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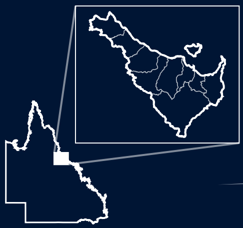

WATER QUALITY POLLUTANT TYPES AND SOURCES REPORT: BLACK ROSS WATER QUALITY IMPROVEMENT PLAN

Improving Water Quality
from Creek to Coral

SEPTEMBER 2009

Australian Government

Queensland Government

Townsville

TOWNSVILLE CITY COUNCIL

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Australian Government

Document disclaimer statement

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Prepared for Creek to Coral by:

Earth Environmental
ABN 76 870 019 854

PO Box 802
Mackay
Queensland 4740 Australia

Telephone: 0413019359
Email: earth@mackay.net.au

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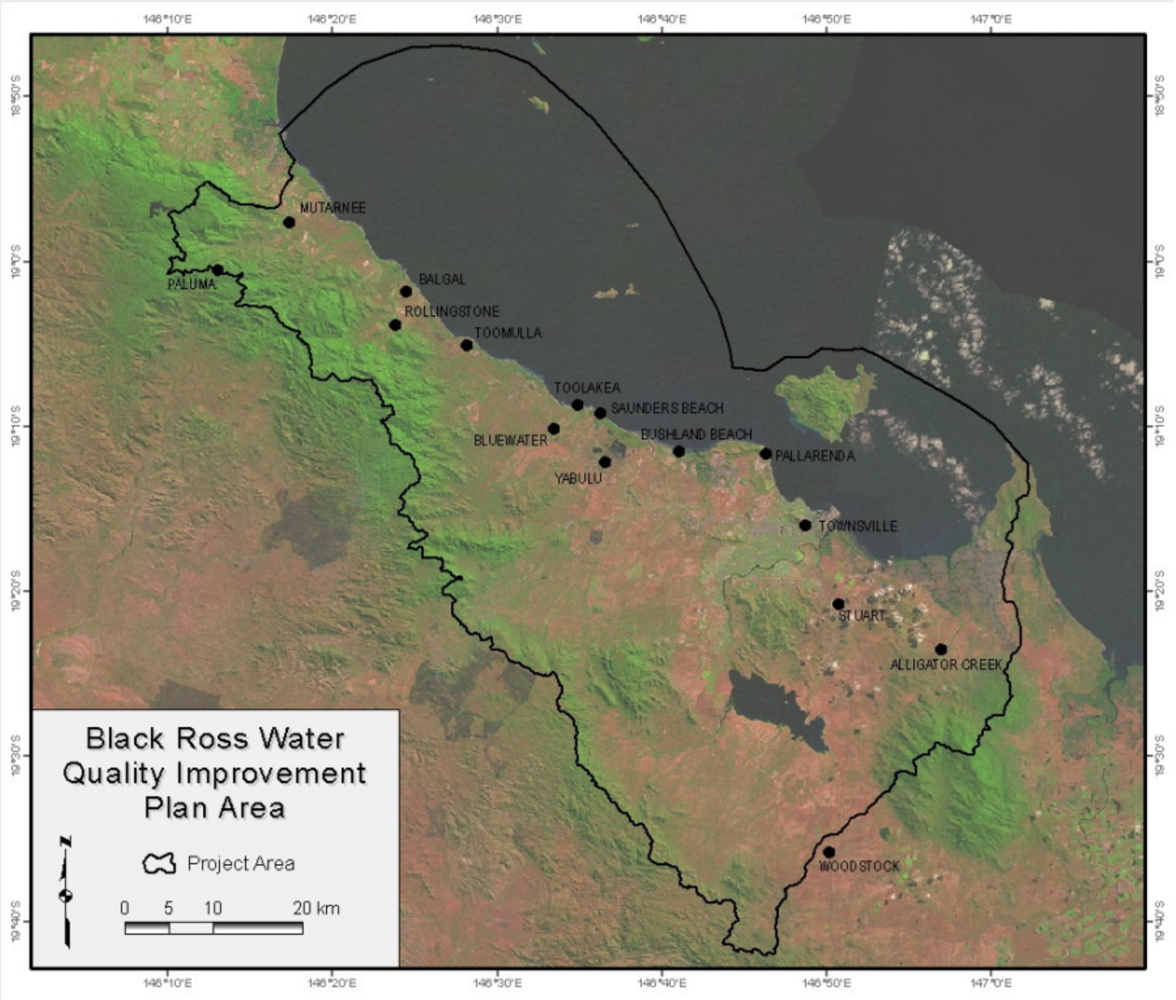
1. *Introduction*

1.1 Background

Creek to Coral managed the Townsville Coastal Catchments Initiative (CCI) project and along with its many partners prepared a Water Quality Improvement Plan (WQIP) for the Black and Ross River Basins. The Black Ross (Townsville) WQIP area extends from Crystal Creek in the north to Cape Cleveland in the south and encompasses all the waterways that flow to Cleveland Bay and Halifax Bay. The area also covers Magnetic Island and surrounding marine waters (see Figure 1.1).

Figure 1.1 Black Ross WQIP Area



One of the main tasks associated with the development of the WQIP was the identification of pollutants and their sources including; the location of major constructed discharge points for pollutants, the location of near shore facilities that are likely to contribute pollutant loads to receiving waters and the amount of diffuse source pollutants impacting waterways.

This document provides information on potential point source pollutant emitters including the location of discharge points in relation to waterways, pollutant types and known emissions. Diffuse pollutant types and potential sources are also identified and discussed in terms of both the urban and rural settings.

2. Point Sources

2.1 Point Source Discharge

Point source pollution is relatively easily identified as it involves intensive land use in a relatively small area. The pollutants, generally waste products, generated by the intensive activity are discharged from the facility at a specific point or points e.g. pipe or chimney, hence the name point source discharge.

2.2 Identifying Point Sources

Many of the potential point source activities are relatively well known in the Townsville region, as they are a conspicuous part of the landscape. The two main data sets used to identify less obvious point source discharges and to confirm discharge types are:

- Environmentally Relevant Activities (licensed through the Environmental Protection Agency); and
- The National Pollutant Inventory (http://www.npi.gov.au).

2.2.1 Environmentally Relevant Activities

A list of licensed Environmentally Relevant Activities (ERAs) in the Black Ross WQIP area were provided to Creek to Coral by the Environmental Protection Agency (EPA). A summary of the ERA information is listed in Table 2.1 including a qualitative assessment of the potential risk to surface water quality of the activity.

Table 2.1 ERAs in the Black Ross WQIP area

ERA No.	ERA description	Count	Potential Discharge	WQ Risk
1	Aquaculture	5	Water, Land	Moderate
6 [7]	Chemical manufacturing, processing or mixing	10	Air, Land	Low
7 [8]	Chemical storage	15	Air, Land	Low
9 [10]	Gas producing	1	Air	Low
10 [7]	Paint manufacturing	1	Air, Land	Low
11 [8]	Crude oil storing or petroleum product storing	21	Air, Land	Low
14 [x]	Crematorium	1	Air	Low
15 [63]	Sewage treatment	18	Water, Land, Air	High
16 [64]	Municipal water treatment plant	4	Water, Land	Moderate
17 [15]	Fuel burning	6	Air	Low
18 [14]	Power station	4	Air, Land, Water	Moderate/High
19 [16]	Dredging material	16	Water, Land	Moderate
20 [16]	Extracting rock or other material	20	Air, Land	Low
22 [16]	Screening etc. materials	13	Air, Land	Low
23 [17]	Abrasive blasting	7	Air, Land	Low
24 [18]	Boiler making or engineering	3	Air, Land	Low
25 [38]	Metal surface coating	11	Air, Land	Low
26 [19]	Metal forming	2	Air, Land	Low
28 [21]	Motor vehicle workshop	18	Air, Land	Low
32 [25]	Meat processing	1	Air, Land, Water	Moderate/High
35 [x]	Smoking, drying or curing works	1	Air	Low
40 [29]	Metal foundry	4	Air, Land, Water	Moderate/High
41 [30]	Metal works	2	Air, Land	Moderate
52 [37]	Printing	1	Air	Low
53	Soil conditioner manufacturing	2	Air, Land	Moderate
57 [13]	Tyre manufacturing or retreading	1	Air, Land	Low
62 [43]	Concrete batching	4	Air, Land	Low
67 [47]	Sawmilling or woodchipping	2	Air, Land	Moderate

71 [x]	Port	1	Air, Land, Water	High
72 [x]	Railway facility	1	Land, Air	Moderate
73 [x]	Marina or seaplane mooring	1	Water, Air	Moderate
74 [50]	Stockpiling, loading or unloading goods in bulk	17	Air, Land	Moderate
75 [60]	Waste disposal	2	Land, Air, Water	Moderate
76 [61]	Incinerating waste	3	Air, Land	Low
78 [55]	Chemical or oil recycling	3	Land	Low
79 [54]	Drum reconditioning	1	Air, Land	Low
81 [55]	Recycling or reprocessing regulated waste	1	Air, Land	Low
83 [57]	Regulated waste transport	32	Land	Low
84 [56]	Regulated waste storage	14	Land	Low
85 [58]	Regulated waste treatment	4	Land	Low
	Total ERAs	274		

Note: ERA numbers have been changed since EPA provided the listing. The new numbers (2008) from EP Regulations are provided in square brackets beside the old numbers, if they have changed. [x] indicates that the activity is no longer listed as an ERA.

[1] Certain types of agricultural activity were added to the list of ERAs in 2009 with the passing of the Great Barrier Reef Protection Amendment Act 2009 (Act No. 42 of 2009)

Risk levels

The low level of risk assigned to activities involving potentially toxic chemicals and hydrocarbons is based on the proximity of the activities to waterways and the assumption that the ERA licensing process ensures that the chemicals are stored in a safe and secure manner i.e. bunded. It is recognised that chemical contamination of waterways is a potentially serious issue however the risk level is not considered to be high given the low likelihood of uncontained spills entering waterways.

