



Northern  
Territory  
Government

Department of Land Resource Management

# Darwin Harbour Water Quality Protection Plan



Australian Government

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Department of Land Resource Management (DLRM)

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# Summary

Darwin Harbour is appreciated for its wide-ranging cultural, recreational, economic and natural values. There are few tropical harbour-side cities with such an expanse of mangroves, supporting plentiful fishing and mud crabbing, offering regular dolphin and dugong-spotting opportunities, and providing such an impressive backdrop for tropical living.

Water quality in Darwin Harbour and its catchment is generally good to excellent, particularly in comparison to waterways surrounding other major Australian cities. Presently, we have an opportunity for sustainable development of our working Harbour, provided land and water resources continue to be well-managed.

This Water Quality Protection Plan (WQPP), funded by the Australian Government, takes a practical, action-focused approach to sustainable development. It identifies management actions being undertaken by government, industry and community stakeholders that are focused on monitoring, assessing and/or managing nutrient and sediment inputs to Darwin Harbour waterways. Through this approach it will be possible to avoid costly actions to improve degraded water quality, as required for the waterways adjacent to other Australian cities.

In consultation with stakeholders, more than one hundred broad management actions have been identified. Many of these actions cover more than one on-ground activity, and include initiatives to reduce soil erosion, minimise off-site sediment transport, protect native vegetation alongside waterways, improve management of wastewater and stormwater, reduce runoff, remove or control potential pollutant sources, improve the design and operation of infrastructure and monitor potential environmental impacts.

Water quality protection is viewed as one element of a broader coordinated approach to Darwin Harbour management, monitoring and research, which includes other activities such as aquatic pest surveillance, mapping of seafloor habitats, and fish, dolphin and seagrass monitoring. This coordinated approach, with contributions from a range of government, industry and community stakeholders, is helping to ensure that Darwin Harbour's multiple values and uses can be maintained into the future.

# Introduction

Darwin Harbour is one of the least-disturbed working harbours around the Australian coastline and across the Asia Pacific region. It forms part of a valued tropical coastal environment that is home for most of the Northern Territory's (NT's) residents, and is the country of the Larrakia people (see Box 1).

Darwin Harbour supports a range of ecosystems including mudflats, mangroves, coral reefs and seagrass. It is also home to varied animal life such as dolphins, dugong, sea turtles, shorebirds, sponges, and a large variety of fish.

Thousands of residents and visitors explore and appreciate Darwin Harbour year-round. Many enjoy its foreshore parks and gardens and its recreational opportunities including boating, sailing, kayaking, fishing, and mudcrab and mangrove snail harvesting.

Alongside its social, natural and cultural values, Darwin Harbour is a working harbour with further opportunities for economic development. It is an important hub for industry and trade, particularly given its proximity to the Asian region. The Harbour is presently developing into a major service centre for the mining and energy sectors. This development will complement other economic activities across the greater Darwin region, including tourism, horticulture, agriculture and aquaculture.

## Larrakia Country

### Box 1

Larrakia people have a profound spiritual connection to land. The land owns Larrakia people and every aspect of our lives is intertwined with it, including our law, culture and sovereignty. The land and sea provides for Larrakia people both spiritually and physically.

Our resources have been communally owned by Aboriginal people for as long as we know. Our customary laws have provided one of the oldest land and sea management structures in the world.

The health of land and water is central to Larrakia culture. Land is Larrakia mother, is steeped in culture, but also gives us a responsibility to care for it.

What we the Larrakia land and sea rangers do today as conservationists will always reflect back on our cultural heritage. We the Larrakia people are independent now and we believe in self-esteem, self-management and caring for land and sea.

*John Williams, Senior Ranger, Larrakia Nation Aboriginal Corporation*





“Beneficial Uses” summarise the range of cultural, social, natural and economic values placed on Darwin Harbour by the community. Beneficial Uses were first declared for Darwin Harbour in 1996 under the NT *Water Act*, following extensive community consultation. In 2010 the declared Beneficial Uses were confirmed (see Box 2).

Beneficial Uses for Darwin Harbour are related to, or dependent on, the maintenance of healthy waterways. Since 2009, Darwin Harbour Region Report Cards have been produced on an annual basis and they have indicated that water quality in Darwin Harbour and its catchment is generally good to excellent, particularly in comparison to waterways surrounding other major Australian cities. This rating means the Beneficial Uses are currently well-supported across the Darwin Harbour region and the focus is on water quality *protection*, rather than water quality *improvement*. The good health rating also means we have an opportunity for sustainable development of our working Harbour, provided land and water resources continue to be well-managed.

The Darwin Harbour Water Quality Protection Plan (WQPP), funded by the Australian Government, aims to support good management and sustainable development through its focus on protecting Darwin Harbour waterways from excessive sediment and nutrient inputs. Sediment and nutrient pollution are the priority water quality issues that have been identified by the Australian Government, with nitrogen and phosphorus considered to be the nutrients of prime concern. These water quality issues are to be addressed in plans developed by all states and territories.

## Box 2

### Beneficial Uses for Darwin Harbour listed under the NT *Water Act*

#### For saline waters

- Aquaculture
- Environment
- Cultural

#### For freshwaters

- Agriculture
- Environment
- Cultural
- Rural stock and domestic

## Box 3

### How does the WQPP fit into the regional planning and management framework?

This Water Quality Protection Plan (WQPP) is the action plan resulting from the broader WQPP Project funded by the Australian Government. The project has comprised two phases over six years and has been guided by the Framework for Marine and Estuarine Water Quality Protection, under the National Water Quality Management Strategy. The objective of the National Water Quality Management Strategy is to achieve sustainable use of the nation’s water resources by protecting and enhancing their quality while maintaining economic and social development. The Framework for Marine and Estuarine Water Quality Protection supports this objective by focusing on the reduction of land-based pollution. In line with the national approach, the WQPP focuses on nitrogen, phosphorus and suspended sediment inputs to Darwin Harbour. The WQPP is supported by the NT *Water Act* with Beneficial Uses and Water Quality Objectives declared under section 73. The WQPP complements but does not replace other plans, strategies or programs that have been established for the broader management of the Darwin Harbour region, such as the Darwin Harbour Strategy. It has been designed to integrate and coordinate water quality management actions undertaken by a wide range of stakeholders.

The Darwin Harbour WQPP outlines a range of management actions focused on monitoring, assessing and managing the impacts of sediment and nutrient (nitrogen, phosphorus) inputs to Darwin Harbour. It also highlights key considerations for future water quality protection.

The WQPP contributes to a coordinated Darwin Harbour monitoring and management approach that seeks to address sediment and nutrient pollution alongside other key threatening processes (see Box 7) that may impact on waterway health. The WQPP reflects the regional context of the Harbour, its environmental conditions and values, and the capacity of different stakeholder groups to undertake on-ground action. It shows that a range of agencies and groups within government and the wider community are contributing to, and planning actions to support, the protection of water quality and the Darwin Harbour asset. The WQPP is a useful resource for people seeking an understanding of the various activities happening around Darwin Harbour to support sustainable development. It has been developed as a tool for raising awareness of water quality issues and promoting behaviour change amongst individuals and organisations.



*Credit David Hancock*

## Box 4

### The broader Water Quality Protection Plan Project

#### Phase 1

1. Community consultation and declaration of Beneficial Uses (values) for Darwin Harbour
2. Declaration of Water Quality Objectives and consideration of maximum pollutant loads
3. Consideration of interim river flow objectives
4. Establishment of a Darwin Harbour-wide water quality monitoring program
5. Commencement of the annual release of Darwin Harbour Region Report Cards

#### Phase 2

1. Monitoring and modelling – development of a Catchment Planning and Estuarine Response Decision Support System (CAPER DSS) (see Appendix 3 for an overview)
2. Consideration of legislation, policy and planning for protecting water quality
3. Study of the potential use of market based instruments for protecting water quality by Charles Darwin University (Greiner et al. 2012)
4. Development of a procedure for evaluating the nutrient assimilative capacity of Darwin Harbour (Butler et al. 2013)
5. Development and collation of WQPP management actions in consultation with stakeholders
6. Delivery of an action plan – the WQPP



# The Darwin Harbour Region

The Darwin Harbour region extends from Charles Point in the west to Gunn Point in the east, and includes Port Darwin and Shoal Bay (Figure 1). It covers the tributaries, catchment and estuarine areas of Cox Peninsula, Woods Inlet, West Arm, Middle Arm, East Arm and the Howard River. Unlike the estuaries of other large Australian cities (e.g. Perth, Brisbane), which receive most of their catchment inflow from one large river, Darwin Harbour receives inflow from several major rivers (Howard, Elizabeth and Blackmore) and numerous small streams. Darwin Harbour is also distinguished by the small area of its land catchment relative to its estuarine area, particularly in comparison to places like Port Phillip Bay in Victoria, Port Jackson in New South Wales and Moreton Bay in Queensland. This means the area that can potentially generate polluted runoff into the Harbour is relatively small.

