

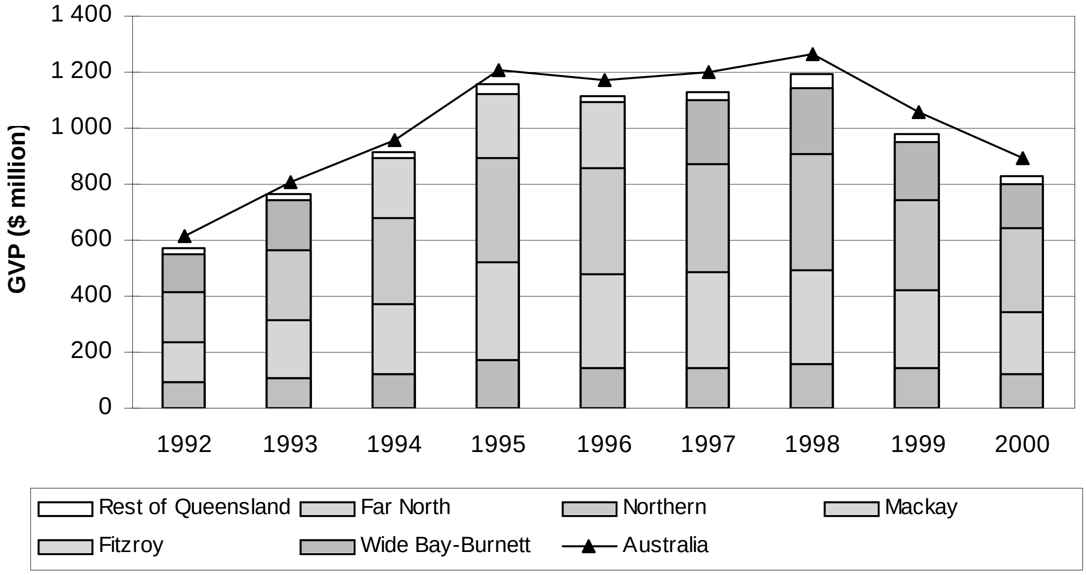
Figure E.1 **Agriculture gross value of production, 1992 to 2000[a]**



[a] Years ending 30 June.

Data source: ABS (unpublished data).

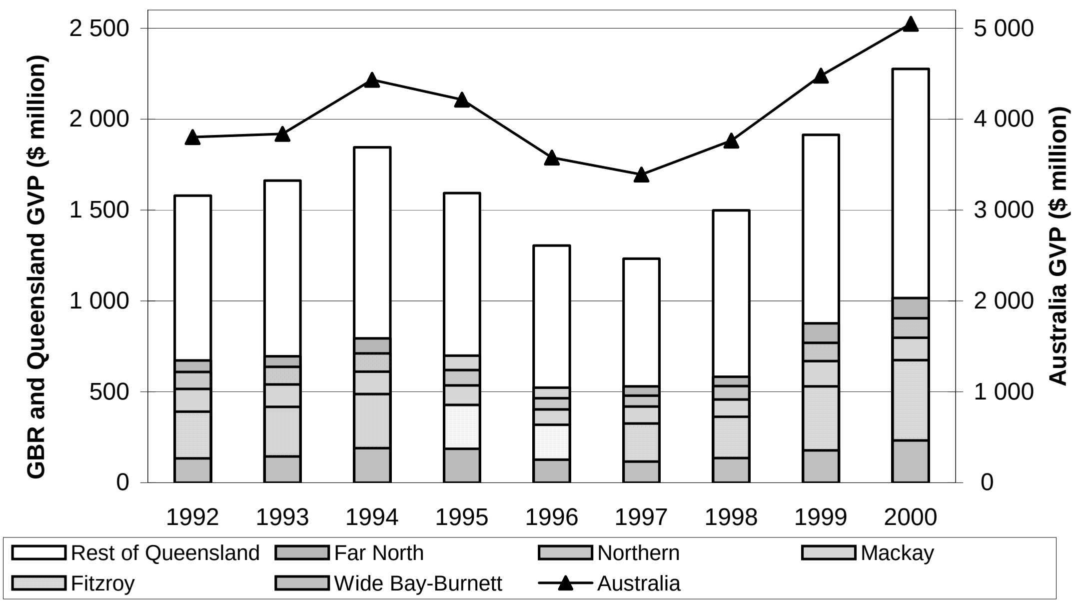
Figure E.2 **Sugar cane gross value of production, 1992 to 2000[a]**



[a] Years ending 30 June.

Data source: ABS (unpublished data).

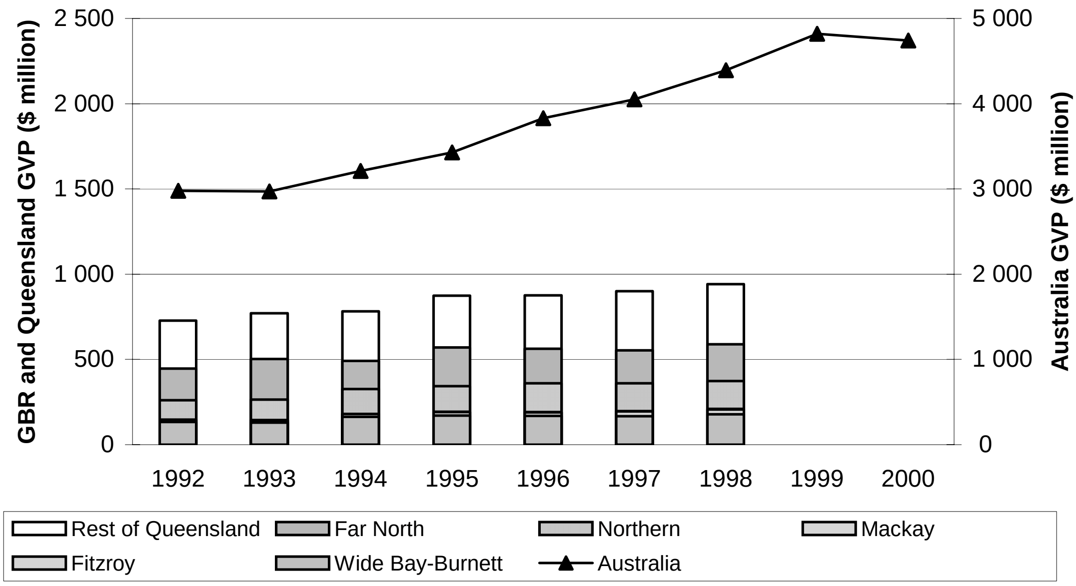
Figure E.3 **Beef gross value of production, 1992 to 2000[a]**



[a] Years ending June.

Data source: ABS (unpublished data).

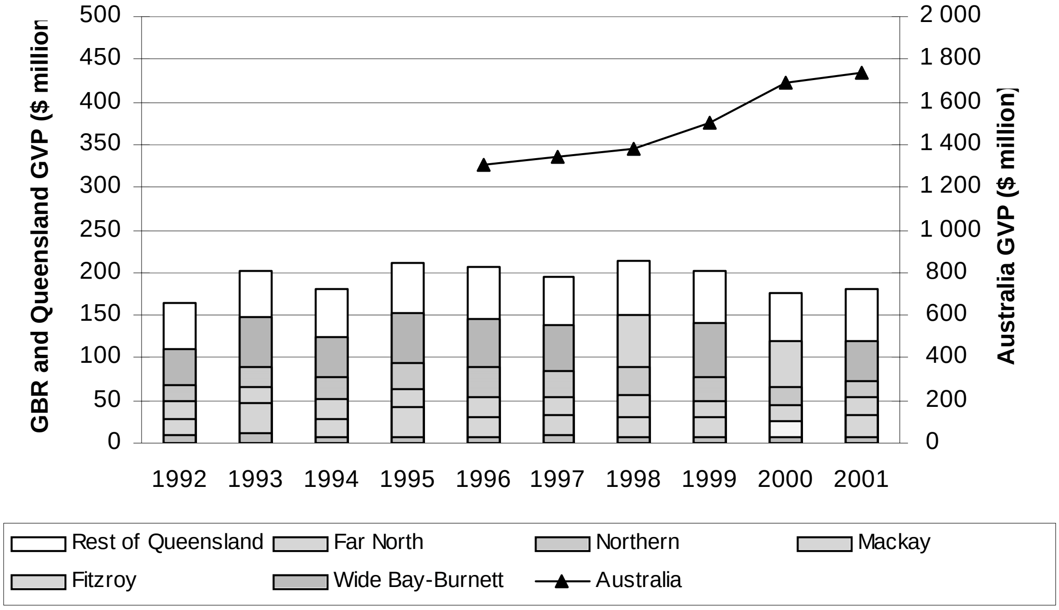
Figure E.4 **Horticulture gross value of production, 1992 to 2000[a]**



[a] Years ending 30 June. Statistical division data not available for years 1998-99 and 1999-00.

Data source: ABS (unpublished data).

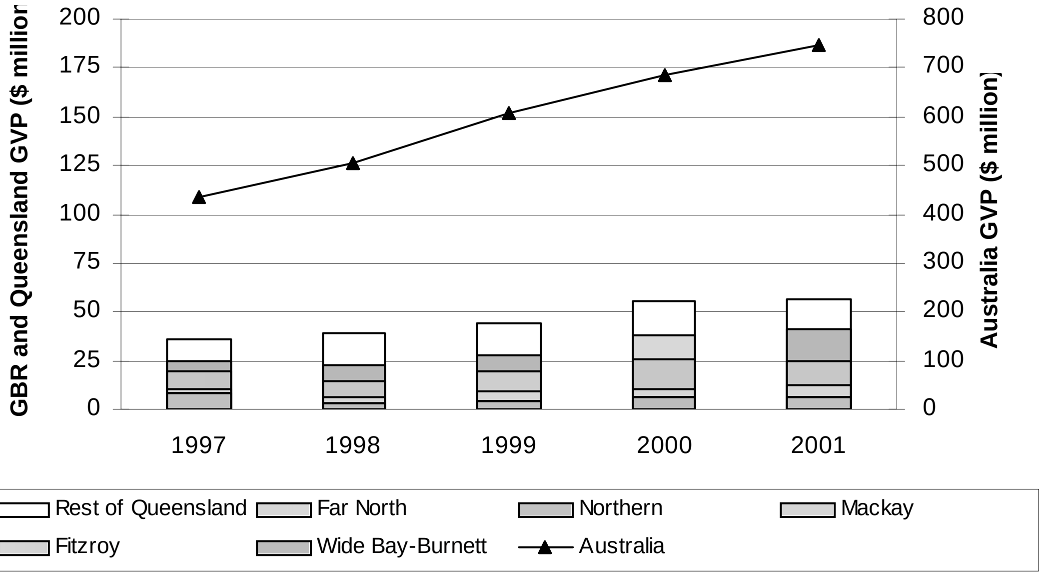
Figure E.5 **Commercial fishing gross value of production, 1992 to 2001[a]**



[a] Years ending 30 June.

Data sources: QFS (unpublished data); ABARE (*Australian Fisheries Statistics*, various years).

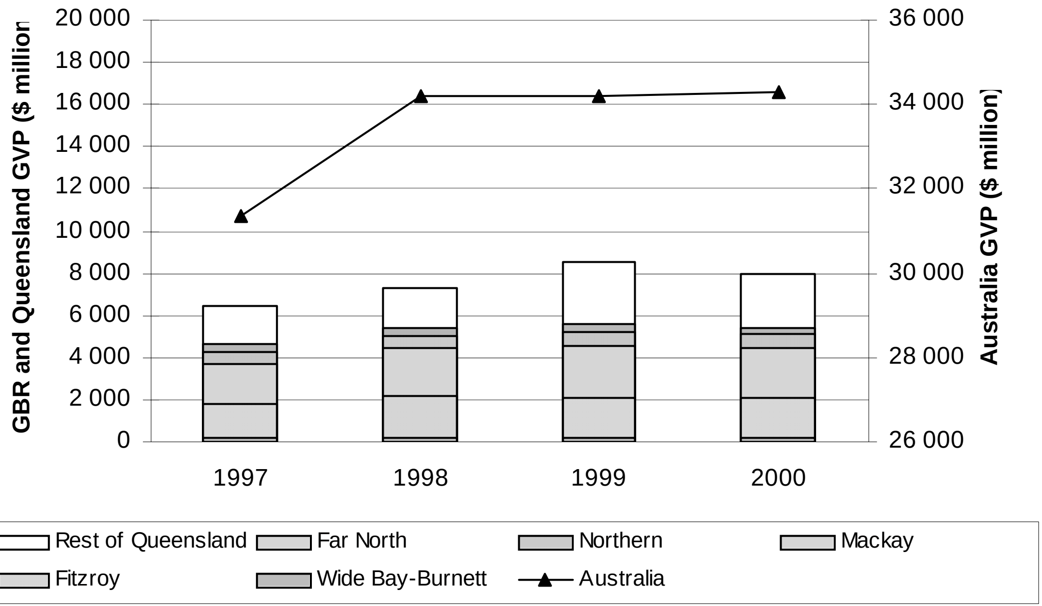
Figure E.6 **Aquaculture gross value of production, 1997 to 2001[a]**



[a] Years ending 30 June.

Data sources: QFS (unpublished data); ABARE (*Australian Fisheries Statistics*, various years).

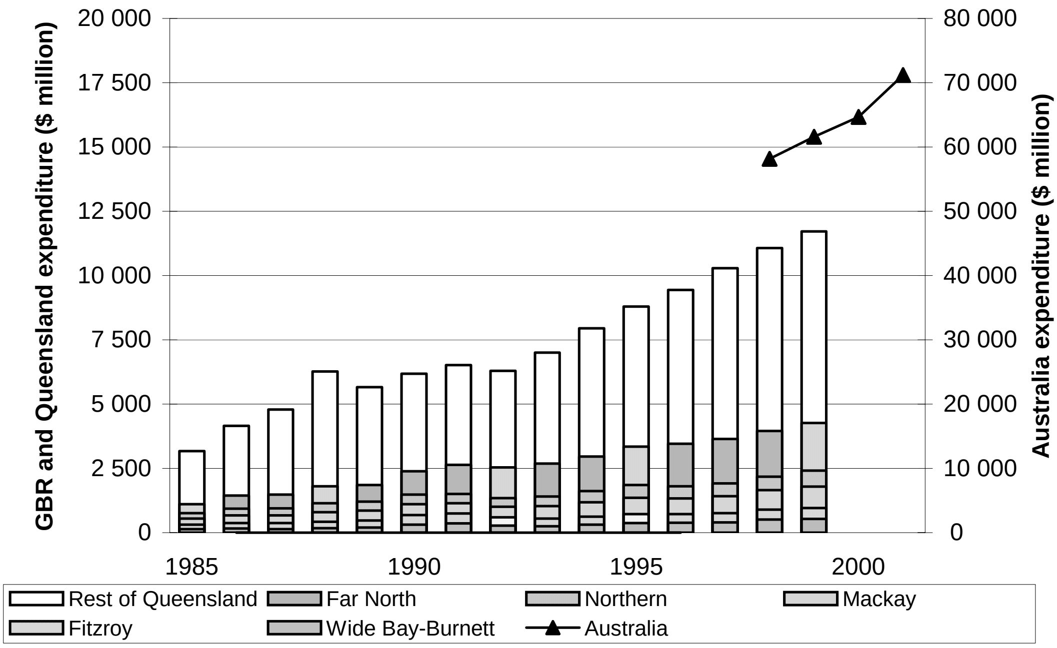
Figure E.7 **Mining gross value of production, 1997 to 2000[a]**



[a] Years ending 30 June.

Data sources: DNRM (unpublished data); ABS (*Australian Mining Industry 1998-99*, Cat. No. 8414.0; *Mining Operations Australia 1999-2000*, Cat. No. 8415.0).

Figure E.8 **Expenditure by visitors, 1985 to 2001**



Data sources: ABS (*Australian National Accounts: Tourism Satellite Account 2000-01*, Cat. No. 5249.0); OESR (2001c).

E.7 Additional regional data

Table E.9 **Age and education characteristics of employed persons in the Far North region**

7 August 2001, unless otherwise stated

Industry	*Median age*	*Level of education completed*[a] *Year 8 or below*	*Year 9, 10 or 11*	*Year 12*	*Certificate or Diploma*[b]	*Tertiary*[c]
	years	%	%	%	%	%
Primary production						
Sugar cane	49	22	41	11	24	2
Beef[d]	44	18	48	12	17	4
Horticulture	39	13	45	18	21	3
Total agriculture	43	17	44	15	21	3
Commercial fishing[e]	42	7	41	14	35	3
Aquaculture	37	5	28	20	28	18
Mining						
Coal	42	9	39	9	42	0
Metal ore	40	4	29	11	45	11
Oil & gas	42	0	17	0	67	17
Other minerals	41	8	33	16	36	7
Processing						
Sugar processing	43	8	28	15	45	4
Meat processing	32	7	35	15	43	0
Horticulture processing	35	10	42	21	23	4
Seafood processing	37	8	33	33	18	8
Mineral processing						
Alumina production	np	np	np	np	np	np
Aluminium smelting	np	np	np	np	np	np
Basic iron & steel mfg	37	1	26	11	62	0
Base metals	np	np	np	np	np	np
Other						
Recreational fishing	na	na	na	na	na	na
Tourism	na	na	na	na	na	na
All employed persons[f]	38	5	31	19	32	13

(Continued next page)

[a] Excludes employed persons who are still studying, or who did not clearly answer relevant questions on Census paper. [b] Refers to employed persons who have completed diploma, advanced diploma or trade certificate studies. [c] Refers to employed persons who have completed bachelor, graduate diploma, graduate certificate, masters, post-doctoral or other postgraduate studies. [d] Refers to employed persons categorised to ANZSIC industry 0125 (Beef cattle farming). Excludes employed persons categorised to ANZSIC industries 0122 (Grain-sheep and grain-beef cattle farming) and 0123 (Sheep-beef cattle farming). [e] Refers to employed persons categorised to ANZSIC industry 041 (Marine fishing). [f] Refers to all employed persons in region, not only those classified to the industries detailed in this table. **na** Not available. **np** No production or no employed persons in the region..

Source: ABS (unpublished data).

Table E.10 **Income and household characteristics of employed persons in the Far North region**

7 August 2001, unless otherwise stated

Industry	*Median annual income*		*Same Statistical Division of residence in 1996*[a]
	Individual	*Household*	
	$	$	%
Primary production			
Sugar cane	21 670	39 113	96
Beef[b]	20 309	39 866	86
Horticulture	21 667	36 333	86
Total agriculture	21 429	37 340	89
Commercial fishing[c]	30 991	57 719	87
Aquaculture	27 766	46 526	67
Mining			
Coal	68 545	91 000	55
Metal ore	62 791	72 573	80
Oil & gas	78 000	82 333	50
Other minerals	37 989	50 439	84
Processing			
Sugar processing	32 612	49 936	94
Meat processing	32 760	56 333	76
Horticulture processing	23 053	40 299	85
Seafood processing	28 600	35 359	78
Mineral processing			
Alumina production	np	np	np
Aluminium smelting	np	np	np
Basic iron & steel mfg	31 460	49 399	84
Base metals	np	np	np
Other			
Recreational fishing	na	na	na
Tourism	na	na	na
All employed persons[d]	26 935	48 183	79

a Excludes employed persons who did not state place of residence five years ago. **b** Refers to employed persons categorised as ANZSIC industry 0125 (Beef cattle farming). Excludes employed persons categorised as ANZSIC industries 0122 (Grain-sheep and grain-beef cattle farming) and 0123 (Sheep-beef cattle farming). **c** Refers to employed persons categorised as ANZSIC industry 041 (Marine fishing). **d** Refers to all employed persons in region, not only those classified to the industries detailed in this table. **na** Not available. **np** No production or no employed persons in the region..

Source: ABS (unpublished data).

Table E.11 **Hours worked by employed persons in the Far North region[a]**

Week prior to 7 August 2001, unless otherwise stated

Industry	*Less than 15 hours*	*16-34 hours*	*35-40 hours*	*41 hours or more*
	%	%	%	%
Primary production				
Sugar cane	9	9	18	65
Beef[b]	9	9	20	62
Horticulture	9	20	35	36
Total agriculture	9	14	26	50
Commercial fishing[c]	24	18	22	35
Aquaculture	7	7	32	54
Mining				
Coal	0	9	9	81
Metal ore	13	3	10	74
Oil & gas	47	0	0	53
Other minerals	8	8	23	62
Processing				
Sugar processing	2	2	53	44
Meat processing	8	6	23	64
Horticulture processing	19	27	32	22
Seafood processing	12	19	33	37
Mineral processing				
Alumina production	np	np	np	np
Aluminium smelting	np	np	np	np
Basic iron & steel mfg	10	6	39	45
Base metals	np	np	np	np
Other				
Recreational fishing	na	na	na	na
Tourism	na	na	na	na
All employed persons[d]	13	21	33	33

a Excludes employed persons who did not respond correctly to question. Due to rounding, figures might not sum to 100 per cent. **b** Refers to employed persons categorised to ANZSIC industry 0125 (Beef cattle farming). Excludes employed persons categorised to ANZSIC industries 0122 (Grain-sheep and grain-beef cattle farming) and 0123 (Sheep-beef cattle farming). **c** Refers to employed persons categorised to ANZSIC industry 041 (Marine fishing). **d** Refers to all employed persons in region, not only those classified to the industries detailed in this table. **na** Not available. **np** No production or no employed persons in the region..

Source: ABS (unpublished data).

Table E.12 **Age and education characteristics of employed persons in the Northern region**

7 August 2001, unless otherwise stated

Industry	*Median age*	*Highest level of education completed*[a] *Year 8 or below*	*Year 9, 10 or 11*	*Year 12*	*Certificate or Diploma*[b]	*Tertiary*[c]
	years	%	%	%	%	%
Primary production						
Sugar cane	45	17	46	13	23	2
Beef[d]	43	14	51	14	16	5
Horticulture	44	16	43	15	21	5
Total agriculture	44	16	46	13	21	3
Commercial fishing[e]	38	9	50	7	30	4
Aquaculture	34	0	24	19	31	26
Mining						
Coal	40	7	35	6	48	4
Metal ore	36	3	28	13	37	19
Oil & gas	np	np	np	np	np	np
Other minerals	38	4	36	9	35	17
Processing						
Sugar processing	40	6	27	17	45	5
Meat processing	39	10	48	17	23	2
Horticulture processing	39	6	49	16	22	6
Seafood processing	39	0	67	0	33	0
Mineral processing						
Alumina production	np	np	np	np	np	np
Aluminium smelting	np	np	np	np	np	np
Basic iron & steel mfg	36	1	25	18	55	1
Base metals	31	4	16	26	43	12
Other						
Recreational fishing	na	na	na	na	na	na
Tourism	na	na	na	na	na	na
All employed persons[f]	37	4	31	21	30	14

a Excludes employed persons who are still studying, or who did not clearly answer relevant questions on Census paper. Due to rounding, figures might not sum to 100 per cent. **b** Refers to employed persons who have completed diploma, advanced diploma or trade certificate studies. **c** Refers to employed persons who have completed bachelor, graduate diploma, graduate certificate, masters, post-doctoral or other postgraduate studies. **d** Refers to employed persons categorised to ANZSIC industry 0125 (Beef cattle farming). Excludes employed persons categorised to ANZSIC industries 0122 (Grain-sheep and grain-beef cattle farming) and 0123 (Sheep-beef cattle farming). **e** Refers to employed persons categorised to ANZSIC industry 041 (Marine fishing). **f** Refers to all employed persons in region, not only those classified to the industries detailed in this table. **na** Not available. **np** No production or no employed persons in the region.

Source: ABS (unpublished data).

Table E.13 **Income and household characteristics of employed persons in the Northern region**

7 August 2001, unless otherwise stated

Industry	*Median annual income*		*Same Statistical Division of residence in 1996*[a]
	Individual	*Household*	
	$	$	%
Primary production			
Sugar cane	23 152	38 497	96
Beef[b]	23 730	40 529	84
Horticulture	19 270	33 414	86
Total agriculture	22 757	38 350	92
Commercial fishing[c]	25 399	49 919	79
Aquaculture	28 600	54 600	65
Mining			
Coal	71 809	82 875	52
Metal ore	62 554	74 016	62
Oil & gas	np	np	np
Other minerals	47 728	63 000	68
Processing			
Sugar processing	34 231	50 424	93
Meat processing	29 275	48 635	87
Horticulture processing	23 872	54 080	81
Seafood processing	23 400	57 200	70
Mineral processing			
Alumina production	np	np	np
Aluminium smelting	np	np	np
Basic iron & steel mfg	32 659	55 250	84
Base Metals	42 730	60 489	73
Other			
Recreational fishing	na	na	na
Tourism	na	na	na
All employed persons[d]	29 681	53 438	77

[a] Excludes employed persons who did not state place of residence five years ago. [b] Refers to employed persons categorised to ANZSIC industry 0125 (Beef cattle farming). Excludes employed persons categorised to ANZSIC industries 0122 (Grain-sheep and grain-beef cattle farming) and 0123 (Sheep-beef cattle farming). [c] Refers to employed persons categorised to ANZSIC industry 041 (Marine fishing). [d] Refers to all employed persons in region, not only those classified to the industries detailed in this table. **na** Not available. **np** No production or no employed persons in the region.

Source: ABS (unpublished data).

Table E.14 **Hours worked by employed persons in the Northern region**[a]

Week prior to 7 August 2001, unless otherwise stated

Industry	*Less than 15 hours*	*16-34 hours*	*35-40 hours*	*41 hours or more*
	%	%	%	%
Primary production				
Sugar cane	8	7	16	69
Beef[b]	10	9	19	62
Horticulture	13	20	26	42
Total agriculture	9	10	18	63
Commercial fishing[c]	21	17	12	50
Aquaculture	22	8	18	51
Mining				
Coal	9	4	6	81
Metal ore	8	2	9	80
Oil & gas	np	np	np	np
Other minerals	4	5	14	76
Processing				
Sugar processing	1	3	50	46
Meat processing	7	13	63	18
Horticulture processing	8	20	42	30
Seafood processing	0	30	30	40
Mineral processing				
Alumina production	np	np	np	np
Aluminium smelting	np	np	np	np
Basic iron & steel mfg	8	5	47	41
Base metals	7	0.7	36	56
Other				
Recreational fishing	na	na	na	na
Tourism	na	na	na	na
All employed persons[d]	14	17	34	35

a Excludes employed persons who did not respond correctly to question in Census paper. Due to rounding, figures might not sum to 100 per cent. **b** Refers to employed persons categorised to ANZSIC industry 0125 (Beef cattle farming). Excludes employed persons categorised to ANZSIC industries 0122 (Grain-sheep and grain-beef cattle farming) and 0123 (Sheep-beef cattle farming). **c** Refers to employed persons categorised to ANZSIC industry 041 (Marine fishing). **d** Refers to all employed persons in region, not only those classified to the industries detailed in this table. **na** Not available. **np** No production or no employed persons in the region.

Source: ABS (unpublished data).

Table E.15 **Age and education characteristics of employed persons in the Mackay region**

7 August 2001, unless otherwise stated

		Highest level of education completed[a]				
Industry	*Median age*	*Year 8 or below*	*Year 9, 10 or 11*	*Year 12*	*Certificate or Diploma*[b]	*Tertiary*[c]
	years	%	%	%	%	%
Primary production						
Sugar cane	46	21	48	9	20	2
Beef[d]	43	15	48	16	17	4
Horticulture	40	13	52	16	16	3
Total agriculture	43	17	49	13	18	3
Commercial fishing[e]	42	9	41	14	36	0
Aquaculture	37	0	36	21	32	11
Mining						
Coal	40	7	30	11	44	8
Metal ore	41	4	36	9	41	10
Oil & gas	35	0	14	19	52	14
Other minerals	39	9	59	10	19	4
Processing						
Sugar processing	42	9	28	15	43	6
Meat processing	35	12	52	17	20	0
Horticulture processing	40	12	50	12	26	0
Seafood processing	45	0	25	25	50	0
Mineral processing						
Alumina production	np	np	np	np	np	np
Aluminium smelting	np	np	np	np	np	np
Basic iron & steel mfg	37	5	24	12	57	3
Base metals	np	np	np	np	np	np
Other						
Recreational fishing	na	na	na	na	na	na
Tourism	na	na	na	na	na	na
All employed persons[f]	39	6	35	16	32	10

[a] Excludes employed persons who are still studying, or who did not clearly answer relevant questions on Census paper. Due to rounding, figures might not sum to 100 per cent. [b] Refers to employed persons who have completed diploma, advanced diploma or trade certificate studies. [c] Refers to employed persons who have completed bachelor, graduate diploma, graduate certificate, masters, post-doctoral or other postgraduate studies. [d] Refers to employed persons categorised to ANZSIC industry 0125 (Beef cattle farming). Excludes employed persons categorised to ANZSIC industries 0122 (Grain-sheep and grain-beef cattle farming) and 0123 (Sheep-beef cattle farming). [e] Refers to employed persons categorised to ANZSIC industry 041 (Marine fishing). [f] Refers to all employed persons in region, not only those classified to the industries in this table. **na** Not available. **np** No production or no employed persons in the region.

Source: ABS (unpublished data).

Table E.16 **Income and household characteristics of employed persons in the Mackay region**

7 August 2001, unless otherwise stated

Industry	*Median annual income* Individual	Household	*Same Statistical Division of residence in 1996*[a]
	$	$	%
Primary production			
Sugar cane	20 970	35 575	97
Beef[b]	24 643	42 670	79
Horticulture	22 416	39 241	79
Total agriculture	22 605	38 427	88
Commercial fishing[c]	28 600	45 066	87
Aquaculture	25 782	33 800	71
Mining			
Coal	78 000	90 530	75
Metal ore	57 121	58 933	61
Oil & gas	65 000	70 200	53
Other minerals	34 542	48 359	75
Processing			
Sugar processing	33 153	48 533	93
Meat processing	33 239	48 799	79
Horticulture processing	22 000	46 800	69
Seafood processing	29 466	70 200	100
Mineral processing			
Alumina production	np	np	np
Aluminium smelting	np	np	np
Basic iron & steel mfg	34 449	51 167	87
Base metals	np	np	np
Other			
Recreational fishing	na	na	na
Tourism	na	na	na
All employed persons[d]	28 325	52 666	79

a Excludes employed persons not stating a place of residence five years ago. **b** Refers to employed persons categorised to ANZSIC industry 0125 (Beef cattle farming). Excludes employed persons categorised to ANZSIC industries 0122 (Grain-sheep and grain-beef cattle farming) and 0123 (Sheep-beef cattle farming). **c** Refers to employed persons categorised to ANZSIC industry 041 (Marine fishing). **d** Refers to all employed persons in region, not only those classified to the industries detailed in this table. **na** Not available. **np** No production or no employed persons in the region.

Source: ABS (unpublished data).

Table E.17 **Hours worked by employed persons in the Mackay region**[a]

Week prior to 7 August 2001, unless otherwise stated

Industry	*Less than 15 hours*	*16-34 hours*	*35-40 hours*	*41 hours or more*
	%	%	%	%
Primary production				
Sugar cane	7	7	15	70
Beef[b]	8	6	18	68
Horticulture	5	18	28	48
Total agriculture	7	9	19	65
Commercial fishing[c]	19	19	13	49
Aquaculture	14	14	32	41
Mining				
Coal	6	3	16	75
Metal ore	13	4	7	76
Oil & gas	25	0	19	56
Other minerals	9	4	16	71
Processing				
Sugar processing	2	2	50	46
Meat processing	7	7	64	21
Horticulture processing	13	15	19	54
Seafood processing	40	20	20	20
Mineral processing				
Alumina production	np	np	np	np
Aluminium smelting	np	np	np	np
Basic iron & steel mfg	3	5	42	50
Base metals	np	np	np	np
Other				
Recreational fishing	na	na	na	na
Tourism	na	na	na	na
All employed persons[d]	13	17	30	40

[a] Excludes employed persons who did not respond correctly to question in Census paper. Due to rounding, figures might not sum to 100 per cent. [b] Refers to employed persons categorised to ANZSIC industry 0125 (Beef cattle farming). Excludes employed persons categorised to ANZSIC industries 0122 (Grain-sheep and grain-beef cattle farming) and 0123 (Sheep-beef cattle farming). [c] Refers to employed persons categorised to ANZSIC industry 041 (Marine fishing). [d] Refers to all employed persons in region, not only those classified to the industries detailed in this table. **na** Not available. **np** No production or no employed persons in the region.

Source: ABS (unpublished data).

Table E.18 **Age and education characteristics of employed persons in the Fitzroy region**

7 August 2001, unless otherwise stated

Industry	*Median age*	*Highest level of education completed*[a] *Year 8 or below*	*Year 9, 10 or 11*	*Year 12*	*Certificate or Diploma*[b]	*Tertiary*[c]
	years	%	%	%	%	%
Primary production						
Sugar cane	np	np	np	np	np	np
Beef[d]	46	17	46	16	17	5
Horticulture	42	13	48	14	20	5
Total agriculture	45	16	47	15	18	5
Commercial fishing[e]	41	12	44	4	40	0
Aquaculture	42	0	33	20	47	0
Mining						
Coal	40	7	30	10	46	8
Metal ore	41	7	18	10	39	26
Oil & gas	38	5	19	12	47	16
Other minerals	39	12	35	12	37	4
Processing						
Sugar processing	np	np	np	np	np	np
Meat processing	32	8	48	18	24	2
Horticulture processing	36	0	100	0	0	0
Seafood processing	40	8	68	14	11	0
Mineral processing						
Alumina production	41	5	24	8	49	15
Aluminium smelting	37	2	30	14	45	9
Basic iron & steel mfg	38	5	29	15	49	2
Base metals	np	np	np	np	np	np
Other						
Recreational fishing	na	na	na	na	na	na
Tourism	na	na	na	na	na	na
All employed persons[f]	39	6	35	18	29	13

[a] Excludes employed persons who are still studying, or who did not clearly answer relevant questions on Census paper. Due to rounding, figures might not sum to 100 per cent. [b] Refers to employed persons who have completed diploma, advanced diploma or trade certificate studies. [c] Refers to employed persons who have completed bachelor, graduate diploma, graduate certificate, masters, post-doctoral or other postgraduate studies. [d] Refers to employed persons categorised to ANZSIC industry 0125 (Beef cattle farming). Excludes employed persons categorised to ANZSIC industries 0122 (Grain-sheep and grain-beef cattle farming) and 0123 (Sheep-beef cattle farming). [e] Refers to employed persons categorised to ANZSIC industry 041 (Marine fishing). [f] Refers to all employed persons in region, not only those classified to the industries detailed in this table. **na** Not available. **np** No production or no employed persons in the region..

Source: ABS (unpublished data).