Where the principal discharge pathway of an activity is to air it was assumed that only high emission activities had the potential to have an impact on water quality so low emission activities were rated as low risk. Where the secondary discharge pathway of a low risk activity was to land it was assumed that ERA licensing conditions would also ensure that any potential discharge to land is managed appropriately and will not result in a subsequence discharge to water. No discharge data was available for the ERAs.

Moderate and high-risk activities involve either potential direct discharge to water or high levels of emissions to air. While emanating from a point source the emissions to air will be treated as diffuse sources as the plume containing the pollutants disperses and some of the pollutants will eventually settle on the land and water over a broader area. Dispersion modelling is required to more accurately determine the extent and concentration of the pollutants and potential implications for water quality.

Townsville ERAs

At the time of listing (early 2008), there were 168 ERA approvals in the Black Ross (Townsville) WQIP area, with many enterprises having more than one ERA attached. These are listed in Table 2.2. The assumed primary ERA activities associated with the licenses are listed in Table 2.3.

Table 2.2 Number of ERAs per approval/licence

ERAs	1	2	3	4	5	6	7	8	14
Count	121	25	9	7	0	3	0	2	1
Percentage	72	14.9	5.4	4.2	0.0	1.8	0.0	1.2	0.6

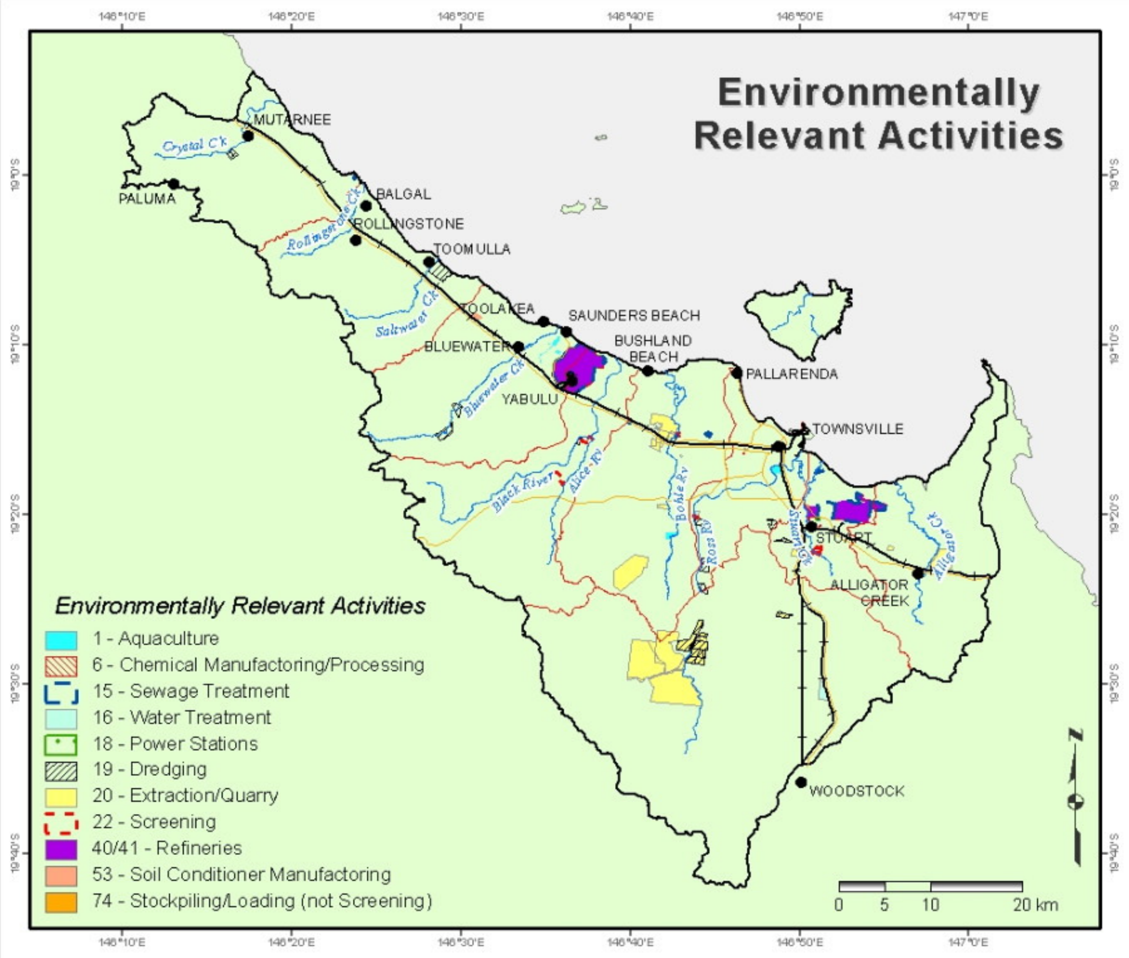
Table 2.3 Primary ERA Count

ERA No.	ERA description	Primary ERA (assumed)				
		1 Count	2 Count	3 Count	4 Count	6 Count
1	Aquaculture	5				
6 [7]	Chemical manufacturing, processing or mixing	3	3			
7 [8]	Chemical storage	3	2			
9 [10]	Gas producing	1				
10 [7]	Paint manufacturing	1				
11 [8]	Crude oil storing or petroleum product storing	4	1			
14 [x]	Crematorium	1				
15 [63]	Sewage treatment	14				
16 [64]	Municipal water treatment plant	3	1			
17 [15]	Fuel burning	2				
18 [14]	Power station		1	2		
19 [16]	Dredging material	10	3	1	2	
20 [16]	Extracting rock or other material	6	4		3	
22 [16]	Screening etc. materials	2	1			
23 [17]	Abrasive blasting	1	2	1		
24 [18]	Boiler making or engineering		1		1	
25 [38]	Metal surface coating		4			
28 [21]	Motor vehicle workshop	9				
32 [25]	Meat processing					1
35 [x]	Smoking, drying or curing works	1				
40 [29]	Metal foundry	2				
52 [37]	Printing			1		
53	Soil conditioner manufacturing	1				
57 [13]	Tyre manufacturing or retreading	1				
62 [43]	Concrete batching	2				
67 [47]	Sawmilling or woodchipping	2				
71 [x]	Port			1		
72 [x]	Railway facility	1				
73 [x]	Marina or seaplane mooring			1		
74 [50]	Stockpiling, loading or unloading goods in bulk	11	1	1		
75 [60]	Waste disposal			1		
76 [61]	Incinerating waste					1
78 [55]	Chemical or oil recycling	1			1	
84 [56]	Regulated waste storage	4	1			
85 [58]	Regulated waste treatment					1
	Total ERAs	91	25	9	7	3

Note: 30 of the ERA licences were for regulated waste transport and were not included as a potential point source discharge as it is an itinerant activity. From Table 2.2 the 2 metal foundries (Sunmetals and Xstrata) had 8 ERAs and the activity with 14 ERAs was a metal works (Yabulu) and power station.

ERA numbers have been changed since EPA provided the listing. The new numbers (2008) from EP Regulations are provided in square brackets beside the old numbers, if they have changed. [x] indicates that the activity is no longer listed as an ERA

Figure 2.1 ERA Locations in the Black Ross WQIP Area



Note: ERA numbers have changed since EPA provided the listing. See Table 2.3 for relevant new numbers

2.2.2 About the National Pollutant Inventory data

The National Pollutant Inventory (NPI) is the Australian Government central pollutant reporting and information system, which reports on pollutant emissions from industry and diffuse sources.

"*The NPI holds pollutant emissions data reported by industrial facilities, and diffuse data determined by state and territory environment agencies. Industrial facilities are required to annually report emissions to the NPI if they exceed NPI reporting thresholds for one or more NPI substances*". Reporting thresholds are listed in Appendix A.

"*The 90 NPI substances span a wide range of toxicities. A small amount of a highly toxic substance may be of more concern than a larger emission of a less toxic substance.*"

"*Commonwealth, state and territory environment agencies have approved the techniques used to estimate emissions for the NPI. It is important to note that the accuracy of these techniques varies. Industrial facilities estimate pollutant emissions using techniques described in an industry NPI manual, or else otherwise approved.*" (Source: http://www.npi.gov.au/database/data-explanation.html)

The ultimate fate of NPI substances emitted to the environment varies the impacts they have on human health and the environment. The pollution exposure to humans and the environment cannot be determined solely from the NPI point source data. Many additional factors determine whether a pollutant emission to air is felt as ground level pollution.

Examples of additional factors are the:

- Height of an emission above the ground (high stacks versus ground level vehicle exhausts);
- Nature of receiving environments;
- Chemical reactivity of the substance; and
- Prevailing weather conditions.

Since NPI does not attempt to collect information about these additional factors, NPI data can only reflect pollutant emissions at the emission source. The data for emissions to air from point source facilities will therefore be treated as diffuse source pollutants as they are dispersed and settle over a broader area. This is also the case for fugitive emissions i.e. emissions that ‘escape’ to the air rather than being released from a smoke stack.

Townsville facilities that report emissions through the NPI are listed in Table 2.4. Emissions to air may be either from a stack, fugitive or both.