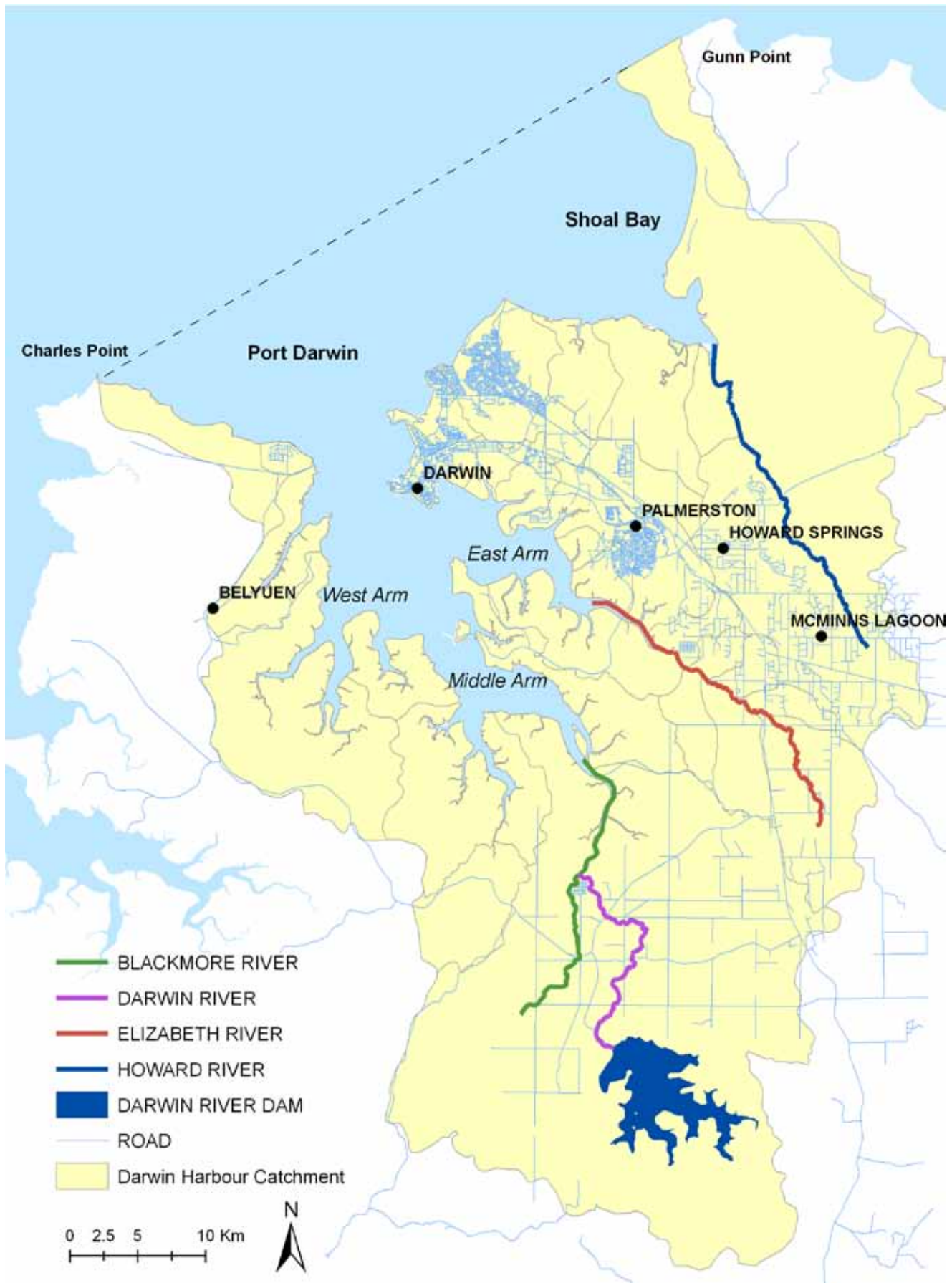
The total catchment area is 3230 km<sup>2</sup>, including a land area of 2010 km<sup>2</sup> above the high water mark. The region is considered to be in an early development phase with approximately 30% of its land currently developed. About 13% of the developed area is subject to urban and other intensive land-uses in and around the cities of Darwin and Palmerston, including residential living, manufacturing, industry, roads, airport infrastructure and defence facilities. The remaining developed area is devoted to rural land-uses, including horticulture and agriculture.



Aerial view of Darwin city.

*Credit David Hancock*





**Figure 1** The Darwin Harbour region



# Water Quality Issues

Research by the NT Government's Department of Land Resource Management has found that urban development has increased the amount of nutrients and sediments entering Darwin Harbour's waterways above natural levels, via point source and diffuse discharge (see Box 5). Point source discharge occurs in Harbour waterways at specific sites, e.g. wastewater treatment plant discharge, via a pipe to the environment. Diffuse discharge occurs when polluting substances (e.g. fertilisers, contaminants) originate from the catchment surface and are transported by streams and drains. Diffuse discharge cannot be attributed to one point of dispersal.

On a whole-of-Harbour scale, the current contribution of point and diffuse discharges to nutrient and sediment pollution is relatively minor. There are, however, localised areas of concern, particularly in tidal creeks and in the upper estuary reaches. Although Darwin Harbour is macro-tidal, the upper estuary reaches are not well-flushed and are most vulnerable to pollution.

Figures 2 and 3 provide a conceptual overview of nutrient and sediment dynamics within the Harbour. Nutrient and/or sediment inputs to waterways are typically higher in catchment areas that have been cleared of vegetation, receive excessive fertiliser application, involve development activities (e.g. construction), produce point source sewage and stormwater discharges, and incorporate extensive hard surface areas with no capacity to filter nutrients and which produce increased volumes of runoff.



*Credit Simon Townsend*

### Impact of urban land-use (Skinner et al. 2009)

Urban land-use has been found to contribute higher pollutant loads (i.e. nutrients, metals, sediments) to Darwin Harbour than rural and undisturbed land areas, and to approximately double the volume of stormwater runoff in any given wet season, compared to an undisturbed landscape.

Increased nutrient loads in waterways (Figure 2) can promote the growth of phytoplankton (microscopic plants), which may produce algal blooms that may be toxic to marine life and result in unsightly scums and human health and odour issues. Where higher nutrient levels become stored in sediments this can change the composition of sediment-dwelling plants, animals and bacteria and alter nutrient cycling. Higher nutrient concentrations may also promote excessive growth of macroalgae and epiphytes (plants that grow on other plants), which can smother seagrass and coral. Mangroves have an important role to play in addressing additional nutrients, acting to trap and recycle nutrients within the mangrove ecosystem.

Darwin Harbour has naturally high levels of suspended sediments due to it being a tide-dominated estuary with large tidal movements and strong currents, and due to its storage of a huge volume of mangrove sediments. Additional sediment loads can enter the Harbour from soil erosion associated with urban and rural development (Figure 3). Excessive sediments can smother and contribute to the loss of seagrass, coral and other plants and animals living on the Harbour floor. Increased suspended sediments can clog gills; reduce the feeding efficiency of filter-feeding organisms; and make water appear darker and murkier, reducing light penetration, decreasing photosynthesis and resulting in the death of aquatic plants (e.g. seagrass). Reduced water clarity may also impact on the foraging of fish, dolphins and dugong.



Water quality sampling. A sample bottle is being attached to a rod to take a water sample from a Darwin drain.

*Credit David Hancock*





Other potential impacts include the introduction of sediment-bound toxins to the aquatic environment, which may affect the health of various plants and animals. Mangroves tend to grow well on shorelines where fine sediment material is deposited; however, they suffer if excess sediments form muddy deposits that smother tree roots.

Knowledge of Darwin Harbour's capacity to receive additional nutrients and sediments without detrimental impacts on water quality and aquatic plants and animals will be improved through further monitoring and research. Improved knowledge will allow for areas of concern to be identified at an early stage and mean that appropriate management and mitigation actions can be taken before problems become too advanced (see Box 6).

A significant management challenge for the region is detecting small or slowly developing changes, which over time can combine to produce major impacts, also known as cumulative impacts. Cumulative impacts can detrimentally affect environmental and cultural values, and recreational and other uses of Darwin Harbour.

### **Australian Institute of Marine Science research plan for Darwin Harbour – nutrient pollution**

#### **Box 6**

The Australian Institute of Marine Science (AIMS) has prepared a research plan that provides a broad coordinating framework for all Darwin Harbour stakeholders engaged in future research activities. The Plan identifies questions that need to be addressed to help develop better understanding of how Darwin Harbour receives and copes with nutrient pollution.

Key questions include:

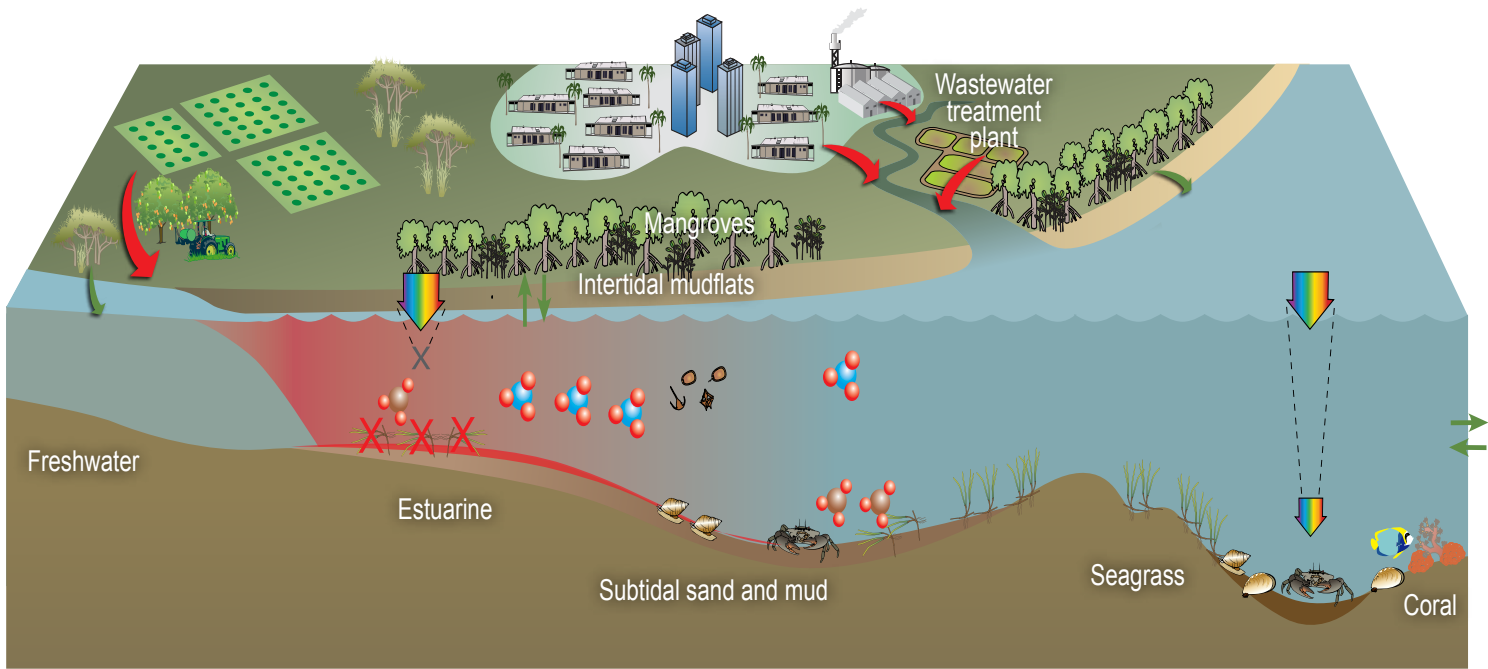
How much nutrient pollution enters the Harbour? Where does it enter the Harbour?

What happens to this pollution? Is it absorbed to sediments or taken up by algae and mangroves? What are the wider impacts on the Harbour's ecology, for example, on fish?

Does the ecological impact of nutrient pollution vary over the wet and dry seasons, and in different parts of the Harbour?

How much nutrient pollution can be added to the Harbour before there are unacceptable ecological impacts?

What are the long term implications of sea level rise for nutrient dynamics and the assimilative capacity of the Harbour?