Table E.19 Income and household characteristics of employed persons in the Fitzroy region

7 August 2001, unless otherwise stated

Industry	*Median annual income*		*Same Statistical Division of residence in 1996*[a]
	Individual	*Household*	
	$	$	%
Primary production			
Sugar cane	np	np	np
Beef[b]	24 811	40 981	87
Horticulture	20 323	35 186	78
Total agriculture	24 545	41 583	87
Commercial fishing[c]	28 600	50 699	82
Aquaculture	33 799	54 599	100
Mining			
Coal	78 000	92 684	79
Metal ore	60 666	68 250	57
Oil & gas	63 266	74 099	56
Other minerals	40 485	60 171	84
Processing			
Sugar processing	np	np	np
Meat processing	32 595	49 578	76
Horticulture processing	20 149	23 400	100
Seafood processing	17 680	66 299	83
Mineral processing			
Alumina production	58 608	71 243	87
Aluminium smelting	53 077	66 213	73
Basic iron & steel mfg	34 504	54 503	82
Base metals	np	np	np
Other			
Recreational fishing	na	na	na
Tourism	na	na	na
All employed persons[d]	29 383	54 338	81

a Excludes employed persons who did not state place of residence five years ago. **b** Refers to employed persons categorised to ANZSIC industry 0125 (Beef cattle farming). Excludes employed persons categorised to ANZSIC industries 0122 (Grain-sheep and grain-beef cattle farming) and 0123 (Sheep-beef cattle farming). **c** Refers to employed persons categorised to ANZSIC industry 041 (Marine fishing). **d** Refers to all employed persons in region, not only those classified to the industries detailed in this table. **na** Not available. **np** No production or no employed persons in the region..

Source: ABS (unpublished data).

Table E.20 **Hours worked by employed persons in the Fitzroy region**[a]
Week prior to 7 August 2001, unless otherwise stated

Industry	*Less than 15 hours*	*16-34 hours*	*35-40 hours*	*41 hours or more*
	%	%	%	%
Primary production				
Sugar cane	np	np	np	np
Beef[b]	7	8	16	69
Horticulture	12	16	21	51
Total agriculture	8	9	16	67
Commercial fishing[c]	31	10	11	48
Aquaculture	21	0	21	57
Mining				
Coal	4	3	19	74
Metal ore	8	3	19	70
Oil & gas	5	5	14	76
Other minerals	7	7	25	61
Processing				
Sugar processing	np	np	np	np
Meat processing	6	9	60	24
Horticulture processing	0	0	36	64
Seafood processing	39	27	15	18
Mineral processing				
Alumina production	4	2	35	60
Aluminium smelting	4	3	17	76
Basic iron & steel mfg	6	5	43	45
Base metals	np	np	np	np
Other				
Recreational fishing	na	na	na	na
Tourism	na	na	na	na
All employed persons[d]	15	17	32	36

a Excludes employed persons who did not respond correctly to question in Census paper. Due to rounding, figures might not sum to 100 per cent. **b** Refers to employed persons categorised to ANZSIC industry 0125 (Beef cattle farming). Excludes employed persons categorised to ANZSIC industries 0122 (Grain-sheep and grain-beef cattle farming) and 0123 (Sheep-beef cattle farming). **c** Refers to employed persons categorised to ANZSIC industry 041 (Marine fishing). **d** Refers to all employed persons in region, not only those classified to the industries detailed in this table. **na** Not available. **np** No production or no employed persons in the region.

Source: ABS (unpublished data).

Table E.21 **Age and education characteristics of employed persons in the Wide Bay-Burnett region**

7 August 2001, unless otherwise stated

		Highest level of education completed[a]				
Industry	*Median age*	*Year 8 or below*	*Year 9, 10 or 11*	*Year 12*	*Certificate or Diploma*[b]	*Tertiary*[c]
	years	%	%	%	%	%
Primary production						
Sugar cane	47	21	49	9	19	2
Beef[d]	54	25	43	11	17	5
Horticulture	42	13	51	15	18	3
Total agriculture	46	19	48	12	18	4
Commercial fishing[e]	41	11	43	12	33	0
Aquaculture	43	15	24	18	28	15
Mining						
Coal	43	6	40	5	38	11
Metal ore	38	6	37	13	32	11
Oil & gas	41	13	17	17	52	0
Other minerals	44	13	48	12	27	0
Processing						
Sugar processing	43	10	28	11	45	6
Meat processing	30	6	47	17	28	2
Horticulture processing	40	6	56	17	19	3
Seafood processing	45	19	52	16	12	0
Mineral processing						
Alumina production	np	np	np	np	np	np
Aluminium smelting	np	np	np	np	np	np
Basic iron & steel mfg	39	3	27	11	54	4
Base metals	np	np	np	np	np	np
Other						
Recreational fishing	na	na	na	na	na	na
Tourism	na	na	na	na	na	na
All employed persons[f]	41	7	38	15	29	11

a Excludes employed persons who are still studying, or who did not clearly answer relevant questions on Census paper. Due to rounding, figures might not sum to 100 per cent. **b** Refers to employed persons who have completed diploma, advanced diploma or trade certificate studies. **c** Refers to employed persons who have completed bachelor, graduate diploma, graduate certificate, masters, post-doctoral or other postgraduate studies. **d** Refers to employed persons categorised to ANZSIC industry 0125 (Beef cattle farming). Excludes employed persons categorised to ANZSIC industries 0122 (Grain-sheep and grain-beef cattle farming) and 0123 (Sheep-beef cattle farming). **e** Refers to employed persons categorised to ANZSIC industry 041 (Marine fishing). **f** Refers to all employed persons in region, not only those classified to the industries detailed in this table. **na** Not available. **np** No production or no employed persons in the region..

Source: ABS (unpublished data).

Table E.22 **Income and household characteristics of employed persons in the Wide Bay-Burnett region**

7 August 2001, unless otherwise stated

Industry	*Median annual income*		*Same Statistical Division of residence in 1996*[a]
	Individual	*Household*	
	$	$	%
Primary production			
Sugar cane	21 818	36 693	96
Beef[b]	18 791	33 098	90
Horticulture	19 241	33 923	81
Total agriculture	19 356	34 606	88
Commercial fishing[c]	25 720	46 800	87
Aquaculture	18 200	38 133	67
Mining			
Coal	70 934	88 174	80
Metal ore	58 651	62 237	62
Oil & gas	65 000	91 000	68
Other minerals	28 373	44 850	75
Processing			
Sugar processing	34 655	47 930	92
Meat processing	30 422	46 552	72
Horticulture processing	22 822	40 733	80
Seafood processing	20 056	35 879	87
Mineral processing			
Alumina production	np	np	np
Aluminium smelting	np	np	np
Basic iron & steel mfg	29 691	50 179	90
Base metals	np	np	np
Other			
Recreational fishing	na	na	na
Tourism	na	na	na
All employed persons[d]	24 554	43 212	82

[a] Excludes employed persons who did not state place of residence five years ago. [b] Refers to employed persons categorised to ANZSIC industry 0125 (Beef cattle farming). Excludes employed persons categorised to ANZSIC industries 0122 (Grain-sheep and grain-beef cattle farming) and 0123 (Sheep-beef cattle farming). [c] Refers to employed persons categorised to ANZSIC industry 041 (Marine fishing). [d] Refers to all employed persons in region, not only those classified to the industries detailed in this table. **na** Not available. **np** No production or no employed persons in the region..

Source: ABS (unpublished data).

Table E.23 **Hours worked by employed persons in the Wide Bay-Burnett region[a]**

Week prior to 7 August 2001, unless otherwise stated

Industry	*Less than 15 hours*	*16-34 hours*	*35-40 hours*	*41 hours or more*
	%	%	%	%
Primary production				
Sugar cane	8	10	19	63
Beef[b]	10	12	15	63
Horticulture	11	23	31	35
Total agriculture	10	16	22	53
Commercial fishing[c]	21	15	11	53
Aquaculture	11	17	29	43
Mining				
Coal	6	2	29	63
Metal ore	13	1	24	62
Oil & gas	28	0	10	62
Other minerals	13	4	31	52
Processing				
Sugar processing	2	5	50	43
Meat processing	6	7	38	48
Horticulture processing	14	16	36	34
Seafood processing	36	19	25	20
Mineral processing				
Alumina production	np	np	np	np
Aluminium smelting	np	np	np	np
Basic iron & steel mfg	6	7	49	38
Base metals	np	np	np	np
Other				
Recreational fishing	na	na	na	na
Tourism	na	na	na	na
All employed persons[d]	16	20	32	32

[a] Excludes employed persons who did not respond correctly to question in Census paper. Due to rounding, figures might not sum to 100 per cent. [b] Refers to employed persons categorised to ANZSIC industry 0125 (Beef cattle farming). Excludes employed persons categorised to ANZSIC industries 0122 (Grain-sheep and grain-beef cattle farming) and 0123 (Sheep-beef cattle farming). [c] Refers to employed persons categorised to ANZSIC industry 041 (Marine fishing). [d] Refers to all employed persons in region, not only those classified to the industries detailed in this table. **na** Not available. **np** No production or no employed persons in the region.

Source: ABS (unpublished data).

F Assistance estimates

The Commission calculates estimates of government assistance to industry in a range of contexts. Each year it publishes national estimates of industry assistance in its *Trade and Assistance Review* (TAR). These estimates include Commonwealth tariff and budgetary assistance, and assistance derived from nationally significant statutory marketing arrangements (box F.1). On occasion, the Commission supplements its national estimates with estimates of state government budgetary assistance to industry. The Commission also produces more detailed and tailored estimates for particular inquiries or studies.

Box F.1 **The Commission's national assistance estimates**

Assistance to industry takes many forms. It includes tariffs, quotas, anti-dumping duties and regulatory restrictions on imported goods and services, as well as tax concessions and subsidies for domestic producers.

The Commission's national assistance estimates do not seek to measure all government support for industries, but rather capture government measures that *selectively* assist particular firms, industries or activities and which can be quantified given practical constraints in measurement and data availability. The estimates cover assistance provided through tariffs, Commonwealth budgetary outlays and tax expenditures, and nationally significant statutory marketing arrangements. Some of the exclusions from the Commission's estimates include:

- for agricultural industries, certain drought assistance and any assistance effect that might be associated with the diesel fuel rebate, water underpricing, quarantine restrictions or the absence of policies to address land degradation due to farming practices;
- capital depreciation subsidies for mining, and the impact of tariffs on capital items;
- for fisheries, any positive (or negative) assistance that might arise from production quotas; and
- for the service sector, any assistance from regulations (such as entry requirements to the professions). The Commission measures the assistance effects of services regulations separately, using a trade restrictiveness index methodology (PC 2001b).

As part of this study, the Commission has estimated the dollar value of government assistance to selected industries in the GBR catchment. The main estimates in this report — summarised in chapter 4 — cover the 'national' forms of assistance measured by the Commission (tariffs, Commonwealth budgetary outlays and tax expenditures, and nationally significant statutory marketing arrangements). The Commission has also examined the Queensland Government's budgetary assistance to industries in the GBR catchment, although data limitations have prevented the development of comprehensive estimates.

This appendix documents the data and methodology employed in calculating assistance estimates. The fine level of industry disaggregation and the regional scope of the study have posed challenges and limited the precision attainable in some instances. In developing its estimates, the Commission has:

- prepared national estimates of the dollar value of assistance for the industry categories of interest for this study;
- scaled these estimates to reflect the size of the industries in the GBR catchment; and
- in the case of 'other agriculture', adjusted (or regionalised) the estimates to account for significant differences identified in the composition of this industry category within the GBR catchment, compared to its national composition.

The assistance estimates in this appendix have been revised since the release of this study's interim report. This was done in order to reflect methodological changes introduced in the Commission's latest TAR (PC 2002b). The changes are due in part to the use of updated input-output data from the ABS, and revised measures of budgetary assistance from the Commonwealth Treasury.

The following three sections explain the data and methodologies used for the separate components of the estimates — tariffs, budgetary assistance and statutory marketing arrangements. The approach used to estimate assistance to the tourism industries is reported separately (section F.4). Section F.5 sets out the estimates in full.

F.1 Tariff assistance

The Commission estimates tariff assistance using the Australian Customs Tariff Schedules in conjunction with ABS Input-Output (IO) data (PC 2002b). Estimates of the dollar value of assistance are generated for commodities/industries as defined under the ABS IO Industry Group classification. Some of the industry/commodity categories match the industries examined elsewhere in this study — namely, beef, metal ore, other minerals, and horticulture processing. In most cases, however, national estimates of tariff assistance are not directly available for industries of interest. For example, the Commission generates national estimates of tariff assistance for the IO Industry Group 0107 (Other agriculture), but not for the more disaggregated commodities/industries that comprise it, including Sugar and Horticulture.

To derive tariff assistance estimates at the level of industry detail required, the Commission first separated its estimates into tariff assistance on outputs and tariff assistance, or penalties, on inputs.

For tariff assistance on outputs:

- The Australian Customs Tariff Schedules were consulted to distinguish, to the extent possible, between assistance received by GBR and non-GBR catchment commodities/industries in the IO group. For example, while tariff assistance on outputs for the IO group containing Sugar and Horticulture amounted to $34 million, output tariffs on sugar imports were zero in 1999-2000. In this case, the entire tariff assistance on outputs for this IO group was allocated to horticulture.
- Where it was not possible to separate tariff assistance on outputs at the IO group level, assistance was allocated to commodities/industries based on their production share (by value) of the IO group. For example, estimates of output tariff assistance are available for the IO Industry Group 2101 (Meat and meat products). This IO group comprises the ANZSIC 4-digit industries Meat processing (for which estimates were required), Poultry processing, and Bacon, ham and smallgoods manufacturing. As it was not possible to separate output tariff assistance between each of these 4-digit ANZSIC industries, assistance to Meat processing was estimated based on its share of the production value of the Meat and meat products IO group.

Estimates of tariff assistance on outputs, thus derived, are reported in table F.1.

Allocating assistance to a commodity or industry based on its production share (by value) of the IO group was repeated for tariff assistance on inputs (also reported in table F.1). Where there are tariffs on inputs, the resulting dollar value of assistance to the activity from those tariffs is negative.

Estimates of output and input tariff assistance were then summed to derive estimates of net tariff assistance nationally for each commodity or industry (table F.1).

To determine the dollar value of tariff assistance for the production of each commodity/industry within the GBR catchment, the relevant national tariff assistance estimate was multiplied by the share of each commodity/industry's production in the GBR catchment as a proportion of the commodity/industry's national production. These catchment-level estimates are reported in table F.6 at the end of this appendix.

Table F.1 **National estimates of output and input tariff assistance for selected industries, 1999-00 to 2001-02**

$ million

Commodity/Industry	*1999-00* *Output Assistance*	*1999-00* *Input Assistance*	*1999-00* *Net Tariff Assistance*	*2000-01* *Output Assistance*	*2000-01* *Input Assistance*	*2000-01* *Net Tariff Assistance*	*2001-02* *Output Assistance*	*2001-02* *Input Assistance*	*2001-02* *Net Tariff Assistance*
Primary production									
Agriculture	33.5	-44.9	-11.4	35.1	-46.9	-11.9	39.8	-53.7	-13.9
Sugar cane	0.0	-2.6	-2.6	0.0	-2.7	-2.7	0.0	-3.0	-3.0
Beef	0.0	-4.2	-4.2	0.0	-4.4	-4.4	0.0	-5.1	-5.1
Horticulture[a]	33.5	-9.2	24.3	35.1	-9.6	25.5	39.8	-10.9	29.0
Other agriculture	0.0	-28.9	-28.9	0.0	-30.3	-30.3	0.0	-34.7	-34.7
Fisheries	0.1	-17.9	-17.8	0.1	-20.5	-20.5	0.1	-23.1	-23.0
Commercial fishing	0.1	-13.3	-13.2	0.1	-15.3	-15.2	0.1	-17.1	-17.0
Aquaculture	0.0	-4.6	-4.6	0.0	-5.3	-5.3	0.0	-6.0	-6.0
Mining[b]	1.9	-119.8	-117.9	2.4	-148.9	-146.6	2.4	-149.9	-147.5
Coal	0.0	-26.7	-26.7	0.0	-33.1	-33.1	0.0	-33.3	-33.3
Metal ore	0.0	-52.7	-52.7	0.0	-65.6	-65.6	0.0	-66.0	-66.0
Oil & gas	0.0	-24.9	-24.9	0.0	-30.9	-30.9	0.0	-31.1	-31.1
Other minerals	1.9	-15.5	-13.6	2.4	-19.4	-17.0	2.4	-19.5	-17.1

(Continued next page)

Table F.1 (continued)

Commodity/Industry	1999-00 *Output Assistance*	1999-00 *Input Assistance*	1999-00 *Net Tariff Assistance*	2000-01 *Output Assistance*	2000-01 *Input Assistance*	2000-01 *Net Tariff Assistance*	2001-02 *Output Assistance*	2001-02 *Input Assistance*	2001-02 *Net Tariff Assistance*
Processing									
Food processing	252.9	-70.7	182.1	234.1	-65.3	168.8	239.2	-66.7	172.5
Sugar processing	25.9	-10.2	15.7	16.9	-9.5	7.4	17.3	-9.7	7.5
Meat processing	107.5	-14.2	93.3	105.2	-13.1	92.1	107.5	-13.4	94.1
Horticulture processing	108.8	-42.1	66.7	105.0	-38.7	66.3	107.3	-39.6	67.7
Seafood processing	10.7	-4.2	6.5	7.0	-3.9	3.0	7.1	-4.0	3.1
Mineral processing[c]	270.4	-84.8	185.6	282.7	-87.2	195.5	303.5	-93.7	209.9
Alumina production	0.0	-3.8	-3.8	0.0	-3.8	-3.8	0.0	-4.1	-4.1
Aluminium smelting	0.0	-4.0	-4.0	0.0	-4.0	-4.0	0.0	-4.3	-4.3
Basic iron and steel manufacturing	270.4	-73.9	196.5	282.7	-76.3	206.4	303.5	-81.9	221.6
Base metals	0.0	-3.0	-3.0	0.0	-3.1	-3.1	0.0	-3.3	-3.3

a Comprises fruit-growing and vegetable-growing. **b** Comprises Coal and Other minerals. **c** Comprises ANZSIC industries 2722 (alumina production), 2721 (aluminium smelting) and 2711 (basic iron and steel manufacturing).

Source: PC estimates.

F.2 Budgetary assistance

Commonwealth budgetary assistance

The Commission publishes estimates of the dollar value of Commonwealth budgetary assistance to industry in its annual TAR. In the most recent estimates (PC 2002b), the Commission identified around 100 budgetary programs that provide selective assistance to industry, and allocated this assistance among 40 industry groupings (36 based on the Australian and New Zealand Standard Industrial Classification (ANZSIC) and four other unallocated categories). The methodology used to allocate budgetary assistance is set out in PC (2000).

The industries of interest for this study fall within the Primary Production sector and three other industry groupings used in the TAR — Mining, Food Beverages & Tobacco and Metal Product Manufacturing. The Commission has used its most recently published estimates (PC 2002b) for the Primary Production sector and the three other industry groupings as the basis for the Commonwealth budgetary assistance estimates in this study. It has disaggregated them to the specific industries required (eg horticulture and sugar) as well as several *other* and *unallocated* industry groupings. The industry categorisations used are shown in table F.2. The 'other' groups (and Services to mining) contain assistance that is allocated to the broader TAR industry groups but does not assist one of the specific industries of interest. The 'unallocated' groups contain assistance that can be allocated to the broader TAR industry group but not to any of the finer industries within it. That is, the Commission cannot estimate with sufficient accuracy the extent to which each of the finer industries benefit from the program.

Table F.2 **Industry categorisations**

TAR industry grouping	*Primary Production* [a]	*Mining* [a]	*Food, beverages and tobacco*	*Metal product manufacturing*
Industries of interest for this study	Horticulture Beef Sugar Other agriculture Commercial fishing Aquaculture	Coal Metal Ore Oil and gas Other minerals	Sugar processing Meat processing Fruit and vegetable processing Seafood processing	Alumina production Aluminium smelting Basic iron and steel production Copper, silver, lead and zinc smelting
Other categories used in this study	Other primary production Unallocated primary production	Services to mining Unallocated mining	Other food, bev. and tobacco Unallocated food, bev. and tobacco	Other metal product manufacturing Unallocated metal product mfg.

[a] The Trade & Assistance Review (TAR) sector Primary Production does not include Mining.

Estimates of budgetary assistance for the industries are contained in table F.3. That table also breaks down the estimates to show which programs assist each industry. In deriving the estimates, the Commission examined each program in the relevant TAR industry group and assessed which industry or industries they benefit, and the extent of such assistance.

Programs that assist only a single industry, such as the Sugar Industries Program or the Grape and Wine Research and Development Corporation, are allocated directly to that industry (sugar production and horticulture respectively). However, most programs assist multiple industries. For example, the Rural Industries R&D Corporation assists horticulture, other agriculture and other primary production. The Commission has used a variety of methods to determine how each industry benefits from these programs.

- Where the Commission could obtain sufficiently detailed data for a program, it has used this data to distribute the program's funding among the benefiting industries. For example, the Commission obtained four digit ANZSIC claims data for the Export Market Development Grants scheme, which was sufficiently detailed to determine the degree to which each industry of interest to this study benefited from the program.
- For programs that provide grants to industry and where the Commission has details on the individual grants, it has used this information to assign each grant to a particular industry. For example, the Department of Agriculture, Fisheries and Forestry Australia publishes project details for grant recipients under the Farm Innovation Program. These details are used by the Commission to determine which industries benefit from the program.
- Where the Commission could not obtain data to indicate which industries benefited from a particular program, the assistance given under that program has been left unallocated.
- In many cases, the Commission has obtained sufficient data to allocate assistance to a certain level of disaggregation — for example, to the ANZSIC three-digit level — but not to the fine level of disaggregation required for this study. For example, data available to the Commission allowed it to determine the amount of funding under the R&D tax concession that assists 'other food processing', but it had insufficiently detailed data to split this between the three finer industries of Sugar processing, Seafood processing and Other food beverages and tobacco. In these cases, the Commission has used the data available to disaggregate the assistance as far as possible and has then allocated the assistance pro rata based on gross value of production data.

Table F.3 **Commonwealth budgetary assistance to selected industries – by program**

$ million

Program	*99-00*	*00-01*	*01-02*
Horticulture			
Citrus Industry Market Diversification Subsidy	0.3	0.2	0.7
Cooperative Research Centres	2.2	2.3	2.1
CSIRO	10.6	9.7	9.8
Drought Investment Allowance	2.0	1.0	0.0
Export Market Development Grants Scheme	0.9	1.0	1.0
Farm Help (formerly Farm Family Restart program)	3.4	4.3	3.0
Farm Innovation Program	0.0	1.5	3.0
Farm Management Deposits Scheme	3.6	2.3	1.9
FarmBis (skilling farmers for the future)	0.0	1.3	2.7
Grape and Wine R&D Corporation	5.3	5.7	6.3
Horticulture Australia	12.2	18.0	23.3
Income Equalisation Deposits Scheme	1.3	0.0	0.0
Income tax averaging provisions	5.2	5.5	5.9
New Industries Development Program	0.0	0.0	1.2
R&D Start & related programs	0.1	0.1	0.1
Rural Financial Counselling Service	0.0	0.0	0.6
Rural Industries R&D Corporation	2.4	2.4	2.4
Small business Capital Gains Tax exemption	0.4	0.3	0.3
South West Forests Structural Adjustment	0.0	0.0	0.2
Tax deduction for conserving or conveying water	4.2	4.2	4.2
Wide Bay Burnett Structural Adjustment Program	0.0	0.0	0.1
Total	*54.0*	*59.8*	*69.6*

Program	*99-00*	*00-01*	*01-02*
Beef			
CSIRO	11.6	9.8	9.8
Beef expo + Gracemere saleyards	0.0	0.0	1.8
Cooperative Research Centres	2.5	3.2	2.7
Drought Investment Allowance	0.8	0.4	0.0
Export Market Development Grants Scheme	0.1	0.1	0.2
Farm Help (formerly Farm Family Restart Program)	5.2	6.6	4.6
Farm Innovation Program	0.0	0.1	0.1
Farm Management Deposits Scheme	3.2	4.9	4.1
FarmBis (skilling farmers for the future)	0.0	1.3	2.8
Income Equalisation Deposits Scheme	1.2	0.0	0.0
Income tax averaging provisions	9.9	10.6	11.3
Meat and Livestock Australia	14.2	12.9	16.5
New Industries Development Program	0.0	0.0	0.1
R&D tax concession	0.4	0.5	0.4
Rural Financial Counselling Service	0.0	0.0	0.8
Small business Capital Gains Tax exemption	0.3	0.2	0.2
Tax deduction for conserving or conveying water	1.7	1.7	1.7
Total	*51.1*	*52.3*	*57.2*
Sugar			
CSIRO	3.3	3.3	3.3
Cooperative Research Centres	2.6	2.3	2.4
Drought Investment Allowance	0.3	0.1	0.0
Farm Help (formerly Farm Family Restart Program)	10.9	13.8	9.7
Farm Innovation Program	0.0	0.4	0.7
Farm Management Deposits Scheme	1.4	0.4	0.4
FarmBis (skilling farmers for the future)	0.0	0.1	0.2
Income Equalisation Deposits Scheme	0.5	0.0	0.0

Program	*99-00*	*00-01*	*01-02*
Income tax averaging provisions	0.6	0.6	0.7
Sugar Industries Package	4.8	29.6	19.3
Sugar Industry Program	0.9	1.8	1.8
Sugar Research and Development Corporation	3.6	3.8	4.2
Tax deduction for conserving or conveying water	0.6	0.6	0.6
Total	29.4	56.9	43.3
Other Agriculture			
Cooperative Research Centres	4.8	4.6	6.4
Cotton Research and Development Corporation	5.8	6.8	7.6
CSIRO	75.7	51.0	51.1
Dairy Research and Development Corporation	13.4	12.7	14.7
Drought Investment Allowance	6.9	3.4	0.0
EFIC National Interest Business	16.6	19.5	15.5
Export Market Development Grants Scheme	2.7	2.0	1.8
Farm Help (formerly Farm Family Restart Program)	10.9	13.9	9.7
Farm Innovation Program	0.0	1.0	1.9
Farm Management Deposits Scheme	16.5	22.1	18.4
FarmBis (skilling farmers for the future)	0.0	5.9	12.8
Grains R&D	31.9	34.5	37.3
Horticulture Australia	1.5	2.3	3.0
Income Equalisation Deposits Scheme	5.9	0.0	0.0
Income tax averaging provisions	46.3	49.6	52.9
Lamb Industry Development Program	8.6	1.7	4.0
Meat and Livestock Australia	6.0	5.4	7.0
New Industries Development Program	0.0	0.0	1.5
Pig R&D Corporation	3.6	3.8	4.0
Pork Industry Development Group Grant	4.1	0.5	0.0
Pork Producer Exit Program	5.0	0.0	0.0
R&D Start & related programs	3.4	5.3	5.8

Program	*99-00*	*00-01*	*01-02*
R&D tax concession	3.4	3.5	3.4
Rural Financial Counselling Service	0.0	0.0	3.7
Rural Industries R&D Corporation	6.0	6.8	6.7
Small business Capital Gains Tax exemption	1.3	0.9	0.9
South West Forests Structural Adjustment	0.0	0.0	0.1
Tasmanian Wheat Freight Subsidy	0.8	0.8	0.8
Tax deduction for conserving or conveying water	14.5	14.5	14.5
Wool R&D	9.2	9.6	13.8
Total	304.8	282.0	299.2
Commercial Fishing			
CSIRO	24.0	25.8	25.8
Eden Structural Adjustment Program	0.0	0.4	0.2
Export Market Development Grants Scheme	0.6	0.3	0.2
Farm Innovation Program	0.0	0.2	0.5
Farm Management Deposits Scheme	0.2	0.2	0.1
FarmBis (skilling farmers for the future)	0.0	0.1	0.1
Fishing Industry R&D	7.0	7.8	8.8
Income Equalisation Deposits Scheme	0.1	0.0	0.0
Income tax averaging provisions	6.6	7.1	7.6
New Industries Development Program	0.0	0.0	0.2
R&D Start & related programs	0.8	1.2	1.3
Small business Capital Gains Tax exemption	0.6	0.4	0.4
Total	39.9	43.4	45.1
Aquaculture			
CSIRO	2.2	1.9	1.9
Cooperative Research Centres	2.4	0.4	1.5
Development Allowance	2.3	2.0	1.9
Export Market Development Grants Scheme	0.2	0.0	0.2
Farm Innovation Program	0.0	0.1	0.2

Program	99-00	00-01	01-02
FarmBis (skilling farmers for the future)	0.0	0.1	0.2
Fishing Industry R&D	5.6	6.7	7.1
Income tax averaging provisions	0.7	0.8	0.8
New Industries Development Program	0.0	0.0	0.3
R&D Start & related programs	0.6	0.9	1.0
Total	14.1	12.9	15.2
Other primary production			
CSIRO	13.1	12.1	12.1
Cooperative Research Centres	2.3	2.3	2.4
Eden Structural Adjustment Program	0.0	0.2	0.1
Forest Industry Structural Adjustment	4.5	3.4	18.9
Forrest and Wood Products Research and Development	3.2	3.7	4.0
Income tax averaging provisions	0.8	0.8	0.9
National Forest Policy Program	3.9	2.0	0.0
Rural Industries R&D Corporation	2.4	2.2	2.2
Total	30.3	26.7	40.6
Unallocated Primary Production			
Agricultural Development Partnership	0.0	0.0	1.0
Australian Animal Health Laboratory	6.0	6.0	5.9
Biotechnology Innovation Fund	0.0	0.0	0.1
Cooperative Research Centres	6.7	10.2	10.2
Exotic Disease Preparedness Program	15.9	3.6	1.2
Farm Assistance Program	0.0	1.0	0.0
Farm Business and Community Programs	11.7	17.1	0.0
Food and Fibre Supply Chain Program	7.0	6.0	0.0
Land and Water Resources R&D	11.0	11.3	11.6
Major National Research Facilities	0.4	0.4	0.3
National Landcare Program	37.0	37.0	38.2

Program	99-00	00-01	01-02
Rural Industries R&D Corporation	4.2	4.0	3.9
Rural Adjustment Scheme	29.0	18.0	21.6
Supermarket to Asia Scheme	4.0	0.0	0.0
Tasmanian Freight Equalisation Scheme	4.0	4.1	4.4
Total	137.0	118.7	98.4
Coal			
CSIRO	20.6	21.3	20.5
Development Allowance	34.7	30.5	27.8
R&D tax concession	3.5	3.6	3.4
Total	58.7	55.5	51.7
Metal Ore			
CSIRO	7.9	8.8	8.7
Development Allowance	16.4	14.5	13.1
Export Market Development Grants Scheme	0.2	0.2	0.1
Gold Mining Tax Deduction	5.0	0.0	0.0
Investment Incentive to Rio Tinto	0.0	0.0	0.0
R&D tax concession	27.2	28.5	26.6
Total	56.8	52.0	48.6
Oil and Gas			
CSIRO	14.1	17.4	17.1
Development Allowance	13.0	11.5	10.4
Export Market Development Grants Scheme	0.2	0.1	0.1
R&D tax concession	1.3	1.4	1.3
Total	28.6	30.4	28.9
Other Minerals			
CSIRO	1.8	2.0	2.0
Development Allowance	40.7	35.8	32.5

Program	99-00	00-01	01-02
Export Market Development Grants Scheme	0.6	0.5	0.6
New Industries Development Program	0.0	0.0	0.1
R&D tax concession	6.3	6.6	6.2
Total	49.4	44.8	41.4
Services to mining			
CSIRO	2.9	3.2	3.2
Cooperative Research Centres	9.0	5.8	7.3
Development Allowance	10.1	8.9	8.0
Export Market Development Grants Scheme	1.1	1.5	1.5
Major National Research Facilities	0.0	0.0	0.0
R&D tax concession	6.8	7.1	6.6
Total	29.9	26.4	26.7
Unallocated mining			
Innovation Investment Fund	0.0	0.0	0.8
R&D Start & related programs	23.0	12.0	13.3
Regional Minerals Program	1.0	0.3	0.3
TRADEX	0.0	0.3	0.4
Total	24.0	12.6	14.8
Meat Processing			
CSIRO	2.5	2.7	2.7
Export Market Development Grants Scheme	1.6	0.9	0.6
New Industries Development Program	0.0	0.0	0.2
Pigmeat Processing Grants Program	4.1	2.8	1.6
R&D tax concession	0.4	0.4	0.4
Small business Capital Gains Tax exemption	0.1	0.0	0.0
Total	8.7	6.9	5.5

Program	99-00	00-01	01-02
Fruit and Vegetable Processing			
CSIRO	1.3	1.4	1.4
Export Market Development Grants Scheme	0.4	0.6	0.3
R&D tax concession	1.1	1.1	1.0
Wide Bay Burnett Structural Adjustment Package	0.0	0.0	0.3
Total	2.8	3.1	3.0
Sugar Processing			
CSIRO	0.9	1.0	1.0
Development Allowance	0.2	0.2	0.2
New Industries Development Program	0.0	0.0	0.2
R&D tax concession	1.3	1.4	1.3
Total	2.4	2.6	2.6
Seafood Processing			
CSIRO	0.4	0.4	0.4
Development Allowance	0.1	0.1	0.1
Eden Structural Adjustment Package	0.0	0.7	0.3
Export Market Development Grants Scheme	0.5	0.3	0.4
R&D tax concession	0.6	0.6	0.6
Total	1.5	2.1	1.8
Other Food, Beverages and Tobacco			
Brandy excise preferential rate	5.0	3.0	3.0
Cooperative Research Centres	3.6	2.7	3.7
CSIRO	13.3	14.4	14.4
Development Allowance	4.0	3.5	3.2
Eden Structural Adjustment	0.0	0.8	0.4
Export Market Development Grants Scheme	6.5	6.9	7.1
New Industries Development Program	0.0	0.0	0.2

Program	*99-00*	*00-01*	*01-02*
R&D tax concession	16.4	17.1	16.0
Small business Capital Gains Tax exemption	0.3	0.2	0.2
Tasmanian Wheat Freight Subsidy	0.4	0.4	0.4
Wide Bay Burnett Structural Adjustment Program	0.0	0.0	0.1
Total	49.5	49.1	48.7
Unallocated Food, Beverages and Tobacco			
Cooperative Research Centres	2.4	4.9	5.0
National Food Industry Strategy	0.0	0.0	0.0
R&D Start & related programs	2.0	2.0	2.3
Tasmanian Freight Equalisation Scheme	8.0	9.0	12.2
TRADEX	0.0	0.4	0.6
Total	12.4	16.3	20.1
Aluminia Production			
CSIRO	3.8	3.9	3.9
Cooperative Research Centres	1.3	1.7	1.4
Development Allowance	16.3	14.4	13.1
R&D tax concession	1.2	1.3	1.2
TRADEX	0.3	0.1	0.2
Total	22.9	21.5	19.7
Aluminium Smelting			
CSIRO	4.3	4.4	4.3
Cooperative Research Centres	1.4	2.0	1.5
Development Allowance	18.3	16.1	14.6
Export Market Development Grants Scheme	0.0	0.2	0.2
R&D tax concession	1.4	1.5	1.4
TRADEX	0.3	0.1	0.2
Total	25.7	24.2	22.2

Program	*99-00*	*00-01*	*01-02*
Basic Iron and Steel Manufacturing			
CSIRO	10.1	10.2	10.2
Cooperative Research Centres	1.8	2.3	1.3
Development Allowance	4.2	3.7	3.4
Export Market Development Grants Scheme	0.2	0.1	0.1
R&D tax concession	11.4	12.0	11.2
TRADEX	0.1	0.0	0.0
Total	27.8	28.3	26.2
Copper, Silver, Lead and Zinc Smelting			
CSIRO	2.6	2.7	2.7
Cooperative Research Centres	0.9	1.2	0.9
Development Allowance	11.2	9.9	9.0
R&D tax concession	0.9	0.9	0.8
TRADEX	0.2	0.1	0.1
Total	15.8	14.8	13.5
Other Metal Product Manufacturing			
CSIRO	7.1	7.2	7.1
Cooperative Research Centres	3.7	4.2	3.7
Development Allowance	8.9	7.8	7.1
Export Market Development Grants Scheme	3.8	3.6	2.9
R&D tax concession	8.0	8.4	7.8
TRADEX	4.2	2.0	3.0
Total	35.6	33.2	31.6
Unallocated Metal Product Manufacturing			
R&D Start & related programs	6.0	5.0	7.4

Source: PC estimates

State budgetary assistance

The Commission published estimates of state government budgetary assistance to industry, including budgetary assistance provided by the Queensland Government, in its most recent TAR (PC 2002b). Those estimates were disaggregated to the sectoral level — manufacturing, mining, primary production and services — although information gaps meant that a significant proportion of the assistance was classified as ‘unallocated’. Data limitations also precluded further disaggregation of estimates to the individual industry level.

