CRC Reef Research Centre

Land Use

and the Great Barrier Reef

CURRENT STATE OF KNOWLEDGE

June 2003 (revised edition)

Photo by GBRMPA Design by WWd: www.wwd.net.au

The Myer Foundation

Great Barrier Reef Research Foundation

Run-off of sediment and nutrients to the Great Barrier Reef has increased several-fold due to past and current land-use practices. There is significant concern that coastal ecosystems in the Great Barrier Reef World Heritage Area (GBRWHA) are suffering as a consequence of this increase.

While significant improvements have been made in sustainable land use, other practices continue to threaten the GBRWHA. More effective action is needed to further reduce run-off of sediment, nutrients and other pollutants, and alleviate the present threat to these ecosystems.

Where does run-off come from?

There is an interdependent relationship between the land and the reef ecosystem. Water, sediment and nutrients drain into the Great Barrier Reef World Heritage Area from a catchment of 424,000 km^2. The Great Barrier Reef (GBR) catchment covers 25% of the State of Queensland and comprises 38 drainage basins both on the mainland and large islands. Most of the catchments are small (less than 10,000 km^2), except the Burdekin (130,000 km^2) and Fitzroy River (142,000 km^2) catchments which comprise 64% of the total GBR catchment area.

Most of the GBR catchment is naturally vegetated by seasonally dry woodlands of eucalypt and acacia trees, shrubs and grass. Approximately 13,000 km^2 of rainforest once grew on the wetter coastal plains and mountains.

Open-range cattle grazing on native and cleared pasture is the major land use, covering more than 75% of the GBR catchment. Sugarcane takes up 1% of the whole GBR catchment (approximately 4,000 km^2), with a proportion of more than 10% in seven river catchments. However, sugarcane is mainly grown adjacent to waterways on fertile coastal floodplains where it takes up a much larger area. A variety of grain, tropical fruit, vegetables and fibre (e.g. cotton) crops are also grown.

Almost one million people live within the GBR catchment. Nearly half of the population (43%) live in six coastal cities. Some of the stormwater run-off and treated sewage effluent from these cities is discharged to waters that will reach the GBR. The growing coastal aquaculture industry also discharges effluent into coastal waterways. These inputs are locally significant but are small compared with sediment, nutrient and pollutant inputs from agricultural sources.

Photo by DPI

Cattle are grazed on more than 75% of the Great Barrier Reef catchment

How much run-off is there?

On average, 380 billion cubic metres of rain (380 km^3) falls on the GBR catchment each year. Of this rainfall, approximately 70 billion cubic metres (70 km^3) of water eventually leaves the catchment in rivers and streams. Most run-off occurs during the summer wet season, particularly when rivers are in flood. A large proportion of the annual run-off from catchments occurs during floods after a cyclone.

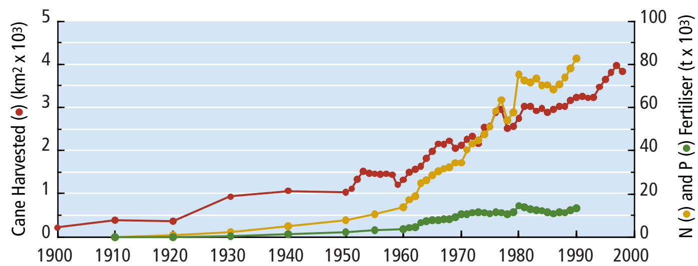
The frequency of floods varies from several times per year in rivers of the Wet Tropics (Tully and Russell Rivers) to once per decade in the large, dry southern catchments (Fitzroy and Burnett Rivers). These floods are a natural and important part of the ecology of catchments as well as the Reef.

River and floodwaters carry sediment and nutrients eroded from the land into the GBR. The amount of sediment and nutrients transported depends on the volume of freshwater run-off to the Reef. At present, rivers carry an average of 14 million tonnes of sediment, 49,000 tonnes of nitrogen and 9,000 tonnes of phosphorus into the GBR each year. In the last 150 years, sediment in run-off is estimated to have increased three- to ten-fold, nitrogen in run-off at least two-fold, and phosphorus in run-off at least three-fold.