**Legend:**

Sources of nutrients from human activities

Natural sources of nutrients

Nutrients (●) are transported in the water column (●) or attached to sediments (●); they are stored in sediments and phytoplankton, microscopic plants (🌱)

High light availability Low Light availability

Higher nutrient levels represented by red shading

Mangroves can act as sinks for both natural and human sources of nutrients as they remove nutrients from the water column and sediments

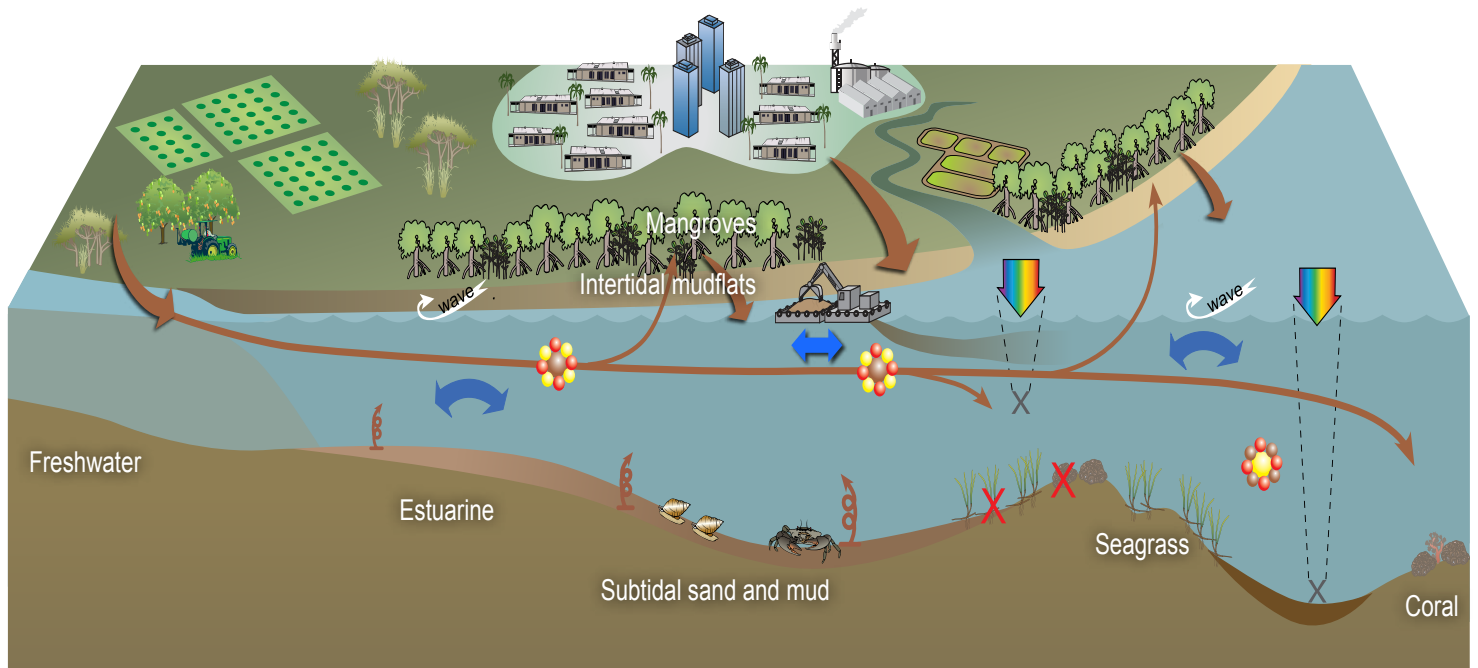
Nitrogen is lost from estuaries through the denitrification process and movement to oceans; nitrogen also enters the Harbour from oceanic sources

Seagrass loss can occur due to shading from increased algae growing on seagrass leaves and algae in the water column




Nutrient bound sediment settles on seabed

**Figure 2** Conceptual diagram of nutrients entering Darwin Harbour and potential impacts on the receiving environment.

Adapted from Geoscience Australia: [http://www.ozcoasts.gov.au/conceptual\\_mods/index.jsp](http://www.ozcoasts.gov.au/conceptual_mods/index.jsp)



### Legend:

-  Erosion of catchment soils from urban, rural and undeveloped areas contributes to aquatic sediments in estuarine waters
-  Sediment can smother and cause the loss of seagrass (X) and coral (X)
-  Suspended sediments can decrease light penetration  (affecting primary production) and impact on filter feeders, oxygen uptake (clog gills) and predator/prey interactions
-  Toxins (●) and nutrients (●) attach to sediment particles (●) and are readily transported
-  Deposition of fine sediments favours the expansion of mangrove areas
-  Resuspension (  ) of fine sediments is (naturally) caused by both tidal (  ) and wave movements (  ); or via human activities such as dredging (  )
-  Sediment settles on seabed

**Figure 3** Conceptual diagram of sediments entering Darwin Harbour and potential impacts on the receiving environment.  
Adapted from Geoscience Australia: [http://www.ozcoasts.gov.au/conceptual\\_mods/index.jsp](http://www.ozcoasts.gov.au/conceptual_mods/index.jsp)

# Coordinated Monitoring, Research and Management

Management of nutrient and sediment inputs is part of a coordinated approach to protecting the overall health of Darwin Harbour and the values and Beneficial Uses that it supports. Alongside sediment and nutrient pollution, six additional pressures or potential threats to Harbour health have been identified (see Box 7).

## Darwin Harbour threats and monitoring of ecological health

### Box 7

Eight threats have been identified that may impact on the health of Darwin Harbour's aquatic ecosystems, plants and animals:

1. Sediment pollution
2. Nutrient pollution
3. Pollution by toxins (e.g. heavy metals, hydrocarbons, pesticides, herbicides, pharmaceuticals)
4. Changes in freshwater inflow
5. Outbreaks of pest animals and aquatic weeds
6. Changed hydrodynamics (i.e. changed movement of water)
7. Habitat loss
8. Removal or disturbance of marine animals.

In the context of these eight threats, water quality monitoring can be seen as one aspect of broader ecological health monitoring across Darwin Harbour.

Additional Darwin Harbour monitoring and management activities undertaken by the Department of Land Resource Management include:

- Annual seagrass monitoring based on the Seagrass Watch program, involving school groups and Parks and Wildlife rangers;
- Annual fish biodiversity monitoring using underwater video cameras;
- Coordination of the North Australia Marine Research Alliance Indigenous Marine Ranger Trainees program that will contribute to conservation of marine fauna and flora in Darwin Harbour; and
- Coordination of the Marine WildWatch program to conserve marine mega-fauna (marine turtles, dolphins and dugongs) in Darwin Harbour. This program includes a hotline and call-out service to respond to animal strandings.





The multiple threats to Darwin Harbour are being addressed through a coordinated monitoring, research and management effort that draws together information from a range of programs undertaken by different government, industry, academic and community stakeholders. Coordinated monitoring, research and management across Darwin Harbour is based on the principles of collaboration, comprehensiveness, scientific credibility, resource efficiency and communication. It occurs within a cycle of adaptive management, whereby policy and planning provide a framework for management actions; monitoring and research contribute to an evaluation of on-ground outcomes and environmental conditions following action implementation; this then leads to better understanding of Darwin Harbour; which in turn, informs the revision and development of improved plans, policies and management actions (Figure 4). This WQPP will be reviewed in three to five years as part of the adaptive management cycle.

One of the main objectives of coordinated monitoring and research is to detect any deterioration in river or estuary condition at an early stage, so that actions can be taken to avoid negative impacts and costly environmental restoration and catchment rehabilitation. Another objective of the coordinated approach is to identify relationships between threats and impacts, so management measures can be developed and implemented with reasonable assurance that the cause of water quality issues will be directly addressed.



**Figure 4** Adaptive management cycle for coordinated monitoring, research and management



### Adaptive management in action

One example of adaptive management involves the revision of Water Quality Objectives for Darwin Harbour. The Water Quality Objectives were originally declared under the *Water Act* in 2010 to provide quantitative guideline levels for different water quality parameters (e.g. pH, dissolved oxygen, total nitrogen, total phosphorus, total suspended sediments). They have been used to assess water quality for the Darwin Harbour Region Report Cards; to evaluate the impact of licensed wastewater discharges on the environment; and to set performance measures for monitoring and reporting. It has been found that the Water Quality Objectives can successfully identify highly degraded water quality (e.g. in Buffalo Creek), however, their use is limited in waters that are close to the baseline (or natural) condition because they do not account for water quality changes due to natural tidal and seasonal variability. Work is currently underway to revise the Water Quality Objectives to account for tidal and seasonal effects, and to improve the framework for decision-makers.



Water quality monitoring. A water quality instrument is being lowered into Darwin Harbour to measure profile temperature, salinity, pH, dissolved oxygen, sunlight, chlorophyll and turbidity. The instrument is lowered from the surface to the bottom to detect changes in water quality with depth. Turbidity is used as a surrogate measure of suspended sediment concentration.

*Credit David Hancock*



# Management Actions for Water Quality Protection

The basis of the WQPP is a series of stakeholder management actions that are focused on monitoring, assessing and managing the impacts of sediment and nutrient (nitrogen, phosphorus) inputs to Darwin Harbour waterways (Tables 1 – 3). In turn, these management actions support the maintenance of Beneficial Uses for Darwin Harbour, i.e. the use of water for environmental, cultural, aquaculture, agricultural and rural stock and/or domestic needs (see Box 2).

The management actions have been compiled following consultation with key stakeholders who hold responsibility for action implementation (see Appendix 1). More than one hundred broad management actions have been identified, many of which cover more than one on-ground activity. The actions are listed under three themes: (1) land management, (2) water management (including stormwater and wastewater), and (3) infrastructure management. Expected outcomes and timeframes have also been provided alongside the management actions. Some management actions may sit under more than one theme but for simplicity they have only been listed once, under the most relevant theme.



Erosion and sediment controls such as perimeter and internal mulch banks with returns, check dams, grass filter strips and protected flow release areas can result in substantial improvement to stormwater quality from construction sites.

*Credit David Hancock*

Land management actions are directed at reducing soil erosion; minimising off-site sediment transport; supporting protection of native vegetation; particularly alongside waterways, and the maintenance of ecological processes. Water management actions are primarily focused on urban water management, including improved management of wastewater and stormwater flows, reduction in runoff containing potential pollutants, and removal or control of potential pollutant sources. Water management actions also include monitoring of water quality and of potential impacts on marine plants and animals, due to water quality degradation. Infrastructure management covers actions that support improved maintenance, design, operation and/or upgrading of infrastructure, which can help with mitigating sediment and nutrient inputs to Harbour waterways.

It is recognised that there are other actions being taken around the region to support water quality protection more generally, e.g. Darwin Harbour Clean Up days. While such actions are not the focus of the WQPP, they are nonetheless important for protecting the health of Darwin Harbour.

The extensive range of documented management actions highlights that water quality protection is not solely the responsibility of government; management contributions are also required from industry, community groups and individual landholders. Overall, the WQPP shows that there is a substantial commitment being made to protect water quality across the Darwin Harbour catchment.



The Gurumbai walking trail alongside Rapid Creek passes by riparian (stream-side) vegetation, which protects the creek's banks from erosion and traps sediment.