In 2001-02, Queensland budgetary outlays that assisted industry were estimated by the Commission at $732 million, of which around $545 million was delivered via industry development programs, with the remainder constituting ‘incidental’ assistance (see PC 2002b for further information). Services ($267m) and primary production ($219m) recorded the highest levels of assistance in dollar terms, although most assistance to services was ‘incidental’ assistance. As a proportion of sectoral output, primary production received by far the highest level of Queensland budgetary assistance.

Given that the GBR catchment comprises about one-third of Queensland’s gross state product, state budgetary assistance to all industries in the catchment may have been around $200 million to $250 million in 2001-02.

F.3 Statutory marketing arrangements

The Commission’s national estimates of the dollar value of assistance derived from statutory marketing arrangements (SMAs) cover domestic regulatory arrangements for dairy and rice and dominate total measured assistance to the agricultural sector. Formerly, the Commission’s estimates covered a wider range of SMAs. However, over recent years, many of these schemes have been discontinued. As well as assistance from SMAs, a small amount of non-tariff/budgetary assistance is derived from the Commonwealth Australian Quarantine and Inspection Service Export Inspection Program. It has not been included in the current study.

Dairy and rice farming activities form part of the commodity group of Other agriculture. The regional composition of these activities in the GBR catchment is quite different from the national composition. Rice production in Queensland is negligible. Hence, none of the assistance derived from the regulatory arrangements for rice has been allocated to the GBR catchment. In contrast, there is significant dairy activity in the GBR catchment, and dairy assistance arrangements provide proportionally more assistance to producers outside Victoria. In deriving estimates of the dollar value of assistance for dairy farming in the GBR catchment, assistance was first divided into two parts — assistance to market milk (or drinking milk) and assistance to manufacturing milk.

National assistance for market milk production in 1999-2000 was derived from state government price and regulatory controls. The Commission estimates assistance from these arrangements at the state level. For manufacturing milk in 1999-2000, national assistance was derived from Commonwealth regulatory arrangements in the form of Market Support Payments. On a per litre basis, market milk has traditionally been more highly assisted than manufacturing milk. In 1999-2000, over 70 per cent of manufacturing milk was produced in Victoria.

Market milk assistance in the GBR catchment was derived by scaling the Commission's estimate of market milk assistance in Queensland by the GBR catchment's share of Queensland market milk production in 1999-2000. The Australian Dairy Corporation has indicated to the Commission that the GBR catchment accounts for around 25 per cent of Queensland milk production. In the absence of specific information on the composition of the dairy industry within the GBR catchment, it is assumed that the ratio of manufacturing to market milk production in the GBR catchment is the same as for Queensland as a whole. This implies that the GBR catchment produced around one quarter of Queensland's market milk.

Manufacturing milk assistance in the GBR catchment was derived by scaling national manufacturing milk assistance by the GBR catchment's share of national manufacturing milk production in 1999-2000. In 1999-2000, the GBR catchment accounted for around two per cent of national milk production. Manufacturing milk accounts for around 55 per cent of milk production in Queensland. Applying this proportion to the GBR catchment, it is estimated that the region's dairy farmers produced just over one per cent of national market milk production in 1999-2000.

The regulatory arrangements covering the dairy industry were changed in 2000-01. As well as reducing the total quantum of assistance, the new arrangements removed the (price) distinction between market and manufacturing milk at the farm gate level, although payments from the new arrangements continue to reflect the previous distribution of assistance. For the purposes of estimating assistance in the GBR catchment, the production shares of market and manufacturing milk were assumed to have remained largely unchanged in 2000-01 and 2001-02.

The resulting 'regionalised' estimates of assistance from statutory marketing arrangements to industries within the GBR catchment are set out in table F.4. For comparative purposes, the table also includes a national estimate for other agriculture, together with a scaled (but not 'regionalised) estimate for other agriculture within the GBR catchment.

Table F.4 **Assistance to 'other agriculture' from statutory marketing arrangements, 1999-00 to 2001-02[a]**

$ million

	1999-00	*2000-01*	*2001-02*
National estimate	452.8	191.3	260.1
GBR scaled[b]	16.5	7.0	9.5
GBR regionalised[c]	24.3	8.1	13.6

a Assistance derived from SMAs includes domestic regulatory arrangements for dairy and rice. **b** National estimates scaled downwards based on the GBR catchment's share of the value of national production. **c** National estimates have been regionalised based on the GBR catchment's share of national rice, market milk and manufacturing milk production.

Source: PC estimates.

F.4 Tourism

The Commission has not previously published an estimate of assistance for tourism. Nor, in the context of this study, has the Commission been able to thoroughly investigate all forms of assistance that may benefit or penalise tourism. The Commission also has been unable to closely consider the merits of different definitions of the tourism industry for the purposes of measuring assistance, or the significance and resource allocation implications of a net measure of assistance to tourism. Accordingly, *the Commission cautions that particular care is required in drawing inferences based on the assistance estimates for tourism prepared for this study*.

In developing the estimates, the Commission has drawn on its national estimates of tariff and budgetary assistance together with ABS data on the composition of the tourism industries. The Commission reports budgetary and tariff assistance by industry groupings as defined under the ANZSIC system. Tourism is not separately defined under ANZSIC. This is because tourism is normally considered to be a consumption activity, rather than a production activity. A range of disparate industries produce the goods and services consumed by tourists. However, the ABS (2002c) has published a Tourism Satellite Account which reports on the size and scope of the tourism industries in Australia, based on information about the range of goods and services purchased by tourists. The Account provides a means for the Commission to apportion its existing assistance estimates to tourism.

The ABS (2002c) defines tourism broadly to include ‘visitors whose primary purpose is private or government business, as well as the more familiar tourism for leisure purposes’. Tourism, as defined in the Satellite Account, includes ‘tourism characteristic’ industries such as travel agency and transport services, and ‘tourism connected’ industries such as Clubs and pubs, and certain manufacturing industries (for example, Food manufacturing). The industry groups reported in the ABS Satellite Account can be readily concorded to the ANZSIC system. For example, the industry group Accommodation in the Satellite Account is part of Accommodation, cafes and restaurants in the ANZSIC system.

For this report, the Commission has developed a national estimate of the dollar value of assistance to tourism, which it has then scaled to reflect the size of tourism in the GBR catchment. The national estimate comprises estimates of:

- targeted budgetary assistance to tourism;
- other budgetary assistance programs that assist tourism-related industries; and
- tariff assistance that assists tourism related industries.

The targeted budgetary programs identified by the Commission are:

- funding for the Australian Tourist Commission ($90 million in 1999-2000); and
- the Regional Tourist Program, funding to develop an On-line Tourism Industry, and the Domestic Tourism Campaign ($6.8 million in total in 1999-2000).

Other (non-targeted) budgetary assistance and tariff assistance to tourism has been estimated according to the industry composition data in the Satellite Account. Using data on gross value added (GVA), the Commission has calculated the percentage of each ANZSIC industry group that is classified as being part of tourism. For example, the sum of GVA for Accommodation, cafes, restaurants and takeaway food outlets and Clubs, pubs, taverns and bars reported in the Satellite Account is divided by the industry GVA of the Accommodation, cafes and restaurants ANZSIC group. For 1999-2000, this process indicated that 44 per cent of Accommodation, cafes and restaurants is dedicated to tourism (table F.5).

The Commission has applied these percentages to the budgetary and tariff assistance estimates reported for the ANZSIC groups in its 2001-02 TAR to arrive at a dollar value of assistance to tourism at a national level (table F.5). This estimate has been scaled to reflect the size of tourism in the GBR catchment (table F.6).

Table F.5 **Estimates of national assistance to tourism, by ANZSIC industry grouping**
1999-00

ANZSIC industry grouping	*Share of ANZSIC group comprising tourism*	*Budgetary assistance*	*Net tariff assistance*	*Total assistance*
	%	$m	$m	$m
Retail trade	7.0	1.7	-13.4	-11.7
Accom., cafes & restaurants	43.6	6.1	-85.8	-79.7
Transport & storage	16.5	18.8	-27.3	-8.5
Property & business services	3.6	3.9	-8.6	-4.8
Education	3.9	0.6	-1.5	-0.8
Cultural & recreational services	11.0	11.1	-5.7	5.4
Food, beverages & tobacco	7.6	5.9	60.0	65.9
Machinery & equipment[a]	1.5	13.0	12.5	17.3
Other manufacturing[a]	2.3	0.8	3.0	3.6
All other ANZSIC[b]	1.2	26.5	-14.6	11.9
Generic tourism[c]	100.0	104.8	-	104.8
Total tourism[a]	**na**	**193.2**	**-81.4**	**103.4**

[a] The estimates of tariff and budgetary assistance for Machinery & equipment and Other manufacturing include some overlap. Totals have been adjusted to avoid double counting. [b] All tariff assistance is allocated to a particular ANZSIC group. [c] Non-ANZSIC category. Assistance to this category comprises only targeted budgetary assistance. **na** Not applicable.

Source: PC estimates.

F.5 Combined estimates for the GBR catchment

Table F.6 reports combined estimates of the dollar value of assistance to the industries in the GBR catchment for the years 1999-2000 to 2001-02. These have been derived by summing the scaled national estimates of tariff and budgetary assistance, which are also reported in the table, and a regionalised estimate of assistance provided through SMAs. The estimates in table F.6 do not include Queensland budgetary assistance to industries in the GBR catchment, the magnitude of which may be significant.

Table F.6 **Estimates of measured net subsidy equivalents[a] for selected industries in the GBR catchment, 1999-00 to 2001-02**

$ million

	1999-00				*2000-01*				*2001-02*
Commodity/Industry	*Tariff*	*Budgetary*	*SMAs*[b]	*Total*	*Tariff*	*Budgetary*	*SMAs*[b]	*Total*	*Total*
Primary production									
Agriculture	-1.1	55.8	24.3	79.5	-0.6	80.7	8.1	88.3	84.5
Sugar cane	-2.3	26.3	0.0	24.0	-2.4	51.0	0.0	48.6	36.1
Beef	-0.8	10.3	0.0	9.4	-0.9	10.5	0.0	9.6	10.5
Horticulture[c]	3.6	8.1	0.0	11.7	3.8	8.9	0.0	12.7	14.7
Other agriculture[d]	-1.1	11.1	24.3	34.3	-1.1	10.3	8.1	17.3	23.2
Fisheries	-1.2	3.7	–	2.5	-1.4	3.9	–	2.5	2.6
Commercial fishing	-0.9	2.8	–	1.9	-1.1	3.0	–	2.0	2.0
Aquaculture	-0.3	0.9	–	0.6	-0.3	0.8	–	0.5	0.6
Mining[e]	-18.8	50.4	–	31.7	-23.3	46.8	–	23.4	19.9
Coal	-12.4	27.2	–	14.9	-15.3	25.7	–	10.4	8.5
Metal ore	ne	ne	–	ne	ne	ne	–	ne	ne
Oil & gas	ne	ne	–	ne	ne	ne	–	ne	ne
Other minerals	-6.4	23.2	–	16.8	-8.0	21.0	–	13.0	11.4

(Continued next page)

Table F.6 (continued)

Commodity/Industry	1999-00				2000-01				2001-02
	Tariff	Budgetary	SMAs[b]	Total	Tariff	Budgetary	SMAs[b]	Total	Total
Processing									
Food processing	25.2	3.1	–	28.2	18.6	3.0	–	21.6	21.8
Sugar processing	12.0	1.8	–	13.8	5.6	2.0	–	7.6	7.8
Meat processing	12.4	1.2	–	13.6	12.3	0.9	–	13.2	13.3
Horticulture processing	0.5	0.0	–	0.6	0.5	0.0	–	0.6	0.6
Seafood processing	0.2	0.0	–	0.3	0.1	0.1	–	0.2	0.2
Mineral processing[f]	-0.2	10.6	–	10.2	-0.1	9.9	–	9.8	8.9
Alumina production	-1.0	6.0	–	4.9	-1.0	5.6	–	4.6	4.0
Aluminium smelting	-0.7	4.4	–	3.6	-0.7	4.1	–	3.4	3.0
Basic iron and steel mfg	1.5	0.2	–	1.7	1.6	0.2	–	1.8	1.9
Base metals	ne	ne	–	ne	ne	ne	–	ne	ne
Other									
Tourism[g]	-6.0	14.3	–	7.7	-5.3	13.2	–	7.9	11.6

a Net Subsidy Equivalent estimates in the GBR catchment (for each commodity/industry group other than tourism and other agriculture) were derived by multiplying national NSE estimates by a constant ratio of the Gross Value of Production (GVP) in the GBR catchment to national GVP. For agriculture and fishing, mining, and processing commodities/industries, these ratios are based on 1999-2000, 2000-01 and 1996-97 production values, respectively. Other agriculture has been adjusted to reflect regional characteristics. **b** Statutory Marketing Arrangements. **c** Comprises fruit-growing and vegetable-growing. **d** Estimates were adjusted to reflect regional characteristics in relation to dairy and rice. **e** Comprises Coal and Other minerals. **f** Comprises ANZSIC industries 2722 (alumina production), 2721 (aluminium smelting) and 2711 (basic iron and steel manufacturing). Sum of tariff and budgetary assistance adjusted to avoid double counting. **g** Tourism estimate preliminary. Sum of tariff and budgetary assistance adjusted to avoid double counting. **ne** Not estimated.

Source: PC estimates.

G Projections of future economic importance

This appendix provides detailed information about the projections used in chapter 4.

These projections should be interpreted with caution, since they depend on assumptions that are subject to considerable uncertainty. While they provide useful background, the projections are not the basis for developing or assessing policy options in this study. This is because an industry's projected economic importance is not an appropriate criterion for deciding which land users should or should not abate diffuse pollution entering the GBR lagoon. As noted in part II of this report, abatement options should be selected on the basis of their effectiveness in reducing threats to reefs and associated ecosystems, and their cost per unit reduction of those threats. These criteria are not necessarily related to industry size.

G.1 Selection of consultant

In undertaking this study, the Commission was directed to estimate the economic importance of the main industries in 2010 and 2020 in the GBR lagoon and adjacent catchment areas, based on available growth projection scenarios and assuming that current management approaches are continued.

There are few projections of the major industries in the GBR lagoon and adjacent catchment to 2010 or 2020. Given the expertise and resources required to undertake detailed projections of the major industries, the Commission called for public tenders to undertake the task.

The Commission advertised the tender in *The Australian*, *Courier Mail*, *Cairns Post*, *Rockhampton Morning Bulletin*, *Mackay Daily Mercury* and *Townsville Bulletin* on 16 August 2002. Major consultancies and forecasting organisations were directly notified of the tender by electronic mail. The consultancy was also listed on the Commission website. A consultancy brief describing tender specifications was subsequently sent to interested parties.

Tenders closed on 27 August, and nine proposals were received. The proposals were assessed by a selection panel in accordance with the following criteria:

- price;
- capabilities of the personnel who would work on the consultancy;
- the methodologies that would be used; and
- the extent to which projections would be provided for all of the industries, variables and regions specified above.

Two proposals were short listed and the projection teams interviewed. The Australian Bureau of Agricultural and Resource Economics (ABARE) was subsequently awarded the tender.

G.2 Projected state and national importance

The state and national importance of most industries in the GBR catchment is projected to remain relatively stable under the base case as industry growth patterns largely mirror state and national GVP and employment trends (tables G.1 and G.2). Horticulture, aquaculture and mining's share of Queensland employment are projected to increase, whereas mining's national share is projected to decline.

Table G.1 **Projected share of Queensland and Australian gross value of production by industries in the GBR catchment**[a]

	2001		*2010*		*2020*	
Industry	*Qld*	*Aust*	*Qld*	*Aust*	*Qld*	*Aust*
	%	%	%	%	%	%
Sugar cane	98	90	98	92	98	92
Beef	45	20	44	20	44	20
Horticulture	64	16	66	16	69	17
Commercial fishing	46	6	58	8	59	8
Aquaculture	73	5	75	8	75	15
Mining	63	13	66	12	69	11
Mineral processing	57	13	59	15	58	16
Recreational fishing	37	na	38	na	37	na
Tourism	32	6	33	6	34	7

a Base case. In constant 2000-01 prices rounded to the nearest whole percentage value. **na** Not available.

Source: ABARE projections.

Table G.2 **Projected share of Queensland and Australian employment by industries in the GBR catchment[a]**

Industry	2001 Share of Qld	2001 Share of Aust	2010 Share of Qld	2010 Share of Aust	2020 Share of Qld	2020 Share of Aust
	%	%	%	%	%	%
Primary production						
Sugar cane	95	89	95	89	95	89
Beef	45	19	45	19	45	19
Horticulture	54	17	57	17	59	17
Commercial fishing	45	na	45	na	45	na
Aquaculture	72	na	75	na	75	na
Mining	65	15	66	13	66	12
Processing						
Sugar processing	95	83	95	83	95	83
Meat processing	na	na	na	na	na	na
Horticulture processing	3	1	3	1	3	1
Mineral processing	57	9	59	10	59	10
Other						
Recreational fishing	na	na	na	na	na	na
Tourism	na	na	na	na	na	na

[a] Base case. Rounded to the nearest whole percentage value. **na** Not available.

Source: ABARE projections.

G.3 Regional projections

GVP and employment projections for the main industries in each of the regions are summarised in tables G.3 and G.4 at the end of this section. Given the differing importance of industries to particular regions, some regions may be more affected than others as particular industries grow or contract.

Far North

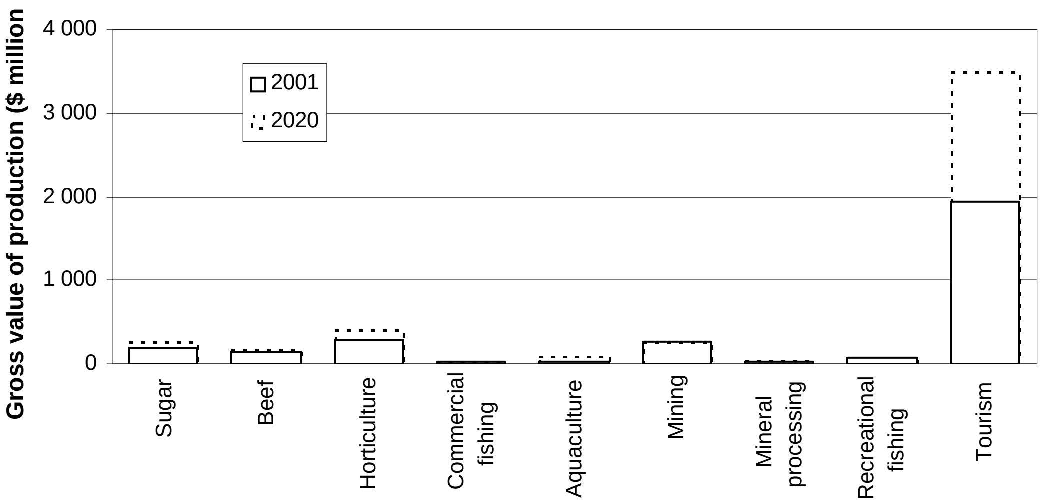
Gross value of production

Tourism is by far the largest industry in the Far North region and is likely to further increase in importance as tourist expenditure is projected to increase by 80 per cent by 2020 (figure G.1). The relative importance of agriculture is also likely to increase as sugar cane and horticulture industries experience moderate rates of GVP growth. The mining industry is likely to remain important, even though its GVP is projected to contract. Aquaculture is likely to remain a relatively small industry, despite its GVP almost quadrupling by 2020. The commercial fishing industry is likely to remain small, as its GVP is projected to fall by about 20 per cent.

Employment

Horticulture is expected to increase in importance as a major employer, with projected growth of more than 30 per cent by 2020 (figure G.2). The sugar cane, sugar processing and beef industries are projected to remain large employers, even though employment is projected to decline in each. Employment in the beef cattle industry is projected to grow and exceed the level of mining employment by 2020. Employment in aquaculture is projected to increase substantially and exceed the level of employment in commercial fishing in 2020.

Figure G.1 **Projected gross value of production in the Far North region**[a]
2001 and 2020

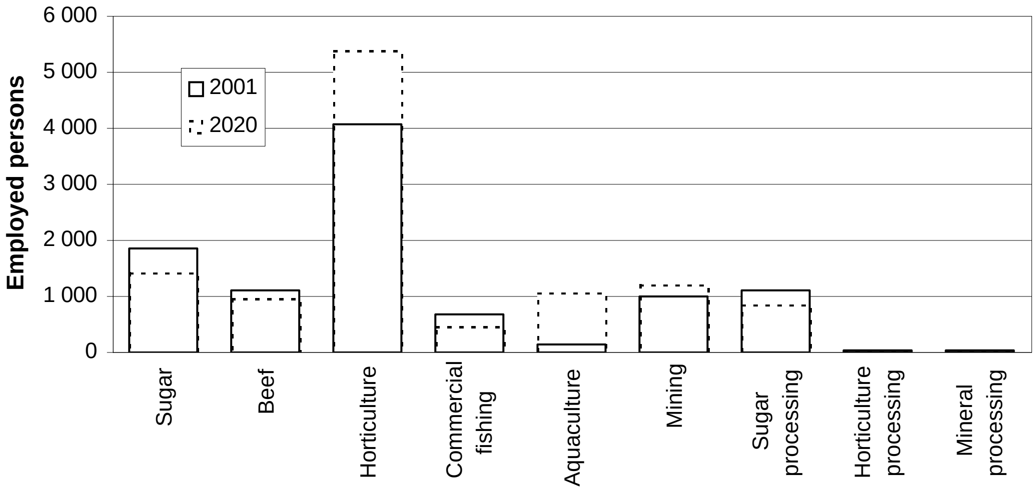


a Base case. In constant 2000-01 prices. Calculated using wholesale prices (sugar, beef and horticulture); landed prices (commercial fishing and aquaculture); mine site prices (mining); turnover (mineral processing); expenditure by recreational fishers (recreational fishing); and expenditure by visitors (tourism).

Source: ABARE projections.

Figure G.2 **Projected employment in the Far North region**[a]

2001 and 2020



[a] Base case.

Source: ABARE projections.

Northern

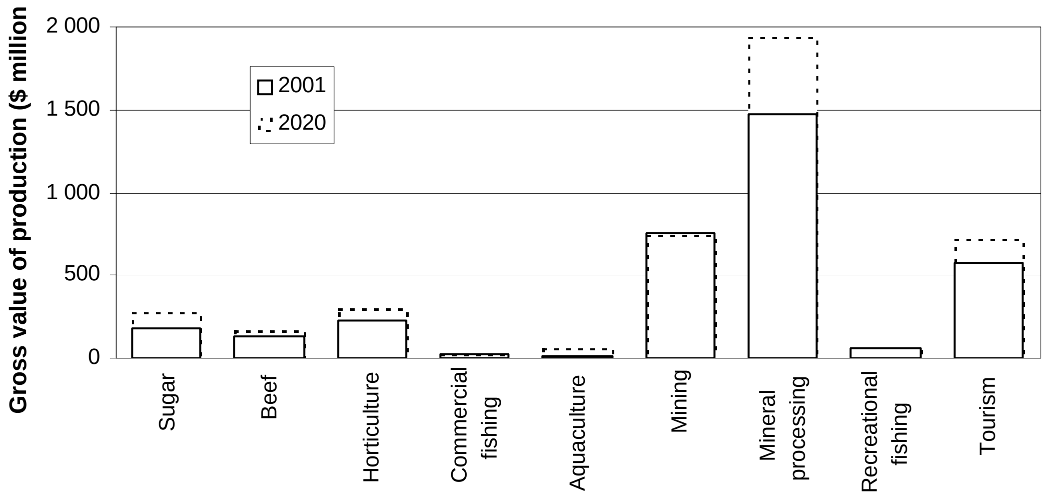
Gross value of production

The GVP of the mineral processing industry in the Northern region in 2001 is projected to be almost twice as large as the next largest industry (mining) (figure G.3). GVP of mineral processing is projected to grow by more than 30 per cent between 2001 and 2020, while the GVP of the mining industry is also likely to remain large, despite being projected to fall slightly. Tourism expenditure — currently the third largest industry — is projected to grow 25 per cent. GVPs of the main agricultural industries are projected to remain below mineral processing, mining and tourism. Nevertheless, the main agricultural industries will still be important to the regional economy, as their GVPs are projected to grow by between 26 and 56 per cent. Commercial and recreational fishing and aquaculture are projected to remain small industries. Aquaculture GVP is projected to exceed that of commercial fishing in 2020, as aquaculture grows substantially and commercial fishing contracts.

Employment

The major agriculture industries are projected to remain significant employers in the region in 2020, although horticulture employment is projected to increase while sugar and beef employment are projected to decline (figure G.4). Sugar processing is projected to remain a major employer, even though employment is projected to fall by more than 20 per cent. In contrast, mineral processing is projected to increase in importance as a major employer (and exceed sugar processing), with employment growing by more than 40 per cent.

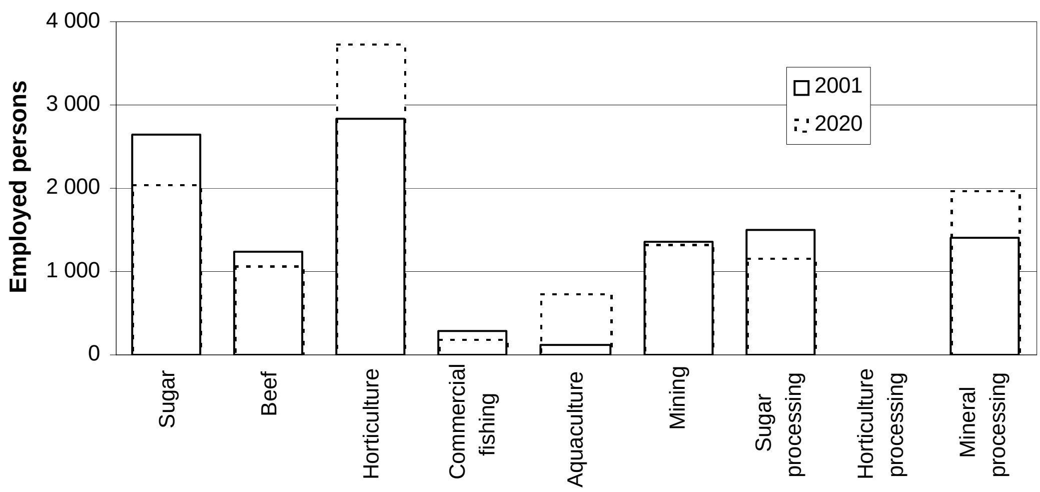
Figure G.3 **Projected gross value of production in the Northern region[a]**
2001 and 2020



a Base case. In constant 2000-01 prices. Calculated using wholesale prices (sugar, beef and horticulture); landed prices (commercial fishing and aquaculture); mine site prices (mining); turnover (mineral processing); expenditure by recreational fishers (recreational fishing); and expenditure by visitors (tourism).

Source: ABARE projections.

Figure G.4 **Projected employment in the Northern region[a]**
2001 and 2020



a Base case.

Source: ABARE projections.

Mackay

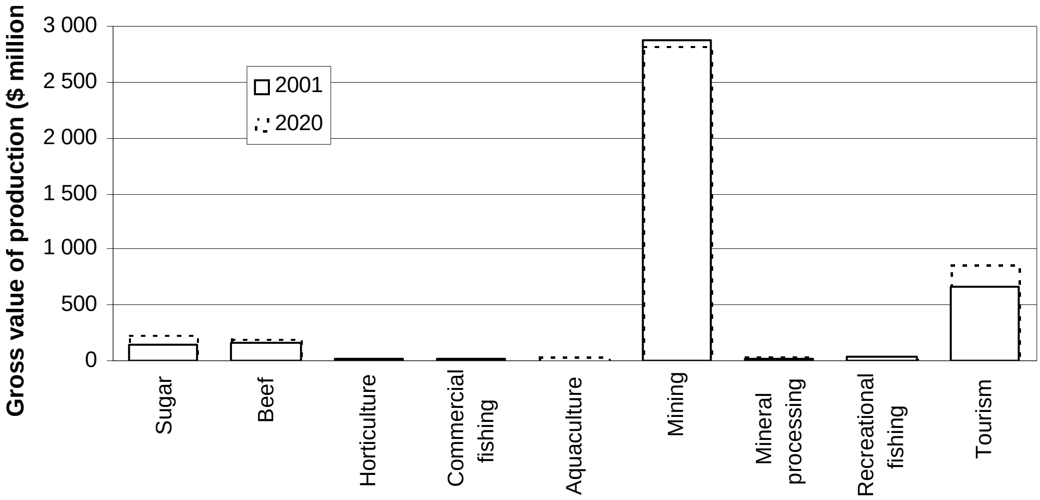
Gross value of production

The mining industry is likely to remain a substantial industry in the Mackay region (figure G.5), even though its GVP is projected to fall marginally due to slightly lower projected returns for black coal. Tourism is also likely to remain a major industry, as expenditure is projected to grow by about 30 per cent between 2001 and 2020. Sugar and beef are projected to remain major agricultural industries in the region — the GVP of sugar cane is projected to grow by more than 60 per cent, whereas GVP growth of the beef industry is projected to be more moderate. Horticulture is projected to remain a relatively small industry. Similar to other regions, commercial and recreational fishing and aquaculture are projected to remain relatively small industries.

Employment

The mining industry is projected to remain a major employer in the Mackay region, even though it is likely to shed significant levels of labour (figure G.6). Similarly, sugar and beef are also projected to remain major employers, despite projected reductions in employment. Smaller employers, such as commercial fishing and horticulture, are projected to remain so. However, the relative importance of those two industries is expected to change as horticulture employment expands and commercial fishing employment contracts.

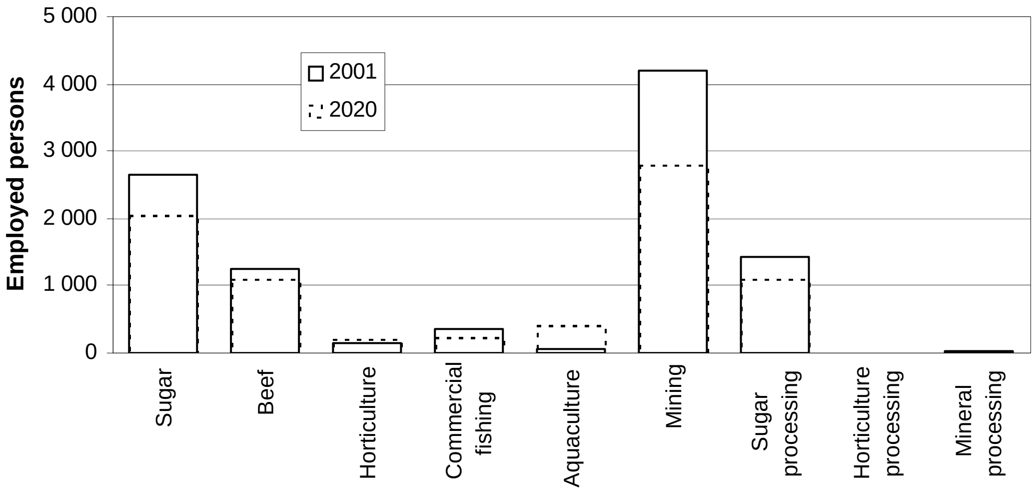
Figure G.5 **Projected gross value of production in the Mackay region**[a]
2001 and 2020



a Base case. In constant 2000-01 prices. Calculated using wholesale prices (sugar, beef and horticulture); landed prices (commercial fishing and aquaculture); mine site prices (mining); turnover (mineral processing); expenditure by recreational fishers (recreational fishing); and expenditure by visitors (tourism).

Source: ABARE projections.

Figure G.6 **Projected employment in the Mackay region**[a]
2001 and 2020



a Base case.

Source: ABARE projections.

Fitzroy

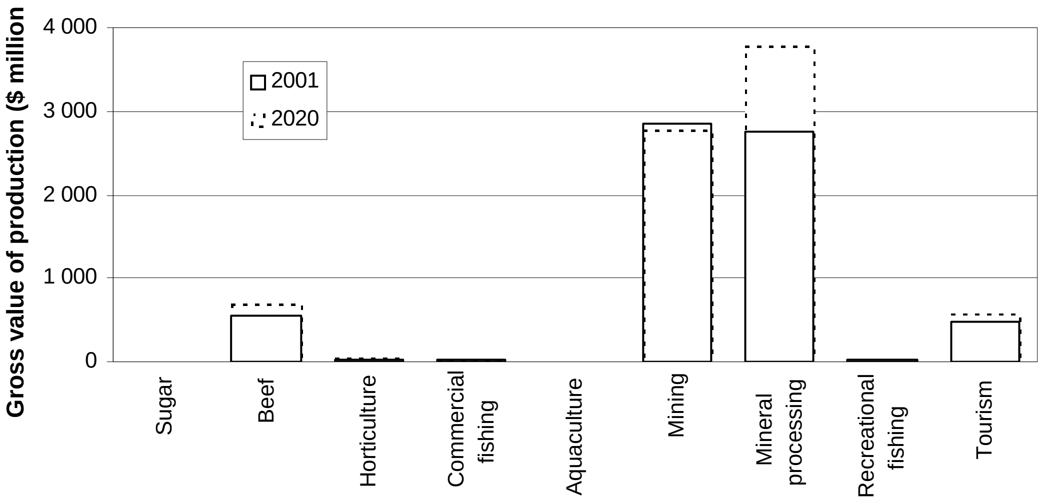
Gross value of production

The mining and mineral processing industries are projected to remain by far the largest industries in the Fitzroy region (figure G.7). The mining industry is projected to contract only marginally whereas the mineral processing industry is projected to grow by nearly 40 per cent. Tourist expenditure in the Fitzroy region is relatively low compared to the other regions, but it is projected to increase by 20 per cent. The beef industry is projected to remain the major agricultural activity in the region as its GVP grows moderately. In contrast, horticulture is likely to remain a small industry.

Employment

The mining and mineral processing industries are projected to remain substantial employers in the Fitzroy region (figure G.8). Mineral processing employment is projected to exceed mining employment in 2020, as mining industry employment contracts and mineral processing employment expands. The beef industry is projected to remain the other major employer in the region despite employment falling by more than 10 per cent. Employment in the other industries is likely to remain relatively small.