Table 2.4 NPI Point Sources for Black Ross WQIP

Facility	Manager	Location	Emission type/s	Waterway
BP Australia - Townsville Terminal	BP Australia Pty Ltd	South Townsville	Air	
Cannington Port Facility	BHP Billington Mineral Pty Ltd	Townsville	Air	
QNI Townsville Port Bulk Fuel Facility	Queensland Nickel P/L	South Townsville	Air	
QNI Yabulu Refinery - Materials Handing Facility	Queensland Nickel P/L	Townsville	Air Water	Ross Creek / Cleveland Bay
Queensland Terminals	Queensland Terminals Pty Ltd	South Townsville	Air	
Southern Cross Fertilisers - Townsville Port Facility	Southern Cross Fertilisers Pty Ltd	Townsville	Air	
Townsville Port	Northern Shipping and Stevedoring P/L	Townsville	Air	
Townsville Terminal	The Shell Company of Aust. Ltd	Townsville	Air	
Xstrata Copper - Townsville Port Ops	Copper Refineries P/L	Townsville	Air Water	Ross Creek / Cleveland Bay
Townsville Port in general	All of the above	Townsville Port	As above	As above
Cleveland Bay STP	Townsville City Council	Townsville	Water	Sandfly Creek / Cleveland Bay
Copper Refinery	Copper Refineries Pty Ltd - Xstrata Copper	Stuart	Air	
Origin Power Station (Near Xstrata)	Origin Energy Aust Holding B.V.	Stuart	Air	Stack
New Railway Facility	Queensland Rail	Stuart	Air	
Stuart Railway Facility	Queensland Rail	Stuart	Air	
Zinc Refinery	Sunmetals Corp Pty Ltd	Stuart	Air Land	Stack
Townsville Abattoir	Australia Meat Holdings Pty Ltd	Stuart	Air	Stack
Douglas Water Treatment Plant	Townsville City Council	Douglas	Air	Ross River
Hanson Townsville Quarry	Hanson Construction Materials Pty Ltd	Townsville	Air	NW quarry

Condon Sewage Treatment Plant	Thuringowa City Council	Condon	Land Water	Bohle River
Townsville Airport Fuelling Service	The Shell Company of Aust. Ltd	Garbutt	Air	
Townsville Laundries	Ushers Investments Pty Ltd	Garbutt	Air	
AIR BP Townsville	BP Australia Pty Ltd	Townsville	Air	
Industrial Galvanizers Nth Qld	Industrial Galvanizers Corp P/L	Bohle	Air	
Bohle quarry	CSR Ltd	Bohle	Air	
Deeragun Sewage Treatment Plant	Thuringowa City Council	Deeragun	Land Water	Saunders Creek / Bohle River
Mount Low Sewage Treatment Plant	Thuringowa City Council	Mt Low	Land Water	Black River
Mt St John STP	Townsville City Council	Mt St John	Water	Bohle River
QNI - Yabulu Refinery	Queensland Nickel P/L	Yabulu	Air	Stack
Townsville Power Station	Transfield Townsville Pty Ltd	Yabulu	Air	Stack

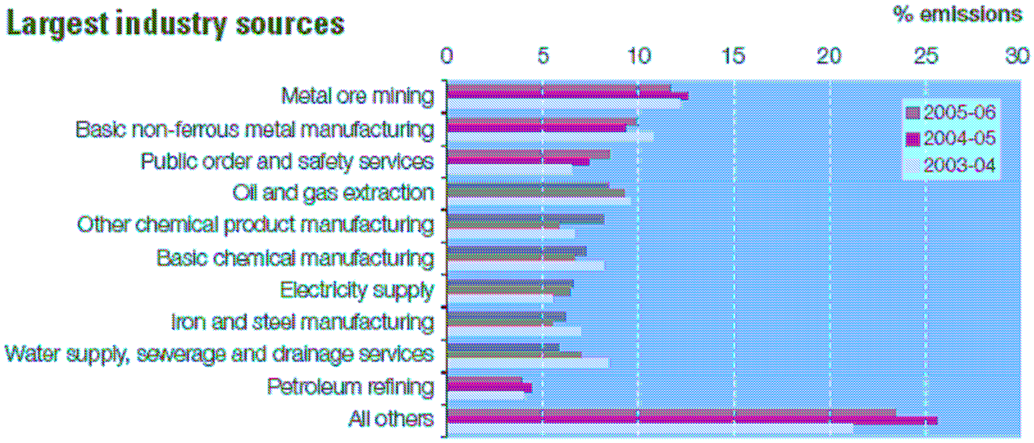
Source: http://www.npi.gov.au/overview/reports/qld-facility-location.html at 8 October 2007

Point source pollutant emissions, according to NPI records, from facilities listed in Table 2.4 are provided in Appendix A. Location of the main NPI emitters in Townsville are shown on Figure 2.3.

2.3 Industry Emission Sources

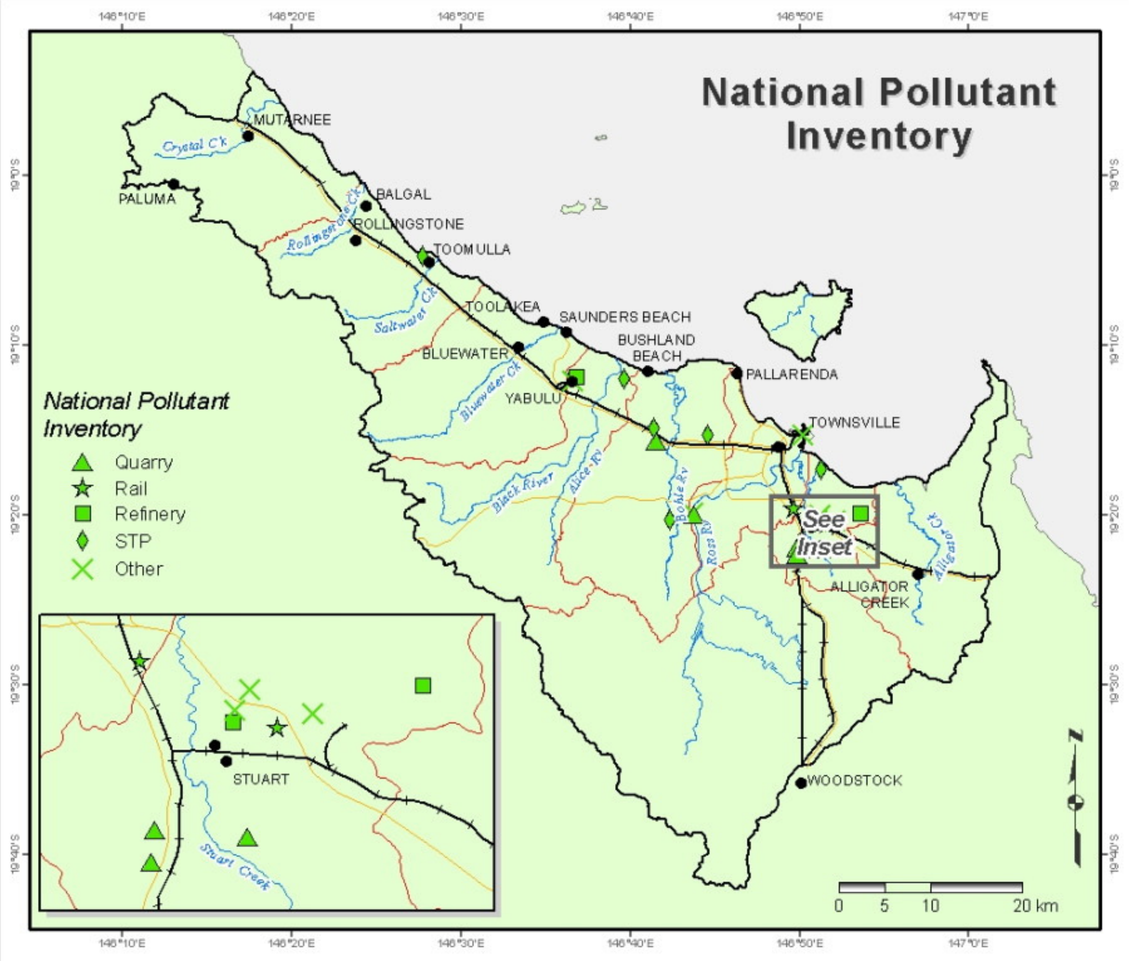
The main industry sources of emissions in Australia, reporting to the NPI, are shown in Figure 2.2 (NPI 2008, p.5). The two main industry sources in Townsville are "*Basic non-ferrous metal manufacturing*" and "*Water supply, sewerage and drainage services*".

Figure 2.2 Main Industry Emission Sources



Source: NPI 2008, p.5

Figure 2.3 NPI Point Source Discharge Locations Townsville City



2.4 Emissions to Water

According to the NPI "*the water, sewerage and drainage sector is the largest emitter of substances to water, followed by the basic chemical manufacturing and metal ore mining sectors*" (NPI 2008, p.13).

This is also the case for the Black Ross WQIP area where sewage, or wastewater treatment plants (WWTPs) are the main source of emissions to water. Details of emissions from these and other point sources are provided in Appendix A with additional information about each of the WWTP sites included in Appendix B.

The majority of the emissions are in the form of nutrients i.e. nitrogen, ammonia and phosphorus. According to the NPI, point source emissions of total nitrogen to water in 2005/06 was 35,000 tonnes compared to diffuse source emissions of 210,000. On the basis of these figures point source emissions account for 14% of total nitrogen emissions to water across Australia.

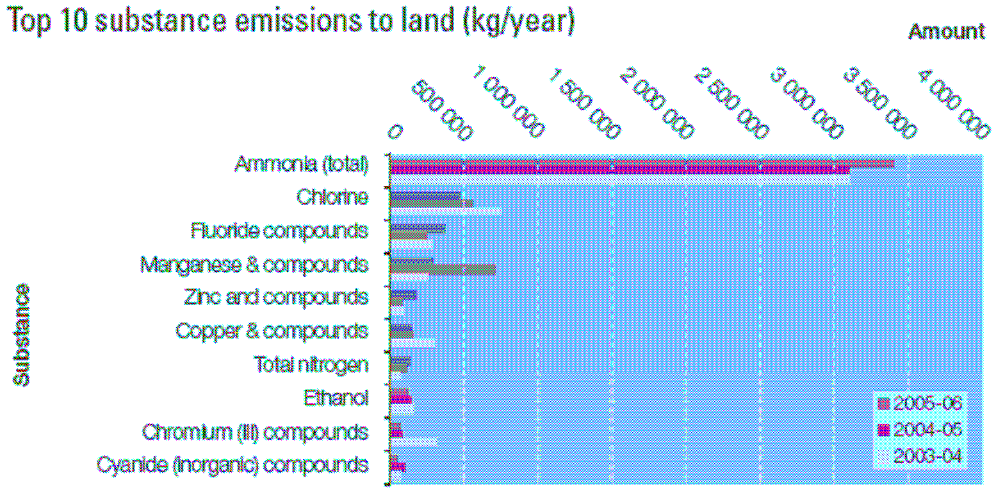
In 2005-06, eighteen facilities reported 76 tonnes of total phosphorus to water in the Murray Darling Basin compared to an estimated 12,000 tonnes of total phosphorus from diffuse sources. Point source emissions of total phosphorus accounted for less than 1% of total phosphorus emissions to water emphasising the relative importance of assumed fertiliser impacts on water quality.