Why has sediment and nutrient run-off increased?

Prior to European settlement, woodlands, grasslands and forests covered the GBR catchment. Since 1850, native forests and woodlands have been cleared for grazing, farming, urban and mining activities. About half of the GBR catchment is now cleared to some extent. Most of the clearing is in the inland sections of the Fitzroy and Burdekin River catchments. Heavy grazing during droughts has caused the recurrent, but temporary, loss of most grass cover from large areas. Removal of vegetation (whether by clearing, cultivation, over-grazing or frequent burning) causes accelerated soil erosion and loss of nutrients from the land. The removal of elements of the landscape that act as natural filters for sediments and nutrients, such as riparian vegetation lining rivers and creeks, and coastal wetlands, have exacerbated these losses.

Approximately 95% of the sediment delivered to the coast is generated by hotspots covering only 13% of the Burdekin catchment area. A total of 85% of sediment is delivered to the coast from grazing lands in the Bowen River Basin and the lower Burdekin. Canelands close to the coast are estimated to deliver 9% of the total sediment export to the coast.



Increase in the area harvested for sugarcane, and the application of nitrogen and phosphorus fertilisers to the GBR catchment. Graph supplied by Miles Furnas.

Farming in the GBR catchment is supported by extensive use of fertilisers, most of which are applied to sugar crops on the coastal plain. Over the last 50 years, fertiliser use has risen because there is a larger area of sugarcane under cultivation and the rates of fertiliser application have increased. At present, approximately 100,000 tonnes of nitrogen and 20,000 tonnes of phosphorus are applied in fertiliser to crops in the GBR catchment annually. In sugar cane and other crops, about one third to half of the fertiliser nitrogen is used for growth and a portion remains in the soil, building fertility. The remainder of the fertiliser nitrogen moves from the root zone either to deeper layers of the soil and/or is lost to the atmosphere, surface run-off and groundwater. The latter processes are probably the cause of the recent increase in the concentration of soluble nitrogen in rivers to the Wet Tropics. Most of the added phosphorus becomes bound to the soil and is transported with eroded soil into waterways.

What does run-off carry?

Sediments

During floods, river waters contain higher levels of suspended sediment because of enhanced soil erosion in the catchment and stronger river flow. The amount of sediment suspended in rivers can reach about 500 mg per litre in small rivers of the Wet Tropics, and more than 3,000 mg per litre in muddy or turbid rivers of the Dry Tropics. The difference is due to more natural vegetation in wet tropical catchments and differences in the volume of run-off, catchment size, land use and soil types between catchments.

A large proportion of the nitrogen and phosphorus, heavy metals and pesticides carried by rivers are attached to fine sediment particles.

Fine sediment can stay in suspension much longer than larger particles and can carry toxic materials further than they would travel alone.

Nutrients

Nitrogen and phosphorus are the main nutrients carried by rivers into the GBR. Nearly half of the nitrogen (40%) and most of the phosphorus (80%) is associated with the fine sediment carried by run-off. Because the amount of nutrients carried into the GBR is related to the volume of run-off from individual rivers, more nutrients are exported to the Reef in wet years than in dry years.

Nitrate is the main form of dissolved nitrogen in river waters. Rivers in the Wet Tropics export relatively more nitrogen in dissolved form, while rivers in the dry catchment rivers of the central and southern GBR (Burdekin, Fitzroy Rivers) export nitrogen mostly in particulate form. Aquatic organisms take up dissolved inorganic nitrogen more easily than particulate nitrogen.