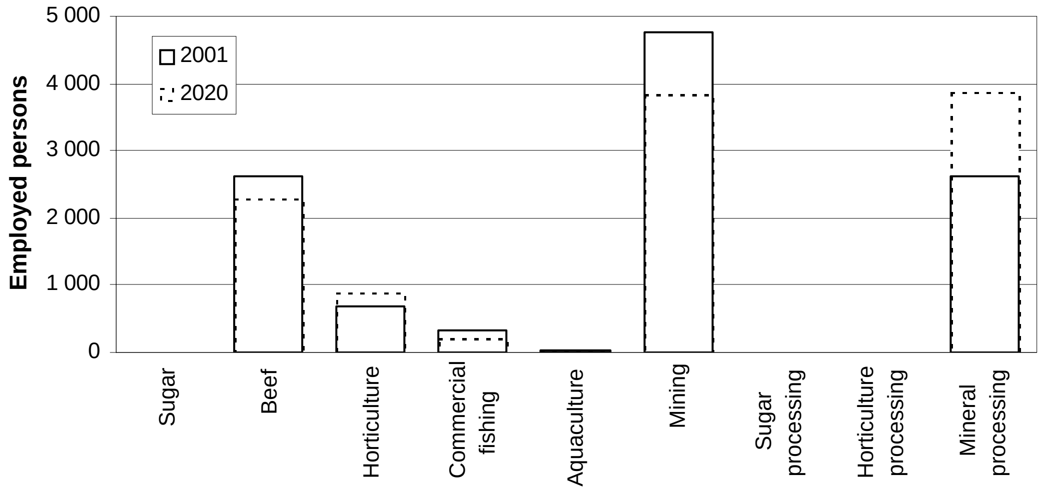
Figure G.7 **Projected gross value of production in the Fitzroy region**[a]
2001 and 2020



[a] Base case. In constant 2000-01 prices. Calculated using wholesale prices (sugar, beef and horticulture); landed prices (commercial fishing and aquaculture); mine site prices (mining); turnover (mineral processing); expenditure by recreational fishers (recreational fishing); and expenditure by visitors (tourism).

Source: ABARE projections.

Figure G.8 **Projected employment in the Fitzroy region**[a]
2001 and 2020



[a] Base case.
Source: ABARE projections.

Wide Bay-Burnett

Gross value of production

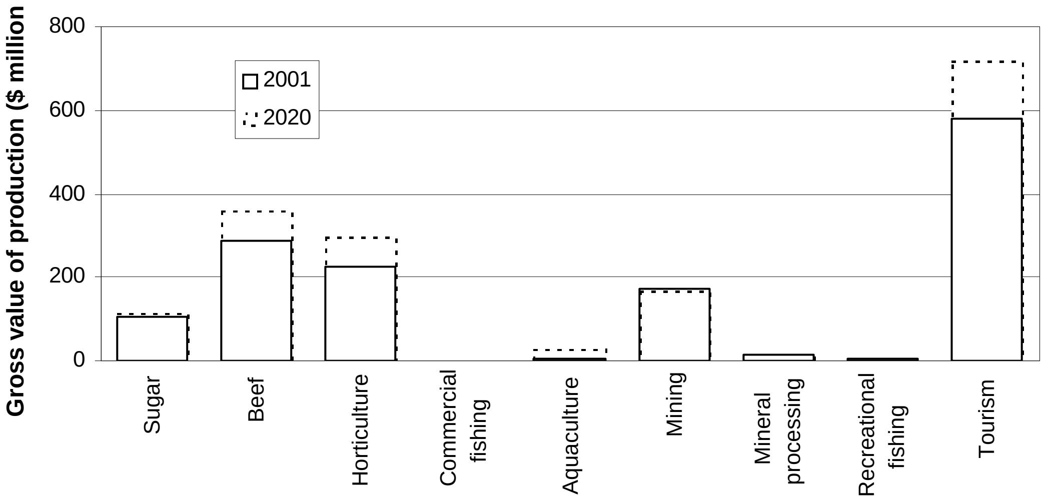
Tourism is projected to remain the dominant industry in the Wide Bay-Burnett region (figure G.9), as the already large tourist expenditure is projected to grow substantially. Agriculture is also projected to remain a significant component of the region's economy, as GVP grows moderately for beef and horticulture. Mining and sugar cane GVPs are projected to remain largely unchanged.

Employment

Agricultural industries are projected to remain major sources of employment in the Wide Bay-Burnett region (figure G.10). Horticulture is projected to increase in importance as a major employer as employment grows by more than 30 per cent. In contrast, both sugar and beef are projected to experience major declines in employment, but remain large employers. Commercial fishing and aquaculture are projected to remain small employers.

Figure G.9 **Projected gross value of production in the Wide Bay-Burnett region[a]**

2001 and 2020

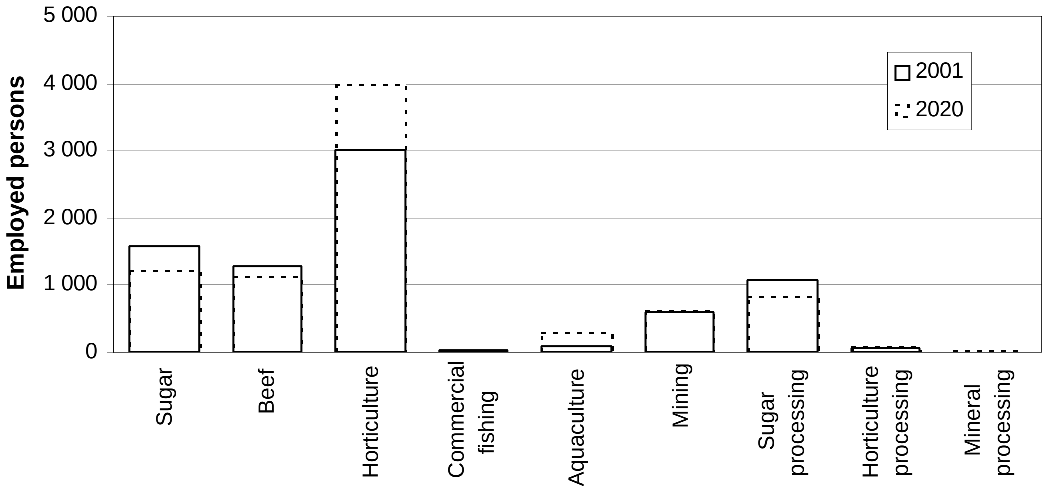


[a] Base case. In constant 2000-01 prices. Calculated using wholesale prices (sugar, beef and horticulture); landed prices (commercial fishing and aquaculture); mine site prices (mining); turnover (mineral processing); expenditure by recreational fishers (recreational fishing); and expenditure by visitors (tourism).

Source: ABARE projections.

Figure G.10 **Projected employment in the Wide Bay-Burnett region[a]**

2001 and 2020



[a] Base case.

Source: ABARE projections.

Table G.3 **Projected value of output by industry and region[a]**

	Far North region			*Northern region*			*Mackay region*			*Fitzroy region*			*Wide Bay-Burnett region*		
Industry	*2001*	*2020*	*Growth*	*2001*	*2020*	*Growth*	*2001*	*2020*	*Growth*	*2001*	*2020*	*Growth*	*2001*	*2020*	*Growth*
	$m	$m	%	$m	$m	%	$m	$m	%	$m	$m	%	$m	$m	%
Primary production															
Sugar cane	183	254	39	177	276	56	150	241	61	0	0	0	107	113	5
Beef	138	174	25	131	164	25	154	193	25	544	683	25	285	358	25
Horticulture	291	406	40	224	304	36	19	25	34	35	47	35	224	296	32
Commercial fishing	48	37	-23	19	16	-16	23	17	-23	28	23	-18	0	0	-24
Aquaculture	17	94	472	12	65	448	6	36	500	0.2	2	1000	6	27	335
Mining	271	266	- 2	755	741	- 2	2 871	2 816	- 2	2 840	2 785	- 2	173	170	- 2
Processing															
Sugar processing	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Meat processing	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Horticulture processing	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Mineral processing	33	43	30	1 468	1 936	32	22	29	32	2 752	3 791	38	12	15	25
Other															
Recreational fishing	72	73	1	54	55	1	36	36	1	21	22	1	3	3	1
Tourism	1 937	3 490	80	579	724	25	658	868	32	475	568	20	579	718	24

a Base case. In constant 2000-01 prices; rounded to the nearest whole number. **na** Not available.

Source: ABARE projections.

Table G.4 **Projected employment by industry and region[a]**

	Far North region			*Northern region*			*Mackay region*			*Fitzroy region*			*Wide Bay-Burnett region*		
Industry	*2001*	*2020*	*Growth*	*2001*	*2020*	*Growth*	*2001*	*2020*	*Growth*	*2001*	*2020*	*Growth*	*2001*	*2020*	*Growth*
	no.	no.	%	no.	no.	%	no.	no.	%	no.	no.	%	no.	no.	%
Primary production															
Sugar cane	1 864	1 443	- 23	2 639	2 044	- 23	2 657	2 057	- 23				1 579	1 223	- 23
Beef	1 097	963	- 12	1 230	1 080	- 12	1 260	1 106	- 12	2 608	2 291	- 12	1 274	1 119	- 12
Horticulture	4 063	5 389	33	2 826	3 749	33	160	213	33	683	906	33	3 011	3 994	33
Commercial fishing	691	450	- 35	294	191	- 35	363	236	- 35	322	209	- 35	22	14	- 36
Aquaculture	156	1 057	578	124	730	489	49	403	722	16	25	56	78	302	287
Mining	1 016	1 202	18	1 368	1 325	- 3	4 190	2 793	- 33	4 752	3 831	- 19	603	621	3
Processing															
Sugar processing	1 118	866	- 23	1 511	1 170	- 23	1 419	1 099	- 23				1 062	822	- 23
Meat processing	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Horticulture processing	23	40	74										46	79	72
Mineral processing	31	44	42	1 394	1 979	42	21	30	43	2 612	3 876	48	11	16	45

[a] Base case. Rounded to the nearest whole number. **na** Not available. Tourism and recreational fishing employment were not projected.

Source: ABARE projections.

G.4 ABARE report to the Productivity Commission

1 Introduction

As part of its study on the economic importance of the main industries in the GBR lagoon and catchment, the Productivity Commission (PC) requires certain growth projections for specified industries for the years 2010 and 2020. ABARE was commissioned by the PC to provide these projections. As requested by the PC, the projections are based on the assumption that current management approaches are continued.

Growth projections are provided for the following industries:

- aquaculture;
- beef
- commercial fishing;
- horticulture;
- recreational fishing;
- sugar;
- tourism;
- mining; and
- mineral processing.

Projections were sought for the following variables:

- gross value of production (GVP);
- gross value added (GVA); and
- employment.

For tourism and recreational fishing, GVP is represented by tourist expenditure and recreational fishing expenditure.

Projections are presented for the GBR catchment as a whole. For the purpose of this consultancy, the GBR catchment was defined as the five statistical divisions of Far North, Northern, Mackay, Fitzroy, and Wide Bay-Burnett.

Where feasible, growth projections have been provided for individual statistical divisions within the GBR catchment area, the state of Queensland and for Australia.

In most cases, these projections are presented for all the above industries. The exception is the fishing industries, where projections for some variables could not be derived at a national level, as relevant historical data on which to base such projections are not available.

Historical data, from which the projections are based, were provided by the PC and were sourced from the Australian Bureau of Statistics (ABS) and relevant Queensland government departments.

A reference projection (base case) of GVP, GVA and employment is reported for each industry. In addition, projections for higher or lower values of these variables for 2010 and 2020 are presented to indicate the sensitivity of the projections to changes in the underlying assumptions — thus highlighting the importance of uncertainty when considering possible future outcomes. Details of how the high and low case projections were arrived at are presented in the discussion of each particular industry.

In addition, a common set of macroeconomic variables used in developing projections for all industries are discussed in section 2 and the specific industry projection methodologies employed are described in section 3.

2 Macroeconomic assumptions

The macroeconomic assumptions used in deriving the projections are presented in table G.5. Provided below is a discussion of how these assumptions were developed.

Economic activity in the near term, say 12-18 months ahead will be an important precursor for how the world develops further into the future. The discussion which follows will therefore focus initially on some near term factors that may influence events into the key projection years of 2010 and 2020.

Table G.5 **Macroeconomic assumptions**

	Unit	2001	2010			2020		
			Base	*Low*	*High*	*Base*	*Low*	*High*
World GDP	% growth	2.00	3.70	3.20	4.20	3.50	3.00	4.00
Exchange rate	US$/A$	0.54	0.55	0.45	0.65	0.55	0.45	0.65
Australian GDP	% growth	2.00	3.50	3.00	4.00	3.50	3.00	4.00
Australian CPI	% growth	6.00	2.50	2.50	2.50	2.50	2.50	2.50

World economic growth

Since early July 2002, sharp declines in major US stock market indices and slides in share market valuations in western Europe, Japan and other Asian countries have led to considerable concern that consumer demand and business investment spending in the major world economies will be adversely affected. The US Dow Jones share price index, for example, fell by 9 per cent in the month of July alone and was around 25 per cent lower in late September 2002 than the high achieved over the past year.

Economic indicators released recently in the United States, suggest that the pace of economic recovery in the world's largest economy is slowing. Because the United States is an important destination for exports from many western European and Asian countries, taking around 20-30 per cent of their exports, a slowdown of economic activity, especially consumer spending and import demand, in the United States could adversely affect economic performance (including business investment) in other parts of the world.

Sharply lower stock market valuations will lead to a significant decline in household wealth and have the potential to adversely affect consumer spending. Since consumer spending accounts for around two-thirds of economic activity in the major world economies, significant declines in stock market valuations could result in renewed weakness in world economic activity. Furthermore, with retirees and those saving for retirement typically having a substantial portion of their savings invested in the share market, any prolonged downturn in that market can be expected to have significant effects on longer term spending and business investment.

World economic growth is assumed to be 2.3 per cent in 2002, before increasing to around 3 per cent in 2003 and 4 per cent in 2004 and 2005. This compares with growth of 2 per cent in 2001 and 4.4 per cent in 2000.

Over the medium to longer term, the prospects for world economic growth will depend heavily on continued technological innovation and growth in productivity.

While technological progress may temporarily slow in the short term as a result of slower economic growth, and hence weaker growth in company profits, the trend of technological advance is expected to resume over the medium to longer term, providing support for continued increases in productivity.

In a base case, it is assumed that growth in productivity over the medium to longer term will be slower than the high rates observed in the latter part of the 1990s. However, the longer term benefits from the substantial investment in productivity enhancement that has occurred in recent years is expected to be reflected in higher economic growth overall. Under this scenario, world economic growth is assumed to increase gradually from an average of 3.3 per cent a year in the five years to 2001, to around 3.7 per cent by 2010. Some slowing in productivity enhancing investment during the balance of this decade is assumed to be a key factor in economic growth moderating to around 3.5 per cent by 2020.

The above discussion notwithstanding, there is considerable uncertainty surrounding the outlook for growth in productivity over the longer term. In an alternative (high growth) scenario, it is assumed that the high rates of productivity growth achieved in the late 1990s will be maintained over the medium to longer term. Consequently, world economic growth under this scenario is expected to be higher than in the base case. In the high growth scenario, the world economy is assumed to grow by around 4.2 per cent in 2010 and 4.0 per cent in 2020.

In contrast, there remains a possibility that the recent slowdown in productivity growth could be permanent if investment in productivity enhancement weakens significantly. Under this scenario, world economic growth will be markedly slower than in the base case over the medium to longer term. In this low growth scenario, world economic growth is assumed to be 3.2 per cent in 2010 and 3 per cent in 2020.

Economic prospects in Australia

Despite the near term weaker global economic outlook, the performance of the Australian economy remains strong. The Australian economy grew strongly at a year on year rate of 3.8 per cent in the June quarter 2002, following an increase of 4.2 per cent in the March quarter. Factors contributing to this strong growth in the June quarter were higher private capital spending and household final consumption expenditure. These positive effects were partly offset by increased imports of goods and services and changes in private non-farm inventories.

Looking forward, growth in domestic demand is likely to be relatively robust, supported by higher non-farm activity. Nevertheless, a weaker economic performance in Australia's major trading partners could adversely affect trade performance. With a severe drought in rural Australia, both agricultural production and exports are projected to decline this year and, in the case of livestock, may be slow in recovery over the next two to three years. Economic growth in Australia is assumed to be 3.3 per cent in 2002-03, before increasing to 3.8 per cent in 2003-04. This compares with 3.8 per cent in 2001-02.

Over the past few years, economic growth in Australia has been generally higher than the average rates observed for the OECD region as a whole. A factor that has underpinned stronger economic performance in Australia than most other OECD countries is higher growth in productivity as a result of continued microeconomic reform. It is assumed that the process of microeconomic reform (and the resulting benefits) will continue in the Australian economy over the medium to longer term. Consequently, economic performance in Australia is expected to remain strong, with economic growth averaging around 3.5 per cent a year to 2020 (base case).

Economic performance in Australia will also be influenced by developments in the world economy. Under the high growth scenario, higher economic growth in the world economy is likely to flow through to higher rates of economic activity in Australia. Higher income growth in the major world economies, especially those in the Asia-Pacific region, is expected to provide further support for Australia's export performance. Under this scenario, Australia's economic growth is assumed to be stronger than in the base case, averaging around 4.0 per cent a year to 2020.

In contrast, under the low growth scenario, slower economic growth in the major world economies would be reflected in Australian economic performance. Economic growth in Australia is assumed to average around 3.0 per cent a year over the medium to longer term under this scenario.

Australian exchange rate

The exchange rate is one of the key domestic macroeconomic variables for Australia's primary industries. Because international contracts are mostly denominated in US dollars, significant movements in the Australian exchange rate, especially against the US dollar, will markedly influence the returns from commodity exports, as well as the prices of traded inputs to primary industries.

The Australian exchange rate, especially against the US dollar, is assumed to remain relatively weak in the near term, due mainly to the increased uncertainty surrounding the world economic outlook. In 2003, the Australian dollar is assumed to strengthen as the world economy picks up. The Australian dollar is assumed to average around US55c in 2002-03, compared with US52c in 2001-02 and US54c in 2000-01.

Over the medium to longer term, the Australian dollar is assumed to depreciate gradually as world commodity prices, in real terms, resume their long term downward trend. However, this tendency is likely to be countered by continued progress on microeconomic reform and increased productivity in the Australian economy, that should provide support for the Australian exchange rate. On balance therefore, the Australian dollar is assumed to average around US55c by 2020 in the base case.

Under the high growth scenario, stronger world economic growth is expected to lead to higher commodity prices on world markets than in the base case. Stronger economic growth in Australia under this scenario is likely to provide additional support for the Australian currency. The Australian dollar is assumed to average around US65c by 2020 under the high growth scenario.

Under the low growth scenario, weaker world economic growth is likely to result in a greater decline in world commodity prices (in real terms) than in the base case, thus adversely affecting Australia’s terms of trade. Consequently, the Australian dollar is assumed to be markedly weaker over the medium to longer term than in the base case. By 2020, the Australia dollar is assumed to average around US45c under the low growth scenario.

A major uncertainty surrounding the outlook for the Australian exchange rate is what happens with the US dollar. The US dollar has appreciated significantly over the past few years and there have been considerable debates about its sustainability. (For a discussion of the potential implications for the Australian commodity sector of a marked change in the value of the US dollar, see Penm et al. 2002).

3 Preliminary industry projections

Sugar

The GBR catchment area contains the vast bulk of the Australian sugar industry. In 2001-02, the area produced 4.2 million tonnes of sugar — 90 per cent of total Australian production. Production in the various GBR regions was Wide Bay-Burnett (635 000 tonnes), Mackay (1.1 million tonnes), Northern (1.1 million tonnes) and Far Northern (1.3 million tonnes). Note that sugar is not produced in the Fitzroy region.

However, total production for the GBR catchment region in 2001-02 was well below the record 5.1 million tonnes achieved in 1997-98, following a decade of expansion in the industry. Over the past four seasons, cane yields have been badly affected by weather damage, pests and plant diseases. The Northern region has been hardest hit with production in 2001-02 just over half of that recorded in 1997-98.

Apart from the fall in production, returns to farmers have also been adversely affected by low international sugar prices. Given that around 80 per cent of sugar produced in the GBR catchment region is exported, movements in international prices are a key determinant of GVP and GVA.

Projection assumptions

ABARE's economic model of the world sugar market, SUGABARE, was used to derive projections for world prices and sugar production in Queensland. The model consists of 22 regions or countries representing large exporters (Australia, Brazil, Cuba, the European Union, South Africa and Thailand); large importers (Canada, eastern Europe, countries of the former Soviet Union, Japan, Republic of Korea, Malaysia, Singapore and the United States); and a number of other trading or consuming countries or regions (China, India, north Africa, Persian Gulf, non-EU western Europe, other Asia and Pacific countries, other western hemisphere countries and Sub-Saharan Africa).

For each of the countries and regions in the SUGABARE model, behavioural equations are specified for production, consumption, stocks, some policy variables, the share of white sugar in both total imports and exports, and export equations where a region both exports and imports sugar. Exports from the pure exporters and importers of sugar are given as a residual of each individual sector. Detailed descriptions of the SUGABARE model may be found in Wong, Sturgiss and Borrell (1989) and Hafi, Connell and Sturgiss (1993).

In the base case international prices stage a moderate recovery from current low levels before continuing a longer term downward trend in real terms. The world indicator price for sugar is projected to be US6.6 c/lb in 2010 (measured in 2000-01 dollars) and to decline by a further 6 per cent to US6.2 c/lb by 2020. Assuming an exchange rate of $US0.55, this translates into average pool returns to the Australian industry of around $260 and $246 a tonne, respectively. The analysis also assumes a continuation of current international policy settings. Breaking down protection policies in major producing countries such as the United States, European Union and Japan offer potential for higher international prices. However, the reform process, to date, has been very slow.

Other factors that will influence international prices over the longer term include changes in people’s tastes and income levels, particularly in developing countries. Currency movements in Brazil — the world’s largest producer — as well as policy mandated fuel ethanol usage in that country and world demand for ethanol will also be important.

Another key factor affecting returns to GBR catchment area growers will be their ability to remain internationally competitive. Sugar cane yields over the past four years have been well below those achieved throughout much of the 1990s. Consequently, the Australian industry has lost market share to low cost exports from Brazil. Although this loss of market share has been largely due to severe weather events, there are ongoing problems with pests and fungal diseases in GBR catchment area crops. In the base case it is assumed that there will be a significant recovery in yields and that over the longer term yields similar to the average for the mid 1990s will be achieved. It is also assumed that the industry is able to make the productivity gains and cost savings necessary to maintain its international competitiveness.

For the respective higher/lower sugar prices facing Australian farmers, a domestic supply price elasticity of 0.16 has been used. ABARE research has shown that Australian sugar plantings respond quite slowly to changes in prices. A major reason is the comparative lack of opportunities to profitably substitute crops on any significant scale and, when sugar prices rise, there are major constraints against bringing new land into production. Some of these latter constraints relate to the cost and availability of irrigation water and to State legislation concerning environmental issues such as vegetation management and tree clearing.

Output

Projections for GVP and value added for sugar at the farm level are presented in tables G.6 and G.7. Value added projections for sugar processing are presented in table G.8.

In the base case for sugar, it is estimated that there will be a small decline in sugar areas across the GBR catchment region, with production increases coming from yield improvements. In the low world economic growth scenario, cane production is estimated to be 15 per cent lower in 2010 and 20 per cent lower in 2020. The outcome reflects the likelihood that land will be taken out of production and that sugar cane yields will be 10 per cent lower than in the base case, because of the reduced economic incentive to apply as many inputs such as fertiliser, pesticides and higher yielding varieties, to cane growing. In the high growth scenario, production is assumed to be 11 per cent greater than in the base case due to the supply response to higher prices and better productivity performance.

In making the GVP calculations, it is assumed that the returns to the Australian industry (delivered to the export terminal) will be split in the same proportion as currently applies, that is around 63 per cent to growers and 37 per cent to millers.

For value added projections for sugar at farm level, the relationship between farm sector GVA and GVP over the last five years — where GVA has averaged around 57 per cent of GVP — was used.

In developing the value added projections for sugar processing, an historical relationship between farm level GVP and sugar processing turnover at the state and Australian level was used in deriving turnover estimates for 2010 and 2020 across all scenarios. To derive estimates for turnover in the GBR catchment area and its statistical divisions, turnover data from ABS for those areas for 1996-97 were used. A similar historical relationship between industry value added and turnover at the state and Australian level was used to derive all the value added estimates for 2010 and 2020 across all scenarios in each of the statistical divisions.

Employment

Projections for sugar industry employment are presented at two levels— those employed in sugar growing (table G.9) and those employed in sugar processing (table G.10). The data for 2001 are taken from the ABS Census of Population and Housing.

The forward projections are based on sugar production associated with the different GVP scenarios presented above. It is assumed that labour productivity (that is, sugar output per unit of labour employed) will increase by 2 per cent a year at both the growing and milling stages. With production projected to rise by around on 1 per cent year, this translates into a decline in industry employment of around 1 per cent a year.

Table G.6 **Gross value of production projections for sugar at farm level**[a]

	2001	*2010*			*2020*		
		Base	*Low*	*High*	*Base*	*Low*	*High*
		$'000	$'000	$'000	$'000	$'000	$'000
Far North	182 873	235 025	165 597	303 239	254 265	171 009	328 062
Northern	176 946	254 778	179 514	328 725	275 634	185 382	355 635
Mackay	149 652	222 303	156 633	286 825	240 501	161 752	310 304
Wide Bay-Burnett	107 136	104 288	73 481	134 557	112 825	75 882	145 572
GBR catchment	616 606	816 395	575 224	1 053 345	883 226	594 026	1 139 574
Queensland	631 781	832 499	586 571	1 074 124	900 648	605 743	1 162 052
Australia	683 000	882 952	622 119	1 139 219	955 230	642 453	1 232 476

a In constant 2000-01 prices.

Table G.7 **Value added projections for sugar at farm level**[a]

	2001	*2010*			*2020*		
		Base	*Low*	*High*	*Base*	*Low*	*High*
		$'000	$'000	$'000	$'000	$'000	$'000
Far North	95 094	136 315	96 046	175 879	147 473	99 185	190 276
Northern	92 012	147 771	104 118	190 661	159 868	107 521	206 268
Mackay	77 819	128 936	90 847	166 358	139 491	93 816	179 976
Wide Bay-Burnett	55 710	60 487	42 619	78 043	65 439	44 012	84 432
GBR catchment	320 635	473 509	333 630	610 940	512 271	344 535	660 953
Queensland	328 526	482 850	340 211	622 992	522 376	351 331	673 990
Australia	355 160	512 112	360 829	660 747	554 033	372 623	714 836

a In constant 2000-01 prices.

Table G.8 **Value added projections for sugar processing**[a]

	2001	*2010*			*2020*		
		Base	*Low*	*High*	*Base*	*Low*	*High*
		$'000	$'000	$'000	$'000	$'000	$'000
Far North	43 657	56 438	39 766	72 819	61 058	41 066	78 780
Northern	43 657	56 438	39 766	72 819	61 058	41 066	78 780
Mackay	88 599	114 536	80 701	147 780	123 912	83 339	159 877
Wide Bay-Burnett	80 895	104 577	73 684	134 929	113 137	76 092	145 974
GBR catchment	256 808	331 990	233 917	428 347	359 166	241 562	463 411
Queensland	273 200	353 181	248 848	455 688	382 092	256 981	492 990
Australia	341 500	441 476	311 060	569 610	477 615	321 227	616 238

a In constant 2000-01 prices.

Table G.9 **Sugar cane employment projections**

	2001	2010			2020		
		Base	*Low*	*High*	*Base*	*Low*	*High*
		No.	No.	No.	No.	No.	No.
Far North	1 864	1 653	1 438	1 835	1 443	1 203	1 602
Northern	2 639	2 341	2 035	2 598	2 044	1 703	2 268
Mackay	2 657	2 357	2 049	2 616	2 057	1 715	2 284
Wide Bay-Burnett	1 579	1 401	1 218	1 555	1 223	1 019	1 357
GBR catchment	8 742	7 754	6 743	8 607	6 769	5 641	7 514
Queensland	9 183	8 145	7 083	9 041	7 111	5 926	7 893
Australia	9 855	8 741	7 601	9 703	7 631	6 359	8 471

Table G.10 **Sugar processing employment projections**

	2001	2010			2020		
		Base	*Low*	*High*	*Base*	*Low*	*High*
		No.	No.	No.	No.	No.	No.
Far North	1 118	992	862	1 101	866	721	961
Northern	1 511	1 340	1 165	1 488	1 170	975	1 299
Mackay	1 419	1 259	1 094	1 397	1 099	916	1 220
Wide Bay-Burnett	1 062	942	819	1 046	822	685	913
GBR catchment	5 116	4 538	3 946	5 037	3 962	3 301	4 397
Queensland	5 405	4 794	4 169	5 322	4 185	3 488	4 646
Australia	6 182	5 483	4 768	6 087	4 787	3 989	5 314

Beef

Queensland is the largest beef producing state in Australia, producing around 1 million tonnes of beef in 2001 — representing almost 50 per cent of total Australian beef and veal production.

Around 470 000 tonnes, or 47 per cent of Queensland beef production is produced within the GBR catchment. The Fitzroy region produced an estimated 35 per cent of beef in the GBR catchment area in 2001, making that region the largest beef producer in the study area. The Wide Bay-Burnett and Mackay regions were the second and third largest beef producing areas, accounting for approximately one third of total production in the GBR catchment. Beef production in the Far North region is lowest, accounting for 15 per cent of total output for the catchment area.

In 2001, the GVP of Australian beef and veal was approximately $6.2 billion, with Queensland accounting for almost half ($2.8 billion) of the GVP of beef.

In 2001, the gross value of beef production in the GBR catchment area was estimated at around $1.3 billion. Reflecting higher production, the GVP was highest in the Fitzroy and Wide Bay-Burnett regions, at approximately $544 million and $285 million respectively. The GVP was lowest in the Northern region, at $130 million in 2001.

Nationally, approximately $3.4 billion dollars was value added to the beef industry in 2001 (table G.12). Of this total, over half ($1.5 billion) was value added by the Queensland beef industry.

An estimated 40 000 people were employed in the beef industry in 2001 (table G.13). Beef industry employment in Queensland was less than half of this total, at around 17 000 people in 2001. In the GBR catchment area, around 7500 people were employed in the beef industry in 2001. Reflecting higher beef production, the Fitzroy region employed the largest number of people in the GBR catchment area — approximately 2600 people in 2001. Employment was lowest in the Far North region at around 1100 people.

Projection assumptions

In developing forward projections for the beef industry, the base data for 2001 was overlaid with national and broad regional ABARE projections of Australian agricultural activity. These projections of agricultural land use and livestock numbers were derived from the TRANSPLANT model (a dynamic, multiregion, multicommodity competitive equilibrium model) developed by ABARE. The TRANSPLANT model contains agricultural land resource constraints on cropping and grazing activity in the six temperate and tropical broadacre zones of ABARE's nationwide agricultural surveys. Time paths of annual projections are derived in the model for volume of production, consumption and trade, and for the price that balances all regional supplies with domestic and export demand for each agricultural commodity.

The beef industry component of the sector projections include data on cattle numbers, turnoff rates, beef production and prices. These data provided the basis for the GVP, industry value added and employment estimates reported here.

Output

Cattle numbers, cattle turnoff and beef production were projected to 2020 for Queensland, the GBR catchment area, and associated regions by applying percentage changes in total Australian cattle numbers and stock turnoff rates to state and regional estimates of cattle numbers. Cattle slaughter weights are projected to increase by 10 per cent to 2020 — mainly as a result of productivity gains such as — genetic improvement and better herd and pasture management, that allow stock to reach higher weights at an earlier age.

In real terms, beef prices are projected to continue their long run downward trend over the projection period as beef cattle numbers and beef production increase.

Three scenarios were generated for the GVP estimates, which are presented in table G.11. In the base case, beef prices are projected to decrease by 4 per cent to 2020 in real terms. Beef production is estimated to increase by 21 per cent over this period. GVP in the GBR catchment area is estimated to increase by 25 per cent to 2020.

Under the low growth scenario, the fall in real beef prices over the projection period is projected to be 2 per cent greater than in the base case. The GVP for beef in the GBR catchment is estimated to increase by 23 per cent over the projection period.

For the high growth scenario, the rate of decline in real beef prices is projected to be 2 per cent lower than in the base case over the period to 2020. GVP in the GBR catchment is estimated to increase by 28 per cent.

Estimates of value added by the beef producing industry are presented in table G.12. Beef industry value added for the base year is estimated to be around the average for the previous ten years at approximately 55 per cent of GVP. For the projection exercise, this proportion is assumed to increase by 0.8 per cent annually, reaching 64 per cent in 2020, as beef producers better tailor their livestock turnoff to feedlot and processor needs, and adopt improved marketing methods.

For the base case, value added by the beef producing industry in the GBR catchment is estimated to increase by 46 per cent to 2020. Under the low growth scenario, value added by the beef industry increases by 43 per cent to 2020, while for the high growth scenario, industry value added in the study area is projected to increase by 49 per cent over the projection period.

Employment

Projections for employment were estimated by using historical averages for employee ratios per head of cattle for Australia, Queensland and areas within the GBR region.

These ratios were then multiplied by percentage changes in stock numbers in order to project changes in employment. Following observed changes over the past five years, labour productivity in the beef industry was also assumed to increase by 1 per cent each year for the projection period.

Beef industry employment projections are presented in table G.13. Over the projection period, employment in the beef industry for the GBR catchment area is estimated to decrease by 12 per cent.

Table G.11 **Gross value of production projections for beef**[a]

	2001	*2010*			*2020*		
		Base	*Low*	*High*	*Base*	*Low*	*High*
		$'000	$'000	$'000	$'000	$'000	$'000
Far North	138 478	154 975	154 137	155 847	173 711	170 794	176 884
Northern	130 523	146 073	145 283	146 895	163 732	160 983	166 723
Mackay	153 919	172 256	171 324	173 225	193 081	189 839	196 607
Fitzroy	544 258	609 098	605 801	612 523	682 733	671 270	695 203
Wide Bay-Burnett	285 059	319 018	317 292	320 813	357 585	351 582	364 117
GBR catchment	1 252 238	1 401 420	1 393 836	1 409 303	1 570 843	1 544 468	1 599 534
Queensland	2 801 947	3 151 582	3 134 526	3 169 309	3 569 506	3 509 573	3 634 702
Australia	6 216 000	6 992 501	6 954 664	7 031 837	7 922 155	7 789 141	8 066 851

a In constant 2000-01 prices.

Table G.12 **Value added projections for beef**[a]

	2001	*2010*			*2020*		
		Base	*Low*	*High*	*Base*	*Low*	*High*
		$'000	$'000	$'000	$'000	$'000	$'000
Far North	76 163	91 573	91 078	92 089	111 158	109 291	113 188
Northern	71 788	86 313	85 846	86 799	104 772	103 013	106 686
Mackay	84 656	101 785	101 233	102 357	123 552	121 478	125 809
Fitzroy	299 342	359 910	357 962	361 934	436 882	429 546	444 861
Wide Bay-Burnett	156 782	188 505	187 485	189 565	228 819	224 977	232 999
GBR catchment	688 731	828 087	823 605	832 744	1 005 184	988 307	1 023 543
Queensland	1 541 071	1 862 242	1 852 163	1 872 716	2 284 130	2 245 780	2 325 849
Australia	3 418 800	4 131 811	4 109 449	4 155 050	5 069 395	4 984 279	5 161 986

a In constant 2000-01 prices.