Emissions to water also occur indirectly from the settling of industrial and vehicular atmospheric emissions to air as well as through runoff from land-based substances from industry, agriculture and roads. These indirect emissions to water are further considered in the section on diffuse sources (section 3).

2.5 Emissions to Land

Emissions to land can stem from a variety of sources including industry, vehicular emissions, fertiliser and chemical use in agricultural practices, and atmospheric deposition. While some of the deposition onto land may be secondarily transferred to water bodies through stormwater run-off, a high proportion is likely to remain insitu and have little subsequent impact on water quality; however there may be localised impacts on ecological processes and soil health.

Figure 2.4 Australian Top Ten Land Emissions



Source: NPI 2008, p.14

The main reported sources of emissions to land in the Black Ross WQIP area are wastewater treatment plants (WWTPs).

According to the NPI the main emissions to land are (see Figure 2.4):

- Ammonia - mainly from water supply, sewerage and drainage services and meat and meat product manufacturing;
- Chlorine - mostly from landfill (see waste disposal sector or the public order and safety services sector on the NPI database);
- Fluoride compounds - a range of sources mostly from salt production;
- Manganese and compounds;
- Zinc and compounds – the largest industry source of emissions of zinc and compounds to land is zinc smelting and refining.

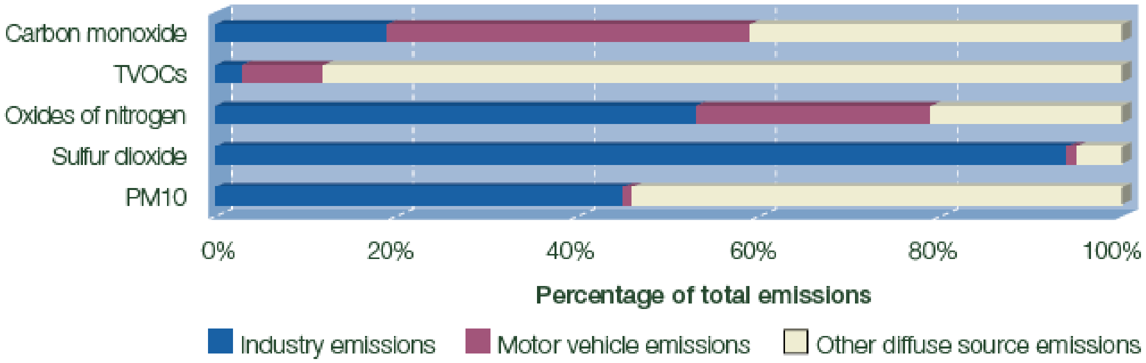
In the case of industry most emissions to land are substance emissions onto a facility's site, which include solid wastes, slurries and sediments, as well as accidental spills, and leaks from facilities. Emissions are usually contained in tailings dams which when decommissioned are capped to prevent water infiltration and subsequent seepage to groundwater.

Point source emissions to land are strictly regulated through the Environmental Protection Act and licensing of ERAs (see section 2.2.1) and are not considered further as a source of surface water quality pollution for this report.

2.6 Emissions to Air

There are a number of industrial activities in the Black Ross (Townsville) WQIP area that produce pollutants that are released into the atmosphere. The main point source emissions to air in the Townsville WQIP area (see Appendix A) include metal refineries such as the Sunmetals Zinc Refinery and the QNI Yabulu Nickel Refinery.

Figure 2.5 NPI Top Five Substances Emitted to Air in Australia 2005-06



Source: NPI 2008, p.12

Emissions to air take two different forms i.e. from chimneys/stacks and as fugitive emissions. Fugitive emissions are more disperse and are not a result of combustion or the burning of fuels in a contained environment where the exhaust emissions are channeled to a specific emission point. Fugitive emissions include vapour loss from tanks and ponds and dust from stockpiling operations.

The likely eventual fate of the non-fugitive industry emissions can be predicted using dispersion models. Inputs to dispersion models include; pollutant types and quantities, emission point above ground, settling rates and wind speed and direction. The fate of fugitive emissions can also be modeled however the results are less accurate due to the semi-diffuse starting point of the emissions. Tracking the fate of fugitive emissions would only be done where emissions are extremely high and the fate was likely to have significant localised impacts e.g. dust or ammonia.

Due to the dispersion of these pollutant emissions to air they are considered as diffuse sources in terms of water quality and are included in section 3 (Diffuse Sources).

2.7 Main Townsville Industry

The main point source pollutant emitters in Townsville have been identified through the Environmentally Relevant Activities (ERA) listing or by their reporting to the National Pollutant Inventory (NPI). The main industrial activities in Townsville are discussed below in terms of their potential to impact water quality. Industries identified as having low potential impact in previous sections are either discussed briefly or not included in the discussion.

2.7.1 Metal Refineries

There are three non-ferrous metal refineries in the Black Ross WQIP area, two in the Stuart industrial area and one at Yabulu (see Figure 2.2). The main emissions from the refineries are to air and as such are initially a potential air quality issue. If the volume of emissions is substantial and the settling rate of the emissions (dryfall atmospheric deposition) is high within a relatively small land and water area then there is also potential for water quality issues. Alternatively if the emissions are retained in the airshed in high quantities then there is potential for wet fall deposition via rainfall (see section 4.1).

Emissions from the refineries as reported to the NPI are included in Appendix A. Air quality monitoring associated with industry emissions from the metal refineries are discussed in sections 4.3 and 4.4, with additional information for the Yabulu nickel refinery in Appendix C.

From the available information it appears that the airborne emissions from the metal refineries are not a significant water quality issue. The emissions are within acceptable air quality standards and the dispersion of the pollutants throughout the airshed renders them innocuous in terms of water quality.

The main potential for water quality issues associated with the metal refineries relates to the land-based disposal of waste from the refining process, which is stored in ‘tailings’ dams. These are engineered stockpiles with requirements to ensure there is no leakage to the surrounding environment. Issues for water quality could arise if there was a failure in the waste management system either through failure of the physical infrastructure e.g. dam lining or walls, or the environmental management systems e.g. turning the wrong valve.

Given the number of ERAs associated with the refineries it is assumed that the necessary safeguards and systems are in place to prevent any such failures occurring. Results of water quality monitoring programs have not identified any water quality issues associated with the metal refineries in the Black Ross WQIP area.

2.7.2 Power Stations

There are two power stations listed in the NPI, one in the vicinity of the Yabulu nickel refinery and the other near the Xstrata copper refinery.

The Townsville Power Station at Yabulu was commissioned in 1996 after the Queensland Supply and Transmission Corporation sought competitive proposals to meet growing electricity demand utilising private power plants. The 160 megawatt peak-load power station was completed in 1999 by Transfield.

Transfield completed a $115 million redevelopment of the power station in 2005 increasing its capacity to a 240 MW gas fired, base loading plant. The upgrade was in conjunction with development of coal seam gas supplies in Moranbah and the construction by Enertrade of the 400km North Queensland Gas Pipeline. In the first 12 months of operation over 12 petajoules of gas was delivered to the Townsville Power Station by the gas pipeline, the equivalent of over 12,000 semi-trailer loads of LPG.

The Origin power station at Mt Stuart is a 288 MW gas turbine peaking plant which runs on kerosene. The plant can be readily converted to natural gas. In early 2008 Origin announced a $92 million expansion with the installation of a 126MW Frame 9E gas turbine generator set. This will result in a 45% increase in electricity output and is planned to come online in mid-2009. With the extra generator on site, Mt Stuart will have the capacity to generate power to around 255,000 homes.

As both power stations are either gas or kerosene fuelled, and relatively small compared to coal fired power stations (20% of the capacity of Tarong), their emissions are not as voluminous or ‘dirty’ and as coal-fired power stations. Emissions as reported to the NPI are listed in Appendix A and are not considered to be a significant water quality issue.

In 2006-07 Australia had 47,400 MW of installed electricity generation capacity. By comparison the combined capacity of Townsville’s power stations is approximately 520 MW i.e. approximately 1% of Australia’s capacity.

2.7.3 Townsville Port

The Townsville Port has a history dating back to the 1890s. A number of facilities in and around the port have been identified through the NPI and ERA licences. The main facilities. The main port facilities are shown in Figure 2.6, including those listed through the NPI or ERA licenses. The facilities are listed in Table 2.5 with reference to the numbering in Figure 2.6.

Figure 2.6 Potential Pollutant Sources at Townsville Port

Source: http://www.townsville-port.com.au/

The main berths are listed below with reference to the numbering in Figure 2.6.


BERTHS

1	Berth 1 (Bulk Liquids)
2	Berth 2 (Bulk Commodities & Containers)
3	Berth 3 (Containers & Break Bulk)
4	Berth 4 (Bulk Commodities)
7	Berth 7 (Bulk Minerals)
8	Berth 8 (Common User General Purpose)
9	Berth 9 (Bulk Sugar)
10	Berth 10 (Containers & Break Bulk)
11	Berth 11 (Bulk Minerals)

Table 2.5 Townsville Port Facilities

No.	Facility	No.	Facility
13	Magnetic Island Car Ferry	29	Queensland Terminals
17 & 18	Queensland Sugar (Bulk sugar sheds)	31	Incitec Pivot
19	Northern Shipping and Stevedoring	32	Cement Australia
21	Xstrata	33	Shell
22	Australian Molasses Trading	37	Incitec Pivot
23	Chemtrans	38	Tropical Distributors
24	Origin Energy	39	Simsmetal
27	BHP Billiton Yabulu	40	BP Australia
28	BHP Billiton Cannington	47	Powerlink

Source: http://www.townsville-port.com.au/

Townsville Port handles a variety of imports and exports and involves bulk handling and storage of a number of materials including metal ores, fuel and chemicals. Products and materials handled at the Townsville Port are listed in Table 2.6.