Photo by GBRMPA

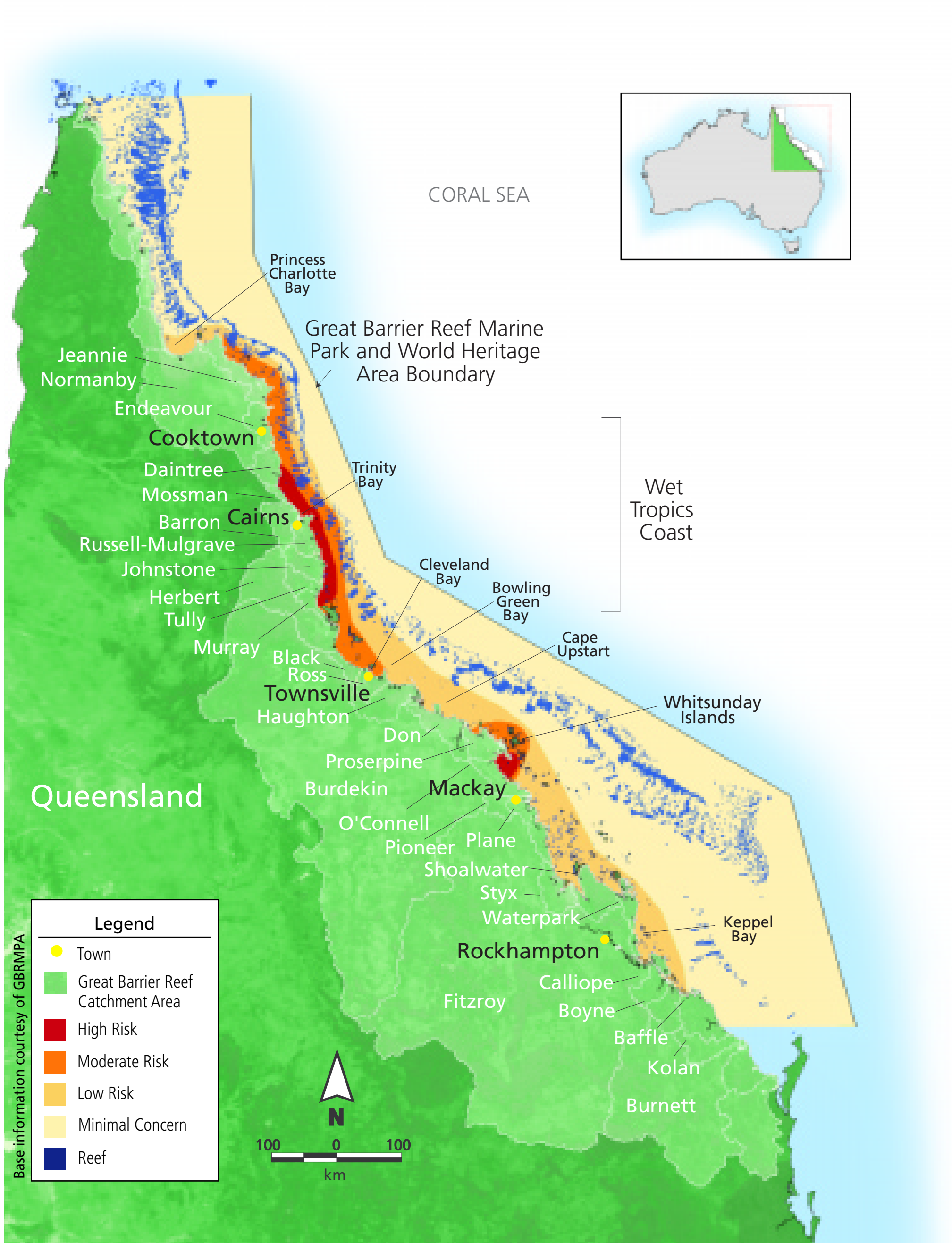
Run-off from fertilised cropping land is a significant source of the nutrients washed into the Great Barrier Reef

The concentration of dissolved phosphorus is low in all rivers because the phosphorus mostly remains to soil particles. Most of the total nitrogen and phosphorus in run-off comes from grazing lands of the large, dry catchments because they have the greatest area; volume of run-off; and soil loss. Fertilised cropping land is also a significant source of the nutrients in run-off, particularly nitrate. The concentrations of nutrients in rivers and streams draining agricultural lands on floodplains are consistently higher than in streams draining pristine or uncleared catchments.