Table G.13 **Beef employment projections**

	2001	*2010*	*2020*
	No.	No.	No.
Far North	1 097	1 042	963
Northern	1 230	1 169	1 080
Mackay	1 260	1 197	1 106
Fitzroy	2 608	2 478	2 291
Wide Bay-Burnett	1 274	1 211	1 119
GBR catchment	7 468	7 097	6 560
Queensland	16 483	15 785	14 704
Australia	38 568	36 692	33 961

Horticulture

A large number of horticultural crops are grown throughout Queensland, with the state producing an estimated 24 per cent of the nation's fruit and vegetable crops by value (table G.14). Many of these horticultural crops are grown in the GBR catchment with the Wide Bay-Burnett, Northern and Far North statistical divisions being the largest contributors in terms of gross value of horticultural production.

In the Wide Bay-Burnett region, vegetables grown include asparagus, capsicum/chillies/peppers, cucumbers, marrows/squash/zucchinis, pumpkins and tomatoes, while important fruit crops include oranges, mandarins, peaches, avocados, melons, macadamia, pawpaws and pineapples. The gross value of horticultural production in this region is estimated at around $224 million in 2000-01 with mandarins and tomatoes being the most valuable crops worth an estimated $42 million and $30 million respectively.

The total gross value of horticultural production in the Northern region is also estimated at around $224 million in 2000-01. The Northern statistical division produces around half of Queensland's mango crop valued at an estimated $31 million in 2000-01. Tomatoes are also a very important horticultural crop in the region, with producers growing close to 60 per cent of Queensland's tomato crop valued at an estimated $70 million. Other important horticultural crops in this region include beans, capsicums/chillies/peppers, melons, marrows/squash/ zucchinis, pumpkin and sweet corn.

Bananas are the most valuable horticultural crop produced in the Far North region. It produced around 95 per cent of Queensland's commercial banana crop in 2000-01 with an estimated gross value of $211 million. Other important horticultural crops produced in the Far North region include avocados, mangos, pawpaws, watermelons, potatoes and pumpkins. The total GVP of horticultural crops in this region in 2000-01 is estimated to have been $291 million, 24 per cent of the gross value of Queensland's horticultural crop production.

The Fitzroy and Mackay regions are less important in terms of horticultural production. Major crops grown in the Fitzroy region include watermelons, pumpkins, mandarins, mangoes, pawpaws and pineapples. In the Mackay region, mangoes are an important fruit crop, while marrows, squashes and zucchinis are important vegetable crops. The gross value of horticultural production in the Fitzroy region is estimated at around $35 million in 2000-01 and an estimated $19 million in the Mackay region.

The horticulture crop growing industry value added an estimated $707 million to Queensland's economy in 2000-01, while around $453 million was value added by horticultural producers in the GBR catchment area (table G.15).

There are few fruit and vegetable processing establishments in the GBR catchment area — four in the Wide Bay-Burnett region, five in the Far North region and two each in the Mackay and Northern regions — and value added statistics are not available at the regional level (table G.16). Therefore, value added estimates for the processing sector have only been provided for Queensland and for Australia. In 2000-01 an estimated $145 million was value added by the 53 fruit and vegetable processing establishments in Queensland, around 14 per cent of the value added by the fruit and vegetable processing industry nationally.

An estimated 20 000 people were employed in Queensland's horticultural industries in 2000-01 including producers, farm labour (paid and unpaid) and those employed in fruit and vegetable processing (table G.18). The state's fruit and vegetable processing sector employed an estimated 2152 people in 2000-01, 10 per cent of total horticultural sector employment (table G.17).

Almost half of these people were estimated to have been employed in the GBR catchment area with enterprises in the Far North region being the largest employers, employing around 4000 labour units. Horticultural enterprises in the Wide Bay-Burnett and Northern regions follow as the next largest employers of labour, employing around 3000 and 2800 people, respectively.

Projection assumptions

ABS estimates of production, GVP and gross unit value of production were obtained for fruit and vegetable crops in Queensland and Australia for the five years to 1999-2000. The latest available data for horticultural production by statistical division was that produced in the 1996-97 Agricultural Census. In order to estimate production by region, Queensland’s production for each of the horticultural crops in 1999-2000 was distributed across each of the regions according to their share of Queensland’s production in the Census year.

Projections for industry GVP are presented in table G.14. In the base case, modest growth in production areas or tree numbers is assumed over the projection period. This expansion in activity, combined with small annual yield improvements, ensures moderate growth in production for each of the horticultural crops. Under the low economic growth scenario much slower production growth results as reduced demand for horticultural products leads to lower producer prices in real terms. Producers respond to lower prices by reducing area planted of annual crops and by cutting inputs such as fertiliser usage and (possibly) some pest and weed management activities. Under the high growth scenario, faster production growth is projected via increased plantings and greater yield improvements for each horticultural crop. This scenario would be a possibility if access to water is increased, say through improved water delivery technology or more effective use of water trading by the Queensland horticultural industry.

Queensland’s horticulture production is currently oriented mainly to domestic markets, therefore exchange rate changes and other global macroeconomic assumptions are not expected to substantially affect producer prices for fruits and vegetables over the projection period. Under the base case, fruit and vegetable producer prices are assumed to remain relatively unchanged in real terms over the projection period, as the effect of cost reducing technological change on supply prices is offset by growing consumer demand. Under the low growth scenario, modestly lower producer prices in real terms are assumed over the projection period with supplies of produce rising only as a result of continuing yield improvements. Under the high growth scenario, producer prices are assumed to rise in real terms over the projection period, thus stimulating a greater increase in fruit and vegetable production.

Output

GVP projections to 2020 for Queensland, the GBR catchment area and each of the regions are presented in table G.14. Under the base case, with moderate production growth and producer prices keeping pace with inflation, gross value of horticultural production in the GBR catchment area is projected to rise by 38 per cent over the projection period to reach $1060 million by 2020.

Under the low economic growth scenario, with slower production growth as a result of falling real producer prices, gross value of horticultural production in the GBR catchment area is projected to rise by only 6 per cent to around $814 million at the end of the projection period.

Expansion in fruit and vegetable production encouraged by higher real producer prices under the high growth scenario, is projected to result in the GBR catchment region's gross value of horticultural production rising to $1350 million to 2020, a 76 per cent rise over the period.

Estimates of value added by the fruit and vegetable growing industries are presented in table G.15. Value added by Australia's agricultural industries over the past decade has averaged 55 per cent of GVP with growth in value added rising annually by an average of 0.8 per cent. The same proportion of value added has been assumed in this study for the GBR catchment area's horticultural industries and value added has been projected to grow at the rate of 0.8 per cent to 2020 as more producers adopt innovative ways of marketing their products, such as moving away from marketing bulk produce and moving toward marketing pre-packaged consumer ready products.

For the base case, value added by horticulture producers in the GBR catchment regions is projected to increase from $453 million in 2000-01 to around $672 million by 2020, a rise of 48 per cent. Under the low economic growth scenario, value added by producers is projected to rise by around 5 per cent over the period while higher production under the high growth scenario is estimated to result in value added rising by 89 per cent by 2020 to around $856 million.

As indicated earlier, absence of data by statistical division limits presentation of projections of value added by the fruit and vegetable processing sector to Queensland and Australia. Margins in the fruit and vegetable processing sector are assumed to remain unchanged over the projection period. As a result, value added by the processing sector is assumed to change in line with GVP projections. The projections for value added in fruit and vegetable processing are presented in table G.16.

Employment

Employment projections for the horticulture producing sector are presented in table G.17. Farm labour in each region is estimated as a proportion of the number employed on farm for the state as a whole apportioned according to each region's share of horticulture production. Labour productivity growth on farms is assumed to rise over the projection period by 0.5 per cent a year.

Under the base case, horticulture farm employment in the GBR catchment is projected to rise from around 10 700 people in 2000-01 to 14 250 people in 2020.

The Far North region is projected to be the largest employer, with over 5000 people by 2020. The Wide Bay-Burnett and the Northern regions follow as the next most important employers.

In the low growth scenario, employment in the GBR regions is projected to rise by 10 per cent to around 11 800 people by 2020. The high production growth scenario is projected to result in a 57 per cent growth in employment to close to 17 000 people by 2020.

Regional projections of employment in the fruit and vegetable processing sector have been estimated for only two of the statistical divisions in the GBR catchment for which data were available — the Wide Bay-Burnett and the Far North regions (table G.18). Labor productivity in the processing sector over the projection period is assumed to rise by an average of 1 per cent a year over the projection period, a figure consistent with observed historical changes in industry value added per person employed in the Queensland fruit and vegetable processing sector. The same rate of change in labour productivity was applied in projecting processing sector employment in the two statistical divisions in the GBR catchment.

Fruit and vegetable processing industry employment under the base case is projected to rise by 72 per cent from an estimated 69 people in 2000-01 to around 120 people in 2020. In the low growth scenario, processing sector employment in the GBR regions is projected to only employ a further 30 people by 2020, while the high production growth scenario is projected to result in an additional 100 jobs by 2020.

Table G.14 **Horticulture gross value of production projections**

	2001	*2010*			*2020*		
		Base	*Low*	*High*	*Base*	*Low*	*High*
	$'000	$'000	$'000	$'000	$'000	$'000	$'000
Far North	290 696	338 849	299 389	374 782	406 472	310 775	519 527
Northern	223 955	256 961	228 596	282 790	304 033	235 244	385 299
Mackay	19 009	21 643	19 253	23 819	25 494	19 699	32 341
Fitzroy	35 004	40 103	35 935	43 898	47 337	37 229	59 278
Wide Bay-Burnett	224 463	253 481	226 547	278 009	296 178	230 855	373 348
GBR catchment	766 808	888 487	787 170	980 747	1 060 122	814 409	1 350 400
Queensland	1 196 775	1 338 289	1 231 554	1 537 779	1 543 332	1 277 327	2 125 229
Australia	4 910 553	5 433 687	4 921 227	5 900 343	6 217 886	4 975 067	7 686 120

a In constant 2000-01 prices.

Table G.15 **Horticulture value added projections**

	2001	2010			2020		
		Base	*Low*	*High*	*Base*	*Low*	*High*
	$'000	$'000	$'000	$'000	$'000	$'000	$'000
Far North	171 776	197 899	168 510	218 884	257 081	180 699	328 581
Northern	132 338	150 976	129 724	166 150	193 446	138 212	245 149
Mackay	11 232	12 639	10 860	13 910	16 124	11 498	20 454
Fitzroy	20 684	23 467	20 358	25 687	29 997	21 917	37 561
Wide Bay-Burnett	132 638	148 581	128 446	162 959	188 010	135 679	236 998
GBR catchment	453 115	520 397	444 732	574 424	672 392	475 738	856 477
Queensland	707 187	783 973	695 724	900 978	978 870	745 818	1 348 382
Australia	2 901 700	3 196 933	2 799 021	3 455 482	3 961 750	948 396	4 875 574

[a] In constant 2000-01 prices.

Table G.16 **Fruit and vegetable processing value added projections**

	2001	2010			2020		
		Base	*Low*	*High*	*Base*	*Low*	*High*
	$'000	$'000	$'000	$'000	$'000	$'000	$'000
Queensland	144 804	161 927	149 012	186 064	186 736	154 551	257 143
Australia	1 009 426	1 116 963	1 011 620	1 212 890	1 278 164	1 022 687	1 579 789

[a] In constant 2000-01 prices.

Table G.17 **Horticulture employment projections[a]**

	2001	2010			2020		
		Base	*Low*	*High*	*Base*	*Low*	*High*
	No.	No.	No.	No.	No.	No.	No.
Far North	4 063	4 645	4 245	4 977	5 389	4 457	6 374
Northern	2 826	3 231	2 953	3 462	3 749	3 100	4 434
Mackay	160	183	167	196	213	176	251
Fitzroy	683	781	713	836	906	749	1 071
Wide Bay-Burnett	3 011	3 442	3 146	3 688	3 994	3 303	4 723
GBR catchment	10 744	12 282	11 225	13 159	14 250	11 784	16 853
Queensland	19 968	21 655	20 862	24 457	23 984	21 902	31 323
Australia	63 452	72 534	66 293	77 719	84 158	69 597	99 535

[a] Total paid and unpaid workers, including proprietors.

Table G.18 **Fruit and vegetable processing employment projections**

	2001	2010			2020		
		Base	Low	High	Base	Low	High
	No.	No.	No.	No.	No.	No.	No.
Far North	23	30	27	34	40	33	54
Wide Bay-Burnett	46	59	54	68	79	65	109
GBR catchment	69	89	82	102	119	98	163
Queensland	2 152	2 773	2 552	3 187	3 706	3 068	5 104
Australia	12 381	15 790	14 301	17 146	20 939	16 753	25 883

Commercial fishing

The major factors affecting development of the commercial fisheries sector are expected to be:

- catches remaining at levels consistent with the long term biological sustainability of target and byproduct species and consistent with community expectations regarding the impacts of fishing on the broader marine ecosystem;
- continued improvements in the effectiveness of fisheries management in capturing the economic and social benefits associated with the exploitation of wild fish stocks;
- changes in the rate of productivity improvement; and
- changes in output prices.

Most fisheries resources in Australia are fully or over-harvested, and there are very few opportunities to open up additional fisheries (FRDC 2001). Current exploitation of major species in Queensland fisheries is generally considered sustainable, however the potential for catches to increase seems limited (see Williams (2002) for a detailed discussion). Apart from any actions required to ensure sustainable exploitation of target species, there is potential for activity in commercial fisheries to be negatively impacted by a number of other factors, including community concern about the impact of fishing on other aspects of the marine environment (bycatch, impacts on marine mammals, impacts of trawling on seagrass beds etc).

Projection assumptions

Under the high scenario it is assumed that catch levels remain at current levels (an average of catches over the 1996-97 to 2000-01 period). Under the base case it is assumed that catches are 3 per cent lower in 2010-11 and 5 per cent lower in

2020-21 than currently. Under the low scenario it is assumed that catches in 2010-11 and 2020-21 are 5 per cent and 10 per cent lower than currently. These assumptions have been applied at the national, state and regional levels.

Due to fluctuations in annual catches, the average catch over the period 1996-97 to 2000-01 for major species groups, by region and for the Queensland and national totals, have been used in projecting growth to 2010-11 and 2020-21. Catch shares by Statistical Division have been projected based on average share over the 1996-97 to 2000-01 period.

The effectiveness of fisheries management in capturing the potential economic benefits from the exploitation of fisheries resources will play a significant role in the level of value added associated with commercial fishing. While fisheries management policies will affect the gross value of fisheries production through catch levels (and possibly catch composition), the most significant impact will be through their effect on aggregate industry costs. Management policies that effectively constrain catches to efficient levels while allowing industry participants to minimise costs (and maximise revenues) allow the economic benefits of commercial fishing activities to be maximised (see Rose (2002) for more detail).

Aggregate fishing costs will also be affected by conditions in relevant input markets and the structure of the fishing industry. Lower long term output prices can be expected to lead to industry restructuring due to less efficient operators exiting the industry.

Under the base case it is assumed that general productivity increases, input price movements and fisheries management policies evolve in a manner that allows fishing costs to decrease at a rate of 2 per cent a year in real terms over the projection period. Under the high growth scenario it is assumed that further improvements in management policies more than offset the impact of higher input prices and allow fishing costs to decrease at a rate of 2.5 per cent a year. Under the low growth scenario, fishing costs are assumed to decrease at a rate of 3.8 per cent a year due to the fisheries management cost induced change assumed under the base case and an additional decrease associated with further restructuring due to significantly lower output prices.

Fisheries product prices are assumed to decrease in real terms by around 1.4 per cent a year under the base case. Under the high and low scenarios, prices are assumed to decrease by around 0.6 and 3.6 per cent a year, respectively, in line with assumed exchange rates and world economic growth under each scenario. The rationale behind the baseline price projection has been explained in detail above. It is assumed that exchange rate movements translate directly to fisheries product prices. A large proportion of national and Queensland fisheries production is exported and Australia is also a significant importer of fisheries products.

Output

GVP projections are presented in table G.19. Projections of real price declines result falling GVP under each scenario.

Value added projections for Queensland are presented in table G.20. Estimates for 2000-01 and projections are based on fishery survey data provided by Queensland DPI.

In the base case, assumed cost reductions (due to improved fisheries management and general productivity gains) offset declines in real prices and result in value added increasing by around 1.3 per cent a year over the projection period. In the high scenario, improved fisheries management, an assumed marginal increase in productivity gains, and higher receipts due to favourable world price and exchange rate movements, results in a significant increase in value added of around 5.3 per cent a year.

Under the low scenario, value added is assumed to remain relatively constant throughout the projection period — industry restructuring due to low prices is assumed to deliver productivity increases so that current industry profits remain at around current levels. Economic returns from fisheries management in Queensland at levels lower than those implied by the QDPI surveys are not considered sustainable in the long term (value added is not a measure of economic return as no allowance is made for the value of owner/operator labour or a return on capital investment). Over the projection period, average annual cost decreases of around 3.8 per cent are required under the low scenario to maintain value added at around the 2001 level.

Value added projections at a national level are not available as relevant historical data exists for relatively few fisheries.

Employment

Employment projections are presented in table G.21. Employment data for 2001 was provided by QDPI. Under each scenario employment is projected to fall as productivity gains are achieved and industry restructuring takes place. Under the base case an average annual increase in labour productivity of 1.5 per cent is assumed. Under the high and low scenarios, increases of 2 and 2.25 per cent, respectively, are assumed. In the base case and low scenario, further employment falls are projected due to assumed lower catches.

Table G.19 **Commercial fishing gross value of production projections[a]**

	2001	*2010*			*2020*		
		Base	*Low*	*High*	*Base*	*Low*	*High*
	$'000	$'000	$'000	$'000	$'000	$'000	$'000
Far North	47 687	43 450	33 866	53 902	36 533	27 008	47 678
Northern	19 174	19 251	15 004	23 881	16 186	11 966	21 124
Mackay	22 617	20 809	16 219	25 815	17 497	12 935	22 834
Fitzroy	27 869	27 160	21 169	33 693	22 836	16 882	29 803
Wide Bay-Burnett[b]	476	432	392	548	363	346	531
GBR catchment	117 823	111 103	86 651	137 840	93 415	69 137	121 970
Queensland	254 569	191 851	146 406	239 001	159 306	113 765	211 403
Australia	1 831 455	1 474 132	1 114 251	1 773 484	1 237 452	888 615	1 568 697

a In constant 2000-01 prices. **b** Figures are for the portion of the Wide Bay-Burnett Statistical Division within the study area. It is assumed that 5 per cent of total Wide Bay-Burnett activity occurs in the study region.

Table G.20 **Commercial fishing value added projections[a]**

	2001	*2010*			*2020*		
		Base	*Low*	*High*	*Base*	*Low*	*High*
		$'000	$'000	$'000	$'000	$'000	$'000
Far North	9 122	10 788	8 767	18 044	11 783	8 769	25 162
Northern	4 467	5 786	4 703	9 207	5 963	4 419	12 987
Mackay	3 494	4 227	3 431	7 223	4 675	3 464	10 197
Fitzroy	4 908	5 786	4 703	9 207	6 308	4 697	13 429
Wide Bay-Burnett[b]	327	388	316	653	425	316	913
GBR catchment	22 318	26 584	21 598	45 775	29 155	21 666	62 689
Queensland	41 606	49 519	40 232	83 337	54 283	40 345	116 625

a In constant 2000-01 prices. **b** Figures are for the portion of the Wide Bay-Burnett Statistical Division within the study area. It is assumed that 5 per cent of total Wide Bay-Burnett activity occurs in the study region.

Table G.21 **Commercial fishing employment projections**

	2001	2010			2020		
		Base	*Low*	*High*	*Base*	*Low*	*High*
	No.	No.	No.	No.	No.	No.	No.
Far North	691	572	523	564	450	394	461
Northern	294	244	223	240	191	168	196
Mackay	363	300	274	296	236	207	242
Fitzroy	322	266	243	263	209	184	215
Wide Bay-Burnett	22	18	16	18	14	12	14
GBR catchment	1 691	1 400	1 280	1 382	1 100	965	1 129
Queensland	3 771	3 121	2 853	3 081	2 454	2 153	2 518

[a] Figures are for the portion of the Wide Bay-Burnett Statistical Division within the study area. It is assumed that 5 per cent of total Wide Bay-Burnett activity occurs in the study region.

Seafood processing

Seafood processing statistics are available at the national level through the annual ABS survey of manufacturing establishments (ABS 2001c). Reliable estimates at a state level are not available.

In 1999-2000 turnover of Australian seafood processing establishments was estimated at $1270 million. Value added was estimated at $270 million and employment at 4179 people. If the ratio of each of these variables to the gross value of Australian commercial fisheries and aquaculture production remains constant, then, in real terms, turnover could be expected to increase to $1440 million by 2010 and $1726 million by 2020-21, value added to $306 million (2010) and $367 million (2020) while employment would be expected to increase to 4739 (2010) and 5681 (2020).

Recreational fishing

The major factors influencing growth in the recreational fishing sector will be population growth and changes in the recreational fishing participation rate (the proportion of the population that fishes for recreation in a particular year).

Projection assumptions

The ABS has projected population growth in Australia under a variety of assumptions (ABS 2000) — these projections have been used in projecting recreational fishing activity in 2010 and 2020. The Australian and Queensland populations are projected to grow at an average rate of 0.8 per cent and 1.4 per cent a year, respectively, over the projection period (ABS Series II population projections). Between 2001 and 2020 the Australian population is projected to increase by 3.52 million people and the Queensland population by 1.18 million. The ABS Series II population projections for Australia, Queensland and 'Balance of Queensland' (ie Queensland excluding Brisbane) are used in the base case projection. The ABS series I and III population projections are used for the low and high case projections, respectively. It is assumed that the rate of population increase, by age group, is constant across Statistical Divisions and is equal to that of Queensland as projected by the ABS.

To the extent that recreational fishing participation rates vary across age groups, changes in the age distribution of the population will also have some impact on the level of recreational fishing undertaken. For example, in Queensland, the proportion of the population aged between 5 and 49 is projected to fall from 66 per cent in 2001 to 57 per cent in 2020 (ABS series II). The proportion of the population aged over 50 years is projected to rise from 27 to 38 per cent over the same period. In 2001 the average participation rate in the 5 to 49 years group was 28 per cent while it was only 16 per cent in the over 50 years group.

Recreational fishing participation rates in Queensland appear to have been falling in recent years. It is estimated that in 1996, 28.1 per cent of the Queensland population fished recreationally, subsequent estimates have the rate falling to 26.1 per cent in 1998 and to 24.6 per cent in 2001 (DPI RFISH survey data). Significant falls in participation have been estimated for ages 29 and below. While there has not been a detailed study as to what is driving this change, it seems likely an important factor would be the increasing range of other recreational opportunities available.

It is assumed that recreational fishing participation rates will continue to fall over the projection period and that they will fall at a faster rate for younger age groups (at 1.5 per cent a year in the base case). Participation rates are assumed to fall faster under the low scenario and slower under the high scenario. The participation rate assumptions for Queensland (total) are outlined in table G.22.

The participation rate for the study area in 2001 has been estimated at 32.5 per cent (from DPI data), which is higher than that of Queensland as a whole. It is assumed that participation rates in the study area change at the same average annual rate as assumed for Queensland (total). In calculating recreational fishing expenditure by statistical division DPI estimates of average expenditure by fisher by statistical division for 2001 have been used. It is assumed that average expenditure per fisher remains constant in real terms throughout the projection period.

Recreational fishing expenditure

Recreational fishing expenditure in Queensland is expected to remain at around $500 million in real terms under the base case (table G.23). Declining participation rates are offset by an increase in the population. For the study area, the base case projections also involve expenditure remaining at around current levels in 2010 and 2020.

Table G.22 **Queensland recreational fishing participation rate assumptions**

	2001[a]	*2010*			*2020*		
Age		*Base*	*Low*	*High*	*Base*	*Low*	*High*
	%	%	%	%	%	%	%
5 to 14	37	32	31	35	28	25	32
15 to 19	27	23	22	25	20	18	23
20 to 29	24	20	19	22	18	16	20
20 to 39	27	23	22	25	20	18	23
40 to 49	25	23	22	24	21	19	23
50 to 59	23	23	22	23	23	21	23
60 and over	12	12	11	12	12	11	12

a Derived from QDPI RFISH data.

Table G.23 **Recreational fishing expenditure projections**[a]

	2001[b]	*2010*			*2020*		
		Base	*Low*	*High*	*Base*	*Low*	*High*
	$'000	$'000	$'000	$'000	$'000	$'000	$'000
Far North	72 313	73 181	67 531	80 877	73 133	62 382	88 473
Northern	54 434	55 087	50 834	60 881	55 051	46 958	66 598
Mackay	35 833	36 263	33 464	40 077	36 240	30 912	43 841
Fitzroy	21 366	21 622	19 953	23 897	21 608	18 432	26 141
Wide Bay-Burnett[c]	2 808	2 842	2 623	3 141	2 840	2 423	3 436
GBR catchment	186 755	188 966	174 405	208 873	188 873	161 107	228 489
Queensland	500 326	502 323	462 645	550 493	505 454	429 948	603 785

a In constant 2000-01 prices. **b** QDPI RFISH data. **c** Figures are for the portion of the Wide Bay-Burnett Statistical Division within the study area. It is assumed that 5 per cent of total Wide Bay-Burnett activity occurs in the study region.

Aquaculture

The major factors affecting the development of the aquaculture sector are expected to be:

- steady increases in aquaculture production of prawns, barramundi, redclaw crayfish and other freshwater species such as silver perch, jade perch and Murray cod, and hatchery output;
- changes in output prices; and
- increased productivity improvement.

Over the period 1996-97 to 2000-01, production of farmed prawns increased by 86 per cent, production of farmed barramundi by 63 per cent, and production of farmed redclaw crayfish by 38 per cent. Most of the prawns farmed are black tiger prawns. Of the other main prawn species that are farmed, production of banana prawns is increasing, while production of kuruma prawns has fallen.

Projection assumptions

Although there have been few new recent approvals for prawn farms, several large new developments are in the proposal stage. Farmed prawn production in Queensland is projected to continue to increase over the next two decades. Techniques for minimising nutrient outflows from farms are being trialed. If these trials are successful it is expected that new farms will adopt such techniques. Consequently, appreciable increases in farmed prawn production could occur without appreciably increasing nutrient outflows from farms.

Due to the controlled conditions in which they are produced, Australian farmed prawns are of high quality and have considerable potential for export as well as potential to displace imports on the domestic market. Australia's total consumption of prawns is of the order of 20 000 tonnes a year, of which around half is imported from Thailand, Vietnam, India and Indonesia. The main overseas markets for prawns such as Japan, Europe and North America are demanding product free of contaminants and Australian consumers are likely to follow suit in this regard.

Farmed barramundi production is expected to jump significantly over the next few years as some of the bigger farms start to sell larger fish in fillet form. Although farmed barramundi in Australia faces strong competition from imports, especially of Nile perch, barramundi has secured a profile on the domestic market and demand is expected to continue to increase.

Production of farmed redclaw crayfish is expected to increase steadily in the next few years as larger producers come in with more capital. Most of the redclaw produced is sold on the Queensland market, however, sales on the export market and to the southern states are expected to increase as production increases.

Expected trends in fish prices were discussed in the section on commercial fishing. At the assumed exchange rates, nominal prices in Australian dollars are projected to trend slightly upward over the 20 year projection period. However, given the assumed rate of inflation over the projection period, real prices are expected to trend slightly down.

Refinement of existing fish farming techniques, together with increased scale of production units, is expected to lead to further reductions in the number of labour units employed per dollar of production over the next 20 years.

Output

Based on projected production, prices, and productivity, the real value, at the farm gate, of aquaculture production in the study area is projected to rise from $41 million in 2000-01 to $98 million in 2010 and $225 million in 2020 (table G.24). This is a considerable real increase but one which is expected to mirror future trends in aquaculture development in Australia and the world in the next two decades.

The real value of production in the study area is expected to continue to constitute about three quarters of the value of Queensland's aquaculture production, while Queensland's share of Australian aquaculture production is projected to increase from 7-8 per cent currently to around 15 per cent. It should be noted that the projected real aquaculture GVP for Australia shown in table G.24 is not directly comparable with the government/industry target of $2.5 billion in aquaculture product sales by 2010. The latter is expressed in nominal dollars and measures value at a point generally further along the value chain than at the producer's gate.

Under the low economic growth scenario, aquaculture real GVP in the study area is estimated to be $194 million in 2020, compared with the baseline projection of $225 million. Under the high growth scenario, real aquaculture GVP is estimated to be close to $280 million.

Employment

In 2000-01, the number of labour units used in the aquaculture sector in the study area (that is, full time employment plus the full time equivalent of casual labour) was estimated to be 423 people (table G.25). Although some further reduction in the number of labour units employed per dollar of production is expected over the next twenty years, because of significant increases in production, employment in the aquaculture sector in the study area is projected to rise to nearly 1100 people by 2010 and to around 2500 people by 2020.

Table G.24 **Aquaculture gross value of production projections**[a]

	2001	2010			2020		
		Base	*Low*	*High*	*Base*	*Low*	*High*
	$m	$m	$m	$m	$m	$m	$m
Far North	17	41	35	50	94	81	117
Northern	12	28	24	34	65	56	81
Mackay	6	16	13	19	36	31	45
Fitzroy	0	1	1	1	2	2	3
Wide Bay-Burnett	6	12	10	14	27	23	33
GBR catchment	41	98	82	118	225	194	279
Queensland	56	130	109	157	300	258	372
Australia	746	1 275	1 032	1 485	2 004	1 726	2 484

a In constant 2000-01 prices; rounded to the nearest million.

Table G.25 **Aquaculture employment projections**

	2001	2010			2020		
		Base	*Low*	*High*	*Base*	*Low*	*High*
	No.	No.	No.	No.	No.	No.	No.
Far North	156	461	450	473	1 057	1 006	1 111
Northern	124	319	311	326	730	695	767
Mackay	49	176	171	180	403	383	423
Fitzroy	16	11	11	11	25	24	26
Wide Bay-Burnett	78	132	129	135	302	288	317
GBR catchment	423	1 098	1 071	1 126	2 518	2 396	2 645
Queensland	589	1 464	1 429	1 501	3 357	3 194	3 527

Mining

Based on ABS data (ABS 2002a) and ABARE estimates for states and industries not covered by the ABS, the gross value of Australian mineral production in 2000-01 is estimated to be around $51.8 billion (table G.26). The value of Queensland's mineral production was $10.9 billion, giving it a 21 per cent share of the total and making it the second largest mineral producing state in Australia. (Western Australia is the largest producing state, contributing around 45 per cent of the total value of Australian mine production).

In Queensland, black coal and metal mining dominate. In 2000-01, the value of Queensland's black coal production was $6234 million, or 57 per cent of the total value of Queensland mineral production (table G.27). The value of Queensland's metal mine production was $3751 million, or 34 per cent of the total. In volume terms, Queensland produced 54 per cent of Australia's black coal.

The bulk of Queensland's coal — around 97 per cent — is produced in the GBR catchment area, with two statistical divisions, Fitzroy and Mackay, contributing over 90 per cent of the GBR region's total value of coal production. The value of coal production in these regions in 2000-01 was $2687 million and $2871 million respectively. Around 17 per cent by value ($625 million) of Queensland's metal mining production came from the GBR catchment area. Metal mining production is concentrated in the Northern and Far North statistical divisions with bauxite and copper/gold the main products.

Based on ABS 1999-2000 data (ABS 2001e), value added in the Australian mining industry in 2000-01 is estimated to be $34.2 billion (table G.28). (More recent ABS data for 2000-01 were not used because they are not available on an establishment basis and provide no state disaggregation). Queensland's contribution was estimated to be $6327 million, or 19 per cent of the national total. The GBR catchment region is estimated to account for just over $4 billion, or 63 per cent of the Queensland total. Within the GBR catchment, the Fitzroy and Mackay regions combined contributed around 83 per cent of value added for the GBR catchment.

Using ABS labour force data, employment in the Australian mining industry in 2000-01 is estimated to be 78 000 (table G.30). (ABS employment data from the Mining Census were not used as they appear to exclude contractors and are not on the same basis as data provided by the DNRM on a regional basis). Based on DNRM data, Queensland mining industry employment was estimated to be 18 358 (24 per cent of the Australian total) and GBR catchment area employment was estimated to be 11 929 (65 per cent of the Queensland total). The Fitzroy and Mackay regions combined contributed an estimated 75 per cent of total GBR employment.

Projection assumptions

The size of the coal industry relative to other mining in Queensland, and particularly in the GBR catchment, means that overall mining industry trends in Queensland and the regions will be heavily influenced by expected coal industry developments. Given the importance of the coal industry, and that it is expected to be subjected to somewhat different demand conditions to other minerals, coal projections are provided separately from mining.

Melanie et al. (2002) provided a basis for the coal projections and was supplemented by other ABARE reports including Dickson et al. (2001) and privately commissioned research. For other minerals, projections were based on internal assessments of possible future mining developments in Queensland and the GBR region and expected trends in real prices for the relevant commodities.

The base case projections for coal assume an annual 1.7 per cent increase in production to 2010, followed by a slower increase of around 1 per cent a year between 2010 and 2020. The slower growth beyond 2010 reflects an expected moderation in Asian coal import demand in line with some easing in regional economic growth and an expected decrease in coal's share of total energy use. For the projection period as a whole, Queensland was assumed to retain its current share of Australian production and current GBR regional production shares were assumed to be maintained. Queensland production is projected to increase from 138 million tonnes in 2000-01 to 164 million tonnes in 2010 and 181 million tonnes in 2020. The GBR catchment region's share of this production, as a whole, is 97 per cent.

Coal prices are based on average unit prices per tonne in 2000-01 provided by DNRM ($45/tonne). Real prices reflect historical trends since 1980-81. On this basis, average real coal prices are assumed to decline by 27 per cent to $32.80 a tonne in 2020. The global market, especially for thermal coal, is highly competitive and technological change in the industry means producers are likely to continue to achieve substantial cuts to production costs.

Under the low growth scenario average prices remain the same, but coal production is projected to grow at 1.5 per cent a year from 2001 to 2010 and at 0.6 per cent a year between 2010 and 2020. In the high growth scenario, average real prices are projected to decline at a slower rate and coal production is assumed to grow at 1.85 per cent a year from 2001 to 2010 and at 1.5 per cent a year from 2010 to 2020.

GVP projections for other minerals in Queensland and the GBR catchment are based on 2000-01 production data (volume and value) published by DNRM (2002b) and on regional data supplied separately by DNRM. Projections for the major Queensland commodities such as base metals, gold and petroleum, and commodities important to the GBR region such as bauxite and magnesite, were made individually.

Base case production projections for other minerals were developed using ABARE's internal database and known and likely expected future developments across the full range of commodities produced in Queensland and in the GBR catchment area. A broad assumption is overall mineral reserves will be sufficient to sustain projected production volumes. Examples of expected developments over the projection period include: an increase in MIM's copper mine production to 400 000 tonnes a year; the commencement of the Mount Garnet mine; an expected large increase in magnesite mining to underpin magnesium metal production and the development of other magnesium based products; and a substantial increase in coal seam methane extraction. Individual commodity prices are projected forward at rates that take into account historical declines in real prices.