Table 2.6 Townsville Port Imports and Exports

Imports
Zinc concentrates – for the Sunmetal refinery (244,000)
Nickel ore – for refining at Yabulu (2,928,000)
Oil products – for Shell, BP, Caltex and Ampol (1,140,000 includes 214,000 for Yabulu)
Cement – from Gladstone (582,000)
Fertiliser – principally nitrogen based for Incitec Pivot (96,000)
Sulphur – for use by Southern Cross Fertilisers (SCF) in fertiliser production (126,000)
Sulphuric acid - by Queensland Terminals for SCF to produce phosphate fertiliser
Motor vehicles – various makes (22,000)
General cargo (145,000)
Exports
Metallurgical coke – produced at Bowen and bound for European markets
Metal concentrates – to Europe and Asia (1,427,000)
Refined copper – from Xstrata refinery (177,000)
Nickel (413)
Zinc ingots (140,000)
Lead ingots (187,000)
Cattle – live trade to Phillipines, Brunei, Vietnam and Egypt (14,000)
Meat and meat by-products (8,000 tallow)
Fertiliser – Southern Cross Fertiliser export around 900,000 tonnes a year (778,000)
Sulphuric acid - Southern Cross Fertiliser excess produced at Phosphate Hill fertiliser plant (55,000)
Sugar (1,184,000)
Molasses – from Burdekin and Herbert sugar mills (223,000)
Feed pellets – for cattle on route to final destinations
Timber (115,000)
Sand and gravel – to Palm Island (35,000)
General cargo (176,000)

Source: http://www.townsville-port.com.au/ Note: Figures in brackets are imports/exports in tonnes for the 2007/08 financial year.

With the array of facilities, facility operators and potential for environmental harm associated with activities at the Port of Townsville it is essential to have adequate environmental safeguards in place. The Townsville Port Authority (TPA) is responsible for the overall coordination of environmental management within the limits of the port, which involves working with other port users and setting environmental standards for the operation of the port.

This has involved, amongst other things, the development of an Environmental Management Strategy for the Port of Townsville, in conjunction with the port community, and the preparation of Environmental Management Plans, Codes of Practice, Development Guidelines and the development of a research and monitoring program. Other port users are also responsible for preparing and implementing Environmental Management Plans and Emergency Response Plans specific to their own operations, and linked to the TPA Integrated Environmental Management System.

TPA and port users undertake a wide range of research and monitoring programs throughout the Port of Townsville including monitoring of; air (fugitive dust emissions), sediments (receiving environments), water (receiving waters), noise, stormwater (site specific), groundwater, trade waste and pests.

A water quality monitoring program was implemented in 2004 consisting of bi-annual (pre and post wet season) collection of samples at over 30 sites within Ross Creek, Ross River, Inner Harbour, Outer Harbour and the Sea Channel.

Fugitive dust emissions create nuisance deposits in the vicinity of the port and some of the dust would be washed into stormwater systems in rainfall run-off adding to the input from urban areas. While there are days where air quality is compromised by particulate matter (dust) from port operations the amount of particulate material is not large enough to have a significant direct impact on water quality. Air quality monitoring is discussed in section 4.4.

Figure 2.7 Townsville Port Loading/Unloading Facilities

Source: J Gunn (CCI\Images\20081216 port\wide angle crop)

2.7.4 Fuel and chemical storage

Fuel and chemical facilities are associated with the Townsville Port, Townsville Airport, the metal refineries and a number of other industries around Townsville. The main emissions are fugitive (see section 4.3) and are readily dispersed and volatalised. The main risk to water quality would be through leakage and spills. The activities are ERAs and subject to relatively strict licensing conditions, which covers bunding of storages and emergency back up responses. As this type of activity is a potential hazard rather than a known regular water quality pollutant it is not considered further in this report.

2.7.5 Meatworks

Abattoirs create nutrient rich effluent as a waste product, which is normally held in anaerobic fermentation ponds where a significant proportion of the nitrogen is converted to ammonia. The ammonia escapes as fugitive emissions and is reportable through the NPI. Meat processing is also an ERA and is subject to a variety of conditions associated with the disposal of the effluent i.e. conditions applied to the irrigation of effluent onto pasture etc.

Australian Meat Holdings (AMH) monitors their site, including air monitoring of particles at ground level, and it is assumed complies with its ERA licence conditions. Regardless of compliance with licence conditions the addition of nutrients to the Stuart Creek catchment through effluent irrigation may result in impacts on receiving waters through run-off and infiltration. The incremental accumulation of nutrients can be subtle and may only show up over time with regular monitoring.

2.7.6 Dredging

Dredging is an ERA often associated with sand and gravel extraction from watercourses, or at least environments where water is present. The disturbance to waterways in itself does not necessarily result in an increase in sediment or nutrients but may result in the resuspension and mobilisation of otherwise sedentary materials. As dredging is an ERA and conditions are imposed on the activity and it does not generally create ‘new’ pollutants it is not further considered in this report.

2.7.7 Quarrying

Quarrying is generally a hard rock, dry extraction process for construction materials. As such it has the potential to generate significant quantities of particulate matter (dust). Most of the dust settles in the vicinity of quarry operations and then has the potential to be carried in stormwater to add to the load of sediment in receiving waters. As an ERA the activity is subject to licensing conditions including dust suppression measures and stormwater management.

Regardless of the measures put in place it is assumed that some material will escape the bounds of quarry operations and have some impact on water quality. While the impact is not likely to be high in terms of overall load the actual contribution of sediment from quarrying operations cannot be quantified without targeted water quality monitoring in the vicinity of the operations. As with other industrial activities it is considered that there is an input to catchment loads from quarrying albeit not quantified.

2.7.8 Aquaculture

As an ERA aquaculture is heavily regulated and has additional development assessment criteria to meet as a result of legislation instigated by the Great Barrier Reef Marine Park Authority (GBRMPA). While technically being a point source industry aquaculture is considered to be a diffuse source by the NPI. Aquaculture is discussed in more detail in the section on diffuse sources (see section 3.7.3).

2.7.9 Soil conditioner manufacturing

Soil conditioner manufacturing is the process of turning organic material into compost. While there is potential for nutrient and sediment release from this activity the main issue may be the biochemical oxygen demand (BOD) associated with organic material from a composting operation entering receiving waters. There is only one ERA licence issued for this activity and it is assumed that the conditions attached to the ERA reduce the potential impacts of the activity on water quality.

2.7.10 Sawmilling and woodchipping

Sawmilling and woodchipping can be a precursor stage to soil conditioner manufacturing although the product is coarser and the organic breakdown and release of nutrients has not reached the same level as with compost. There is less potential impact in that respect and again the activity is regulated as an ERA and there is no evidence to suggest the activity has a significant impact on water quality.

2.8 Public Utilities

In addition to the main industrial activities public utilities and infrastructure also have the potential to impact water quality. The main public utilities with potential to impact water quality are discussed below.

2.8.1 Water Treatment

The Douglas Water Treatment Plant (DWTP) is the major water treatment and storage plant in Townsville. The water travels 9.2 kilometres from Ross River Dam to Douglas, in a 1.22m diameter concrete pipe. The DWTP treats on average 150 ML (megalitres) of water everyday. Note that 1ML is equal to 1 million litres.

The DWTP is operated in compliance with the International Quality Standards ISO 9001 and with the International Environmental Management Standards ISO 14001. Treated water meets the standards set out in the National Health and Medical Research Council (NHMRC) report "Australian Drinking Water Guidelines".
(Source: formerly available online at http://www.townsville.qld.gov.au/citiwater/douglas.asp)

Both the Mt Spec (Kinduro) water treatment plant and the DWTP are being upgraded to cope with the increased demand for potable water in Townsville. The Mt Spec plant upgrade involves the construction of a new 40ML per day water treatment plant on elevated land at Kinduro, north of Hencamp Creek ($23.58m from Qld Govt). Treatment modules at Douglas will be upgraded so the facility can better cope with the high level of treated water needed to be produced ($7.72 m from Qld Govt).

A decision on a subsidy for an additional treatment plant at Toonpan was deferred while the Townsville City Council re-assesses its need following a review of its local bulk water usage allowances and charges.
(Source: Media release 14 August 2008: Hon Warren Pitt MP - Minister for Main Roads and Local Government. http://statements.cabinet.qld.gov.au/MMS/StatementDisplaySingle.aspx?id=59695)

The reported emission through the NPI from the Douglas Water Treatment Plant is chlorine as a fugitive emission to air. The plant has in the past backwashed filters and released the backwash water to the Ross River however that activity ceased as a result of a change to licence conditions associated with the ERA. The plant is not considered to have an impact on water quality and is not considered further.

2.8.2 Sewage and Wastewater Treatment

Sewage and wastewater treatment is by its nature a risk to water quality due to the amount of nutrients in wastewater and the disposal method of the treated effluent i.e. generally to receiving waters. While subject to licence conditions as an ERA wastewater treatment facilities still have a significant direct impact on water quality. As the main point source pollutant activity wastewater treatment facilities are viewed in more detail in section 7.3 and Appendix B.

2.8.3 Railways

Railways are discussed in more detail in the diffuse source section (see section 3.7.9).

2.8.4 Roads

While there can be significant impacts associated with road infrastructure, especially during construction, it is the ongoing processes associated with roadways and the interactions with the stormwater network that makes roads an important consideration in water quality in urban areas. Roads and their role in stormwater processes are discussed in more detail in section 3.6.

2.8.5 Solid Waste Disposal

Solid waste disposal i.e. landfill, is discussed in more detail in the diffuse source section (see section 3.7.10).

3. *Diffuse Sources*

3.1 Identifying Diffuse Pollutant Sources

Diffuse pollutant sources were identified in the Worsley Parsons (WP) report for the wider Black and Ross River Basins and are summarised below. Additional information is provided from a literature search, with particular emphasis on urban diffuse pollutant sources including those identified through the National Pollutant Inventory (NPI) and by the Cooperate Research Centre for Catchment Hydrology (Catchment CRC).