Other Pollutants

Many agricultural and industrial chemicals are used in the GBR catchment and find their way into run-off. Although the levels of these chemicals in reef waters and sediments are very low, levels can be high in coastal sites near human activity such as ports and harbours, urban centres, and areas close to intensive agricultural activity.

Herbicides, such as diuron and atrazine, are used widely in the sugar industry. Elevated concentrations of diuron are found in river water draining cropping lands in flood conditions and in coastal sediments adjoining major sugar-growing catchments. In some cases, the concentrations of herbicides in coastal sediments can affect productivity of seagrasses.



Information in map based on Devlin M, Brodie J, Waterhouse J, Mitchell A, Audas D, Haynes D. in press. Exposure of the Great Barrier Reef inner-shelf reefs to river-borne contaminants. In: Dawson N, Brodie J, Rayment G, Porter C. (eds). Sustaining our Aquatic Environments - Implementing Solutions. Dept of Natural Resources and Mines, Queensland.

Small but detectable amounts of the heavy metals, mercury and cadmium, can be found in coastal sediments adjoining major sugar-growing catchments. Mercury is used as a fungicide on sugarcane when it is planted. Cadmium is a natural contaminant of some phosphate fertilisers. In harbour and port areas, very high concentrations of heavy metals are found in marine sediments, usually attributed to ore spillage, stormwater run-off and ship-building. The biological effect of these contaminants is unclear, however, heavy metals accumulate through the food chain and are known to be toxic to animals and plants above certain concentrations.

Earth works during construction activities in the coastal zone have the capacity to expose potential acid sulfate soils, which commonly occur along the Queensland coast. Exposure of these soils leads to the production of sulfuric acid that can acidify soils, groundwater and, through run-off, natural waterways. Apart from direct impacts on animals and plants, acidity reduces oxygen in waterways to critical levels and can release soil-bound heavy metals.

How far does run-off reach?

When freshwater reaches the ocean, it forms plumes which usually turn to the north and hug the coast. Most plumes extend less than 20 km from the coast. During unusually calm or northerly wind conditions, plumes can travel offshore as far as some outer shelf reefs, but their duration offshore is brief. Although most GBR reefs are further than 20 km from shore and are rarely affected by floodwaters, the inshore reefs are regularly influenced by floodwater plumes.

Because river plumes usually stay close to the coast, virtually all land-based sediment reaching the GBR is deposited within 10 km of the coast. Wind, waves and tidal currents move the sediment northward along the coast. Eventually, most of the sediment is trapped in northward facing bays (e.g. Bowling Green Bay, Cleveland Bay, Trinity Bay, Princess Charlotte Bay). However, dissolved material in river discharge can travel much further. For example, nitrate from the Burdekin River remains in high concentrations as far north as Magnetic Island near Townsville.

How does run-off affect the marine environment?

The impacts of run-off are caused by a number of simultaneously acting factors. Although effects of individual factors on short time scales are known, the effects of two or more factors acting together over long periods of time are still poorly understood. However, recent field-based research has shown that the biodiversity of reefs exposed to land run-off is reduced compared with reefs adjacent to undeveloped catchments.

Effects of freshwater

Corals and other organisms on coastal reefs are naturally inundated with freshwater run-off from time to time. Prolonged inundation by freshwater can kill large numbers of animals on coastal reefs, as occurred in the Keppel Islands after cyclone Joy in 1991. Short-term freshwater inundations, combined with high water temperatures, can cause corals to bleach, making them more sensitive to other stresses, and in the worst case, can kill them.

Effects of sediments

Sediment affects coral reefs in several ways: by increasing water turbidity (making water look muddy), by reducing the amount of light reaching bottom-dwelling corals and algae; by covering surfaces and making them less suitable for juvenile corals and other non-mobile animals to settle; and by making corals and other organisms use additional energy to remove sediment.