*Credit David Silva*



Table 1: **Land** management actions

Stakeholder	Management actions	Outcomes		Timeframe
		Monitoring, assessment and/or management of nutrient inputs	Monitoring, assessment and/or management of sediment inputs	
<b>Casuarina Coastal Reserve Landcare Group</b>	Revegetation and weed control throughout the Casuarina Coastal Reserve and on adjacent sand dunes	●	●	Underway and ongoing
	Partner in the "Connecting Corridors of Green" project coordinated by Conservation Volunteers Australia (see below)	●	●	Mid 2012-mid 2014
<b>City of Darwin</b>	Provision of comments on development applications, planning scheme amendments and land use planning, to support water quality protection and sediment control	●	●	Underway and ongoing
	Management of irrigation using a telemetry system for some parks so irrigation point irregularities or over-watering can be promptly attended to. A study on water efficiency at Council is almost complete	●		Underway and ongoing
<b>City of Palmerston</b>	Parks/gardens fertilisation programs only undertaken during the Dry Season	●		Underway and ongoing
	Management of irrigation using a telemetry system so irrigation point irregularities or over-watering can be promptly attended to	●		Underway and ongoing
	Management of erosion and sediment control during construction of urban subdivisions		●	Underway and ongoing
<b>Conservation Volunteers Australia</b>	Coordination of the "Connecting Corridors of Green" project that brings together eight Landcare groups to strategically protect, revegetate and extend vegetation communities around the Darwin Harbour region. Project sites include the East Point Breezeway, Ludmilla Creek, Casuarina Coastal Reserve, Mitchell Creek and Knuckey Lagoon. The project supports monsoon rainforest, wetland, savannah woodland and riverine vegetation communities and aims to facilitate long-term landscape-scale management and connectivity	●	●	Mid 2012-mid 2014
	Submission of a funding application for a proposed project between Conservation Volunteers Australia, Landcare networks, community groups, Indigenous ranger groups, private landholders and local and NT Government to further enhance native vegetation connectivity and create buffer zones around the Darwin Harbour region, with a particular focus on riparian zones. This project, if funded, will include Buffalo Creek as well as the "Connecting Corridors of Green" sites	●	●	Funding-dependent

<b>Darwin International Airport</b>	Establishment of the Rapid Creek Buffer Zone, a 9.77 ha site which provides a 75 m wide buffer from the creek's middle line. Preservation, maintenance and replanting of vegetation has been undertaken within the Buffer Zone with assistance from the Rapid Creek Landcare Group, Larrakia people, Greening Australia, Green Corps and Conservation Volunteers Australia	●	●	Underway and ongoing
	Establishment of a 15 ha Conservation Reserve in the upper catchment of Rapid Creek, in partnership with Greening Australia and with assistance from the community from three community planting days	●	●	Completed
	Establishment of Matboerrma Gardens – a native garden north of the public car park that intercepts run off from the terminal and car park	●	●	Underway and ongoing
	Implementation of erosion and sediment control measures for all developments on the airport site		●	Underway and ongoing
	Revegetation of erosion prone areas and works to fix eroded areas following the wet season		●	Underway and ongoing
	Implementation of an Erosion Monitoring Program based on mapping and photo point monitoring of control sites, with a view towards identifying soil loss or accumulation in drainage lines		●	Underway and ongoing
	Silt removal and drainage works undertaken in the dry season, as necessary		●	Underway and ongoing
	Completion of an 'Introduction to Erosion and Sediment Control' Course facilitated by the International Erosion Control Association (IECA) (Australasia) and the Environment Institute of Australia and New Zealand, by relevant Darwin International Airport staff		●	Completed
	Adoption of the IECA's Best Practice Erosion and Sediment Control document in Darwin International Airport's Development Guidelines		●	Completed
<b>Darwin LNG Pty Ltd</b> (operated by ConocoPhillips Pipeline Australia Pty Ltd)	Surfacing of the DLNG Operations site consists almost entirely of sealed or stabilised ground surface. The site is either sealed hard-stand (concrete, asphalt or aggregate) or has vegetative cover in place (grass)			Underway and ongoing
<b>Darwin Port Corporation</b> (East Arm, Fort Hill, Stokes Hill and Fisherman's Wharves)	Stabilisation of surface soils using methods such as re-contouring, drainage and topsoil re-spreading, where land has been cleared		●	Underway and ongoing
	Regular review of the efficacy of land and soil management measures to ensure implementation of continuous improvement		●	Underway and ongoing
	Provision of waste collection and bin facilities for port users and the general public to reduce litter and other wastes	●	●	Underway and ongoing

<b>Department of Defence</b> (Australian Government)	Requirement that all Department of Defence personnel and contractors adhere to industry best practice, e.g. implementation of sediment controls and soil stabilisation works. Environmental Management Plans are requested from all contractors and their implementation is audited throughout the development process, to ensure risks are appropriately managed and/or reduced		●	Underway and ongoing
	Rehabilitation of landscapes that become damaged over time or as a result of large seasonal flooding, including the implementation of erosion control works and drainage rectification where necessary		●	Underway and ongoing
<b>Department of Infrastructure</b> (DoI)	Revision of the environmental component of specifications for construction projects to ensure the DoI is working towards best practice environmental management. The revision of specifications includes addressing erosion and sediment control management, which will involve DoI adopting the relevant sections of the IECA guidelines		●	September 2013
<b>Department of Land Resource Management</b> (DLRM)	Ongoing advice provided to the Development Consent Authority (DCA) for Erosion and Sediment Control Plans. For relevant developments requiring consent, prior to commencing any construction works, DLRM recommends that a suitably qualified or experienced person in erosion and sediment control planning develop an Erosion and Sediment Control Plan (ESCP). The DCA must be satisfied with the implementation of the ESCP. DLRM recommends that <i>IECA2008, Best Practice Erosion and Sediment Control. International Erosion Control Association (Australasia), Picton NSW</i> (generally referred to as IECA 2008) be referenced as a guide to the type of information, detail and data that should be included in an ESCP		●	Underway and ongoing
	Review of IECA 2008 with the intention that further NT specific data and management methods are included in future amendments of the booklets.		●	Underway and ongoing
<b>Department of Transport</b>	Establishment and ongoing implementation of a risk management framework for capital/road works. This process considers erosion and sediment control and consequently water quality. It is based on a Memorandum of Understanding with the Northern Territory Environment Protection Authority (NT EPA). For works between October and May, ESCPs are required. Developers must produce the ESCPs to the satisfaction of the NT Government. DoI assesses the ESCPs and provides recommendations. Road Networks Division then considers the risk and recommendations and sets the requirements		●	Underway and ongoing

<b>Friends of Mitchell Creek Catchment Landcare Group</b>	Advocacy for appropriate erosion and sediment controls, buffer zones and native vegetation retention around construction works and urban developments	●	●	Underway and ongoing
	Revegetation and water quality testing work with the support of Palmerston Senior College students doing training in Conservation and Land Management	●	●	Underway and ongoing
	Partner in the "Connecting Corridors of Green" project coordinated by Conservation Volunteers Australia	●	●	Mid 2012- mid 2014
<b>Greening Australia NT</b>	Submission of a funding application to undertake a project to re-connect vegetation corridors of Palmerston waterways. Community-based on-ground actions will focus on weed control and revegetation to produce waterway vegetation corridors	●	●	Funding-dependent
<b>INPEX</b>	Design and use of erosion control features, sediment control basins and water quality sampling programs to minimise sediment and potential contaminants from discharge to Darwin Harbour		●	Underway and ongoing
<b>Knuckey Lagoon Landcare Group</b>	Promotion of melaleuca regrowth and weed control around Knuckey Lagoon	●	●	Underway and ongoing
	Partner in the "Connecting Corridors of Green" project coordinated by Conservation Volunteers Australia	●	●	Mid 2012- mid 2014
<b>Ludmilla Creek Landcare Group</b>	Revegetation, protection and extension of areas of natural bushland and mangroves, including weed control work. These actions are directed at maintaining natural water flows in the Ludmilla Creek catchment	●	●	Underway and ongoing
	Partner in the "Connecting Corridors of Green" project coordinated by Conservation Volunteers Australia	●	●	Mid 2012- mid 2014



Credit David Hancock

<b>Northern Territory Farmers Association (NTFA)</b>	Commitment to supporting water quality protection, with an aim to include a range of relevant actions within the NTFA Strategic Plan, such as: <ul style="list-style-type: none"> <li>- increased research into best practice land management</li> <li>- promotion of the use of improved and innovative practices (e.g. introduction of cover crops, strategic and efficient fertiliser use)</li> <li>- provision of extension support to growers</li> </ul>	●	●	Strategic Plan to be finalised by end of 2013
	Minimal use of fertilisers and manures on land, and protection of soil from erosion, practiced by well-engaged NTFA growers (particularly in the mango, melon and citrus industries)	●	●	Underway and ongoing
	Working towards the establishment of stronger connections with Asian vegetable growers, as they are potentially the most intensively fertilised and cultivated production systems. This includes submission of a funding application for a new NTFA role that will coordinate a range of land management activities, with a particular focus on Vietnamese growers through NTFA's Asian Growers Engagement Program	●	●	Underway, ongoing and funding-dependent
<b>Parks and Wildlife Commission of the Northern Territory (PWCNT)</b>	Development of the Casuarina Coastal Reserve Development Strategy, incorporating an Erosion and Drainage Plan that will: <ul style="list-style-type: none"> <li>- identify existing areas of erosion and sedimentation and required remediation methods</li> <li>- assess the functionality of existing stormwater drains that receive high volumes of water from neighbouring residential estates and public infrastructure</li> <li>- assess land suitability and capability for development, to ensure that new or upgraded developments within the Casuarina Coastal Reserve do not cause erosion</li> <li>- consider the potential impacts of storm surge and sea level rise</li> </ul>		●	Development Strategy to be finalised end of 2013/early 2014
	Submission of a funding application to support a proposed study into stormwater flows and erosion and sediment management across the Casuarina Coastal Reserve. The study will help to direct on-ground management activities e.g. extension of a flood control channel and dissipator, construction of vegetative filter strips and strategic planting of riparian vegetation	●	●	Funding-dependent