3.2 Pollutant Source Report (WP)

An investigation was conducted by Worsley Parsons (WP) to identify the key pollutants in the study area and the broad land use classes likely to generate them. The summary results of this study are reproduced in Table 3.1.

Table 3.1 Pollutants by Land Use

Pollutant	Description	Associated Land Use Types
Suspended Solids	Generated when surface water flows collect and transport unstabilised soils and sediment. Can result in smothering of aquatic habitats and restriction of light penetration	Urban (particularly construction), Intensive Agriculture, Rural
Phosphorous	Generated from faecal material, and fertilizers, transported by surface rainfall runoff. Encourages algal growth and eutrophication.	Urban, Industrial, Intensive Agriculture
Nitrogen	Generated from fecal material, and fertilizers, transported by surface rainfall runoff. Encourages algal growth and eutrophication.	Urban, Industrial, Intensive Agriculture
Hydrocarbons	Liquid fuels (diesel, petroleum, oil). Can result in smothering of aquatic habitats. Morbidity and mortality in freshwater species, and impact upon reproductive cycle	Urban, Industrial, Commercial
Tri-butyl Tin	Tri-butyl Tin (TBT) is a common antifouling additive used in paints applied to ship hulls. It is a contaminant that is commonly associated with sediments around ports. Results in morbidity and mortality in freshwater species, and impact upon reproductive cycle	Industrial (Ports)
Herbicides	Applied to gardens and horticulture to control weeds, transported aerially or by surface rainwater runoff. Can result in morbidity and mortality in freshwater species.	Intensive Agriculture, Urban
Pesticides	Applied to gardens and horticulture typically to control pests such as insects, transported aerially or by surface rainwater runoff. Can result in morbidity and mortality in freshwater species.	Intensive Agriculture, Urban
Heavy Metals	Metals such as mercury, arsenic, lead, cadmium. Can result in morbidity and mortality in freshwater species (ecotoxicity).	Urban/Industrial

Source: Worley Parsons 2008, Table 2.2, pp.5-6

Additionally the report identified three non-toxic pollutant sources that could impact water quality:

- Hydrologic stress - results from increases in impervious cover in a catchment, causing higher flow velocities and frequencies than occur naturally;
- Gross pollutants - litter generated typically in commercial areas. This is an aesthetic water quality detractor; however plastic litter in waterways may result in ingestion and associated complications in aquatic animals; and
- Antibiotics and other pharmaceuticals (from treated sewage outflows, septic tanks, intensive animal production) may interfere with normal disease resistance and reproductive cycles of aquatic organisms.

The identified pollutants were then rated based on their properties of; persistence (P), potential to bioaccumulate (B), toxicity (T), and secondary effects (S). The pollutants were then classed as Low, Medium, High or Extreme potential impact [assumed as not stated]. The results of the classification are reproduced in Table 3.2.

Table 3.2 Pollutant Impact Classification

Pollutant	P	B	T	S	Overall score	Score /4	Rank
Total Phosphorous	1	1	1	3	6	1.5	Moderate
Total Nitrogen	1	1	1	3	6	1.5	Moderate
Pathogens	2	1	3	2	8	2	Moderate
Total Suspended Solids	2	1	2	3	8	2	Moderate
Gross Pollutants	3	1	1	3	8	2	Moderate
Hydrocarbons	3	1	2	4	10	2.5	High
Herbicides	3	3	3	2	11	2.75	High
Pesticides	3	3	3	2	11	2.75	High
TBT	3	1	4	3	11	2.75	High
Heavy Metals	4	3	3	3	13	3.25	Extreme

Source: Worley Parsons 2008, Table 3.3, pp.10-1. Note: P is persistence, B is potential to bioaccumulate, T is toxicity, and S is secondary effects. TBT is no longer used for anti fouling of ship hulls in Australia.

On the basis of the [assumed] impact classifications and expected pollutant generation from various secondary land uses the six principal land use classes were then assigned a notional pollutant generation rating (see Table 3.3).

Table 3.3 Pollutant Generation by Land Use

Secondary Land Use Category	Land Use Grouping by Usage Intensity	Notional Pollutant Generation Rating
Nature conservation	Minimal Use (Natural)	Low
Other minimal use		
Marsh/wetland		
Reservoir/dam		
River		
Residential	Urban (residential)/ Rural	Moderate
Grazing natural vegetation		
Intensive animal production	Commercial / Intensive Agricultural	High
Services		
Transport and communication		
Utilities		
Plantation forestry		
Production forestry		
Intensive animal production		
Services		
Transport and communication		
Perennial horticulture		
Irrigated cropping		
Irrigated perennial horticulture		
Irrigated seasonal horticulture		
Manufacturing and industrial	Industry (including ports and railway yards)	Extreme
Mining		
Waste treatment and disposal		

Source: Worley Parsons 2008, Table 3.4, pp.11-12

In essence the QLUMP (1999) land use mapping was transformed into a notional pollutant generation layer based on grouped land uses, associated pollutants and rated pollutant impacts.

The report then assumed that various environmental parameters i.e. slope, vegetation cover, soil erosion potential, rainfall and proximity to waterways, will affect pollutant transport into waterways. These factors were represented as GIS layers and combined with the landuse/pollutant generation layer to produce a pollutant 'hotspot' layer.

"*Pollution hotspots were determined by conducting a raster analysis using 25m cell size grids generated from GIS layers representing environmental pathways. Grids values were non-dimensionalised from 0 to 100 using the ranges described in Table 3.4. The analysis was then conducted by overlaying the grids and summing the values obtained for each. In this way, the effect of the cumulative impacts on waterway health can be investigated holistically and in an objective manner*" (WP 2008, p.14).

Table 3.4 Ranges Used for Hotspot Analysis

Value (0-100)	Variables					
	Landuse	Slope	Vegetation cover	Erosion Potential	Rainfall (mm/yr)	Proximity to Watercourse
0 (No impact)	Minimal use	<2%	Remnant / Bushland	Non erosive	<800	>150m
	Rural / Urban			Moderately erosive		
	Agriculture/ Commercial					
100 (Very High Impact)	Industry	>10%	Cleared	Highly erosive	>2000	0m

Source: Worley Parsons 2008, Table 4.4, p.14

As the hotspot analysis was based on a number of broad assumptions, qualitative assessments, limited data sets and aggregations of data it is difficult for it to accurately reflect the potential for pollutant transport to waterways. As such the hotspot analysis will not be used, as it has the potential to confuse the situation rather than inform it. Some of the background information from the report has been used to further inform this report and is acknowledged where used.

3.3 Other Water Quality Improvement Plans

Water Quality Improvement Plans (WQIPs) have been developed for the (former) Douglas Shire, Mackay Whitsunday NRM region, the Tully catchment and the rural component of Burdekin Dry Tropics NRM region. The Black and Ross WQIP area is part of the Burdekin Dry Tropics NRM region containing the main urban and industrial landuse areas in north Queensland. Some of the key findings from the Mackay Whitsunday and Burdekin WQIPs are presented below.

3.3.1 Mackay Whitsundays WQIP

The WQIP developed for the Mackay Whitsunday NRM region focuses predominantly on grazing and intensive agricultural land uses (sugar cane production) which account for 75% of the area of the region. Point source pollutants were also taken into account through consideration of discharge from sewage treatment plants (STPs) when diffuse source calculations were undertaken. Other minor sources and types of pollution were not considered in determination of pollutant impacts although they were recognised as being present. Relative contributions of the main diffuse source pollutants impacting water quality in the Mackay Whitsunday region were calculated through a combination of modelling and water quality event monitoring. Results are reproduced in Table 3.5.

Areal diffuse source sediment and nutrient generation rates (kg/ha) estimated from local river load data were found to be similar for urban areas and sugar cane growing areas, and the highest of the land use categories. Bushland had the lowest contribution with grazing being intermediate and closer to bushland than the intensive uses.

Table 3.5 MWNRM Land Use Relative Pollutant Contributions

Land use	% land use	% DIN	% PN	% FRP	% PP	% TSS	% Pest1	% Pest2
Conservation	17	1	6	0	2	39	0	0
Grazing	56	12	34	5	28	29	0	100
Horticulture	<1	1	1	1	1	<1	<1	0
Cane	19	77	53	84	62	98	98	0
Intensive uses	1	4	3	5	4	<1	<1	0
Urban	1	4	3	5	4	<1	<1	0
Dams/reservoirs	1							
Wetlands	6							

Source: MWNRM 2008, p.12. Notes: DIN is dissolved inorganic nitrogen, PN is particulate nitrogen, FRP is filterable reactive phosphorus, PP is particulate phosphorus, and TSS is total suspended solids. Pest1 is ametryn, atrazine, diuron and hexazinone (grouping of pesticides predominantly used in sugar cane) and Pest2 is tebuthiuron (predominantly used in grazing).

3.3.2 Burdekin WQIP

The Burdekin WQIP area covers the majority of the Burdekin NRM region including the Burdekin and Haughton River Basins. The volume of pollutants delivered to the marine environment by the Burdekin River far outweighs the amount of material delivered by the other four river basins (Don, Haughton, Ross and Black) in the Burdekin NRM region. On average the Burdekin River contributes around 80% of the total annual discharge of the region.

A summary of the river basins/catchments of the Burdekin region (from north to south) is provided in Table 3.6.