Some corals are well adapted to muddy conditions. Thriving coral reefs with high coral cover and high diversity do occur in nearshore waters where turbidity can be high. Some corals on these reefs are adapted to use the organic matter associated with sediment as a food source.

However, recent work has shown that when fine sediment is mixed with nutrient-rich water it aggregates into large sticky flocs called marine snow. These marine snow flocs amplify the effect of sediment alone because they smother reef organisms and can kill small animals within an hour.

Although anecdotal evidence suggests that some coastal reefs have been degraded and buried in sediment, scientific debate continues about whether modern increases in sediment run-off have increased turbidity and reef degradation.

Effects of nutrients

Nutrient concentrations in GBR waters are naturally very low. Increases in nutrients can change reef communities by subtly altering the capacity of many species to grow and reproduce. They can also disturb the normal competition in reef communities for space, light and food. Microscopic, floating plants and animals (called plankton) initially take up most of the nutrients in run-off, and in turn, form the basic food for many reef and coastal food webs.

Nutrients can trigger plankton blooms that increase turbidity, reduce the health of corals and enhance the growth of large algae (or macroalgae). Algae quickly re-colonise disturbed surfaces, including corals that are killed by other factors such as freshwater, high water temperatures or crown-of-thorns starfish. If algae become established, the regrowth of hard corals can be slowed or disrupted. Algal cover on reefs is also related to the presence of herbivores, especially fish. Factors controlling the abundance of herbivorous fish on coastal reefs of the GBR are not well understood, but fishing is not a direct problem.

It has been suggested that run-off could cause outbreaks of crown-of-thorns starfish by providing additional nutrients as food for the larval starfish. The increased nutrients could be a result of natural run-off, or exacerbated by changes in land use. There is increasing evidence for a link between extreme rainfall events and the last three outbreaks of crown-of-thorns starfish on the GBR. However, a link between starfish outbreaks and changes in land use has not been demonstrated or disproved.

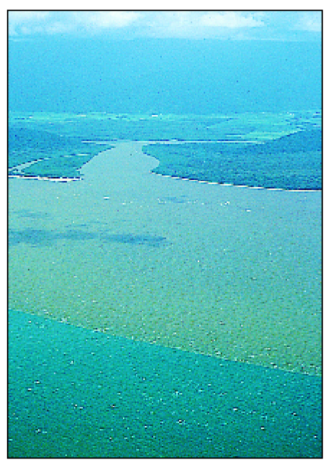


Photo by GBRMPA

Flood plume reaches to inshore islands and reefs

Our understanding of changes to the Great Barrier Reef

Habitats on the GBR are disturbed relatively frequently by natural events such as cyclones, coral bleaching, floods and outbreaks of crown-of-thorns starfish. The habitats usually recover from these acute events. It will take many years to fully understand the cumulative impact of run-off in addition to these events. One of the greatest concerns is that coastal reefs may be stressed by impacts of run-off to a point where they cannot recover from a major disturbance.

Large-scale, systematic studies of the GBR are relatively recent (20 years or less) so we don't know what coral reefs were like before European settlement or how much the system changes over the longer term.

Although most reefs in the GBR are more than 20 km from the coast and unlikely to be directly influenced by run-off, approximately 750 reefs are within 10 km of the coast in the zone strongly affected by run-off. Coastal reefs at risk are between Port Douglas and Gladstone. The greatest concern is for reefs between Port Douglas and Hinchinbrook Island, and between Bowen and Mackay.

The status and quality of waters in the Great Barrier Reef

There are usually low concentrations of dissolved and particulate nutrients and low levels of suspended particulate matter in reef waters. Coral reef organisms obtain most of the nutrients they need by recycling nutrients that are already in the environment.

Nutrient and plankton concentrations vary naturally between regions of the GBR and are typically higher in shallow coastal waters where sediments are an important source of nutrients. This is also where land run-off has its greatest effect.