Under the low growth scenario, average real commodity prices for other minerals were assumed to decline at the same rate as in the base case, but production growth rates were lower. In the high growth scenario, average real commodity prices are projected to decline at a slower rate and production growth rates are assumed to be higher than in the base case.

GVP projections for other minerals for Australia were based on ABS mineral production data for Australia (ABS 2002a). However, ABS data exclude the value of oil and gas production in Victoria and the value of Tasmania’s mineral production. The final base data used in the projections include ABARE estimates of GVP for these sectors.

Output

In the base case, GVP for Australian mining increases by 1 per cent a year in real terms (table G.26). This rate of increase is slower than in the recent past and reflects several offsetting assumptions. On the downside, these include: slower growth in coal production; declining crude oil and gold production; significantly lower crude oil prices than in the recent past; and slower growth in the rate of increase in lead and zinc production. Offsetting rises include: substantial increases in the production of natural gas and LNG; copper; iron ore; nickel; and mineral sands.

Under the high growth scenario, Australian minerals GVP is projected to increase at 1.5 per cent a year and in the low growth case, by 0.5 per cent a year.

In the base case, real GVP in the GBR catchment area increases marginally by 2010 but decreases by around 2 per cent by 2020. With coal continuing to dominate total GVP from the GBR region throughout the projection period, these movements mainly reflect the projected coal production and price assumptions (table G.27). The high and low growth scenarios mainly reflect developments in the coal industry — as outlined earlier.

For Queensland, the base case real GVP is estimated to decline by 4 per cent in 2010 and by a further 6 per cent in 2020. While these outcomes partly reflect the coal assumptions they also reflect the assumed decline in real GVP for base metals (copper, lead and zinc), which make up a significant proportion of the non-coal GVP in Queensland. While the volume of production of all three base metals is projected to increase, particularly copper, the assumed decline in real prices for these metals more than offsets the revenue effects of the projected production increases. The high and low growth scenarios reflect the high and low growth assumptions for coal, as well as the range of price and production volumes for the important non-coal mineral commodities.

Value added projections for the mining industry are based on 1998-99 and 1999-2000 value added data (ABS 2001e) (tables G.28 and G.29). (Data from ABS (2002a) were not used because they are on an 'enterprise' basis). For the purposes of these projections, it has been assumed that industry value added varies in accordance with GVP in line with the ratios of value added to turnover by industry in the ABS data. (Separate value added to turnover ratios are available from ABS data only for coal mining, metal mining and total Queensland mining). On this basis, movements in the value added projections are broadly the same as movements in the GVP projections.

Employment

Employment projections for the GBR region and Queensland are based on historical employment data from DNRM Queensland and assumed productivity increases (tables G.30 and G.31). The assumed productivity increases for coal are different from those for Other mining. The labour productivity growth for both groups of industries are assumed to be the same for the base, high and low growth scenarios. This is because the mining industry must compete in the global market for almost all of its output, and the competitive pressures are likely to remain equally as intense regardless of world economic growth.

Coal employment projections (table G.31) were based on productivity rates assumed in ABARE studies. These indicate productivity growth of 5 per cent to 2010, falling to 2 per cent between 2010 and 2020. These rates are significantly below recent high productivity increases, which would appear not to be sustainable over the long term.

Labor productivity growth for other minerals industries in Queensland (mainly metal mining) was assumed to be 2 per cent over the whole projection period. This rate is lower than for coal mainly because of the physical constraints of metal mining, a significant proportion of which is by underground mining methods. The productivity growth for Australia was assumed to be 3.2 per cent over the projection period. This rate takes into account the coal productivity rate as well as the assumption that there is likely to be scope for productivity rises in some non-Queensland based industries such as iron ore and liquefied natural gas which are relatively capital intensive.

Table G.26 **Mining gross value of production projections**[a]

	2001	2010			2020		
		Base	*Low*	*High*	*Base*	*Low*	*High*
	$m	$m	$m	$m	$m	$m	$m
Far North	271	271	267	282	266	250	297
Northern	755	757	745	786	741	698	827
Mackay	2 871	2 879	2 831	2 989	2 816	2 656	3 146
Fitzroy	2 840	2 847	2 801	2 957	2 785	2 627	3 112
Wide Bay-Burnett	173	173	171	180	170	160	190
GBR catchment	6 910	6 928	6 814	7 194	6 777	6 392	7 571
Queensland	10 909	10 442	9 842	11 539	9 813	8 976	11 789
Australia	51 754	56 811	54 872	58 809	62 755	57 678	68 251

a In constant 2000-01 prices.

Table G.27 **Coal mining gross value of production projections**[a]

	2001	2010			2020		
		Base	*Low*	*High*	*Base*	*Low*	*High*
	$m	$m	$m	$m	$m	$m	$m
Far North	0	0	0	0	0	0	0
Northern	413	403	397	410	393	371	424
Mackay	2 871	2 803	2 757	2 849	2 733	2 578	2 947
Fitzroy	2 687	2 623	2 580	2 666	2 558	2 412	2 759
Wide Bay-Burnett	129	126	124	128	123	116	132
GBR catchment	6 100	5 955	5 857	6 052	5 806	5 476	6 262
Queensland	6 234	6 086	5 986	6 185	5 934	5 597	6 400
Australia	11 610	11 338	11 152	11 524	11 055	10 448	11 802

a In constant 2000-01 prices.

Table G.28 **Mining value added projections**[a]

	2001	2010			2020		
		Base	*Low*	*High*	*Base*	*Low*	*High*
	$m	$m	$m	$m	$m	$m	$m
Far North	157	157	155	163	154	145	172
Northern	438	439	432	456	429	405	480
Mackay	1 665	1 670	1 642	1 734	1 633	1 540	1 825
Fitzroy	1 647	1 651	1 624	1 715	1 616	1 524	1 805
Wide Bay-Burnett	100	101	99	104	98	93	110
GBR catchment	4 008	4 018	3 952	4 172	3 931	3 707	4 391
Queensland	6 327	6 056	5 708	6 693	5 691	5 206	6 838
Australia	34 158	37 495	36 215	38 814	41 418	38 067	45 046

a In constant 2000-01 prices.

Table G.29 **Coal mining value added projections**[a]

	2001	2010			2020		
		Base	*Low*	*High*	*Base*	*Low*	*High*
	$m	$m	$m	$m	$m	$m	$m
Far North	0	0	0	0	0	0	0
Northern	238	233	229	236	227	214	245
Mackay	1 657	1 617	1 591	1 644	1 577	1 487	1 701
Fitzroy	1 550	1 513	1 489	1 538	1 476	1 392	1 592
Wide Bay-Burnett	74	73	71	74	71	67	76
GBR catchment	3 520	3 436	3 380	3 492	3 350	3 160	3 613
Queensland	3 597	3 511	3 454	3 569	3 424	3 229	3 693
Australia	6 232	6 086	5 986	6 185	5 934	5 608	6 335

a In constant 2000-01 prices.

Table G.30 **Mining employment projections**

	2001	2010			2020		
		Base	*Low*	*High*	*Base*	*Low*	*High*
	No.	No.	No.	No.	No.	No.	No.
Far North	1 016	1 208	1 187	1 227	1 202	1 135	1 277
Northern	1 368	1 385	1 362	1 407	1 325	1 250	1 407
Mackay	4 190	3 081	3 030	3 131	2 793	2 634	2 967
Fitzroy	4 752	4 169	4 100	4 237	3 831	3 614	4 069
Wide Bay-Burnett	603	639	628	649	621	586	659
GBR catchment	11 929	10 496	10 321	10 665	9 783	9 230	10 392
Queensland	18 358	15 985	14 903	18 200	14 726	13 326	18 178
Australia	78 000	79 060	76 362	81 840	81 566	74 967	88 709

Table G.31 **Coal mining employment projections**

	2001	2010			2020		
		Base	*Low*	*High*	*Base*	*Low*	*High*
	No.	No.	No.	No.	No.	No.	No.
Far North	0	0	0	0	0	0	0
Northern	711	565	556	574	512	483	544
Mackay	4 180	3 320	3 266	3 375	3 009	2 838	3 196
Fitzroy	4 251	3 461	3 404	3 518	3 136	2 958	3 332
Wide Bay-Burnett	210	85	84	86	77	73	82
GBR catchment	9 352	7 431	7 309	7 553	6 734	6 352	7 154
Queensland	9 661	7 677	7 551	7 803	6 957	6 562	7 390
Australia	17 256	14 302	14 068	14 537	12 962	12 231	13 846

Mineral processing

Mineral processing is defined as including the following ANZSIC industries: 251 Petroleum refining; 252 Petroleum and coal product manufacturing n.e.c; 271 Iron and steel manufacturing; and 272 Basic non-ferrous metal manufacturing.

Based on ABS (2001b), ABARE estimated the Australian mineral processing GVP at $32.1 billion in 2000-01 (table G.32). The value of Queensland's mineral processing production is estimated at $7.5 billion — around 23 per cent of the total Australian mineral processing GVP.

In Queensland, non-ferrous metal manufacturing is the major industry. In 2000-01, the GVP of Queensland's non-ferrous metal production was an estimated $4509 million — around 60 per cent of Queensland's mineral processing GVP. The remaining 40 per cent of the GVP was in petroleum refining and iron and steel manufacturing.

The bulk of Queensland's non-ferrous metal processing — around 92 per cent by value — takes place in the GBR catchment area, specifically in two statistical divisions, Fitzroy and Northern. Only around 4 per cent of the value of other mineral processing in Queensland comes from the GBR catchment. This is mainly basic iron and steel manufacturing.

Using 1999-2000 ABS data, Australian value added in the mineral processing industry in 2000-01 is estimated to be $7.4 billion (table G.33). Queensland's contribution is estimated to be $1664 million — around 22 per cent of the national total. The GBR catchment was estimated to be $991 million, or 60 per cent of the Queensland total. Within the GBR area, the Fitzroy and Northern regions combined contributed around 98 per cent of mineral processing GVP in the GBR catchment.

Projection assumptions

ABARE's database of major minerals and energy projects underpins the projections. In particular, knowledge of the substantial number of proposed processing developments in the GBR catchment area formed the main basis of the GVP projections for Queensland and the GBR region and was supplemented by discussions with DNRM.

A high proportion of the expected developments in the GBR catchment area over the projection period are proposed non-ferrous processing facilities. These are proposed to be located in the GBR region because of factors such as access to raw materials, availability of competitively priced power, infrastructure and port facilities. The growth of these mainly export oriented industries depends significantly on competitive advantage and growth in world demand. Projections for these industries are based partly on publicly announced intentions regarding size and timing of the proposed developments and partly on ABARE's assessments of the likelihood of these developments proceeding within the time frames specified, given expected world demand conditions. The base, high and low growth scenarios presented reflect these factors as well as allowing for the possibility of other, as yet unannounced, projects that may arise.

The assumption is made that growth in other industries in Queensland and the GBR catchment area, such as petroleum refining and iron and steel casting and forging, tend to reflect population growth. Projections for these industries are therefore based on ABS population growth projections (ABS 2000). The base, high and low growth scenarios presented for these industries are based on the ABS Series I, II and III projections for 'Total Queensland' and 'Balance of Queensland'.

Output

Queensland GVP for 2000-01 (based on ABS 2001c) provided a reference point for the projections. Real GVP projections for non-ferrous commodities are based on expected production volumes from existing, proposed and other possible minerals processing developments together with assumed trends in real prices for the relevant commodities. The base, high and low growth cases differ mainly because of varying production assumptions and the timing of developments. For example, in the base case, aluminium production at Gladstone is assumed to include an expansion at the Boyne Island smelter by 2010 and the construction of the proposed greenfield Aldoga smelter before 2020; in the high growth case, both developments occur before 2010; and in the low growth case, only the Boyne Island expansion proceeds but not until after 2010. The high growth scenario also assumes a slower rate of decrease in world metal prices over the projection period.

Australian GVP projections to 2010 and 2020 are based on proposed major project developments in Queensland and other states for a range of commodities, supplemented by projections based on population growth assumptions for industries such as petroleum refining. As for the Queensland and GBR catchment area projections, the main differences between base, high and low growth scenarios reflect varying production assumptions and the timing of developments.

In the base case, real GVP in the GBR catchment area is estimated to increase by 21 per cent to $5208 million by 2010 and by a further 12 per cent to $5813 million by 2020 (table G.32). This is overwhelmingly because of assumptions regarding non-ferrous mineral processing developments in the Fitzroy and Northern regions. In the high growth scenario, real GVP in 2020 is 59 per cent higher than in 2000-01.

In the low growth scenario, real GVP is slightly lower in both 2010 and 2020, mainly because of the assumed decline in real metal prices. Real GVP growth for Queensland reflects the influence of the slower growing petroleum refining and iron and steel industries mainly centred outside the catchment area. In the base case, Queensland's share of Australia's mineral processing GVP increases from 23 per cent in 2000-01 to 27 per cent in 2020.

Mineral processing value added projections are based on historical ABS manufacturing industry value added data. For the purposes of these projections, it has been assumed that industry value added varies in accordance with GVP in line with the ratios of value added to turnover by industry in the ABS data. (Separate value added to turnover ratios are not available from ABS data for Queensland for some industries for some years). On this basis, the value added projections move broadly in the same way as GVP projections. Detailed results are in table G.33.

Employment

Mineral processing employment was projected from ABS employment data. It was assumed that employment growth is directly linked to GVP and that labour productivity growth in the mineral processing industry was a uniform 2 per cent a year across all industries and regions. The productivity growth assumptions remain the same for all three scenarios. On this basis, employment growth reflects movements in GVP and value added (table G.34). The projections show that, under the base case, employment in the GBR region is estimated to increase by 46 per cent between 2000-01 and 2020. This significant increase mainly reflects major non-ferrous metal developments in the Fitzroy region.

Table G.32 **Mineral processing gross value of production projections**[a]

	2001	*2010*			*2020*		
		Base	*Low*	*High*	*Base*	*Low*	*High*
	$m	$m	$m	$m	$m	$m	$m
Far North	33	38	36	40	43	40	47
Northern	1 468	2 109	1 386	2 461	1 936	1 659	2 133
Mackay	22	26	25	27	29	27	32
Fitzroy	2 752	3 022	2 460	3 932	3 791	2 372	4 606
Wide Bay-Burnett	12	13	13	14	15	14	17
GBR catchment	4 287	5 208	3 919	6 474	5 813	4 113	6 835
Queensland	7 532	8 868	7 474	10 273	9 938	8 013	11 265
Australia	32 136	34 526	32 197	39 284	36 866	31 672	41 534

a In constant 2000-01 prices.

Table G.33 **Mineral processing value added projections**[a]

	2001	2010			2020		
		Base	*Low*	*High*	*Base*	*Low*	*High*
	$m	$m	$m	$m	$m	$m	$m
Far North	9	11	10	11	12	11	13
Northern	339	486	320	568	447	383	492
Mackay	6	7	7	8	8	8	9
Fitzroy	634	696	567	905	873	546	1 060
Wide Bay-Burnett	3	4	4	4	4	4	5
GBR catchment	991	1 204	907	1 496	1 344	953	1 580
Queensland	1 664	1 960	1 643	2 280	2 195	1 759	2 492
Australia	7 435	7 920	7 409	9 053	8 414	7 239	9 512

a In constant 2000-01 prices.

Table G.34 **Mineral processing employment projections**

	2001	2010			2020		
		Base	*Low*	*High*	*Base*	*Low*	*High*
	No.	No.	No.	No.	No.	No.	No.
Far North	31	37	35	39	44	41	48
Northern	1 394	2 054	1 349	2 397	1 979	1 696	2 181
Mackay	21	25	24	26	30	28	33
Fitzroy	2 612	2 943	2 395	3 830	3 876	2 425	4 709
Wide Bay-Burnett	11	13	13	14	16	15	17
GBR catchment	4 070	5 072	3 817	6 305	5 944	4 205	6 988
Queensland	7 150	8 636	7 278	10 004	10 160	8 192	11 517
Australia	46 825	51 608	48 125	58 720	57 853	49 701	65 179

Tourism

Tourism accounts for 5 per cent of Australian GDP. Tourism GDP (total market value, including GST, of Australian produced goods and services consumed by visitors after deducting the cost of goods and services used in the process of production) was $31.8 billion in 2000-01. Tourism GVA, (measured as the value of production exclusive of product taxes such as GST) grew 6 per cent in 2000-01 — the same rate as for the economy as a whole (ABS 2002b).

Tourism is not a conventional ANZSIC industry. It is defined by the nature of consumption rather than the product produced. Consequently, tourism expenditure is used as an indicator of tourism's importance to regional economic activity and indicates the total market value (including taxes) of goods and services consumed in Australia by visitors.

Most of the tourism consumption takes place at the point of production. According to the definition used by ABS, tourism encompasses all short-term travel away from the normal place of work and residence, including that undertaken for business and pleasure. It includes both domestic and international travel and involves the consumption of a wide range of goods and services away from usual residence. Because goods and services produced and consumed in meeting tourism demand are embedded in the industry specific accounts in the system of national accounts, tourism expenditure is not readily apparent in the national accounts. Since 2000, ABS has therefore produced a set of tourism satellite accounts (TSA) that highlights tourism within the national accounting framework. TSA thus provides a useful basis to compare tourism activities with other economic sectors. While TSA is currently produced once every three years, the key aggregates can be updated using demand side data that are available annually. In developing these projections for tourism expenditure TSA for 2000-01 was used as the basis.

Projection assumptions

The Australian Tourism Forecasting Council's (AFTC) forecasts to 2012 (of domestic tourism activity and inbound tourist arrivals); the long-term global economic outlook; the pattern of past growth, and likely future tourism trends were used to develop projected tourism activity to 2020. Expenditure patterns for the projection period are based on recent trends. Queensland's share of the Australian tourism market is not assumed to change significantly, and the GBR lagoon and catchment shares are derived from Queensland Treasury estimates for 1998-99 (OESR 2002a).

The major factors influencing tourism activity in Australia are expected to be: disposable income; demography; and factors affecting the choice of destination and the level of participation.

In terms of disposable income, international tourism is generally regarded as a luxury good with income elasticity of between one and two. The economic literature also supports the view that tourism to developed countries has a price elasticity of about one and is therefore responsive to changes in price and exchange rates. Australian GDP growth is assumed to be 3.5 per cent throughout the period (3.7 per cent in 2010 declining to 3.5 per cent in 2020). Alternative estimates for low and high growth scenarios assume an increase or a reduction of 0.5 per cent from the base GDP rate for both the world and Australia. The Australian exchange rate is assumed to remain around US$0.55 during the projection period.

Australia's population growth rate is assumed to be 0.8 per cent over the projection period. Queensland's population is projected to grow faster, at 1.4 per cent a year.

Inbound (international) tourism accounts for 24 per cent of tourist consumption in Australia and is increasing at a faster rate than domestic tourism (for example, tourist arrivals from Asia grew annually by 23 per cent between 1990 and 1996, before being adversely affected by the Asian currency crisis). Australia is expected to remain a popular international tourist destination to 2020. Firstly, political stability and security are significant factors influencing tourist travel decisions (Eliat and Einav 2001) and Australia is considered a clean, safe, and reliable tourist destination — this perception is likely to continue over the projection period. Secondly, Australia is located in the Asia-Pacific which is the fastest growing economic region of the world.

The increasing range of recreational opportunities associated with the growing information technology market are likely to negatively impact on domestic tourism growth (Tourism Forecasting Council (TFC) 2002a). Given the short timetable of this study, growing consumer expenditure on information technology is assumed to have a neutral effect on tourism activity in Australia.

The projections in tables G.35, G.36 and G.37 were derived in three steps. First, tourism activity for inbound and domestic sectors was projected using December 2002 TFC (2002b) forecasts. Second, projected tourism activity (derived in the first step) was used to estimate tourism expenditure (which reflects past expenditure patterns). Third, Queensland expenditure estimates were disaggregated using historical expenditure patterns (OESR (2002) data for the period 1998-99) to estimate tourist expenditure within the GBR catchment.

Visitor numbers

The projections use an average annual inbound tourism growth rate of 4.1 per cent between 2001 and 2010. The rate of growth of inbound tourism is expected to increase slightly thereafter. An average annual growth rate of 5.5 per cent is assumed between 2011 and 2020. Alternative scenarios represent a deviation of 0.5 percentage points from the base rate.

In 2000, 73.4 million domestic tourists aged 15 and over visited other parts of the country and spent an estimated 293.4 million nights away from home. Each trip took an average of four nights, with each tourist making an average of almost five trips (4.8). Travelling within the state accounted for most domestic tourism nights in 2000 (56 per cent). This form of tourism was particularly high in Western Australia (71 per cent), Queensland (67 per cent), Victoria (64 per cent) and New South Wales (62 per cent) because of the wider geographic spread of the resident population. Similar behaviour is assumed during the projection period. Domestic tourism activity is expected to grow at an average annual rate of 0.3 per cent between 2001 and 2020.

Tourism Expenditure

An average inbound visitor spent an estimated $4066 per trip, including prepaid international airfares of $985 in 1999-2000 (ABS 2002c). This information was used to estimate a value per international tourist for 2001 ($3158). This was combined with estimates of international visitor arrivals to derive inbound tourism expenditure. Domestic tourism expenditure is defined as the sum of visitor-night expenditure and same-day travel expenditure. On the basis of various industry and ABS sources, it is estimated that visitor-night expenditure accounts for 87 per cent of total domestic tourism expenditure. Visitor-night expenditure was derived on the basis of $145 per estimated visitor-night.

State level estimates for Queensland are based on TFC (2002b) and information contained in OESR (2002a).

Expenditure projections for the GBR region assume that the region maintains a constant share of total Queensland domestic and international tourist expenditure. Expenditure data by region contained in OESR (2002a) was used as a basis for determining expenditure shares and levels.

Table G.35 **Tourism expenditure: Base case**[a]

	2001			*2010*			*2020*		
	Domestic	*Inbound*	*Total*	*Domestic*	*Inbound*	*Total*	*Domestic*	*Inbound*	*Total*
	$m	$m	$m	$m	$m	$m	$m	$m	$m
Tropical North Queensland	958	979	1 937	956	1 466	2 421	983	2 506	3 490
Northern	495	84	579	493	126	620	507	216	724
Mackay	532	125	658	531	188	719	546	321	868
Fitzroy	422	53	475	421	79	500	433	135	568
Hervey Bay-Maryborough	334	60	394	333	90	423	343	153	496
Bundaberg	164	21	185	164	32	195	168	54	222
GBR catchment	2 906	1 322	4 228	2 898	1 980	4 878	2 981	3 386	6 367
Queensland	9 462	3 562	13 024	9 437	5 333	14 770	9 708	9 121	18 828
Australia	54 499	14 986	69 485	56 117	22 436	78 553	57 790	38 371	96 160

a In constant 2000-01 prices.

Table G.36 **Tourism expenditure: Low case**[a]

	2001			*2010*			*2020*		
	Domestic	*Inbound*	*Total*	*Domestic*	*Inbound*	*Total*	*Domestic*	*Inbound*	*Total*
	$m	$m	$m	$m	$m	$m	$m	$m	$m
Tropical North Queensland	958	979	1 937	914	1 404	2 317	894	2 289	3 183
Northern	495	84	579	472	121	593	461	197	659
Mackay	532	125	658	508	180	688	497	293	790
Fitzroy	422	53	475	403	76	478	394	123	517
Hervey Bay-Maryborough	334	60	394	319	86	404	312	140	452
Bundaberg	164	21	185	156	30	187	153	49	202
GBR catchment	2 906	1 322	4 228	2 770	1 896	4 667	2 711	3 093	5 803
Queensland	9 462	3 562	13 024	9 020	5 108	14 128	8 827	8 330	17 157
Australia	54 499	14 986	69 485	54 593	21 597	76 191	54 593	35 224	89 817

a In constant 2000-01 prices.

Table G.37 **Tourism expenditure: High case**[a]

	2001			*2010*			*2020*		
	Domestic	*Inbound*	*Total*	*Domestic*	*Inbound*	*Total*	*Domestic*	*Inbound*	*Total*
	$m	$m	$m	$m	$m	$m	$m	$m	$m
Tropical North Queensland	958	979	1 937	1 000	1 530	2 530	1 081	2 743	3 824
Northern	495	84	579	516	132	648	558	237	794
Mackay	532	125	658	555	196	752	601	352	952
Fitzroy	422	53	475	441	82	523	476	148	624
Hervey Bay-Maryborough	334	60	394	349	93	442	377	168	544
Bundaberg	164	21	185	171	33	204	185	59	244
GBR catchment	2 906	1 322	4 228	3 031	2 067	5 098	3 277	3 706	6 983
Queensland	9 462	3 562	13 024	9 870	5 567	15 437	10 671	9 982	20 653
Australia	54 499	14 986	69 485	57 269	23 303	80 572	60 800	41 783	102 582

a In constant 2000-01 prices.

4. Validation of the projections

It is difficult to validate projections such as those included in this report as there are no relevant econometric models that have these components, nor are they disaggregated to GBR catchment area level. There were several aspects to the validation process for the projections in this study. The principal aspects involved interaction with relevant Queensland state government departments; checking land implications for possible constraints; and examination of the employment projections in aggregate.

Wherever possible the results were discussed with officers from various Queensland departments, including DNRM, DPI and Treasury.

With respect to competition for future land use, this is only likely to be an issue for aquaculture, sugar and horticulture as other industries do not compete for the same type of land. Horticulture and sugar probably compete in many areas for the same type of land. As discussed in the individual sections, while more land will be required for horticulture and a very small amount of land will be required for aquaculture, the amount of land needed for sugar growing is expected to be less, thus freeing up land for other enterprises.

With respect to employment, the rate of projected increase in employment for the GBR catchment area and for Queensland was compared to ABS population projections as published in ABS (2000). It is important to note that the industries examined provide only a subset of the total employment possibilities in the region. Various service industries, such as tourism and government, tend to be relatively labour intensive. Employment data in these and similar types of industries were not included in this study — in the case of tourism, for example, because of non availability of information.

As can be see in table G.38, for all scenarios, employment growth in the industries studied is much less than population growth between 2001 and 2010 and between 2001 and 2020. In the base case, employment in 2010 is less than in 2001. This is mainly the result of assumed growing labour productivity in one of the main employing sector — the mining industry. In 2020, employment growth is positive in the base case as labour productivity in mining (in particular) is assumed to be lower than in the period to 2010. Most growth in employment is expected to occur in aquaculture, horticulture and mineral processing.

Table G.38 **Total employment projections for industries included in study except tourism**[a]

	Units	2001	2010			2020		
			Base	*Low*	*High*	*Base*	*Low*	*High*
Far North	no.	10 063	10 645	9 813	11 295	11 458	9 958	12 854
Northern	no.	8 562	8 675	7 614	9 629	8 396	7 567	9 199
Mackay	no.	10 120	8 579	8 008	9 042	6 937	7 164	8 527
Fitzroy	no.	10 993	10 648	9 940	11 655	11 138	9 287	12 381
Wide Bay-Burnett	no.	7 689	7 858	6 240	8 384	8 193	7 093	9 231
GBR catchment	no.	50 254	49 827	45 583	53 479	51 004	44 180	56 639
Queensland	no.	83 059	82 358	76 914	90 578	84 387	69 953	99 410
Employment growth since 2001								
GBR catchment	%		-1	-7	9	2	-16	20
Queensland	%		-1	-9	6	2	-12	13
Population growth since 2001								
Queensland	%		15	12	19	31	24	40
Queensland excluding Brisbane	%		15	12	19	30	24	41

a Years ending 30 June; rounded to the nearest whole number.

H Management practices in other industries

The management practices of several agricultural industries that can have significant impacts on water quality in the GBR lagoon, and which face few direct regulatory restrictions, were discussed in chapter 5. In this appendix, the practices adopted in other industries and activities are discussed. Industries and activities covered are aquaculture, beef feedlots, commercial and recreational fishing, mining and mineral processing, other processing industries (including sugar, meat and horticulture), tourism, port activity, and coastal development. The coverage of these activities is less comprehensive than in chapter 5. This reflects their relatively smaller overall contribution to pollution loads entering the GBR lagoon (chapter 2), and the point source nature of much of their pollution which is more extensively regulated (chapter 3). That said, the impacts of these industries and activities can be significant, particularly at the local level.

H.1 Aquaculture

The aquaculture industry in Queensland produces a range of products. However, marine prawns, kurama prawns and barramundi dominate production, making up 65, 19 and 9 per cent respectively of Queensland's gross aquaculture production by value (APFA, sub. 45, p. 6). Production largely involves onshore ponds and tanks, although some offshore aquaculture occurs, such as for pearl oysters. Currently, there are 40 licensed aquaculture operations adjacent to the GBR Marine Park (GBRMPA, sub. 30, p. 11), including 25 prawn farms covering around 542 hectares (APFA, sub. 45, p. 4). Approximately 110 hectares of prawn farms are located at Cardwell, with smaller areas around Mossman, Cairns, Innisfail, Ayr, Mackay and Proserpine (APFA 2002). Most prawn farms cover a small area, averaging around 4 to 5 hectares.

Aquaculture production, which involves processes of breeding, hatching, rearing and processing for sale, can have a number of potential impacts on water quality entering the GBR lagoon. These include:

- land clearing, including the clearing of mangroves;

- increased nutrient, sediment and chemical loads in waterways from flushing water through prawn ponds, either directly or through settling ponds;
- salinisation of downstream water supplies, and releases of water with low dissolved oxygen concentrations or abnormally high phosphorous levels;
- disturbance of acid sulphate soils, which can result in acidic wastewater leaching into waterways; and
- release of pathogenic organisms, such as viruses from wild broodstock.

Of these potential impacts, most concern has tended to focus on habitat destruction and effluent discharge into marine and estuarine water from prawn production (GBRMPA 2000d). Many other forms of aquaculture, such as pearl oyster, scallop, mussel and oyster farming, do not need external feeding and therefore have considerably fewer environmental effects on adjacent ecosystems (GBRMPA 2000d). While the discharge of nitrogen and phosphorous from prawn farming can be very high per hectare of pond (about ten times that lost from one hectare of sugar cane), there are only 542 hectares of prawn farm ponds adjacent to the GBR lagoon. Thus, discharges are small compared to other sources (GBRMPA 2001c; APFA, sub. 45, p. iv).

In general, pollution from aquaculture is ‘point sourced’ and localised. Pollution levels, however, may vary. In the case of prawns, pollution levels depend on rainfall, farm location, season, age of ponds, other activities in the catchment and farm management practices (APFA, sub. 45, p. 12).

Management practices adopted by aquaculture producers to manage water quality include:

- farm planning and pond design;
- operation of settlement and bioremediation ponds;
- activities to reduce ammonia;
- ensuring minimal water exchange; and
- monitoring water quality indicators.

Pond design and maintenance, for example, can be important in managing sediment accumulation, with the main sources of this matter being incoming water and the erosion of pond floors and banks (EPA 2000). Management practices adopted to minimise pond erosion include vegetating or otherwise protecting pond walls above the waterline, and using plastic lining or placement of aerators below the waterline. The modelling and analysis of prawn pond processes has also proved useful in addressing environmental impacts, and advanced pond management software is being used by some operators (Breen, M., APFA, Brisbane, pers. comm., 8 October 2002).

Managing farm location is also important, with aquaculture sites often located in areas of potential acid sulphate soil due to the seawater access requirements of prawn farms (GBRMPA 2000b). The location of aquaculture operations is extensively regulated, however, with pond construction prohibited in intertidal areas and sensitive habitats, such as ephemeral wetlands (McPhee 2001).

Settlement ponds are increasingly used by aquaculture operations to minimise the net export of suspended solids by allowing particulates to settle to the bottom of the pond. They also provide an opportunity for operators to recapture waste nutrients prior to discharge or recirculation. The appropriate design of settlement ponds depends on the features of the particular farm. Bioremediation ponds may also be introduced, using biological processes within or complementary to settlement ponds to filter waste nutrients in pond effluent. These processes can include plankton consumers and filter feeding bivalves (oysters). While the adoption of sediment ponds is fairly common (although less so for older farms), there are currently only a few bioremediation ponds (Breen, M., APFA, Brisbane, pers. comm., 8 October 2002).

Other practices have been introduced to reduce ammonia. These include developing better feeds and feeding practices to reduce the amount of waste nitrogen, reducing sludge production, and improving pond and aeration design.

Management practices have also been aimed at minimising the exchange of water between production sites and open waterways. To date, Queensland prawn farmers have on average reduced water exchanges from 8 to 10 per cent per day to less than 4 per cent per day (EPA 2000).

Monitoring water quality indicators also offers benefits to aquaculture production and management, such as providing information to improve and redesign techniques to minimise water quality impacts. Various monitoring activities are required under state and Commonwealth regulatory requirements. Licence requirements issued by the Environmental Protection Agency (EPA), for example, stipulate independent assessments once a month of a range of parameters, such as suspended sediments, nitrogen and phosphorous. Monitoring water quality is also undertaken regularly by operators as a means of optimising conditions for their stock (Breen, M., APFA, Brisbane, pers. comm., 8 October 2002).

Overall, technological change within the prawn farming industry is rapid. In general, newer prawn farms have been more able to take advantage of leading technologies and practices than older operations (GBRMPA 2000a).

Management practices in the aquaculture industry have been driven in large part by its extensive regulation. Regulations involve a mix of prescribed 'end of pipe' discharge levels for nutrients and sediments, and system based requirements covering matters such as farm design, construction and operation. Importantly, most aquaculture operations are considered an environmentally relevant activity (ERA) under the *Environmental Protection Act 1994* (Qld) (EP Act). Aquaculture operations are also subject to a range of local government planning laws, as well as Queensland's General Environmental Duty under the EP Act. In most cases, regulatory requirements are set out in permits which aquaculture operators must acquire and comply with (chapter 3).

Regulations applying to aquaculture operations in addition to the EP Act include the *Fisheries Act 1994* (Qld); *Integrated Planning Act 1997* (Qld); and *Great Barrier Marine Park (Aquaculture) Regulation 2000*. Other legislation that can apply to aquaculture operations include the *State Development and Public Works Organisation Act 1971* (Qld); *Beach Protection Act 1968* (Qld); and *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act).

APFA has developed a code of practice for its members which has been listed under the EP Act. The *Environmental Code of Practice for Australian Prawn Farmers 2001* aims to provide a mechanism for environmental self-regulation, and help farmers meet their legal obligations under the General Environmental Duty of the EP Act. The Code states that existing farms should, for example, adjust feeding management strategies to minimise nutrient loadings, manage stocking densities to minimise wastes, and implement erosion control measures to minimise solid loading (Price and Breen 2001). The Code also requires new farms to allow for vegetated buffer zones, protection of mangrove communities, acid sulphate soil management, and water treatment including at least settlement ponds. No formal assessment of prawn farmer compliance with the Code has been undertaken. APFA acknowledges that farmer understanding on how it works and can be applied could be improved (Breen, M., APFA, Brisbane, pers. comm., 8 October 2002).