Table 3.6 Burdekin Region River Basins

Parameter	Black	Ross	Haughton	Burdekin	Don
Catchment size (km²)	907	1,296	3,983	130,035	3,347
Grazing (km²)	502	923	2,529	123,758	2,948
Sugar (km²)	8.1	0	678	128	16.8
Horticulture/cereals (km²)	7.4	9.4	37	742	114
Total land use (%)	57.06	71.94	81.45	95.84	91.99
Annual run-off volume (km³)	0.38	0.49	0.74	10.29	0.75
Mean annual run-off (ML)	0.18*	0.15**	0.5	8.64	0.31
Annual sediment export (tonnes)	140,000	180,000	270,000	3,770,000	270,000
Average suspended sediment event (mg/L)	N/A	22	110	394	N/A
Range of suspended sediment event (mg/L)	N/A	3-69	41-200	74-3,559	N/A
DIN export (tonnes)	75	97	1467	2,027	148
DON export (tonnes)	53	68	103	1,430	104
PN export (tonnes)	191	246	372	5,176	377
TN export (tonnes)	319	411	621	8,633	629
DIP export (tonnes)	10	13	19	265	19
DOP export (tonnes)	3	4	7	92	7
PP export (tonnes)	49	64	96	1,338	98
TP export (tonnes)	63	81	122	1,695	124

Extracted from Lewis et al 2006, p.1 (Table 1)

Note: * includes Bohle River and Bluewater Creek ** includes Alligator Creek

"*During very large to extreme Burdekin discharge events (total event discharge >12 million ML), the Burdekin flood plume may reach as far north as Cooktown (~500 km north of the river mouth). During 'average floods' (total discharge of 3.0-7.0 million ML), the northward extent of the Burdekin plume is probably Hinchinbrook Island (~200 km north of the river mouth). Burdekin flood plumes are usually confined to within 30 km from shore but can occasionally extend further offshore and impinge on mid-shelf reefs, up to 120 km from shore*."

"*Discharge from other coastal rivers and creeks in the Burdekin Region (e.g. Black, Ross, Haughton and Don Rivers) are minor when compared to the Burdekin River. The extent of the plumes generated by these coastal rivers has not been studied, although these plumes are probably restricted to the embayments which host the mouth of these particular rivers*." (Lewis et al 2006, p.iii)

"*While flood plumes from rivers of the Burdekin Region may extend as far north as Cooktown, the northward extent of most sediments and particulate nutrients is the Townsville/Cleveland Bay area. The northward limit of the dissolved nutrient phases from the Burdekin Region probably extends as far as the Palm Island Group. The full extent of pesticides in the marine environment is unknown*." (Lewis et al 2006, p.v)

"*The Burdekin Community Water Quality Event Monitoring Project was established in late 2002 by the Australian Centre for Tropical Freshwater Research (ACTFR), James Cook University for the Burdekin Dry Tropics Natural Resource Management (BDTNRM) regional body to investigate sediment and nutrient concentrations in waterways throughout the Burdekin Dry Tropics Region*" (Bainbridge et al 2007. p.i).

[2006/2007 was] "*Consistent with previous wet seasons, the lower Burdekin coastal catchments had considerably lower sediment and particulate nutrient concentrations than the grazed Burdekin sub-catchments. These coastal catchments with more intensive land uses (sugarcane cultivation and horticulture) had disproportionately high nitrate (and nitrite) (NO_x) and phosphate (FRP) event mean concentrations compared to the other larger Burdekin sub-catchments*."

"*Suspended sediment is the key parameter of concern for the Burdekin River catchment (rangeland grazing), with considerable variation in TSS concentrations and loads between the five major sub-catchments (upper Burdekin, Cape, Belyando, Suttor and Bowen Rivers*)" (Bainbridge et al 2007, p.ii).

"*Within the grazed Burdekin catchments particulate nutrients largely follow the pattern of suspended sediments, indicating that managing for sediment reductions will also achieve a reduction in particulate nutrient concentrations. This is particularly so for phosphorus, where particulate phosphorus dominates (70-95%) total phosphorus at most sites throughout the flow hydrograph. The relationship between suspended sediment and particulate nitrogen is not as strong, with the particulate proportion of total nitrogen often varying between 40-70% across sites and throughout the flow hydrograph. In contrast, nitrogen and phosphorus in the lower Burdekin coastal catchments are dominated by the dissolved fractions. The elevated inorganic nutrients (primarily nitrate) reflect the intensive land uses (sugarcane and horticulture) within these coastal catchments. The lower Haughton River and Barratta Creek have consistently produced disproportionately high NO_x loads for small coastal catchments, and as such are priority catchments for nutrient management*."

"*A suite of herbicide residues (diuron, atrazine and ametryn) were commonly detected in the waterways of the lower Burdekin during event and low flow conditions over the previous two wet seasons (Lewis et al., 2007)*" (Bainbridge et al 2007, p.iii).

"*Tebuthiuron residues were detected in four of the major Burdekin sub-catchments (Belyando, Suttor, Cape and Bowen Rivers) during limited sampling in the 2005/06 and 2006/07 wet seasons. This finding is concerning given the size of flow generated by these rivers and warrants further investigation into the presence and potential loads of tebuthiuron being generated within the Burdekin Rangelands during wet season flows. Tebuthiuron has a relatively long half life (around one year) and this herbicide may persist in catchment waterbodies and the larger reservoirs, such as the BFD throughout the year*." (Bainbridge et al 2007, p.iv)

A report on water quality issues in the Burdekin region was prepared for the BDT NRM WQIP in 2007 by the Australian Centre for Tropical Freshwater Research (ACTFR) (Mitchell et al 2007). Findings from the *Burdekin Community Water Quality Event Monitoring Project*, established in late 2002, along with other studies and reports were included in the ACTFR report.

Potential pollutants in the Burdekin region were identified for various broad land uses. An impact rating was applied to each pollutant based on their volumetric importance and their likely in-stream and down-stream impacts (0 no impact to 5 high impact). Nutrient and sediment pollutants are listed in Table 3.7.

Table 3.7 Potential Pollutants in the Burdekin - Nutrients and Sediment

Pollutant	Source	Rating	Notes
Nutrients			
Nitrate (NO_3)	Fertiliser	5	Low natural levels
Ammonia (NH_4)	Fertiliser	2	Low natural levels
DON	Fertiliser	2	Moderate natural levels, slow turnover
PN	Fertiliser and erosion	4	Moderate natural levels, loss to sediments
Phosphate (PO_4)	Fertiliser, salt licks	2	Low natural levels
DOP	Fertiliser	1	Moderate natural levels, slow turnover
PP	Fertiliser and erosion	3	Moderate natural levels, loss to sediments
Silicate ($Si(OH)_4$)	Erosion	0	
Sewage	STP discharge, septics	5	Contains all N, P forms at high levels
Suspended sediment (Varies between sub-catchments, greatly increased by grazing)			
Coarse (>63 µm)	Erosion	0	No likely impact, forms delta fan
Medium (2-63 µm)	Erosion	2	Carried only short distance
Fine (< 2µm)	Erosion	4	Carried widely over shelf, especially following dry year

Source: Mitchell et al 2007, p.7

A range of other pollutant groupings were identified and are listed in Table 3.8.

Table 3.8 Additional Potential Pollutants in the Burdekin

Pollutant Group	Specific Pollutant and Comments
DO reducing materials (organic material)	Sucrose, dunder, mill effluent – are products of sugarcane production and are limited to the Lower Burdekin. Manure principally from cattle grazing. Sewage from urban areas. Plant litter occurs naturally and is increased as by products of intensive agriculture and urban park and garden maintenance
Herbicides	Diuron, AAtrazine, Ametryn, Hexazinone and 2,4-D are principally used in the sugar industry. Simazine used in forestry. Tebuthiuron used in grazing industry. Glyphosate and paraquat used broadly in sugar cane, horticulture and urban areas
Insecticides	Organochlorines e.g. endosulfan, and a variety of others are used principally in horticulture and to a lessor extent sugar cane and the urban setting. Chlorpyrifos used in sugar cane for can grubs
Fungicides	Methoyetholmercuric chloride (MEMC) used in the sugar industry
Non insecticide organochlorines	PCB's from industry (reduced use but residues may persist) and Dioxins from agriculture and industry PAH's (polcyclic aromatic hydrocarbons) from cane firing, forest fires and oil spills
Heavy metals	Cadmium and potassium from fertiliser and mercury from fungicide. Other trace elements
Oil or hydrocarbons	Primarily from liquid fossil fuels and oil spills
Salinity	Both dryland and irrigation salinity resulting from land clearing (dryland) and irrigation activities
Antifoulants	Used primarily in the fishing industry at mooring sites (TBT now banned)
Acid	Principally associated with disturbance of acid sulphate soils

Source: Mitchell et al 2007, pp.7-8

Along with the pollutants and their diffuse sources the report also identified and prioritised the key water quality threats for GBR ecosystems from the main agricultural land uses. These are listed in Table 3.9.

Table 3.9 Priority Pollutants for GBR Ecosystems

Priority	Burdekin Rangelands (Grazing)	Lower Burdekin Area (Sugar)
1	Fine suspended sediment, PN, PP	Nitrate, atrazine, diuron and 2,4-D
2	Nitrate	Ametryn, Hexazinone and Simazine
3	DON	Insecticides and fungicides
4	Tebuthiuron	
5	Phosphate (particularly in the basaltic terrains)	

Threats for freshwater bodies in the Burdekin region were also identified as: turbidity, weeds, dissolved oxygen reducing substances (DORS e.g. sugar, mill mud, dundar), riparian vegetation (lack of), eutrophication (via nitrate), and pesticides (toxicity on freshwater systems) (Mitchell et al 2007, p.2).

Burdekin Dry Tropics NRM commissioned a report to determine "*the results of scenario analysis identifying potential impacts of change on sources, fluxes, and/or storage of sediment and nutrients' in the Burdekin catchment.*" (Kinsey-Henderson et al 2007)

The erosion management strategies investigated for priority catchments included:

- Increasing minimum ground cover;
- Reducing gully erosion; and
- Riparian zone rehabilitation.

The study showed that significant gains could be made in reducing suspended sediment loads at the mouth of the Burdekin River if the strategies were implemented.

In general terms the assumptions made for the Burdekin WQIP area apply to the rural catchments of the Black Ross WQIP area, particularly with regard to grazing, and will be considered as default assumptions for the Black Ross WQIP in the absence of any more specific studies and data. Management actions developed for the Burdekin WQIP will also be adopted for the Black Ross WQIP.

3.4 BDT Townsville Catchments – Black and Ross Basins

The Burdekin Region was divided into fifty-one manageable sub-catchments, including the Black Ross WQIP area (referred to as Townsville Catchments) for SedNet and ANNEX modelling (Mitchell et al 2007, p.19). The following information relevant to the Black Ross WQIP area has been extracted from the Mitchell et al report.