Nutrient levels in coastal shelf waters are extremely variable. Despite increasing sediment run-off and high levels of fertiliser use in catchments adjoining the GBR, consistent increases in the nutrient levels in the last 25 years

Photos by Katharina Fabricius

Above: Heath Reef - an inshore reef, north of Princess Charlotte Bay, which has high cover and diversity of hard corals
Bottom: An inshore reef near Dunk Island, adjacent to the Wet Tropics, which has low cover of hard corals and much dead coral

could not be detected. However, chlorophyll levels, which are an indicator of nutrient status, are generally higher in inshore waters adjacent to the developed catchments of the central and southern GBR region, compared with the less developed Cape York region. This may be the first sign of wide-scale nutrient enrichment in these areas associated with increased nutrient discharge. Changes in water quality caused by run-off will be gradual and difficult to measure. These changes and their effects on the environment will be equally slow to reverse.

Effects on seagrasses

Seagrasses grow in coastal areas and are particularly vulnerable to run-off. Potential impacts from changes to land use include the reduction of light for photosynthesis, burial by sediment and poisoning by herbicides.

Most seagrasses in nearshore regions of the GBR are relatively tolerant of low underwater light levels. These seagrass beds are naturally dynamic and responsive to acute disturbances such as floods and cyclones. It is possible that enhanced run-off of nutrients, sediments and pesticides will increase chronic stress of seagrasses and make them more vulnerable to acute disturbances. Because seagrass beds are naturally dynamic, there is considerable uncertainty about their status. In recent decades, the number of dugongs in the GBR has declined. Because dugongs feed exclusively on seagrass, there is concern that changes in the distribution and composition of seagrass meadows could be contributing to the loss.

Managing run-off

The challenge for reef managers, land managers and land users is to maintain the quality of reef waters and the health of biological communities by reducing and managing the amount of sediment, nutrients and other pollutants in run-off.

Discharges from point sources, such as sewage treatment plants or industrial facilities, are regulated under the Queensland Environmental Protection Act 1994 and, within the Great Barrier Reef Marine Park, by Commonwealth legislation. Inputs of materials from non-point sources, such as agriculture, are not explicitly regulated or monitored.

In July 2000, the Environment Protection and Biodiversity Conservation Act 1999 came into force. The Act prohibits new actions that have, will have, or are likely to have a significant impact on environments which are of national significance, including threatened species and World Heritage Areas.

In the absence of direct regulatory control, the minimisation of sediment, nutrient and pollutant run-off is largely managed through a voluntary approach by land holders. Integrated Catchment Management (ICM) of natural resources combined with education is currently regarded as the best way to reduce run-off losses to the GBR. Agricultural industries have developed or are developing Best Management Practices as self-management tools to minimise the environmental impacts of land use. However, the success of these approaches is limited because they are voluntary and there is a lack of incentives and resources for land-users to implement changes that would significantly reduce land run-off.

Recently, local government planning schemes and a number of specific Natural Resource Management (NRM) plans have been developed or are being developed under the Queensland Integrated Planning Act, with the primary goal of achieving ecologically sustainable development. These planning schemes are performance-based rather than prescriptive plans. However, a major shortcoming of the current management approaches is the lack of mechanisms and criteria to evaluate their effectiveness. Effective audit procedures are needed to test various approaches to land management, and more importantly, to allow individual land users to evaluate the effectiveness of their time and financial investment in land and waterway improvements.

Making changes to land use or correcting past abuses is often expensive. It is estimated that the cost of a significant rehabilitation program for the GBR catchment would exceed $300 million.

Government initiatives to tackle run-off

In August 2002, the Commonwealth and Queensland Governments committed to develop a Reef Water Quality Protection Plan to protect the Great Barrier Reef from land-sourced pollutants (www.ea.gov.au/coasts/pollution/reef/). Both Governments will work with regional Natural Resource Management (NRM) bodies, established under the National Action Plan for Salinity and Water Quality, and the Natural Heritage Trust (see below), to set catchment water quality targets and develop catchment-specific actions.