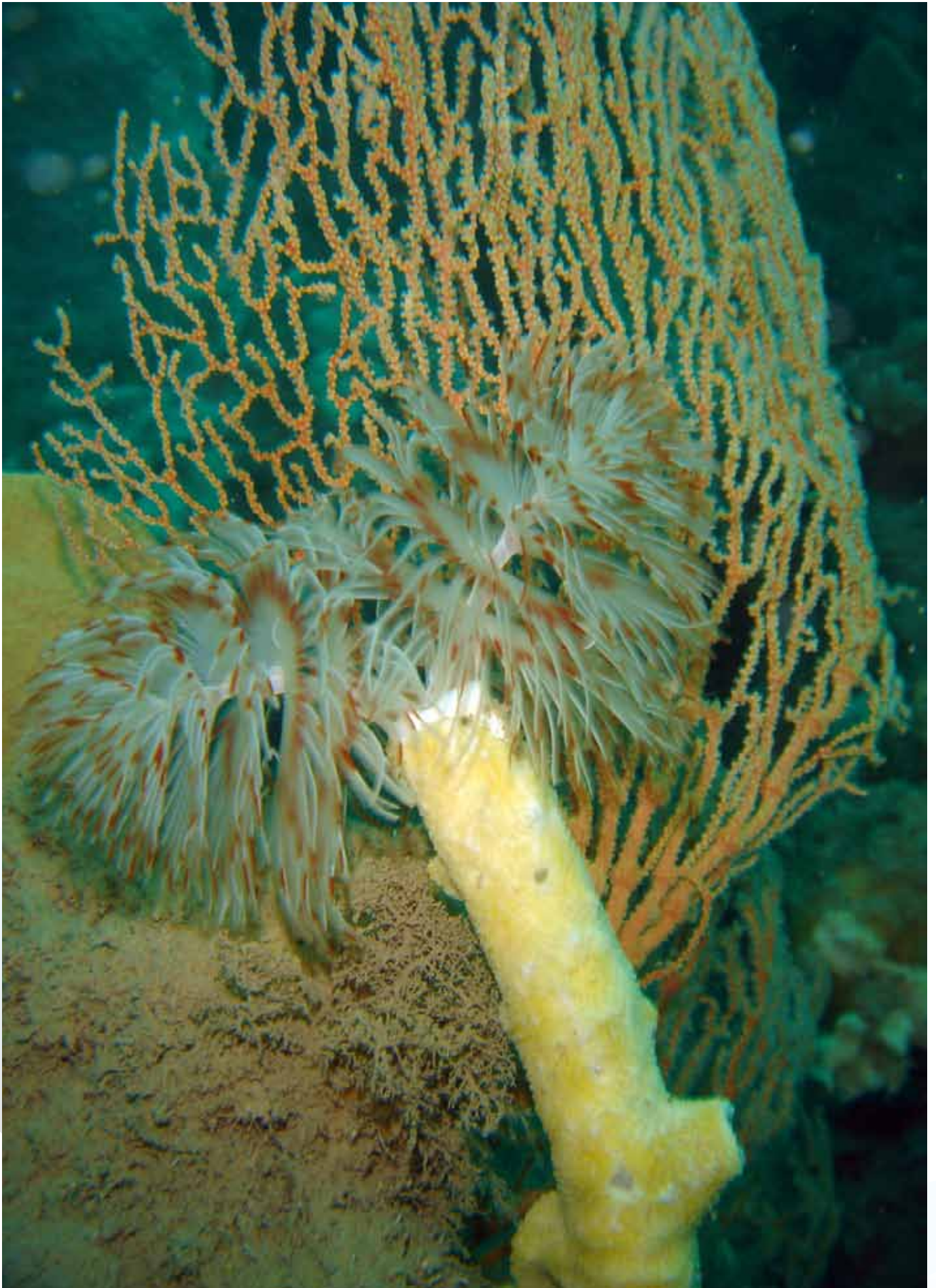


<b>Rapid Creek Landcare Group</b>	Implementation of strategies outlined in the Rapid Creek Management Plan, with a focus on revegetation and protection and enhancement of remnant bushland alongside Rapid Creek (including on the Darwin International Airport and City of Darwin sites)	●	●	Underway and ongoing
<b>Urban Development Institute of Australia, Northern Territory (UDIA NT)</b>	<p>Committed to environmentally sustainable development, including recognition of the importance of managing sediment erosion associated with land development. Typical actions promoted by the UDIA NT for greenfields subdivisions include:</p> <ul style="list-style-type: none"> <li>- installation of erosion and sediment control measures (e.g. sediment basins, bio-retention areas, mulch bunds, check dams) throughout development sites, in accordance with local government guidelines and International Erosion Control Association guidelines</li> <li>- regular maintenance and inspection of erosion and sediment control devices to ensure their effectiveness, while developers remain on-site</li> </ul>		●	Underway and ongoing



The Indo-Pacific humpback dolphin is one of three species of coastal dolphins that call Darwin Harbour “home”. It is vulnerable to pollution and habitat degradation.

*Credit DLRM*



*Protula bispiralis* is a Darwin Harbour worm that lives in a tube and is likely to be affected by excessive sediment loads or water pollution because it is a filter feeder.

Credit Helen Cribb

Table 2: **Water** management actions (including stormwater and wastewater)

Stakeholder	Management actions	Outcomes		Timeframe
		Monitoring, assessment and/or management of <b>nutrient</b> inputs	Monitoring, assessment and/or management of <b>sediment</b> inputs	
<b>Aquaculture industry</b>	Generation of data and maintenance of a database on discharge levels, in line with waste discharge licence monitoring requirements	●	●	Underway and ongoing
	Ongoing implementation of management strategies by two aquaculture farms on the Blackmore River:	●	●	Underway and ongoing
	<p>Lombard Farms (barramundi/prawn farm) – Ongoing treatment of effluent in the 20 ha treatment area (equivalent to 74% of the total grow out area) has the net effect of stabilising and removing nutrients and sediment from all water running from the site's catchment area. This treatment area has been reported as significantly exceeding any aquaculture effluent treatment area used elsewhere in Australia</p> <p>Tasmanian Seafoods (sea cucumber/oyster farm) – Maintains an effluent treatment pond and channel (approximately 0.46 ha), equivalent to 10% of the current production area to reduce nutrients and sediment in the effluent. Good water quality is maintained in the ponds as the farm has a low stocking biomass only being used to maintain sea cucumber and oyster broodstock and to nurse their progeny. There is no exogenous feed input. Sea cucumber and oysters are sediment and filter feeders, respectively, and these feeding behaviours facilitate the recycling of nutrients and reduce sediment load</p>			

<b>City of Darwin</b>	Implementation of elements of Water Sensitive Urban Design (WSUD) wherever possible (see Appendix 2 for WSUD overview). For example: <ul style="list-style-type: none"> <li>- the recent upgrade of Knuckey Street has linked tree planting to the gutter drainage system, allowing trees to be watered by stormwater and promoting water quality improvements</li> <li>- the new suburb of Muirhead has incorporated some elements of WSUD into its design</li> </ul>	●	●	Underway and ongoing
	Development of a Darwin CBD Master plan, including consideration of WSUD principles	●	●	December 2013
	Review of Council's sub division guidelines, including consideration of whether the incorporation of WSUD principles is applicable as part of the review	●	●	December 2013
	WSUD management, including maintenance of: <ul style="list-style-type: none"> <li>- gross pollutant traps</li> <li>- stormwater basins and weirs</li> </ul>	●	●	Underway and ongoing
	Stormwater drainage network management, including: <ul style="list-style-type: none"> <li>- removal of sediment from open drains</li> <li>- maintenance of stormwater infrastructure including inspection of pipes and pits</li> <li>- implementation of sediment control measures for works occurring on roads that may lead to sediment discharge (e.g. stormwater drainage socks put in place along the mouth of stormwater pits)</li> </ul>		●	Underway and ongoing
	Diligent reporting of pollution breaches to the NT EPA by City of Darwin officers	●	●	Underway and ongoing
	Implementation of a water quality monitoring program involving: <ul style="list-style-type: none"> <li>- regular monitoring at Lake Alexander and Golf Links Lake, with testing for enterococci on a fortnightly basis, measured against the Australian Government's <i>Guidelines for Managing Risks in Recreational Water</i></li> <li>- monitoring of stormwater during the wet season. Twelve locations across the municipality are tested for enterococci and physiochemical parameters</li> </ul>	●	●	Underway and ongoing

<b>City of Palmerston</b>	WSUD management, including maintenance of: <ul style="list-style-type: none"> <li>- gross pollutant traps</li> <li>- thirteen stormwater retention ponds that act as silt and dissolved pollutant traps, focusing on aquatic weed harvesting as a means of removing pollutants from stormwater runoff</li> <li>- grassed areas and swales that act as pollution filters for runoff</li> </ul>	●	●	Underway and ongoing
	Stormwater drainage network management, including: <ul style="list-style-type: none"> <li>- removal of sediment from open drains</li> <li>- implementation of sediment control measures for works occurring on roads that may lead to sediment discharge (e.g. stormwater drainage socks put in place along the mouth of stormwater pits)</li> </ul>		●	Underway and ongoing
	Provision of comments on development applications, planning scheme amendments and land use planning, to support water quality protection, including management of trade waste	●	●	Underway and ongoing
	Promotion of a philosophy of maintaining natural runoff volumes to waterways	●	●	Underway and ongoing
	Promotion of the use of low flow drains to avoid year-round flow in seasonal creeks and streams	●	●	Underway and ongoing



Dolphin population monitoring in Darwin Harbour.

Credit DLRM

<b>Darwin International Airport (DIA)</b>	Implementation of a Water Quality Program for Rapid Creek that involves: <ul style="list-style-type: none"> <li>- surface and groundwater monitoring to assess water quality</li> <li>- macroinvertebrate sampling to assess ecological condition, particularly in response to implementation of runoff management measures</li> <li>- provision of results to DLRM's Aquatic Health Unit for the Darwin Harbour Region Report Cards</li> </ul>	●	●	Underway and ongoing
	Implementation of a Groundwater Quality Monitoring Program, as part of a Groundwater Management Plan that involves: <ul style="list-style-type: none"> <li>- sixteen groundwater monitoring wells around particular sites of identified contamination risk</li> <li>- assessment and reporting on water quality with reference to Schedule 2 of the <i>Airports (Environment Protection) Regulations 1997</i> and the Water Quality Objectives derived for Rapid Creek and Darwin Harbour</li> <li>- provision of early warning of groundwater pollution, which can trigger management actions</li> <li>- review of long-term data to identify any ongoing issues and to assess the effectiveness of management actions</li> </ul>	●	●	Underway and ongoing
	Implementation of a Surface Water/Stormwater Quality Monitoring Program that involves: <ul style="list-style-type: none"> <li>- nine sampling sites along the drains and waterways receiving airport runoff</li> <li>- assessment and reporting on water quality with reference to Schedule 2 of the <i>Airports (Environment Protection) Regulations 1997</i> and the Water Quality Objectives derived for Rapid Creek and Darwin Harbour</li> <li>- provision of early warning of surface water pollution, which can trigger management actions</li> <li>- review of long-term data to identify any ongoing issues, to support improvements to the DIA Stormwater Quality Management Plan, and to assess the effectiveness of stormwater system upgrades</li> </ul>	●	●	Underway and ongoing
	Investigation of soil structure and drainage on DIA land, including its influence on the quality of discharged water, with an aim of developing guidelines to improve surface water quality	●	●	Underway and ongoing