H.2 Beef feedlots

In contrast to grazing systems for beef production, feedlot systems involve confined yard areas with watering and feeding facilities where cattle are completely hand or machine fed (often with barley and sorghum). Feedlots are intensive in nature and require much less land than grazing systems. Land and water management remain important, however. Liquid wastes from feedlots include urine and wash water, while solid waste includes livestock faeces and spilled feed. If not managed, these wastes (which are often disposed of on land as a form of fertiliser) can be a potentially high source of nutrients and can damage soil, vegetation and water resources. Other water contaminants may include salt (excreted by cattle when dietary intake is excessive) and vaccines and feed additives (SSCRRA 1992). Solid wastes may also clog soil pores and lower water infiltration rates.

Management practices for feedlot operations include site location (away from sensitive areas), control structures (such as capturing effluent with appropriate drainage and minimising water runoff that can carry high nutrients), and wastewater treatment before being released into the environment. Examples of effluent management systems include:

- systems of diversion banks or drains to exclude extraneous runoff from feedlot complexes;
- a sedimentation basin or debris basin to remove manure entrained in the runoff;
- a retention pond to hold the polluted runoff prior to disposal; and
- use of appropriate land disposal areas on which stored runoff water can be disposed of by irrigation and the solids can be spread (SSCRRA 1992).

Good management practices are outlined in the *National Beef Cattle Feedlot Environmental Code of Practice*. Compliance with the Code is not mandatory, but is a requirement for accreditation under the National Feedlot Accreditation Scheme and may offer marketing benefits and help in the case of complaints and litigation. In terms of the adoption of management practices in feedlots, SSCRRA (1992) reported that:

- 81 per cent of commercial feedlots had drainage systems;
- 63 per cent had sedimentation basins;
- 76 per cent had retention ponds; and
- 49 per cent had land disposal areas.

While there are likely to be several drivers encouraging management practices to protect water quality in feedlot systems, regulatory controls appear to play an important role. As noted in chapter 3, feedlots are listed as an ERA under the EP Act and are controlled by DPI.

H.3 Commercial and recreational fishing

There are over 2500 commercial fishing licence holders in Queensland, with 44 per cent of those businesses located adjacent to the GBR catchment between Gladstone and Cooktown (Fenton and Marshall 2001). Recreational fishers are also active in the GBR Marine Park, with about 25 000 registered boats used for fishing each year (CRC Reef 2002c). Some recreational fishers also fish from the beach. In addition, a charter industry operates in the GBR Marine Park, comprising approximately 120 vessels (including large reef-going and smaller inshore vessels) (GBRMPA 2002c).

To some extent, the different fishing sectors are spatially distinct (RMAC 1996). Fewer than 10 per cent of recreational fishers fish in open waters, except in Cairns where the figure is over 13 per cent (RMAC 1996). In contrast, a relatively small proportion of commercial fishing is undertaken within 20 kilometres of the coast (Hall and Kenway, AIMS, sub. 12, p. 8). Thus, the impacts of the different types of fishing are likely to be felt in different areas of the GBR lagoon.

Most of the environmental effects of fishing relate to its potential impacts on fish stocks. This is reflected in the legislation that governs the industry’s operations — such as catch size, bag limits and zoning. There are also some water quality issues that can arise from fishing, particularly when undertaken from boats (although the size of these impacts is likely to be relatively small (chapter 2)).

Water quality impacts can arise from:

- discharge of vessel sewage (particularly for large boats), grey water (water from sinks and showers), bilge water (water that collects in the lowest part of the boat), and disposal of garbage;
- fuel and oil spillage and leaks;
- the use of antifouling paints;
- in-water boat maintenance;
- sea bottom disturbance, particularly from trawling; and
- on-board fish processing, for commercial fishing.

Many of these potential impacts are controlled by legislation. The *Great Barrier Reef Marine Park Act 1975* (Cwlth) (GBRMP Act), for example, prohibits the discharge of ‘waste’ into the GBR Marine Park from vessels. Waste includes oil, some oil mixtures, noxious liquid substances, packaged harmful substances, sewage and ‘garbage’, although there are some exceptions in regard to sewage from boats. Codes of conduct, established by recreational fishing associations, also deal with some water pollution issues. These include principles such as refuelling on land to avoid pollution and not discharging waste into water.

Changes taking place in fishing practices have the potential to decrease some of the negative effects of fishing on water quality. For example, as noted by Hall and Kenway (AIMS, sub. 12, pp. 7–8):

> It is expected that over the next few years fewer 2-stroke engines will be used and replaced by 4-stroke and 2-stroke rotary engines, which would largely eliminate oil spillage and discharge from this [recreational fishing] sector.

Further, the recreational charter sector is moving toward onboard sewage storage, although few ports currently have the facilities to pump out this waste (Sunfish, pers. comm., 4 September 2002).

H.4 Mining and mineral processing

Although mining is not permitted in the waters of the GBR Marine Park, mining and mineral processing activities are undertaken in the GBR catchment. Black coal production is the main mining activity, with most of it undertaken in the Bowen basin. Other mining operations include shale oil north of Gladstone, silica near Cape Flattery, and magnesia north of Rockhampton (GBRMPA 2001c; sub. 27, p. 9). In addition, several mineral processing activities occur in the catchment — a copper refinery, nickel refinery, zinc refinery and smelter in Townsville–Thuringowa, and an alumina refinery and aluminium smelting operation in Gladstone (GBRMPA, sub. 27, p. 9). A magnesium smelter is under construction in the Gladstone/Rockhampton area (Queensland Mining Council, sub. 13, p. 4).

Mining and mineral processing involve several broad activities — exploration, mine development, extraction, processing, transport, mine rehabilitation, and mine closure. Each of these can present potential water quality issues. The extent of potential water quality impacts depends on the precise nature of the activity (for example, open-cut or underground mining).

Water quality issues can arise from, for example:

- land clearing and soil disturbance — during exploration, mine development or extraction — which may increase the potential for erosion and sediment loads in runoff;
- storage of materials awaiting processing and transportation, and of chemicals used in processing, refining, and smelting;
- water contamination arising from sources such as:
  - the release of chemicals used in flotation (a process used to separate different ores) and leaching (a process used to remove unwanted material from the concentrates that are extracted during the flotation process);
  - the disposal of tailings (unwanted material); and

- acid wastewater from boiler cleaning, and other chemicals and detergents used in vehicle and machinery cleaning;

- the exposure of sulphide-bearing material — during exploration, development or extraction — contributing to the release of acid runoff; and
- the release of acidic water and contaminated sediment, particularly during high intensity rain events, from mines (open-cut pits) that are no longer operational (see, for example, GBRMPA, sub. 27, p. 9).

Several management practices can be, and are to varying degrees, adopted to mitigate potential water quality threats. Water management plans can help to identify risks and possible actions to minimise those risks. The construction of concrete aprons surrounded by concrete walls (bunds) — on which flotation, equipment cleaning and chemical storage can be undertaken — helps to contain spillage and prevent seepage. The use of concrete sedimentation/evaporation/retention ponds to pass runoff and other material through, and recycling of materials for use within the plant, can also help to manage water quality concerns. Acid drainage can be managed either by neutralising waters with lime; or by identifying potential hazards in advance, and then adopting selective mining, burial and isolation techniques to prevent acid entering water (Commonwealth EPA 1995, p. 9).

In practice, legislation drives the adoption of management practices. Mining activities are ERAs under the EP Act (chapter 3), and therefore require an environmental authority. Documentation, such as a plan of operations detailing actions and programs that will achieve compliance, must be submitted for an environmental authority (mining lease). In certain situations an Environmental Impact Statement may also be required, either under the EP Act or the EPBC Act. Examples of conditions and requirements imposed on holders of environmental authorities include:

- for ‘standard’ activities (those presenting a low risk of environmental harm) — design, installation and maintenance of erosion and sediment controls where necessary; and prior removal and stockpiling of topsoil; and
- for ‘non-standard’ activities (those having a medium to high risk of environmental harm) — monitoring of receiving waters, and of sewage effluent released from treatment (with levels not to exceed certain limits); and tailings dam requirements (Queensland Mining Council, sub. 13, pp. 11–19).

The Queensland Mining Council (sub. 13, p. 7) argued that not only is the industry subject to ‘stringent environmental regulations and compliance monitoring’, but that it has ‘an excellent record in this regard’.

In addition, the *Australian Minerals Industry Code for Environmental Management* (MCA 2000a) encourages the adoption of certain environmental principles by minerals companies, and signatories must publish public environmental reports within two years of signing. The Minerals Council of Australia (MCA 2000b, p. 2) noted that the Code was developed to respond to concerns about the industry's environmental performance, and because good environmental performance 'makes good business sense'. It argued, for example, that adoption of the Code, by increasing confidence in the industry, could lead to less regulatory involvement and therefore lower regulatory costs. The potential to improve the industry's standing with insurers and investors was also seen as a way to decrease costs to the industry. Although adoption of principles by signatories varies, many signatories embraced some environmental management tools for the first time (MCA 2001, 2000b).

H.5 Other processing industries

Several processing activities that may affect the quality of water entering the GBR lagoon are undertaken in the GBR catchment. Most of Queensland's 26 sugar mills are located in the GBR catchment, for example. Sugar refining and distilling, meat and horticultural processing, as well as mineral processing (section H.4), also occur in the catchment.

Potential water quality issues from these activities can arise due to:

- discharge of wastewater;
- effluent and nutrient leakage (and its runoff into waterways);
- storage and disposal of inputs and chemicals (for treating or cleaning); and
- discharge of byproducts.

In most cases, processing activities are ERAs under the EP Act. These include commercial meat processing (not undertaken in a retail butcher shop), milk processing (off-farm), commercial seafood processing, sugar milling or refining (off-farm), and bottling or canning food (not involving other ERAs) (Environmental Protection Regulation 1998). Some unwanted byproducts and effluent derived from these activities are regulated wastes, so their storage and transport may also be considered ERAs (Environmental Protection Regulation 1998; EPA 2001b).

All ERAs require an environmental authority. Canegrowers (sub. 34, pp. 9–10) noted that the environmental authority for sugar milling and refining contains environmental performance standards and conditions. In complying with legislative requirements, processing industries have adopted various management practices. Examples from sugar, meat and horticultural processing are discussed below.

In the sugar industry, most mills now operate ‘closed systems’, where water is recycled through cooling towers and used in boiler stack emission collectors. Any emissions are of clean water vapour to air. Some excess water is recycled through effluent treatment systems and reused as irrigation on pastures and cane land. Where fully or partially open systems operate, standards for water discharge quality and monitoring systems have been established under their environmental authority. All sugar mills have Stormwater Management Systems, while risk management strategies cover potentially environmentally harmful liquids, such as petroleum products and processing chemicals (Canegrowers, sub. 34, p. 10).

In addition, several practices by sugar mills deal with specific byproducts. To minimise the risk of sediment and nutrient discharge, for example, recycling protocols are in place for boiler ash (solid residue from boiler fuel that remains in the combustion chamber), and filter mud (cake or residue produced from filtering cane juice). Bagasse (fibrous residue from sugar cane milling) is used as fuel for steam and electricity generation at many mills in northern Queensland, with some surplus power increasingly sold to the electricity network (Queensland Treasury Office of Energy 2002; CSR Sugar, sub. 14, p. 7).

In the meat processing industry, filtration, disinfection, and salt and nutrient reduction processes can be used to prepare wastewater for discharge (MLA 2002). Land-based effluent systems to dispose of effluent have been established at the facilities of Australian Meat Holdings Limited in Townsville and Rockhampton (Australian Meat Holdings Limited, sub. 21, p. 1).

In the horticultural processing industry, QFVG (sub. 49, p. 38) identified wastewater management from packing houses as an issue that has emerged recently. So far, this has been addressed by holding a workshop between banana packhouse managers and the EPA to develop best practice guidelines, and an action plan to resolve concerns. In addition, an eco-efficiency study has been conducted in a vegetable pack house to identify opportunities to improve processes.

H.6 Tourism

Tourism is the main commercial use of the GBR Marine Park (GBRMPA 2002h). In 2000, 730 tourism operators, licensed to use 1492 vessels/aircraft, were permitted to operate in the area (GBRMPA 2001d). Marine visits are concentrated in the Cairns and Whitsunday regions, which account for 85 to 95 per cent of total visits but only about 7 per cent of the area of the Marine Park (Harriott 2002).

Tourist activities and operations include:

- boat-based operations (such as day trips to reef and island destinations; charter boats, particularly for diving and fishing; and international cruise ships);
- pontoon-based operations at fixed sites;
- aircraft operations (for scenic flights and charters); and
- resort-based activities (GBRMPA 1999).

These activities have a variety of potential environmental impacts, including direct damage to coral through poor anchoring and reef walking (GBRMPA 1999).

Water quality issues may arise from, for example:

- boat sources — including those listed in relation to fishing (section H.3), as well as erosion and damage to vegetation caused by launching and disembarking (Rainbow et al. 2002); and
- activities in the GBR catchment — including bushwalking and camping, with potential impacts from litter, sewage, detergents and soaps discharged into waterways.

Tourism-related coastal development also presents potential water quality issues. These are discussed in section H.8.

Water quality issues are managed in a number of ways. As noted in section H.3, the discharge of many boat-sourced pollutants is prohibited under the *Great Barrier Reef Marine Park Act 1975*. In addition, the marine tourism industry is subject to regulation that addresses the environmental impacts (not just concerning water quality) of its operations. For example, operators require a permit to operate, and permit applicants need to demonstrate, among other things, that the environmental impacts of the proposal are acceptable (GBRMPA 2002e). The number of some types of tourist access permit has been capped under plans of management for the Cairns Area and Whitsundays (GBRMPA 2001d). The Association of Marine Park Tourism Operators (sub. 29, p. 2) argued that its industry 'has not been allowed any latitude in its operations where environmental sustainability is in question' and that:

> In the past decade, the marine tourism industry has been subjected to increasing regulation and scrutiny by the GBR Marine Park Authority and the … Environment Protection Agency. These organizations have adopted a 'precautionary' approach when assessing potential environmental impacts from our industry. (sub. 29, p. 1)

A new approach to tourism management is being developed by GBRMPA. This will be based on strategic policy and planning, industry self-regulation and active partnerships (GBRMPA 2002i). GBRMPA is encouraging the adoption of codes of conduct, and compliance with best environmental practices, as well as developing accreditation systems with industry (GBRMPA 2002i). It has published a bareboating policy (GBRMPA 2002g), incorporating codes of practice developed with industry, as well as detailing enforceable industry standards, and accreditation and training requirements (covering areas such as best environmental practice).

Best environmental practices for various tourism activities are published by GBRMPA (2002b), as well as in CRC Tourism 'Green Guides' (such as Rainbow et al. 2002). Examples of best practice relating to water quality include not using detergents and soaps near streams and waterways, using biodegradable products, installing marine toilets on boats, and using environmentally-friendly antifoulants. GBRMPA (2002b) noted that its best practice summaries were intended to complement, not duplicate, legal requirements.

General industry developed accreditation systems, with a focus on environmental management, also exist in the tourism industry. A survey of members of one of these, the Nature and Ecotourism Accreditation Program, indicated that operators joined voluntarily for various reasons. These included to evaluate their own progress in relation to best practice, obtain access to marketing support, achieve formal recognition, and differentiate between genuine and non-genuine ecotourism operators (Tourism Queensland 2002).

H.7 Port activity

Ports adjacent to the GBR lagoon account for a significant proportion of the freight shipped in and out of Queensland (Queensland Transport 2001). Major ports include those at Abbot Point (north of Bowen), Cairns, Gladstone, Hay Point (north of Mackay), Mackay and Townsville. The main commodities exported from these ports include coal, ores and sugar, reflecting the region's major export industries.

Various potential water quality issues can arise from port and shipping activities, including those due to:

- dredging of channels and berths (which can result in short-term turbidity) and placement of dredged material at sea;
- runoff from land (including stormwater from product stockpiles and partially developed sites);
- reclamation of habitats (wetlands), with potential implications for runoff;
- antifouling paints and waste discharge from ships; and
- shipping incidents and accidents, and marine oil spills (Gladstone Port Authority, sub. 6, p. 3; GBRMPA, sub. 27, p. 12; Ports Corporation of Queensland (PCQ), sub. 26, p. 4).

Examples of management practices adopted by ports to address specific water quality concerns include:

- reducing the need for dredging by designing long piers; levelling beds to remove sedimentation high points (PCQ, sub. 26, p. 8); and using trestle jetties and conveyor belts for deep-water loading of bulk cargo (PCQ 2002);
- managing runoff by constructing clean-out pits and sumps (PTEWG 2001), concrete-based settlement ponds (GPA 2002; PTEWG 2001), and evaporation ponds to capture settlement pond overflow (PTEWG 2001); and revegetating, maintaining and enhancing wetlands (Mackay Port Authority, sub. 30, p. 4);
- managing erosion from port landscaping and development works by using sediment curtains, rock filters and revegetation (GPA, sub. 6, p. 3);
- managing ship discharges by having waste reception and oil collection facilities at ports (PCQ, sub. 26, p. 7), best practices for which are summarised in ANZECC (1997); and
- implementing oil spill contingency plans (under the National Oil Spill Response Plan), possible spill control methods include removal using absorbent pads and treatment with dispersants (GPA 2002, p. 6; PCQ, sub. 26, p. 7).

Legislation and government policy — including the EP Act, *Environment Protection (Sea Dumping) Act 1981* (Cwlth) and Queensland Transport Environment Policy for Queensland Ports — are one driver for ports to address water pollution threats. Ports and several activities they undertake are ERAs under the EP Act so they must comply with environmental authorities, as well as with development approvals. Integrated Environment Management Systems (EMSs), approved by the EPA, contain objectives and strategies to protect and enhance water quality, and must be complied with (Cairns Port Authority, sub. 43, p. 2; GPA, sub. 6, p. 3). Queensland Transport will be developing an EMS for ports to 'lead to better environmental outcomes for ports' (GBRMPA, sub. 27, p. 23). Environment Australia (Commonwealth Department of Environment and Heritage) grants permission and imposes conditions, such as monitoring requirements, on the placement of dredged material at sea (GPA, sub. 6, p. 3; Mackay Port Authority, sub. 30, p. 1).

Discharge by ships at sea is also subject to legislation, such as the *Transport Operations (Marine Pollution) Act 1995* (Qld), *Protection of the Sea (Prevention of Pollution from Ships) Act 1973* (Cwlth), and GBR Marine Park Act. Which Act applies depends on specific circumstances, although all three potentially could apply to ships operating in the GBR Marine Park (Great Barrier Reef Shipping Review Steering Committee 2001). Management of ship discharge can be implemented by measures such as onboard treatment facilities. PCQ (sub. 26, p. 7) noted that most large bulk carriers have such facilities. Ship waste can also be managed through waste reduction, segregation and reuse (ANZECC 1997).

H.8 Coastal development

Land modification has occurred along much of the GBR coastline, although some areas in the north of Queensland remain remote and undeveloped. Development has occurred for residential accommodation, tourism infrastructure, agricultural activity, heavy industry, aquaculture, dam construction, ports, and road and rail networks. This section briefly reviews some of the water quality impacts and management activities related to coastal developments not discussed elsewhere in this appendix. In particular, this section covers urban stormwater and sewage, and construction.

Urban stormwater and sewage

Most of the 21 local government areas sharing coastal boundaries with the GBR lagoon have populations less than 25 000. However, the populations of Cairns, Thuringowa–Townsville, Mackay, Rockhampton and Gladstone range between 26 000 and 140 000 (GBRMPA 2001c). Many towns and cities also have significant transient populations, particularly due to flows of tourists, with infrastructure developed to facilitate both transient and permanent populations. In total, there are over 100 urban centres adjacent to the GBR World Heritage Area (GBRMPA 2002d). This section discusses urban stormwater and then urban sewage.

Potential water quality impacts from urban stormwater include the addition to waterways of:

- chemicals, nutrients, and sediments;
- faecal matter, organic debris and depositioned air pollution; and
- freshwater (which can dilute seawater salinity) (GBRMPA, sub. 27, pp. 9, 19).

Stormwater problems in urban environments can be stimulated by both the high availability of pollutants, and increased flow and velocity of water due to impervious surfaces. In addition to rainfall causing urban runoff, dry weather flows may also occur from groundwater movement, garden watering or leaking water pipes (GBRMPA, sub. 27, p. 9). Industrial activity along the coast may also add to stormwater problems. Industrial sites, for example, can pollute stormwaters with dust, spillages, erosion of products and raw materials, and washed up products and wastes. Stormwater from metal refineries can add acidic drainage, sediment and metals (GBRMPA 2001c).

Management practices to manage urban stormwater pollution can include measuring urban stormwater contamination and flow, introducing stormwater quality improvement measures, and developing monitoring systems. Measures can be aimed at improving stormwater control at its source, 'mid-pipe' and/or point of discharge.

Examples of improvement measures include gross pollutant traps, buffer strips, infiltration systems, and constructed wetlands and ponds. Townsville City Council, for example, recently constructed gross pollutant traps and miniature wetlands, and improved pond and waterway filtration systems. This system is multi-objective (aiming for greater recreational fishing and stormwater management); risk based (focusing on low flows in the latter part of the dry season when 'first flush' rainfall can mobilise accumulated pollutants); and uses multiple solutions along the length of the drainage flow. Other councils are also implementing stormwater quality improvements (such as Cairns City Council, sub. 23, p. 2), although the adoption of management practices across the GBR catchment is variable.

At the strategic and planning level, city councils are developing stormwater management plans, with most subdivision proposals required to integrate stormwater management with local government systems (GBRMPA 2001c). Stormwater management is also covered by the *Environmental Protection (Water) Policy 1997* (Qld). This policy requires the cooperative development of water quality objectives, standards and plans, with local governments responsible for implementing an environmental urban stormwater quality management plan. The *Environment Protection (Waste) Policy and Regulation 2000* (Qld) has also been introduced to manage waste disposal practices.

Potential water quality impacts from urban sewage include pollution from:

- organic matter, nutrients, suspended solids and microorganisms (such as bacteria, viruses and fungi);
- heavy metals, and toxic synthetic organic substances such as pesticides and herbicides; and
- crude oil products, detergents and litter (GBRMPA, sub. 27, pp. 8–9).

Urban sewage has been estimated to contribute approximately 6 per cent of the nitrogen and 20 per cent of the phosphorus entering the GBR lagoon from selected land uses (chapter 2). Impacts may be particularly significant at a local scale and under dry season conditions when urban sewage discharges into streams can represent total stream flow (GBRMPA, sub. 27, p. 9). As with stormwater, industrial sites may add to the pollution loads entering waterways, although discharges are regulated under the EP Act. Factors that influence the impact of sewage discharges include the volume and pre-treatment of effluent, dispersal characteristics of the effluent, and location of the discharge. Discharges into enclosed bays, for example, may have extensive impacts (GBRMPA, sub. 27, p. 18). Overall, the majority of sewage effluent from coastal settlement in the GBR catchment is discharged into waterways upstream of the coast, although a small proportion of island resorts discharge directly into the GBR World Heritage Area.

In terms of management practices, the majority of large coastal cities, and most smaller coastal and island settlements adjacent to the GBR, have secondary treatment sewage systems which reduce the organic loading in effluent (GBRMPA, sub. 27, p. 8). Several coastal sewage treatment plants use some secondary treated effluent for land irrigation (AFFA, sub. 53, p. 16). That said, some areas still use septic systems, including parts of Cooktown and Malanda.

Tertiary treatment of sewage is occurring in some areas, and others are moving to do so. Cairns City Council (sub. 23, p. 2), for example, is currently implementing a tertiary treatment upgrade. Improvements in the design, location and operation of septic tanks can also help to manage sewage pollution problems, although progress across the GBR catchment has not been reported. Legislative requirements specifying particular sewage systems do not exist, although several state government plans and policies refer to certain goals. Much of the driving force behind upgrading systems comes from community expectations (Cormick, A., Department of Local Government and Planning, pers. comm., 16 October 2002).

Construction

Potential water quality issues from construction activities include:

- clearing vegetation, including wetlands and mangroves;
- dredging coastal channels and altering river shapes (which can affect natural coastal processes);
- sediment loss during construction;
- potential exposure of acid sulphate soils with potential acidification of soils, groundwater and surface waterways; and
- increased litter and building waste.

The construction of dams to support both coastal industries and urban populations may also cause problems through modifying water regimes. Impacts can include altering water temperature and flow, and degrading water through reduced oxygen levels and release of toxins. There are currently 123 dams and weirs in the GBR catchment (GBRMPA, sub. 27, p. 10).

Management practices relating to construction activities include considering locations for developments, adopting minimal impact approaches, and revegetation activities. Both the location and conduct of construction are regulated by Local Government Planning Schemes, along with Queensland's coastal management plans under the *Coastal Protection and Management Act 1995* (Qld). Cairns City Council (sub. 23, p. 2) noted that developers in Cairns are required to undertake revegetation or make a 'significant contribution to revegetation works in urban areas'. Other management practices can include renovating existing buildings (rather than constructing new ones), recycling materials, and implementing erosion and runoff control during and after construction.

To the extent that developments occur inside the GBR World Heritage Area (either along the coastline or around islands), impacts are managed through an assessment of permit applications by GBRMPA (2002d). GBRMPA has also developed *Plans of Management* for intensely used or particularly vulnerable groups of islands or reefs which can limit uses in such areas (GBRMPA 2002f). Other laws include the *Beach Protection Act 1968* (Qld), which requires local governments to consult with the Beach Protection Authority on rezoning proposals in areas designated as coastal management control districts. In addition, the EPBC Act provides for the assessment and approval of developments that may significantly impact on matters of national environmental significance, such as the GBR (chapter 3).

References

ABARE (Australian Bureau of Agricultural and Resource Economics) 1999, *Australian Farm Surveys Report 1999*, Canberra.

—— 2000, *Australian Farm Surveys Report 2000*, Canberra.

—— 2001, *Australian Fisheries Statistics 2001*, AGPS, Canberra.

—— 2002, *ABARE's Farm Surveys Data*, http://agsurf.abareconomics.com/cgi-bin/abare.pl?_PROGRAM=ags4Home&wh=ter&pr=agsurf (accessed 12 December 2002).

ABS (Australian Bureau of Statistics) 1998, *1995 Census of Population and Housing Socio-Economic Indexes for Areas*, Cat. no. 2039.0, Canberra.

—— 2000, *Population Projections: Australia 1999-2101*, Cat. no. 3222.0, Canberra.

—— 2001a, *Australian Standard Geographical Classification*, Cat. no. 1216.0, Canberra.

—— 2001b, *Manufacturing Industry: Australia*, Cat. no. 8221.0, Canberra.

—— 2001c, *1999-2000 Manufacturing Industry, Australia*, Cat. no. 8415.0, Canberra.

—— 2001d, *Measuring Wellbeing: Frameworks for Australian Social Statistics 2001*, Cat. no. 4160.0, Canberra.

—— 2001e, *1999-2000 Mining Operations: Queensland*, Cat. no. 8221.3, Canberra.

—— 2002a, *2000-01 Mining Operations: Australia*, Cat. no. 8415.0, Canberra.

—— 2002b, *Salinity on Australian Farms*, Cat. no. 4615.0, Canberra.

—— 2002c, *Tourism Satellite Account: Australian National Accounts 2000-2001*, Cat. no. 5249.0, Canberra.

ABS and NZDOS (New Zealand Department of Statistics) 1993, *Australian and New Zealand Standard Industrial Classification*, Canberra.

ACIL Consulting 2002, *Economic Significance of Mining and Mineral Processing to the Northern Region*, Report to the Queensland Department of Natural Resources and Mines, Brisbane.

AIMS (Australian Institute of Marine Science) 2001, *Annual Report 2000-2001*, Townsville, http://www.aims.gov.au/pages/about/ar20002001/pdf/ar20002001a.pdf (accessed 29 October 2002).

ANZECC (Australian and New Zealand Environment and Conservation Council) 1997, *Best Practice Guidelines for Waste Reception Facilities at Ports, Marinas and Boat Harbours in Australia and New Zealand*, http://www.ea.gov.au/coasts/pollution/dumping/waste-reception/pubs/guidmn2.pdf (accessed 8 October 2002).

APFA (Australian Prawn Farmers Association) 2002, *Statistics*, http://www.apfa.com.au/industry/ (accessed 4 July 2002).

Ash, A., Corfield, J., and Ksiksi, T. 2001, *The Ecograze Project: Developing Guidelines to Better Manage Grazing Country*, CSIRO Sustainable Ecosystems and Queensland Department of Primary Industries, ImagePrint, Townsville.

Ash, A.J. and Quirk, M.F. 2001, Grazing Management and Health of Savannas, Paper presented at the Sustaining Our Aquatic Environments conference, Townsville, 20–23 November.

AustLII (Australasian Legal Information Institute) 2002, *Queensland Consolidated Acts and Regulations Database*, http://www.austlii.edu.au/databases.html#qld (accessed on multiple occasions during August and October 2002).

Azzopardi, M. 2001, *COMPASS: A Self–Assessment Workbook*, BSES, Brisbane.

Azzopardi, M., Marohasy, J., Christiansen, I. and Dawson, D. 2001, *Environmental Commitment of the Queensland Sugar Industry*, http://www.canegrowers.com.au/share/Hot_Topics (accessed 1 November 2002).

Barr, N. and Cary, J., 2000, *Influencing Improved Natural Resource Management on Farms: A Guide to Understanding Factors Influencing the Adoption of Sustainable Resource Practices*, Bureau of Rural Sciences, Canberra.

Barraclough and Co. 1999, *Audit of Water and Irrigation Use Efficiencies on Farms within the Queensland Horticultural Industry*, Final Report, November, http://www.ncea.org.au/Downloads/AuditReportHort_1999.pdf (accessed 3 September 2002).

BCG (Boston Consulting Group) 1996, *Report to the Sugar Industry Review Working Party*, Brisbane.

—— 2003, *BCG Report to Canegrowers: Review of Constraints on Industry Competitiveness and Innovation*, http://www.canegrowers.com.au/BostonPowerpoint.pdf (accessed 23 January 2003).

Beal, D. 1997, 'Economic incentives for farm level resource conservation', *Australian Journal of Environmental Management*, vol. 4, pp. 211–223.

Beattie, P. (Premier of Queensland) 2002, *Commonwealth and Queensland join forces to protect Great Barrier Reef*, Media release, 13 August.

Bellamy, J., Ross, H., Ewing, S. and Meppem, T. 2002, *Integrated Catchment Management: Learning from the Australian Experience for the Murray-Darling Basin*, Overview Report, CSIRO Sustainable Ecosystems, Canberra, http://www.mdbc.gov.au/naturalresources/planning/icm/ICM_Learning_from_Australian_Experience.pdf (accessed 14 January 2003).

Bohl, H.P., Mitchell, D.C., Penny, R.S. and Roth, C.H. 2000, 'Nitrogen losses via subsurface flow from sugar cane on floodplain soils in the Australian wet tropics', *Proceedings of the Australian Society of Sugar Cane Technologists*, vol. 22, pp. 302–7.

Bonanno, H. 2000, *What Does the Future Hold for Australian Sugar Producers?*, Canegrowers, Brisbane.

Bowen Collinsville Enterprise 2002, *Regulatory and Approvals Process Impediments to the Development of the Aquaculture Industry in North Queensland*, Submission no. 69 to the Inquiry into Small Business by the Senate Employment, Workplace Relations and Education References Committee, http://www.aph.gov.au/senate/committee/EET_CTTE/smallbus_employ/submissions/sub069_bowencollinsville_att.pdf (accessed 9 October 2002).

Bramley, R.G.V., Edis, R.B., White, R.E. and Wood, A.W. 1998, *Environmentally Sound Phosphorus Management for Sugar Cane Soils*, Final report on SRDC Project no. CSS3C, October, SRDC, Brisbane.

Brodie, J.E. 1996, 'River flood plumes in the Great Barrier Reef lagoon', in Larcombe, P., Woolfe, K. and Purdon, R.G. (eds), *Great Barrier Reef: Terrigenous Sediment Flux and Human Impacts: Current Research*, CRC Reef Research Centre, Townsville, pp. 33–9.

—— 2000, Keeping the wolf from the door: managing land-based threats to the Great Barrier Reef, Paper presented at the 9th International Coral Reef Symposium, Bali, Indonesia, October.

——, Furnas, M.J., Steven, A.D.L., Trott, L.A., Pantus, F. and Wright, M. 1997, 'Monitoring chlorophyll in the Great Barrier Reef lagoon: trends and variability', in *Proceedings of the 8th International Coral Reef Symposium*, vol. 1, pp. 797–802.

Burdekin Dry Tropics Group 2003, *About Us*, http://www.burdekindrytropics.org.au (accessed 15 January 2003).

Caltabiano, T. 2002, *Property Management Planning for Natural Resource Management Guidelines for Landholders*, Queensland Department of Natural Resources and Mines, Brisbane.

Campbell, I. (Parliamentary Secretary to the Treasurer) 2002, *Productivity Commission study into the Great Barrier Reef catchment and lagoon*, Media release no. 039, Canberra, 13 August.

Canegrowers 1996, *Information Handbook 1996*, 5th edition, Brisbane.

—— 1998, *Code of Practice for Sustainable Cane Growing in Queensland*, Brisbane, http://www.canegrowers.com.au/publications.htm (accessed 21 May 2002).

—— 1999, *Australian Sugar Industry Handbook 1999*, Brisbane.

—— 2001, *Australian Sugar Year Book 2001*, Brisbane.

Cary, J., Barr, T., Aslin, H., Webb, T. and Kelson, S. 2001, *Human and Social Aspects of Capacity to Change to Sustainable Management Practices*, Bureau of Rural Sciences, Canberra.

Cary, J., Webb, T. and Barr, N., 2002, *Understanding Landholders Capacity to Change to Sustainable Practices: Insights About Practice Adoption and Social Capacity for Change*, Bureau of Rural Sciences, Canberra.

Cavanaugh, J.E., Burns, K.A., Brunskill, G.J. and Coventry, R.J. 1999, 'Organochlorine Pesticide Residues in Soils and Sediments of the Herbert and Burdekin River Regions, North Queensland — Implications for Contamination of the Great Barrier Reef', *Marine Pollution Bulletin*, vol. 39, no. 1–12, pp. 367–75.

Christiansen, I.H., O'Grady, C.M. and Azzorpardi, M.J. 2001, 'Environmental Management and Canegrowing: A Survey of Farm Practices', *Proceedings of the 23rd Conference of Australian Society of Sugar Cane Technologists*, pp. 236–45, Mackay, 1–4 May.

Chudleigh, P. 2002, 'Australian production costs of sugar as background to policy development', in Hildebrand, C., *Independent Assessment of the Sugar Industry*, Report to the Minister for Agriculture, Fisheries and Forestry, Canberra.

CIE (Centre for International Economics) 2001, *Indicators Within a Decision Framework: Social Economic and Institutional Indicators for Sustainable Management of the Rangelands*, Report to the National Land and Resources Audit, Canberra.

Coles, S.L. and Jokiel, P.L. 1992, 'Effects of salinity on coral reefs', in Connell, D.W. and Hawker, D.W. (eds), *Pollution in Tropical Aquatic Systems*, CRC Press Inc., Boca Raton, Florida, pp. 147–68.

Commonwealth EPA (Environment Protection Agency) 1995, *Mine Planning for Environment Protection*, Commonwealth of Australia, Canberra, June.

Commonwealth of Australia and State of Queensland 2002, *An Agreement between the Commonwealth of Australia and the State of Queensland for the Implementation of the Intergovernmental Agreement on a National Action Plan for Salinity and Water Quality*, http://www.nrm.qld.gov.au/salinity/pdf/bilateral_agreement.pdf (accessed 3 September 2002).