The Queensland Government established a Scientific Review Panel to: summarise evidence on water quality impacts; advise on methods for setting end-of-river targets; and identify the most practical options to reduce water quality impacts on the GBR. The report is available at www.premiers.qld.gov.au/about/reefwater.pdf.

The Commonwealth Government asked the Productivity Commission (an independent Commonwealth agency that reviews and advises the Government on micro-economic policy and regulation) to determine the importance of industries in the GBR catchment, and to report on the costs and benefits of on-ground actions to address declining water quality. The report from the Commission was released in February 2003 (www.pc.gov.au/study/gbr/finalreport/index.html).

The Reef Water Quality Protection Plan is an overarching plan that will influence planning regimes at the State, regional and local levels through partnerships building on existing NRM processes. Funding for the Plan is from the National Action Plan for Salinity and Water Quality (NAP) and the Natural Heritage Trust (NHT). The NAP is a joint initiative of the Commonwealth, State and Territory Governments. A total of $700 million over seven years (2000-01 to 2006-07) is available from the Commonwealth matched by State and Territories. In March 2002, the Queensland and Commonwealth Governments agreed to invest up to $81 million each to implement the NAP. Priority regions in several catchments have been identified adjacent to the Marine Park. These are the Burdekin, Fitzroy and Burnett catchments. Funds will be available to regional Natural Resource Management (NRM) bodies which must develop NAP accredited NRM plans. The NRM bodies must have a majority of community members and include local government and Indigenous interests.

The Australian Commonwealth Government established the Natural Heritage Trust in 1997 to "help restore and conserve Australia's environment and natural resources" (www.nht.gov.au). By 2002, $1.4 billion had been invested in more than 11,900 projects involving 400,000 people across Australia. In 2001, the Commonwealth Government committed a further $350 million to the NHT (often referred to as NHT2). For catchments outside the NAP priority catchments, these funds will be delivered by Coastcare, Landcare, Bushcare and Rivercare programs through accredited NRM plans.

The Commonwealth and Queensland Governments have also agreed to an assistance package for the sugar industry. As part of this package, approximately $30 million will be allocated to environmental management initiatives in sugarcane growing regions such as management of wetlands and riparian vegetation along creeks and streams.

Research

A considerable amount of research is underway by organisations with a commitment to, or responsibility for, managing the effects of land-use practices on the environment adjacent to the GBR. There are studies into land-use practices to reduce environmental impacts, such as green cane cutting (harvesting cane without burning it first), trash blanketing (leaving cane trash on fields after harvest), more efficient fertiliser use, sustainable grazing practices, fencing of riverbank access and re-planting of vegetation along streams. Research activity is now shifting toward integrating the results of these studies with practical plans for land and water management.

CRC Reef Research Centre, with its partner organisations, is supporting a range of research and monitoring activities to determine the quantity and fate of materials in land run-off; and the response of key ecosystems such as nearshore coral reefs to run-off. This research will assess the health and status of reef ecosystems and form a basis for evaluating the effectiveness of land management practices in reducing threats to the Reef.

CRC Reef Research Centre

Ensuring the future of the world's coral reefs

CRC Reef Research Centre Ltd is a knowledge-based partnership of coral reef researchers, managers and industry. Its mission is to provide research solutions to protect, conserve and restore the world's coral reefs. CRC Reef Research Centre Ltd is a joint venture between:

- Association of Marine Park Tourism Operators
- Australian Institute of Marine Science
- Great Barrier Reef Marine Park Authority
- Great Barrier Reef Research Foundation
- James Cook University
- Queensland Department of Primary Industries
- Queensland Seafood Industry Association
- Sunfish Queensland Inc.

Established and supported under the Australian Government's Cooperative Research Centres Program.

CRC Reef Research Centre
PO Box 772 Townsville
Queensland 4810 Australia
Telephone: 61 7 4729 8400
Email: info@crcreef.com
Website: www.reef.crc.org.au

Published by CRC Reef Research Centre Ltd 2003
Printed on recycled paper