	Auditing of tenants to determine the use of fertilisers and other nutrient-containing materials within DIA grounds, to support the review and improvement of current water quality monitoring	●		Underway and ongoing
	Provision of a Trade Waste Fact Sheet to businesses operating on the DIA site	●	●	Completed
	Development of a Stormwater Quality Management Strategy that will: <ul style="list-style-type: none"> <li>- recommend precincts be designed within the DIA area to include a staged stormwater treatment approach at lot- and precinct-scales, with primary treatment devices (e.g. gross pollutant traps), secondary treatment options (e.g. grassed buffer strips, vegetated swales, sediment traps/basins, infiltration systems) and tertiary treatment options (e.g. bioretention basins, constructed wetlands). Treatment measures to be incorporated into site landscaping</li> <li>- recommend the use of native, drought and flood tolerant vegetation with low fertiliser requirements</li> <li>- specify design standards for stormwater treatment systems</li> <li>- provide guidelines for the development of site-based stormwater management plans</li> </ul>	●	●	July 2013
<b>Darwin LNG Pty Ltd</b> (operated by ConocoPhillips Pipeline Australia Pty Ltd)	Sediment retention ponds in place to capture any stormwater runoff from the site which may include residual sediment build up		●	Underway and ongoing
	Monitoring of sediment loads during sediment retention pond discharge events. Discharge limits are specified within the DLNG Environment Protection Licence issued by the NT EPA		●	Underway and ongoing
	Treatment of waste effluent produced on site through an onsite wastewater treatment system. Treated effluent is then utilised for irrigation purposes on site	●		Underway and ongoing
	Monitoring of treated irrigation water undertaken on a monthly basis. Discharge limits are specified within the DLNG Environment Protection Licence issued by the NT EPA	●		Underway and ongoing

<b>Darwin Port Corporation</b>	Installation of gross pollutant traps at Hornibrook's Wharf	●	●	Completed
	Development and implementation of a stormwater management plan at East Arm Wharf with short, medium and long-term actions. This includes installation of new drainage pipes, sediment ponds/traps and large pumps that prevent discharge of contaminants to the Harbour. Further works are planned	●	●	Underway and ongoing
	Installation of improved grease traps at Stokes Hill Wharf and establishment of a new Trade Waste Agreement with Power and Water Corporation to manage the waste load going to their sewage treatment plant	●	●	Completed
	Environmental monitoring of marine water, stormwater and marine sediment around East Arm, Fort Hill, Stokes Hill, Fisherman's and Hornibrook's Wharves	●	●	Underway and ongoing
<b>Department of Defence</b> (Australian Government)	Regular monitoring of ground and surface water quality to determine if there are any on- and/or off-site impacts. Suspended sediment and nutrient concentrations are amongst the parameters analysed	●	●	Underway and ongoing
	Approval sought from the NT Government for a temporary Waste Discharge Licence approximately every five years, to conduct maintenance dredging in the Coonawarra basin. The routine dredges typically involve the removal of a small volume of sediment which is discharged in the outer Harbour. Water quality monitoring is done prior to, throughout and upon completion of the dredging	●	●	Underway and ongoing
<b>Department of Land Resource Management</b> (DLRM)	Annual production of the Darwin Harbour Region Report Cards, which include an assessment of water quality in Darwin Harbour waterways and contributions from stakeholders	●	●	Underway and ongoing
	Development and implementation of an Integrated Monitoring and Research Program (IMRP) for Darwin Harbour that will address ecosystem health, including water quality, with contributions from industry (e.g. ConocoPhillips Company, INPEX Operations Australia Pty Ltd, aquaculture industry) and the NT Government (e.g. DLRM, Department of Primary Industries and Fisheries, and Power and Water Corporation)	●	●	Underway and ongoing
	Implementation of the INPEX Operations Australia Pty Ltd IMRP Offset for Darwin Harbour	●	●	2014-2015
	Coordination of the Darwin Harbour Indigenous Marine Rangers program that will contribute to water quality monitoring as part of the NT Government's offset strategy for the construction of the East Arm Wharf marine supply base	●	●	2013-2015
	Review of Water Quality Objectives for Darwin Harbour to standardise for tidal and seasonal variability	●	●	2014
	Review suitability of national sediment guidelines for Darwin Harbour	●		2014-2015



<b>Department of Transport</b>	Reviewing, and will be adopting, Road Network Division Development Guidelines that will include provisions related to water quality	●	●	To be completed third quarter, 2013
<b>Greening Australia NT</b>	Submission of a funding application to undertake a study of WSUD design in the monsoon tropics. WSUD has been incorporated into several new urban subdivisions of the greater Darwin area. The effectiveness of these designs, particularly in a strongly monsoonal climate, is still in question. The proposed project will undertake water quality monitoring for both environmental and human health. Monitoring will provide evidence of the level of efficacy of WSUD in improving water quality. The project will also promote the use of local native flora to support biodiversity, assess and maintain the current plantings, monitor wildlife, promote the use of constructed habitats, monitor biodiversity outcomes, assess design and develop guidelines for future sites	●	●	Funding-dependent
	Trialling of a selection of Top End floodplain plants for use in artificial wetland filter systems. The ongoing trial involves: <ul style="list-style-type: none"> <li>- planting out of the water-recycling project at the nursery with a range of species to assess growth habits, growth rates and competitiveness in a controlled landscaped setting</li> <li>- utilisation of plants in the water recycling area as a seed bank, for use in the nursery collection</li> </ul>	●	●	Underway and ongoing
<b>INPEX</b>	To date, all sewage has been hauled offsite by a waste removal subcontractor for disposal at local wastewater treatment plants. No raw or treated wastewater has been discharged to the Harbour from the site	●	●	Underway until October 2013
	Implementation of a water monitoring program that monitors nitrogen and phosphorus in surface sea water, surface site (rain) water and site groundwater	●		Underway and ongoing
	Placement of all dredging material at an offshore spoil disposal ground (12 km NW of Lee Point) to minimise risks to Darwin Harbour	●	●	August 2012- July 2014

**Northern Territory Environment Protection Authority**  
(NT EPA)

<p>Development of a Stormwater Strategy for the Darwin Harbour region. This strategy will aim to facilitate a positive, co-ordinated approach toward stormwater management at the local and catchment-wide levels. The Strategy will be developed in the context of contemporary best practice, with government and stakeholder endorsement. The Strategy is anticipated to provide a framework for:</p> <ul style="list-style-type: none"> <li>- decision making by key stakeholders in urban and regional planning decisions and infrastructure upgrades;</li> <li>- cooperation to improve stormwater management on a catchment scale basis;</li> <li>- broad guidance and reference material to enable developers to incorporate appropriate pollution mitigation infrastructure costs into their proposals;</li> <li>- the establishment and/or upgrading of stormwater management systems that will meet the community's expectations on governance and environment management; and</li> <li>- stormwater management processes and priorities which focus on flood mitigation and public safety while improving water quality and reducing environmental impacts from diffuse and point-source pollutants</li> </ul>	●	●	Expected completion February 2014
<p>Ongoing assessment of waste discharge licence (WDL) applications and regulation and compliance activities associated with WDLs approved by the Controller of Water Resources or his/her delegate. WDLs seek to control the quality and/or quantity of pollutants entering a waterway, including nitrogen and phosphorous</p>	●	●	Underway and ongoing
<p>Development of a suite of guidelines that will educate and inform industry and developers on how to meet regulatory requirements, in association with the DLRM. The guidelines will provide insight into how the NT EPA administers part 7 of the <i>Water Act</i>:</p> <ul style="list-style-type: none"> <li>- Guidelines for mixing zones have been finalised</li> <li>- Guidelines for WDLs are currently under development</li> </ul>	●	●	Expected completion June 2014

<b>Power and Water Corporation</b>	Development of site specific trigger values (SSTVs) and targeted water quality, sediment and biological monitoring programs for local waters receiving sewage treatment plant discharge, as detailed below:	●	●	
	- SSTVs have been developed for Buffalo, Myrmidon and Blesers Creeks and are in preparation for Ludmilla Creek and East Point			Ongoing from 2013
	- routine water quality monitoring occurs at Buffalo Creek, Myrmidon Creek, Blesers Creek, East Point, Ludmilla Creek and associated wastewater treatment plants			Ongoing from 2010
	- targeted sediment monitoring at Buffalo Creek, Myrmidon Creek, Blesers Creek, East Point and Ludmilla Creek			Ongoing from 2012
	- targeted biological monitoring at Buffalo Creek, Myrmidon Creek, Blesers Creek, East Point and Ludmilla Creek			Ongoing from 2013
	Development of a hydrodynamic water quality model for local waters receiving sewage treatment plant discharge to determine mixing zones (i.e. area of impact)	●	●	Underway and ongoing
	Assessment of condition of local waters receiving sewage treatment plant discharge	●	●	Underway and ongoing
	Development of the Darwin Region Sewerage Strategy	●	●	2015
	Implementation of a Trade Waste Management Strategy and investigation of opportunities for the development of a third party trade waste receiving and treatment facility	●	●	Underway and ongoing
Development and implementation of a policy for receiving and managing ships' grey/black water	●	●	2014	
Development of the Living Water Smart demand management program to reduce water wastage, which may also assist to reduce sewage discharges to the sewerage system and reduce nutrient runoff due to overwatering	●	●	Commencing in 2014	
Development of a sludge and biosolids management strategy and operational plans, and investigation of opportunities to maximise the beneficial reuse of biosolids	●	●	2015	
Contributor to coordinated monitoring and research across Darwin Harbour	●	●	Underway and ongoing	
<b>Urban Development Institute of Australia, Northern Territory</b>	Committed to engaging in discussions that will help to resolve issues around the application of WSUD in the context of the Darwin Harbour region and the Wet-Dry tropics more broadly	●	●	Underway and ongoing

## Table 3: Infrastructure management actions

Stakeholder	Management actions	Outcomes		Timeframe
		Monitoring, assessment and/or management of nutrient inputs	Monitoring, assessment and/or management of sediment inputs	
<b>City of Darwin</b>	Road maintenance works to help control sediment and nutrient pollution, including: <ul style="list-style-type: none"> <li>- a cyclic street sweeping program</li> <li>- inspection of Council roads</li> <li>- undertaking road repairs and maintaining roads in good condition</li> </ul>			Underway and ongoing
<b>City of Palmerston</b>	Road maintenance works to help control sediment and nutrient pollution, including: <ul style="list-style-type: none"> <li>- a cyclic street sweeping program</li> <li>- a twelve month program of inspecting all Council roads. Where unexpected problems arise in an area before the timing of planned works, that location is attended to as a matter of priority, especially if it is having an impact on nearby waterways</li> <li>- addressing issues with sub-grade roads, trench subsidence and erosion</li> <li>- establishment of high standards for dealing with matters such as correct pavement settlement and ponding</li> </ul>			Underway and ongoing
<b>Darwin Port Corporation</b>	Connection to Power and Water Corporation's sewerage system established as part of the East Arm Wharf (Marine Supply Base) expansion, for treatment of wastewater			Expected completion November 2013



Leanyer – Sanderson wastewater treatment plant. Sewage is treated biologically as it passes through a series of lagoons, and then released to Buffalo Creek in Darwin Harbour.