Cotton Australia 2002, *Chemicals*, http://www.cottonaustralia.com.au/LI_chemicals.html (accessed 9 October 2002).

CRC Reef (Cooperative Research Centre for the Great Barrier Reef World Heritage Area) 2001, *Land Use and the Great Barrier Reef World Heritage Area: Current State of Knowledge*, Townsville, November.

—— 2002a, *Annual Report 2001-2002*, Townsville.

—— 2002b, *Ensuring the Future of the World's Coral Reefs*, http://www.reef.crc.org.au/ (accessed 19 September 2002).

—— 2002c, *Fishing And Fisheries*, http://www.reef.crc.org.au/research/fish/ (accessed 2 October 2002).

CRC Sugar (Cooperative Research Centre for Sustainable Sugar Production) 2000, *The Social Basis of Sustainable Sugarcane Production in Australia: Preliminary Report of a 1998 Survey of Australian Canegrowers*, CRC Sugar Occasional Publication, Townsville.

—— 2002, *Water Quality Pressures and Status in Sugar Catchments*, Exposure Draft, Indooroopilly.

CSIRO (Commonwealth Scientific and Industrial Research Organisation) 2002a, *Patterns of Erosion and Sediment Transport in the Burdekin River Catchment*, http://www.clw.csiro.au/research/tropical/watermanagement/publications/erosion_brochure_2002.pdf (accessed 19 September 2002).

—— 2002b, *Unlocking Success Through Change and Innovation: Options to Improve the Profitability and Environmental Performance of the Australian Sugar Industry*, Submission to the Independent Assessment of the Australian Sugar Industry, Townsville, 5 April, http://www.affa.gov.au/corporate_docs/publications/pdf/sugar_ assessment/csiro.pdf (accessed 28 October 2002).

Curtis, A. and Van Nouhuys, M. 1999, Landcare participation in Australia: the volunteer perspective, *Sustainable Development*, vol. 7, pp. 98–111.

Dairy Farmers 2002, *Dairying on the Tableland — 100 years of Progress*, Malanda.

Devlin, M., Brodie, J., Waterhouse, J., Mitchell, A., Audas, D. and Haynes, D. 2001a, Exposure of Great Barrier Reef inner-shelf reefs to river-borne contaminants, Paper presented at the Sustaining Our Aquatic Environments conference, Townsville, 20–23 November.

Devlin, M., Waterhouse, J., Taylor, J. and Brodie, J. 2001b, *Flood Plumes in the Great Barrier Reef: Spatial and Temporal Patterns in Composition and Distribution*, Research publication no. 68, Great Barrier Reef Marine Park Authority, Townsville.

Dickson, A., Thorpe, S., Harman, J., Donaldson, K. and Tedesco, L. 2001, *Australian Energy: Projections to 2019-20*, ABARE Research Report 01.11, Canberra.

DNR (Queensland Department of Natural Resources) 2000, *Native Vegetation Management in Queensland: Background, Science and Values*, Brisbane.

DNRM (Queensland Department of Natural Resources and Mines) 2001a, *Annual Report 2000-2001*, Brisbane.

—— 2001b, *Managing for Drought in Grazing Lands*, Land Series, http://www.nrm.qld.gov.au/factsheets/pdf/land/LM90w.pdf (accessed 28 October 2002).

—— 2001c, *Managing State Rural Leasehold Land: A Discussion Paper*, Brisbane.

—— 2002a, *Dairy and Lucerne Adoption Program 'Irrigation for Profit'*, http://www.nrm.qld.gov.au/rwue/dairy.html (accessed 8 October 2002).

—— 2002b, *Queensland Minerals and Petroleum Review 2001*, Brisbane.

—— 2002c, *Sugar Adoption Program*, http://www.nrm.qld.gov.au/rwue/sugar.html (accessed 6 February 2003).

—— 2003, *Land Cover Change in Queensland 1999-2001*, Brisbane, http://www.nrm.qld.gov.au/slats/pdf/slats9901.pdf (accessed 10 February 2003).

Douglas, R. 2002, *Potential Effects of Selected Taxation Provisions on the Environment*, Report to the Productivity Commission, Canberra.

DPI (Queensland Department of Primary Industries) 2000, *Managing Coastal Burnett Pastures*, http://www.dpi.qld.gov.au/beef/3312.html (accessed 11 June 2002).

—— 2001a, *Annual Report 2000-2001*, Brisbane.

—— 2001b, *How are Beef Cattle Produced?*, http://www.dpi.qld.gov.au/beef/5496.html (accessed 11 June 2002).

—— 2001c, *Marine Aquaculture Licensing in Queensland: Non-tidal Land*, http://www.dpi.qld.gov.au/fishweb/6101.html (accessed 21 August 2002).

—— 2002, *Queensland Dairy Farming Environmental Code of Practice*, http://www.dpi.qld.gov.au/enviornment/1235.html (accessed 8 October 2002).

Driml, S. 1994, *Protection for Profit — Economic and Financial Values of the Great Barrier Reef World Heritage Area and Other Protected Areas*, Great Barrier Reef Marine Park Authority, Townsville.

Duke, N.C., Roelfsena, C., Tracey, D. and Godson, L. 2001, *Preliminary Investigation into Dieback of Mangroves in the Mackay Region: Initial Assessment and Possible Causes*, Report to the Queensland Fisheries Service, Northern Region (DPI) and the Community of Mackay Region, 15 May, http://www.dpi.qld.gov.au/extra/pdf/fishweb/ExecsummMMDI.pdf (accessed 27 September 2002).

Dunn, T. 1997, Top down theories of extension: use and limitations, *Proceedings of the 2nd Australasia Pacific Extension Conference*, Australia Pacific Extension Network, Albury.

EA (Environment Australia) 2002a, *Guide for Format, Content and Submission of Referrals under Chapter 4 of the Environment Protection and Biodiversity Conservation Act 1999*, http://www.ea.gov.au/epbc/assessmentsapprovals/referrals/guide.html (accessed 9 October 2002).

—— 2002b, *Notification of Variation to Approval: 2000/58*, http://www.ea.gov.au/cgi-bin/epbc (accessed 11 September 2002).

Eliat, Y. and Einav, L. 2001, *The Determination of International Tourism: a Three-Dimensional Panel Data Analysis*, Harvard University, http://www.stanford.edu/~leinav/Tourism.pdf (accessed 26 September 2002).

Environment ACT 2000, *Integrated Pest Management*, http://www.environment.act.gov.au/general/petsandlocalwildlife/integratedpestmanagement.html (accessed 11 December 2002).

EPA (Queensland Environmental Protection Agency) 2000, *Discussion Paper on a Review of Queensland Marine Prawn Aquaculture Licensing under the Environmental Protection Act*, Brisbane.

—— 2001a, *Annual Report 2000-2001*, Brisbane.

—— 2001b, *Conditions Under Which Certain Sugar Industry By-products are not Regulated Waste*, http://www.epa.qld.gov.au/environment/business/licensing/sugar_by-products.pdf (accessed 10 October 2002).

—— 2001c, *State Coastal Management Plan*: *Queensland's Coastal Policy*, Brisbane.

—— 2002, *Information Sheet: Environmentally Relevant Activities (ERAs)*, Brisbane.

Fabricius, K. and De'ath, G. 2001, 'Biodiversity on the Great Barrier Reef: large-scale patterns and turbidity-related local loss of soft coral taxa', in Wolanski, E.

(ed.), *Oceanographic Processes of Coral Reefs: Physical and Biological Links in the Great Barrier Reef*, CRC Press, Boca Raton, pp. 127–44.

Fenton, D., MacGregor, C. and Cary, J. 2000, *Framework and Review of Capacity and Motivation for Change to Sustainable Management Practices*, Bureau of Rural Sciences, Canberra.

Fenton, D.M. and Marshall, N.A. 2001, *A Guide to the Fishers of Queensland, Part A: TRC-Analysis and Social Profiles of Queensland's Commercial Fishing Industry*, CRC Reef Research Centre Technical Report no. 36, Townsville, http://www.reef.crc.org.au/research/fish/commercial.html (accessed 2 October 2002).

FRDC (Fisheries Research and Development Corporation) 2001, *Investing for Tomorrow's Fish: The FRDC Research and Development Plan, 2000-2005*, Canberra.

Fitzroy Basin Association 2002, *About Us - Who is FBA?*, http://www.fba.org.au (accessed 17 December 2002).

Furnas, M. 2002, *Catchments and Corals Terrestrial Runoff to the Great Barrier Reef*, AIMS and CRC Reef, Townsville.

GBRMPA (Great Barrier Reef Marine Park Authority) 1999, *State of the Great Barrier Reef World Heritage Area 1998*, http://www.gbrmpa.gov.au/corp_site/info_services/publications/sotr/ (accessed 2 April 2002).

—— 2000a, 'Aquaculture: Aquaculture Regulations Move to Close Loophole', *Reef Management News*, vol. 10, no. 1, March, http://www.gbrmpa.gov.au/corp_site/info_services/publications/reef_research/issue1_00/rmn_feature_pg16a.html (accessed 18 June 2002).

—— 2000b, 'Aquaculture: Impact on water quality of primary concern to GBRMPA', *Reef Management News*, vol. 10, no. 1, March, http://www.gbrmpa.gov.au/corp_site/info_services/publications/reef_research/issue1_00/rmn_feature_pg19-20.html (accessed 20 June 2002).

—— 2000c, 'Morris review raises growing concerns over effects from land', *Reef Management News*, vol. 10, no. 1, March, http://www.gbrmpa.gov.au/corp_site/info_services/publications/reef_research/issue1_00/rmn_feature_pg17a.html (accessed 27 September 2002).

—— 2000d, 'Aquaculture: Oysters, pearls, fish in wide range of activities', *Reef Management News*, vol. 10, no. 1, http://www.gbrmpa.gov.au/corp_site/info_services/publications/reef_research/issue1_00/rmn_feature_pg18.html (accessed 20 June 2002).

—— 2001a, *Annual Report 2000-2001*, Townsville.

—— 2001b, *Great Barrier Reef Catchment Water Quality Action Plan: A Report to Ministerial Council on Targets for Pollutant Loads,* Townsville, http://www.gbrmpa.gov.au/corp_site/key_issues/water_quality/action_plan/ (accessed 5 April 2002).

—— 2001c, *Great Barrier Reef Water Quality: Current Issues*, September, Townsville.

—— 2001d, *Latency of Tourism Permits in the Great Barrier Reef Marine Park, Audit for the Year 2000*, http://www.gbrmpa.gov.au/corp_site/key_issues/tourism/documents/latency_audit_2000.pdf (accessed 11 June 2002).

—— 2002a, *Annual Report 2001-2002*, Townsville, http://www.gbrmpa.gov.au/corp_site/info_services/publications/annual_reports/2002/annual_rep_2002.pdf (accessed 29 October 2002).

—— 2002b, *Best Environmental Practices*, http://www.gbrmpa.gov.au/corp_site/key_issues/tourism/best_environmental_practice.html (accessed 11 June 2002).

—— 2002c, *Charter Fisheries*, http://www.gbrmpa.gov.au/corp_site/key_issues/fisheries/charter_fisheries.html (accessed 2 October 2002).

—— 2002d, *Coastal Development*, http://www.gbrmpa.gov.au/corp_site/key_issues/water_quality/coastal_development.html (accessed 23 July 2002).

—— 2002e, *Permits*, http://www.gbrmpa.gov.au/corp_site/permits/index.html (accessed 12 June 2002).

—— 2002f, *Plans of Management*, http://www.gbrmpa.gov.au/corp_site/management/plans_of_management.html (accessed 23 July 2002).

—— 2002g, *Policy on Bareboat Operations in the Great Barrier Reef Marine Park*, http://www.gbrmpa.gov.au/corp_site/key_issues/tourism/documents/bareboat_policy_2002_03.pdf (accessed 7 October 2002).

—— 2002h, *Tourism and Recreation*, http://www.gbrmpa.gov.au/corp_site/key_issues/tourism (accessed 11 June 2002).

—— 2002i, *Tourism Management*, http://www.gbrmpa.gov.au/corp_site/key_issues/tourism/management.html (accessed 7 October 2002).

Gippel, C.J. 1995, 'Potential of turbidity monitoring for measuring the transport of suspended solids in streams', *Hydrological Processes*, vol. 9, pp. 83–97.

GPA (Gladstone Port Authority) 2002, *Environmental Performance*, http://www.gpa.org.au/Pages/Publications/Environment/environment.pdf (accessed 8 October 2002).

Great Barrier Reef Shipping Review Steering Committee 2001, *Review of Ship Safety and Pollution Prevention Measures in the Great Barrier Reef*, http://www.amsa.gov.au/SD/gbrreview/final/gbr.pdf (accessed 9 October 2002).

Griliches, Z. 1957, 'Hybrid corn: An exploration of the economics of technological change', *Econometrica*, vol. 25, pp. 501–522.

Gutteridge, Haskins and Davey (GHD) Pty Ltd 1996, *Environmental Audit of the Queensland Canegrowing Industry: Summary*, Brisbane.

Hafi, A., Connell, P. and Sturgiss, R. 1993, *Market Potential for Refined Sugar Exports for Australia*, ABARE Research Report 93.17, Canberra.

Harriott, V.J. 2002, *Marine Tourism Impacts and their Management on the Great Barrier Reef*, CRC Reef Research Centre Technical Report no. 46, Townsville.

Haynes, D. and Johnson, J.E. 2000, 'Organochlorine, heavy metal and polyaromatic hydrocarbon pollutant concentrations in the Great Barrier Reef (Australia) environment: a review', *Marine Pollution Bulletin*, vol. 41, no. 7–12, pp. 267–78.

Haynes, D. and Michalek-Wagner, K. 2000, 'Water quality in the Great Barrier Reef World Heritage Area: past perspectives, current issues and new research directions', *Marine Pollution Biology*, vol. 41, no. 7–12, pp. 428–34.

Haynes, D., Müller, J. and Carter, S. 2000a, 'Pesticide and herbicide residues in sediments and seagrasses from the Great Barrier Reef World Heritage Area and the Queensland Coast', *Marine Pollution Bulletin*, vol. 41, no. 7–12, pp. 279–87.

Haynes, D., Ralph, P., Prange, J. and Dennison, B. 2000b, 'The impact of the herbicide diuron on photosynthesis in three species of tropical seagrass', *Marine Pollution Biology*, vol. 41, no. 7–12, pp. 288–93.

HDRC (Horticultural Research and Development Corporation) and NLWRA (National Land and Water Resources Audit) 2001, *Horticulture. Productivity and Sustainability*, HRDC and NLWRA, Canberra.

Hildebrand, C. 2002, *Independent Assessment of the Sugar Industry*, Report to the Minister for Agriculture, Fisheries and Forestry, Canberra.

Hinchinbrook Shire Council 1997, *The Planning Scheme for the Shire of Hinchinbrook*, http://www.hinchinbrook.qld.gov.au (accessed 7 October 2002).

Hinton, A.W. 1993, *Economics of Beef Production in the Dalrymple Shire*, Project Report Qo93005, Queensland Department of Primary Industries, Brisbane.

Horn, R.V. 1993, *Statistical Indicators for the Economic and Social Sciences*, Cambridge University Press, Cambridge.

HORSCEH (House of Representatives Steering Committee on Environment and Heritage) 2000, *Co-ordinating Catchment Management — Inquiry into Catchment Management*, Canberra, December, http://www.aph.gov.au/house/committee/environ/cminq/cmirpt/Report/fullrpt.pdf (accessed 7 January 2003).

HRIC (Herbert Resource Information Centre) 2002, *Herbert Land and Water Management*, http://www.hric.org.au/hlwm/environment/env_nat_rsrce_mgmnt.Asp (accessed 24 May 2002).

Industry Commission 1996, *Tourism, Accommodation and Training*, AGPS, Canberra.

—— 1998, *A Full Repairing Lease: Inquiry into Ecologically Sustainable Land Management*, Report no. 60, AGPS, Canberra.

JCU (James Cook University) 2002a, *Centre for Coral Reef Biodiversity: Aims of the Centre*, http://www.jcu.edu.au/school/mbiolaq/ccrbio/index.htm (accessed 28 October 2002).

—— 2002b, *Marine Geophysical Lab Sedimentary, Marine & Environmental Geoscience Research Group*, http://www.es.jcu.edu.au/dept/Earth/research/sediment/sediment.html (accessed 29 October 2002).

—— 2002c, *Studies in Marine Biology*, http://www.jcu.edu.au/school/mbiolaq/mbiol/studies/studies.html#studies (accessed 19 September 2002).

Johnson, A. and Bellamy, J. 1998, 'Managing for ecological sustainability: Moving from rhetoric to practice in the Australian sugar industry', *Proceedings from Conference Managing for Ecological Sustainability*, Centre for Conservation Biology, University of Queensland, pp. 163–74.

Johnstone River Catchment Coordinating Committee 1995, *Recommendations to Horticultural Industries, Integrated Catchment Management*, in Queensland Fruit and Vegetable Growers, sub. 49, attachment 1.

King, B., McAllister, F., Wolanski, E., Done, T. and Spagnol, S. 2001, 'River plume dynamics in the central Great Barrier Reef', in Wolanski, E. (ed.) *Oceanographic Processes of Coral Reefs: Physical and Biological Links in the Great Barrier Reef*, CRC Press, Boca Raton, pp. 145–59.

King, B., Zapata, M., McAllister, F. and Done, T. 2002, *Modelling the Distribution of River Plumes on the Central and Northern Great Barrier Reef Shelf*, Technical Report no. 44, CRC Reef, Townsville.

Koop, K., Booth, D., Broadbent, A., Brodie, J., Bucher, D., Capone, D., Coll, J., Dennison, W., Erdmann, M., Harrison, P., Hoegh-Guldberg, O., Hutchings, P., Jones, G.B., Larkum, A.W.D., O'Neil, J., Steven, A., Tentori, E., Ward, S., Williamson, J. and Yellowlees, D. 2001, 'ENCORE: the effect of nutrient enrichment on coral reefs. Synthesis of results and conclusions', *Marine Pollution Biology*, vol. 42, no. 2, pp. 91–120.

Landsberg, R.G. 2002, Applying grazing management principles in the northern savannas, Paper presented at the Australian Rangelands Society 12th Biennial Conference, Kalgoorlie, 2–5 September.

Larcombe, K. and Woolfe, K.J. 1999, 'Increased sediment supply to the Great Barrier Reef will not increase sediment accumulation at most coral reefs', *Coral Reefs*, vol. 18, pp. 163–9.

Lawrence, D., Kenchington, R. and Woodley, S. 2002, *The Great Barrier Reef: Finding the Right Balance*, Melbourne University Press.

Mallawaarachchi, T., Monypenny, R. and Rayment, G., 2002, 'An integrated strategy to enhance profitability and environmental compliance in the Australian sugar industry', *Proceedings Australian Society of Sugar Cane Technologists*, vol. 24.

Marohasy, J. and Johns, G. 2002, *WWF Says 'Jump!', Governments Ask 'How High?' (A publication of the Institute of Public Affairs NGO Project)*, http://www.ipa.org.au/pubs/ngounit/wwftext.html (accessed 22 April 2002).

MCA (Minerals Council of Australia) 2000a, *Australian Minerals Industry Code for Environmental Management*, http://www.minerals.org.au/files/environment/Code2000.pdf (accessed 31 May 2002).

—— 2000b, *2nd Code Progress Report*, http://www.minerals.org.au/defaultx.htm (accessed 1 November 2002).

—— 2001, *3rd Code Progress Report*, http://www.minerals.org.au/defaultx.htm (accessed 1 November 2002).

McCook, L.J. 1999, 'Macroalgae, nutrients and phase shifts on coral reefs: scientific issues and management consequences for the Great Barrier Reef', *Coral Reefs*, vol. 18, pp. 357–67.

McCook, L.J., Wolanski, E. and Spagnol, S. 2001, 'Modelling and visualizing interactions between natural disturbances and eutrophication as causes of coral reef degradation', in Wolanski, E. (ed.), *Oceanographic Processes of Coral Reefs: Physical and Biological Links in the Great Barrier Reef*, CRC Press, Boca Raton, pp. 113–25.

McIvor, J.G., Williams, J. and Gardener, C.J. 1995, 'Pasture management influences runoff and soil movement in the semi-arid tropics', *Australian Journal of Experimental Agriculture*, vol. 35, pp. 55–65.

McPhee, D.P. 2001, *A Comparison of Anthropogenic Discharge Quality and Quantity into Queensland East Coast Catchments*, Report prepared for the Australian Prawn Farmers Association.

Meagher, D. 1991, *MacMillan Dictionary of the Australian Environment*, MacMillan Education Australia, South Melbourne.

Melanie, J., Curtotti, R., Saunders, M., Schneider, K., Fairhead, L. and Ye Qiang 2002, *Global Coal Markets: Prospects to 2010,* ABARE Research Report 02.2, Canberra.

Mitchell, A.W., Bramley, R.G.V. and Johnson, A.K.L. 1997, 'Export of nutrients and suspended sediment during a cyclone-mediated flood event in the Herbert River catchment, Australia', *Marine and Freshwater Research*, vol. 48, pp. 79–88.

Mitchell, A.W. and Furnas, M.J. 1997, 'Terrestrial inputs of nutrients and suspended sediments to the Great Barrier Reef lagoon', in Turia, N. and Dalliston, C. (eds), *The Great Barrier Reef: Science, Use and Management*, GBRMPA, Townsville, pp. 59–71.

MLA (Meat and Livestock Australia) 2002, *Environment*, http://www.mla.com.au/content.cfm?sid=109#processing1 (accessed 10 October 2002).

Moss, A., Rayment, G., Reilly, N. and Best, E., 1992, *A Preliminary Assessment of Sediment and Nutrient Exports from Queensland Coastal Catchments*, Department of Primary Industries and Department of Environment and Heritage, Brisbane.

Murtough, G., Aretino, B. and Matysek, A. 2002, *Creating Markets for Ecosystem Services*, Productivity Commission Staff Research Paper, AusInfo, Canberra.

Musgrave, W. 2002, 'Integrated water management in Australia — some new institutional thoughts', in Garnaut, R. (ed), *Resource Management in Asia Pacific Developing Countries*, Asia Pacific Press, Canberra.

NHT (Natural Heritage Trust) 2002, *About the Natural Heritage Trust*, http://www.nht.gov.au (accessed 18 September 2002).

NLWRA (National Land and Water Resources Audit) 2001a, *Australian Agriculture Assessment 2001*, vol. 1, Canberra.

—— 2001b, *Benchmarking Rural Industries' Practices and Productivity Performance and Review of Industries' Capacity to Change*, http://audit.ea.gov.au/ANRA/agriculture/prod_sugar/AUS.cfm (accessed 14 May 2002).

—— 2002a, *Australian Catchment, River and Estuary Assessment 2002*, vol. 1, Canberra.

—— 2002b, *Australians and Natural Resource Management 2002*, Canberra.

OECD (Organisation for Economic Cooperation and Development) 1999, *Voluntary Approaches for Environmental Policy: An Assessment*, Paris.

—— 2001, *Society at a Glance — OECD Social Indicators*, Paris.

OESR (Office of Economic and Statistical Research) 2001a, *The Contribution of International and Domestic Visitor Expenditure to the Queensland Economy: 1998-99*, Queensland Treasury, Brisbane.

—— 2001b, *International and Domestic Visitor Expenditure in Queensland 1985 to 1999*, Queensland Treasury, Brisbane.

—— 2001c, *International and Domestic Visitor Expenditure in Queensland Regions 1985 to 1999*, Queensland Treasury, Brisbane.

—— 2002a, *The Contribution of International and Domestic Visitor Expenditure to the Queensland Regional Economies 1998-99*, Queensland Treasury, Brisbane.

—— 2002b, *Estimated Resident Population by Statistical Division and Subdivision, Queensland*, http://www.oesr.qld.gov.au/data/tables/compendium/table0030.htm (accessed 9 October 2002).

PC (Productivity Commission) 1998, *Work Arrangements in the Australia Meat Processing Industry*, Labour Market Research Report, AGPS, Canberra.

—— 2000, *Allocating Budgetary Assistance by 27 ANZSIC-based Industry Groupings: Methodological Annex to the Trade & Assistance Review 1999-2000*, December.

—— 2001, *Constraints on Private Conservation of Biodiversity*, Research Paper, AusInfo, Canberra.

—— 2002a, *Pastoral Leases and Non Pastoral Land Use*, Research Paper, AusInfo, Canberra.

—— 2002b, *Trade & Assistance Review 2001-02*, Annual Report Series 2001-02, AusInfo, Canberra.

—— forthcoming, *Social Capital and Public Policy*, Research Paper, AusInfo, Canberra.

PCQ (Ports Corporation of Queensland) 2002, *Eco Ports*, http//www.pcq.com.au/html/03e_ecoports.htm (accessed 8 October 2002).

Penm, J., Maurer, A., Fairhead, L. and Tran, Q.T. 2002, 'US dollar: impacts of a depreciation of the US$ on Australian commodities', *Australian Commodities*, vol. 9, no. 3, pp. 485–94.

Price, C. and Breen, M. 2001, 'APFA Environmental Code of Practice', *Aquaculture News*, issue no. 19, December, Queensland Department of Primary

Industries, http://www.dpi.qld.gov.au/aquaculturenews/8045.html (accessed 20 June 2002).

Prosser, I., Moran, C., Lu, H., Pickup, G., Gallant, J., Young, W., Hughes, A. and Rustomji, P. 2001, Sediment and nutrient budgets for rivers draining to the Great Barrier Reef, Paper presented at the Sustaining our Aquatic Environments conference, Townsville, 20–23 November.

Prosser, I., Moran, C., Lu, H., Scott, A., Rustomji, P., Stevenson, J., Priestly, G., Roth, C. and Post, D. 2002, *Regional Patterns of Erosion and Sediment Transport in the Burdekin River Catchment*, Technical Report no. 5/02, CSIRO Land and Water, Townsville.

PTEWG (Port of Townsville Environmental Working Group) 2001, *Ship to Shore*, Community Awareness Newsletter, issue no. 2, Townsville Port Authority, February, http://www.townsville-port.com.au/pdf/shiptoshore2.pdf (accessed 9 October 2002).

QFVG (Queensland Fruit and Vegetable Growers) 1998, *Farmcare: Cultivating a Better Future, Code of Practice for Sustainable Fruit and Vegetable Production in Queensland*, Rocklea, Queensland.

—— 2002a, *Growing Areas*, http://www.qfvg.org.au/industry/regions.html (accessed 15 May 2002).

—— 2002b, *2002 State Government Budget Submission*, http://www.qfvg.org.au/2002%20QFVG%20State%20%20Budget%20 Submission.pdf (accessed 17 June 2002).

Queensland Government 1999, *Submission (no. 138) to Inquiry into Catchment Management by House of Representatives Standing Committee on Environment and Heritage*, http://www.aph.gov.au/house/committee/environ/cminq/ sub138-e.pdf (accessed 15 October 2002).

Queensland Transport 2001, *Trade Statistics for Queensland Ports, 5 Years Ending June 2000*, Brisbane, http://www.transport.qld.gov.au/qt/railport.nsf/ files/images/$file/ TSR2000.pdf (accessed 8 October 2002).

Queensland Treasury Office of Energy 2002, *Electricity — Generation*, http://www.energy.qld.gov.au/electricity/generation.htm (accessed 10 October 2002).

Rainbow, J., Buckley, R., Byrnes, T. and Warnken, J. 2002, *Green Guide to Blue Seas Best-Practice Environmental Management for Small Boat Tours*, CRC for Sustainable Tourism, http://www.crctourism.com.au/bookshop/default.asp? CatID=1 (accessed 3 June 2002).

Ralph, P.J. 2000, 'Herbicide toxicity of *Halophila ovalis* assessed by chlorophyll *a* fluorescence', *Aquatic Botany*, vol. 66, pp. 141–52.

Reef Protection Steering Committee 2002, *Information Paper on the Proposed Reef Water Quality Protection Plan for Catchments Adjacent to the Great Barrier Reef World Heritage Area*, Brisbane and Canberra.

RSES (Research School of Earth Sciences) 2003, Home Page, http://rses.anu.edu.au/rsesext.html (accessed 22 January 2003).

Reghenzani, J.R., Roth, C.H., Simpson, B.W., Smith, C.D. and Visser, F. 2001, Managing losses from agriculture on floodplain environments, Paper presented at the Sustaining Our Aquatic Environments conference, Townsville, 20–23 November.

Ribaudo, M., Horan, R. and Smith, M. 1999, *Economics of Water Quality Protection from Nonpoint Sources: Theory and Practice*, Agricultural Economic Report no. 782, Economic Research Service, Washington DC.

River, S.W. 2000, *Local Government Environmental Case Studies: Douglas Shire Development and Population Cap*, http://cres.anu.edu.au/lgcases/q11%20douglas.pdf (accessed 30 September 2002).

RMAC (Reef Management Advisory Committee) 1996, *Queensland Tropical Coral Reef Fish Species*, Discussion Paper no. 2 prepared for the Queensland Fisheries Management Authority.

Rogers, E.M., 1962, *Diffusion of Innovations*, The Free Press of Glencoe, New York.

—— 1983, *Diffusion of Innovations*, The Free Press, New York.

Rose, R. 2002, *Factors Affecting the Efficiency of ITQs*, Report for the Fisheries Resources Research Fund, ABARE, Canberra.

Rowland, P. and Begbie, D. 1997, Integrated Catchment Management in Queensland: an overview and review, Paper presented at the 2nd National Workshop on Integrated Catchment Management: Advancing Integrated Resource Management — Processes and Policies, 29 September–1 October, ANU, Canberra.

Scanlan, J.C. and Turner, E.J. (eds) 1995, *The Production, Economic and Environmental Impacts of Tree Clearing in Queensland*, A Report to the Working Group of the Ministerial Consultative Committee on Tree Clearing.

Schaffelke, B. 1999, 'Particulate organic matter as an alternative nutrient source for tropical Sargassum species (*Fucales, Paeophycae*)', *Journal of Phycology*, vol. 35, pp. 1150–7.

Schroeder, B.L. and Wood, A. W. 2001, 'Assessment of nitrogen mineralising potential of soils in two different landscapes in the Australian sugar industry — Implications for N fertiliser management', *Proceedings Australian Society of Sugar Cane Technologists*, vol. 23, pp. 281–288.

Schroeder, B.L., Wood, A.W. and Kingston, G., 1998, Re-evaluation of the basis for fertiliser recommendations in the Australian Sugar Industry, *Proceedings Australian Society of Sugar Cane Technologists*, vol. 20, pp. 239–247.

Science Panel (GBR Reef Protection Interdepartmental Committee Science Panel) 2003, *A Report on the Study of Land-Sourced Pollutants and Their Impacts on Water Quality in and Adjacent to the Great Barrier Reef*, http://www.premiers.qld.gov.au/about/reefwater.pdf (accessed 29 January 2003).

Segerson, K. 1988, 'Uncertainty and incentives for nonpoint pollution control', *Journal of Environmental Economics and Management*, vol. 15, pp. 87–98.

Shannon, E.L., Holden, J.R. and Raine, S.R. 1996, 'Adoption of improved irrigation practices by Burdekin canegrowers', in *Evapotranspiration and Irrigation Scheduling Procedures International Conference*, Texas, 3–6 November 1996, pp. 214–19.

Shortle, J. and Horan, R. 2001, 'The economics of nonpoint pollution control', *Journal of Economic Surveys*, vol. 15, no. 3, pp. 255–89.

SSCRRA (Senate Standing Committee on Rural and Regional Affairs) 1992, *Beef Cattle Feedlots in Australia*, Canberra.

Switala, J. and Taylor-Moore, J. 1999, *Queensland's Commercial Fishing Fleet — Licence Packages, Fleet Structure and Fishing Port Activities 1996-97*, Queensland Department of Primary Industries, Brisbane.

TFC (Tourism Forecasting Council) 2002a, *Tourism Forecasting Council — April 2002 Forecasts*, Canberra.

—— 2002b, *Tourism Forecasting Council — December 2002 Forecasts*, Canberra.

Thain, M. and Hickman, M. 1996, *The Penguin Dictionary of Biology*, 9th edition, Penguin, London.

Tourism Queensland 2002, *Ecotourism Accreditation — Industry Survey*, http://www.tq.com.au/ecotourism/research/neap/industry.asp (accessed 12 June 2002).

Tropical Savannas CRC 2002, *North East Queensland Grazing*, http://savanna.ntu.edu.au/information/r8/t4/r8_t4_1.html (accessed 11 June 2002).

Udy, J.W., Dennison, W.C., Lee Long and McKenzie, L.J. 1999, 'Responses of seagrass to nutrients in the Great Barrier Reef, Australia', *Marine Ecological Progress Series*, vol. 185, pp. 257–71.

VEPA (Victorian Environmental Protection Authority) 1999, *Acid Sulfate Soil and Rock*, EPA Information Bulletin, Publication 655, http://www.epa.vic.gov.au (accessed September 2002).

Weersink, A., McKitrick, R. and Nailor, M. 2001, 'Voluntary cost-share programs: lessons from economic theory and their application to rural water quality programs', *Current Agricultural, Food and Resource Issues*, vol. 2, pp. 23–36.

White, I., Brodie, J. and Mitchell, C. 2002, Pioneer River Catchment Event Based Water Quality Sampling, Australian Centre for Tropical Freshwater Research (unpublished).

Williams, D. McB. 2001, *Impacts of Terrestrial Run-off on the Great Barrier Reef World Heritage Area*, Report to CRC Reef, Townsville.

Williams, L. (ed) 2002, *Queensland's Fisheries Resources: Current Condition and Recent Trends 1988-2000*, Department of Primary Industries, Brisbane.

Wolanski, E., Richmond, R., McCook, L. and Sweatman, H. 2003, 'Mud, marine snow and coral reefs: the survival of coral reefs requires integrated watershed-based management activities and marine conservation', *American Scientist*, vol. 91, January–February (forthcoming).

Wolanski, E. and Spagnol, S. 2000, 'Pollution by mud of Great Barrier Reef coastal waters' *Journal of Coastal Research*, vol. 16, no. 4, pp. 1151–6.

Wong, G., Sturgiss, R., and Borrell, B. 1989, *The Economic Consequences of International Sugar Trade Reform*, ABARE Discussion Paper 89.7, AGPS, Canberra.

Woolfe, K.J and Larcombe, P. 2000, *Sediment dispersal along the inner shelf of the Great Barrier Reef*, in North Johnstone and Lake Eacham Landcare, sub. 36, attachment 2.

Woolfe, K.J, Larcombe, P., Orpin, A.R., Purdon, R.G., Michaelsen, P., McIntyre, C.M. and Amjad, N. 1998, 'Controls upon inner-shelf sedimentation, Cape York Peninsula, in the region of 12°', *Australian Journal of Earth Sciences*, vol. 45, pp. 611–21.

WWF (World Wide Fund for Nature) 2001, *Clear?…or present danger? Great Barrier Reef Pollution Report Card*, WWF Great Barrier Reef Campaign, http://www.gbr.wwf.org.au/_Download_Forms/Reef_Pollution_Report_Card.pdf (accessed 19 April 2002).

—— 2002, *Sugar Cane and Banana Production*, http://www.gbr.wwf.org.au/content/problem/sugarcane.htm (accessed 3 October 2002).