<b>INPEX</b>	Establishment of a temporary wastewater treatment plant designed to discharge wastewater to the Harbour via a multiport diffuser outfall, with nitrogen and phosphorus levels to be below the standard set in the Project approvals (i.e. < 40 mg/L TN; < 10 mg/L TP)			Due to begin operation October 2013-2016
	Establishment of a wastewater treatment and discharge plant before operations commence, with similar design specifications to the temporary system			Commencing in 2016
<b>Power and Water Corporation</b>	Redirection of wastewater from Larrakeyah sewerage catchment to Ludmilla Wastewater Treatment Plant			Completed 2012
	Upgrading of capacity and improvement of treatment efficacy at Ludmilla Wastewater Treatment Plant			Completed 2013
	Duplication of East Point Treated Wastewater Rising Main (including preparation of a Public Environmental Report)			Underway, due 2014
	Extension of the East Point Treated Wastewater Outfall (including preparation of a Public Environmental Report)			Expected 2019
	Ongoing sewerage network upgrade projects			Underway and ongoing
	Development and management of a bulk wastewater (trade waste) receiving pond at Palmerston			Pond completed, improvements ongoing
	Development and implementation of an Inflow and Infiltration Abatement Programme for Darwin region sewerage systems			Underway and ongoing
	Ongoing desludging program at all waste stabilisation ponds			Underway, ongoing cyclic program
	Engagement of experts in waste stabilisation pond technology and operation, to assist with process review and improvement			Underway and ongoing
	Implementation of an operational improvement program at all sewage treatment plants to maintain design treatment capacity and capability, and to optimise treatment outcomes from existing infrastructure			2016
	Engineering studies looking at treatment upgrade options; outfall augmentation options; and recycled water treatment and network options			Completed for Leanyer Sanderson WWTP, ongoing at other sites
	Research into biological markers for sewage treatment plant discharge; microbial assemblages in waste stabilisation ponds; and use of aerated rock filter technology (pilot trial)			2015
Development and publication of waste stabilisation pond planning and design manuals			Completed	

# Considerations for Future Water Quality Protection

A number of stakeholders have identified that industry, NT Government and local government need to work together in establishing standards and guidelines for urban development so that:

- the most efficient and cost-effective approaches can be developed and implemented for individual projects;
- consistent standards and guidelines are used across all areas of government and applied to all types and stages of development;
- the responsibilities of government and industry are well-defined and water management infrastructure can be effectively maintained over the long-term as a community asset rather than a liability; and
- standards and guidelines are applied in the context of an overall catchment management plan, not simply in isolation on individual development sites.

Research programs will be required to support the development of standards and guidelines that are best-suited to Darwin Harbour. Research should focus on measuring the effectiveness of different water treatment solutions, and help to determine which stormwater flow controls can best manage sediment, nutrients and other potential pollutants. Such research will ultimately assist with the identification of new, innovative, practical and cost-effective urban development approaches.



*Credit David Hancock*

### **Darwin Harbour: a unique opportunity to maintain good water quality**

Darwin Harbour has a unique good health rating, particularly in comparison to waterways surrounding other major Australian cities; however, further catchment development is likely to place increasing pressure on the Harbour's water quality (see Appendix 3). Management actions, such as those documented in this WQPP, have an important role to play in mitigating or minimising environmental impacts, protecting water quality, ensuring that costly rehabilitation activities can be avoided in the future, and in turn, reducing impacts on the local economy.

Four simple management steps can be followed to safeguard Darwin Harbour's good health status and to maintain it as a community asset over the long-term:

1. **Protect the valued aspects of the Harbour** – look after conservation areas, public spaces, native vegetation alongside waterways (including mangroves), and landscape aesthetics and amenity, so as to protect environmental resources, maintain the region's "look and feel", support ecological processes and provide some coastline protection with anticipated future sea level rise.
2. **Don't waste resources** – for example, reclaim and use rainwater, stormwater and wastewater where possible, to supplement potable water supplies and to allow for high quality water to be used where it is required (e.g. for drinking and bathing), and lesser quality water to be used where high quality is unnecessary (e.g. toilet flushing, laundry, gardens and outdoor use).
3. **Minimise the impact** – design urban areas and infrastructure so as to disconnect hard surfaces, maximise pervious surfaces (e.g. porous pavements and driveways) and to reduce runoff which can carry pollutants into waterways. Disconnection of hard surfaces can be achieved by placing vegetation at key points in the landscape to intercept water flows, slow down flows and encourage the settling out of pollutants.
4. **Manage the impact** – once steps 1 to 3 have been put in place, implement innovative, cost-effective and climate-suitable stormwater management and wastewater treatment systems to address remaining impacts.



# Further Reading

Butler E.C.V., Streten-Joyce C., Tsang J.J., Williams D.K., Alongi D.M., Furnas M.J. and McKinnon A.D. (2013) *A procedure for evaluating the nutrient assimilative capacity of Darwin Harbour*. Report for Aquatic Health Unit, Northern Territory Department of Land Resource Management. Australian Institute of Marine Science, Darwin.

Darwin Beaches water quality:

[http://health.nt.gov.au/Environmental\\_Health/Beach\\_Water\\_Quality/index.aspx#beach\\_water\\_quality](http://health.nt.gov.au/Environmental_Health/Beach_Water_Quality/index.aspx#beach_water_quality)

Darwin Harbour publications:

<http://www.lrm.nt.gov.au/water/dhac/publications>

Darwin Harbour Region Report Cards, 2009 to 2012:

<http://www.lrm.nt.gov.au/water/aquatic/reportcards>

Darwin Harbour Strategy:

[http://www.lrm.nt.gov.au/water/darwin-harbour/darwin-harbour-strategy#.Up\\_CbZ3SXcs](http://www.lrm.nt.gov.au/water/darwin-harbour/darwin-harbour-strategy#.Up_CbZ3SXcs)

Department of Land Resource Management publications:

<http://www.lrm.nt.gov.au/water/aquatic/publications>

Greiner R., Stanley O. and Speering G. (2012) *The potential role of market-based instruments in safeguarding the water quality in Darwin Harbour*. Report to the Northern Territory Department of Natural Resources, Environment, The Arts and Sport. Charles Darwin University, Darwin.

Skinner L., Townsend S. and Fortune J. (2009) *The Impact of Urban Land-use on Total Pollutant Loads Entering Darwin Harbour*. Report 06/2008D. Aquatic Health Unit, Department of Natural Resources, Environment, The Arts and Sport, Darwin.



# Appendix 1

## Consultation

Development and collation of management actions for this WQPP has been undertaken in consultation with stakeholders who were considered likely to be responsible for potential actions that directly or indirectly mitigate nutrient and sediment inputs to Darwin Harbour. These stakeholders are listed below, the majority of whom contributed management actions:

Belyuen Shire  
Casuarina Coastal Reserve Landcare Group  
City of Darwin  
City of Palmerston  
Conservation Volunteers Australia  
Darwin International Airport  
Darwin LNG Pty Ltd (operated by ConocoPhillips Pipeline Australia Pty Ltd)  
Darwin Port Corporation  
Department of Defence  
Department of Infrastructure  
Department of Land Resource Management  
    Aquatic Health Unit  
    Marine Biodiversity  
    Rangelands  
Department of Lands, Planning and the Environment  
    Land Administration  
    Land Development Corporation  
    Land and Economic Development  
Department of Primary Industry and Fisheries  
    Aquaculture Branch  
Department of Transport  
    Marine Safety  
    Road Networks  
Greening Australia Northern Territory  
INPEX  
Knuckey Lagoon Landcare Group  
Larrakia Nation  
Ludmilla Creek Landcare Group  
Mitchell Creek Catchment Landcare Group  
Northern Territory Environment Protection Authority  
Northern Territory Farmers Association  
Parks and Wildlife Commission of the Northern Territory  
Power and Water Corporation  
Rapid Creek Landcare group  
Territory Natural Resource Management  
Urban Development Institute of Australia Northern Territory  
Wagait Shire

The Department of Land Resource Management wishes to acknowledge and thank stakeholders for their involvement in the WQPP process.



# Appendix 2

## Water Sensitive Urban Design (WSUD)

WSUD is about planning, designing, constructing and maintaining urban areas in a way that minimises impacts on the natural water cycle. It is also about enhancing the liveability of urban areas while protecting the surrounding environment. In a practical sense WSUD is focused on reducing the volume of water runoff from impervious land surfaces, filtering water flows before they reach waterways, and the harvesting and reuse of wastewater and stormwater.

Some management actions in the WQPP have identified or included the use of WSUD elements such as:

### **Vegetated swales**

Open channel drains vegetated with grasses, trees and shrubs that are used to treat and convey stormwater runoff. Pipes fitted at the base of the swales can be used to convey the filtered stormwater to a waterway, stormwater system or storage device for reuse.

### **Gross pollutant traps**

Devices designed to trap litter, coarse sediments and organic matter from runoff before it enters the stormwater system.

### **Buffer zones**

Vegetated areas of land adjacent to a road or waterway, intended to filter surface runoff before it reaches the stormwater system or waterway. Vegetation alongside waterways can also help to stabilise the banks and reduce erosion and sediment input.

### **Bioretention basins**

Densely vegetated areas with a fine media layer (e.g. sandy loam), used to capture and filter stormwater runoff. Pollutants are retained in the basins through fine filtration, adsorption and biological uptake by the vegetation.

Not all WSUD measures will be suitable for the Darwin Harbour region; however, techniques can be tested and tailored to suit the climate and the lifestyle that the Darwin Harbour region offers. Cities such as Townsville, Cairns, Singapore and Kuala Lumpur have successfully implemented WSUD by taking into account regional climatic and lifestyle factors.



An example of Water Sensitive Urban Design  
*Credit Tony Weber*



*Credit David Hancock*



## Appendix 3

### The CAPER DSS: a tool for evaluating different catchment management scenarios

A Catchment Planning and Estuarine Response Decision Support System (CAPER DSS) has been developed for the Darwin Harbour region as part of the broader WQPP Project (see Box 4). The CAPER DSS is a tool that integrates catchment and water quality models and data to allow comparisons to be made between different catchment management scenarios on the basis of their relative sediment and nutrient load outcomes. In other words, the CAPER DSS can show if one scenario is likely to produce higher or lower sediment or nutrient loads than another scenario, and it can indicate how great the difference between scenarios is likely to be. Scenario options can include changes in land use and population, changes in wastewater treatment and other water management options. The model produces results for total catchment, sub-catchment or local government areas on an annual, wet or dry season basis.

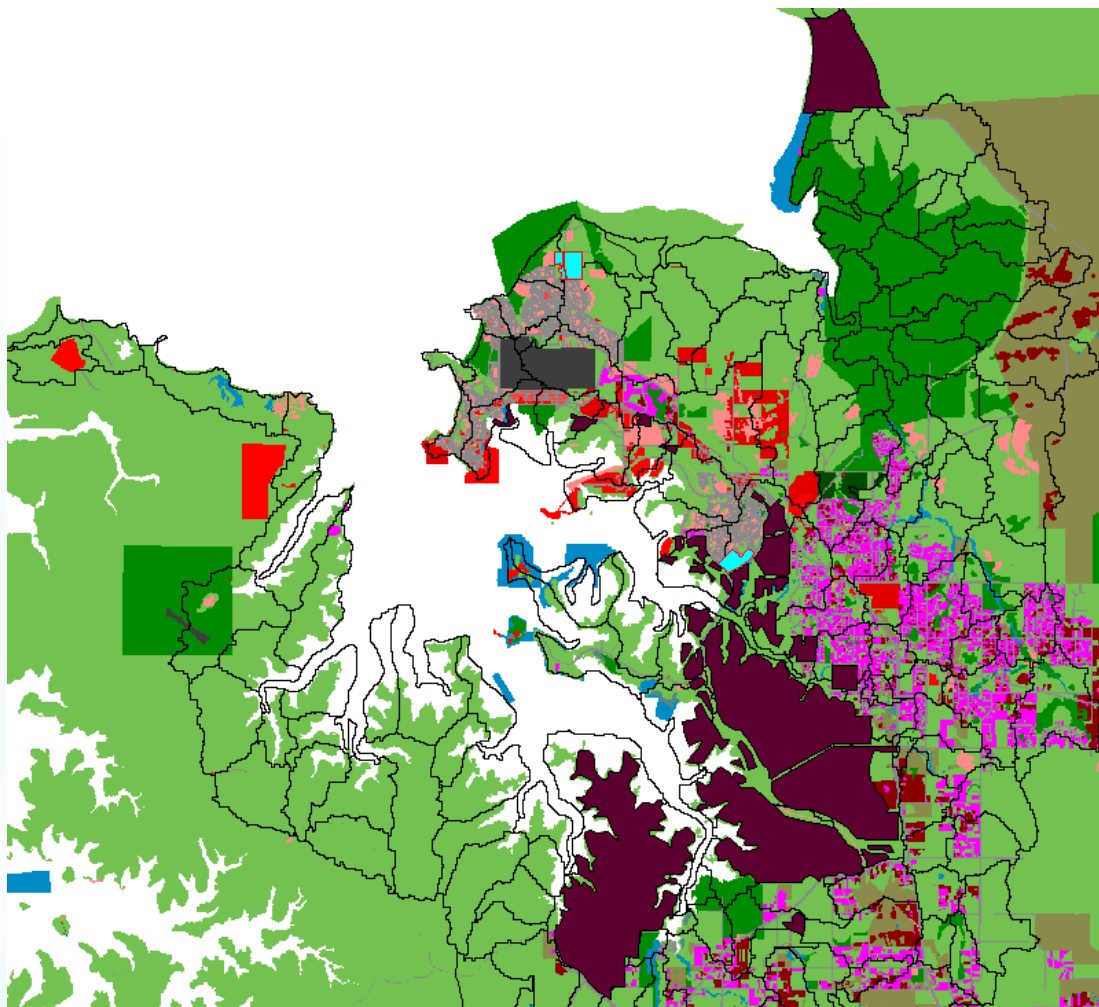
The value of the CAPER DSS is that it provides a focal point for discussions around catchment planning, and it can be used to evaluate broadscale catchment management options and outcomes. The CAPER DSS cannot be used to forecast specific sediment and nutrient loads associated with future development, nor can it be used to predict detailed spatial and temporal impacts, e.g. sediment and nutrient loads generated from a single development site, or during a storm event.

**Urban development example** (source: Rebecca Kelly, isNRM)

Figure 5 shows projected urban development (maroon) in the Darwin Harbour region in 2050, alongside existing urban (grey) and rural residential (pink) areas based on 2009 data. The projected areas correspond to a near doubling of the urban footprint across the catchment. Urban expansion has the potential to generate large exports of sediments and nutrients due to its large impervious area, greater connectivity to waterways through the stormwater drainage network, and through soil erosion during the development phase (see Box 5). Population growth associated with urban expansion also impacts on the volume of flows and loads being processed through wastewater treatment plants (WWTPs), further impacting on water quality.

In this example the CAPER DSS has been used to evaluate likely sediment loads associated with the projected urban development, under two management scenarios:

- 1) The 'worst case' scenario: no WWTP upgrades, erosion and sediment controls (E&SC) or water sensitive urban design (WSUD) measures; and
- 2) The 'best case' scenario: application of WWTP upgrades, E&SC and WSUD measures. The level of E&SC is assumed to be current best practice, involving application of on-site erosion controls, sediment basins, sediment fencing and good site management over a two year period of subdivision and house lot construction. The WSUD measures are applied across 70% of the new urban area and involve the installation of rainwater tanks and wetlands (the wetlands are sized to cover 10% of each contributing catchment).



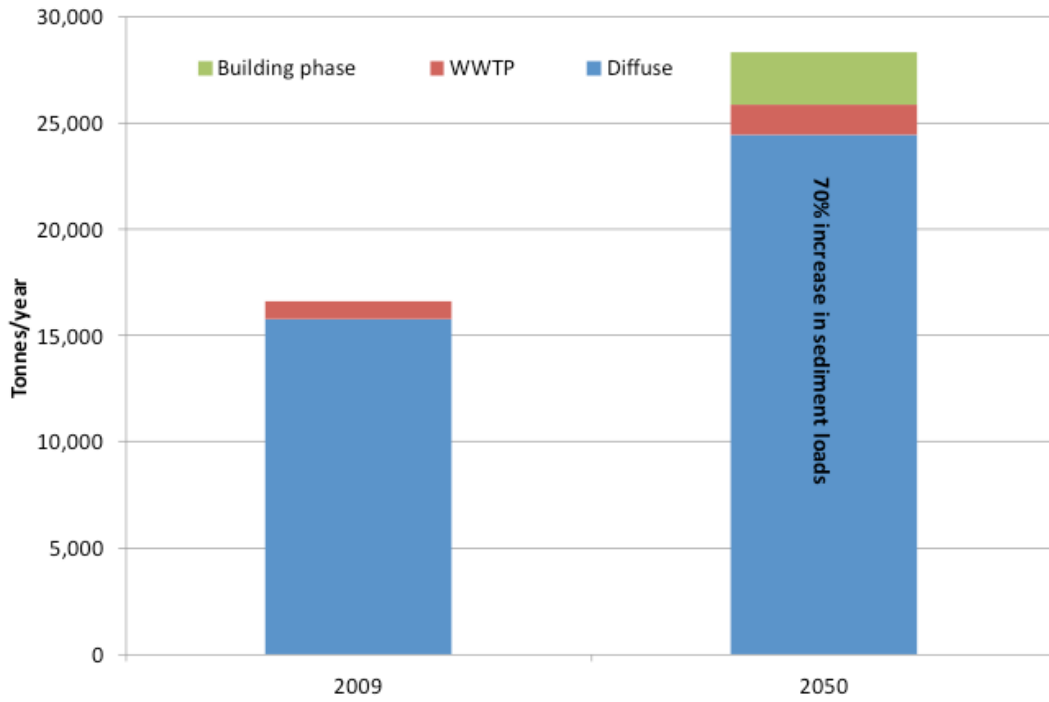
**Figure 5** Urban (grey) and rural residential (pink) development in 2009, and projected urban development in 2050 (maroon).

Source: Tony Weber, BMT WBM

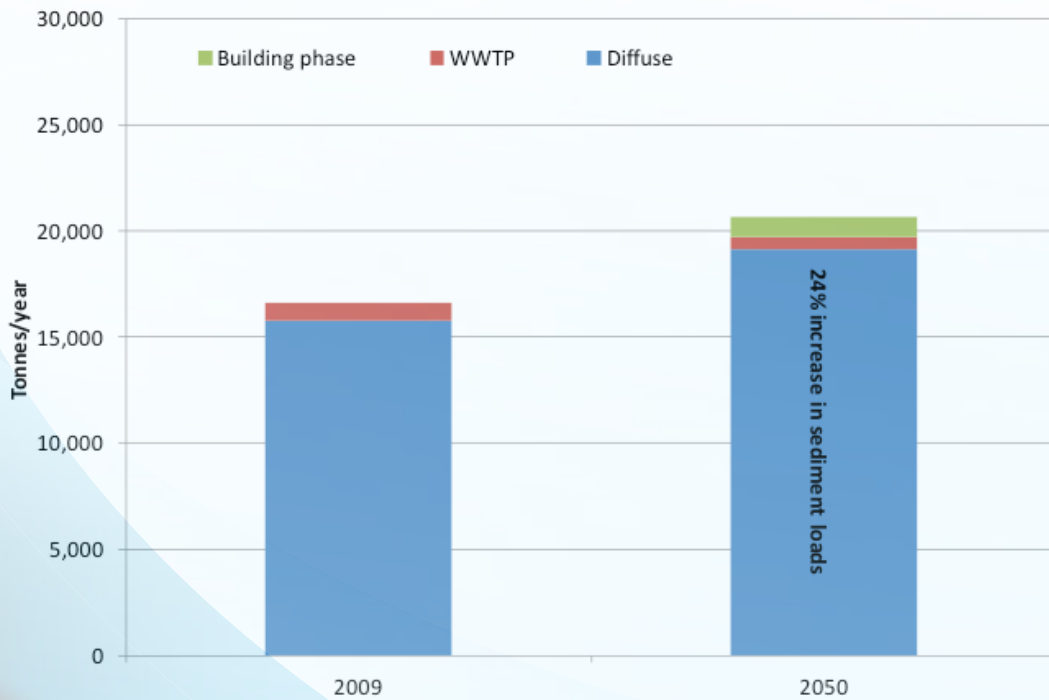




(a)



(b)



**Figure 6** Annual sediment loads to Darwin Harbour in 2009 and 2050 under (a) the 'worst case' management scenario and (b) the 'best case' management scenario. The different colours reflect the division of annual sediment loads according to their source.  
Source: Rebecca Kelly, isNRM

### **'Worst case' management scenario**

Under this scenario annual sediment loads to Darwin Harbour are expected to increase by 70% between 2009 and 2050, based on results from the CAPER DSS (Figure 6a). The development phase of urban expansion, with no E&SC, has the potential to generate a larger annual sediment load than all WWTPs discharging to the Harbour. Diffuse loads derived from urban areas are also expected to greatly increase, and loads from WWTPs are anticipated to rise.

### **'Best case' management scenario**

The CAPER DSS results suggest there is significant potential to reduce annual sediment loads to Darwin Harbour through the application of E&SC on building sites, WWTP upgrades and the implementation of WSUD, which helps to reduce diffuse loads (Figure 6b). With these measures included in the CAPER DSS scenario the projected urban expansion in 2050 is expected to lead to a 24% increase in sediment loads to the Harbour. This expected increase is significantly less than under the 'worst case' scenario.

### **Conclusion**

The CAPER DSS results indicate that if we approximately double the area of urban development in the Darwin Harbour catchment and do not take action to mitigate sediment loads, there is likely to be significant pressure placed on the Harbour's waterways. It is anticipated this pressure will be part of an ongoing trend of development over the next century, which will result in further increases in sediment loads past the 2050 scenario shown here.

Currently we have limited knowledge of Darwin Harbour's capacity to accept additional sediment inputs without detrimental environmental change. The assimilative capacity of the Harbour is an important area of future research. In the meantime, we have an opportunity to undertake actions such as those identified in this WQPP, to support water quality protection and avoid costly environmental rehabilitation.





*Credit David Hancock*