3.4.1 Sediment

Flow weighted mean concentration (mg/L) for total suspended sediments for the Townsville Catchments were calculated to be between 271 mg/L and 375 mg/L (Mitchell et al 2007, from Figure 3, p.22) while erosion levels of total suspended sediments normalised over the total catchment area were calculated to be between 144 kg/ha and 250 kg/ha (Mitchell et al 2007, from Figure 4, p.23).

In terms of sediment exported from the Burdekin River, Bowling Green Bay is estimated to trap approximately 80-90% of the fine sediment while Cleveland and Upstart Bays each hold around 5-10% of the Burdekin sediments (Mitchell et al 2007, p.45). It was also considered that that a typical sediment resuspension event in the bays carries significantly more sediment than a river plume and that "*the extremely low sediment accumulation rates calculated for Cleveland Bay (~ 0.25 mm/year) are further evidence that this particular embayment acts more as a sediment transport system, rather than as a sediment trap (Carter et al., 1993)*" (Mitchell et al 2007, p.46).

"*Despite reports of increased turbidity at inshore coral reefs since European settlement, it is difficult to separate the effects of natural and human-induced change. Since no sediment is resuspended in waters deeper than 22 m (during rare cyclonic events; Orpin et al., 1999), the threat of terrigenous sediments to the GBR is almost entirely restricted to the inner shelf with the exception of the extremely fine and colloidal particles which may travel to the mid shelf"* (Mitchell et al 2007, p.47).

The relatively low volumes of sediment issuing from the Black and Ross Basins, compared to the Burdekin, are unlikely to have a significant impact on any marine areas apart from those in the near vicinity of the river and creek mouths. The marine extent of river influence estimated by CSIRO (Greiner et al 2003) has been adopted for the Black Ross WQIP, with modifications to include Magnetic Island and its influence.

3.4.2 Nutrients

Modelled estimates for DIN and DIP in the 'Townsville catchments' area (the coastal strip from Cape Cleveland north to around Crystal Creek) were considered to be "*almost certainly in gross error*". The small amount of data for the area "*show consistently low levels of DIN and DIP*" and from "*a land-use basis, there is no reason to believe that creeks to the north and south of Townsville will have elevated N or P concentrations*".

The possible land use exceptions noted were; some new cane and fruit tree farms in the north, fruit trees in the Alligator Creek area, the Yabulu Nickel Refinery (ammonia), the Copper Refinery and Sun Metals refinery. These are limited in extent (for intensive agriculture) and emission volume (for industry) and were not considered to be significant pollutant sources. Additionally "*elevated N and P inputs may derive from the Townsville Sewerage Plant discharging into Sandfly creek, but these would only occur in the estuarine, lower reaches. Hence, in a few small areas, some elevated nutrients may occur, but would seem unlikely to reach the same levels as seen in the Lower Burdekin Area*."

It was concluded that the very high modelled DIN load (1235 tonnes; Appendix 1) "*is as mysterious as it is wrong and misleading*" (Mitchell et al 2007, p.26).

Given the comments above the estimates of flow weighted DIN concentrations (>751µg/L) and DIN levels normalised over catchment area (>1.26 kg/Ha to 7.38 kg/Ha) will not be considered as relevant for this report (Mitchell et al 2007, from Figure 6, pp.27-28).

Figure 3.1 Potential Nutrient Source Crystal Creek Sub Basin

3.5 Other Studies

A number of reviews and studies have been undertaken to estimate the amount of additional pollutants impacting the marine environment as a result of land use and management practices on mainland Australia. Estimates of pre-development suspended sediment exports to the Great Barrier Reef are often developed by taking the sediment load of largely undeveloped rivers as the best available baseline reference. In this way, it is possible to estimate the change in nutrient and sediment exports to the Great Barrier Reef since anthropogenic activity began along the coast. Conversely, nutrient modeling allows the generation of similar data.

3.5.1 Catchments and Corals

A comprehensive review of the catchments of the Great Barrier Reef, their associated run-off to the reef and the influence of the run-off on coastal and reef ecosystems was presented in Catchments and Corals (Furnas 2003). Note: In Catchments and Corals the Ross Basin is not the AWR basin but includes part of the Haughton Basin draining to Bowling Green Bay.

Furnas (2003) reviewed a substantial volume of research information associated with the relationship between land-based activities in the Great Barrier Reef (GBR) catchments and the GBR. Some of the salient points are summarised below in relation to suspended sediments (Furnas 2003, pp.165-176) and nutrients (Furnas 2003, p.177-202).

- Fine silts and clays only accumulate in dams and weirs, still backwaters or shallow wetlands on floodplains where flow rates are low and water residence times are long relative to particle sinking velocities;
- Once clay and silt-sized particles reach the stream network, most will be rapidly transported out of the catchment into the GBR;
- Sediment transport in all rivers of the GBRC is dominated by fine sediments [80-95%] i.e. silt and clay;
- Most of the nutrients exported from catchments in particulate form are bound to fine sediments (<2µm);
- Particulate nitrogen (PN) and particulate phosphorus (PP) loads in GBRC rivers follow suspended sediment concentrations;
- GBRC soils, whether fertilised or not, naturally contain substantial stocks of nitrogen (N) and phosphorus (P);
- The average N and P content of particulate matter in rivers draining wet and dry catchments parallel the composition of catchment soils (Black and Ross are classed as mixed catchments);
- Regardless of catchment type, the good correlation between particulate nutrient and suspended sediment concentrations means that useful estimates of PN and PP exports from rivers can be derived from estimates of fine sediment exports from catchments;
- While PN and PP concentrations are correlated with suspended sediment load, they are not well correlated with discharge, due to rapid changes in suspended load in both large and small flood events;
- Rivers transport nutrients in several forms;
    - as free dissolved ions (e.g. ammonium NH_4^+, nitrate NO_3^-, nitrite NO_2^-, phosphate PO_4^{3-}),
    - as part of dissolved organic compounds (urea, amino acids), and
    - in suspended particulate matter.
- Nutrient concentrations in river waters depend on;
    - biological and chemical processes in catchment soils,
    - runoff and erosion which transport water, soil and nutrients to the rivers, and
    - water flows which move dissolved and particulate materials.
- Nitrate (NO_3^-) is the most abundant form of dissolved inorganic nitrogen (DIN) in GBRC rivers largely derived from bacterial oxidation of ammonia (NH_4^+) in oxygenated catchment soils, surface waters and groundwaters;
- Fertilisers are an additional source of nitrate either directly or through breakdown of urea/ammonia etc;
- Nitrate concentrations exhibit only small changes during floods in the two largest dry-catchment rivers i.e. nitrate inputs to the river in surface runoff are diluted by large volumes of water in floods;
- Over half of the nitrogen exports from the Burdekin and Fitzroy catchments (dry catchments) are particulate;
- In wet tropic rivers nitrate concentrations increase significantly during the wet season;

- There is little variation in dissolved organic nitrogen (DON) concentrations relative to river flow in both wet and dry catchment rivers;
- DON is the principle (up to 80%) form of N exported from pristine river catchments;
- The relative contribution of nitrate and DON to river N levels and exports may therefore indicate the degree of human disturbance and associated nitrate inputs;
- Dissolved phosphorus ($PO_4^{3-}$and DOP) concentrations in wet and dry catchment rivers respond differently to floods and seasonal changes in flow;
- Dissolved P concentrations in the large dry catchment rivers exhibit pronounced increases during wet season flood events with peak concentrations in excess of 110µg per litre while wet catchments have relatively stable P levels (20 µg/L);
- PP is the principal form of P export from both wet and dry catchments (66-77%);
- Total annual nutrient exports to the GBR lagoon closely follow the total volume of water discharged.

"*Annual inputs of terrestrial sediment to the GBR can be estimated by multiplying volume-specific sediment export coefficients appropriate for wet, dry and mixed catchments by the mean annual freshwater discharges from the catchments* (basins)" (Furnas 2003, p.208). Volume-specific sediment export coefficients are:

- Wet catchments - 39,000 tonne sediment per km^3 discharge,
- Mixed catchments 135,000 tonne sediment per km^3 discharge, and
- Dry catchments 366,000 tonne sediment per km^3 discharge.

Estimates of exports from the Black and Ross Basins are shown in Table 3.10.

Table 3.10 Estimated Average Annual Exports of Sediment and Nutrients

Element	Black River (117)	Ross River (118)	GBRC
Basin area km^2	1,057	1,707	42,3070
Adjusted runoff volume km^3	0.38	0.49	70.8
DIN export (tonnes)	75	97	12,982
DON export (tonnes)	53	68	7,627
PN export (tonnes)	191	246	22,298
Total N (tonnes)	319	411	42,907
DIP (tonnes)	10	13	1,022
DOP (tonnes)	3	4	517
PP (tonnes)	49	64	5,551
Total P (tonnes)	63	81	7,090
Fine sediment (tonnes)	140,000	180,000	14,400,000

(Furnas 2003, p.209)

Along with nutrient inputs from terrestrial sources the GBR also receives nutrients from:

- Upwelling from the Coral Sea;
- Rainfall;
- Sewage discharge; and
- Nitrogen fixation by cyanobacteria.

Estimates of nutrient inputs from the measured and estimated sources are shown in Table 3.11.

Table 3.11 Nutrient Inputs to the GBR from Various Sources

	Nitrogen tonnes year		Phosphorus tonnes year	
	Range	Average	Range	Average
Current land runoff -total	10,000-120,000	43,000	1,300-22,000	7,000
Current land runoff - soluble	6,000-60,000	20,000	300-4,700	1,500
Pre 1850 land runoff -total	4,000-66,000	23,000 (54%)	360-7,000	2,400 (34%)

Pre 1850 land runoff - soluble	2,900-38,000	12,000 (60%)	160-1,800	600 (40%)
Upwelling	4,400 to 44,000		630 to 6,300	
Rainfall	14,000 to 44,000		1,000 to 3,000	
Sewage		2,250 (5%)		600 (9%)
Prawn aquaculture		200 (0.4%)		20 (0.3%)

Notes: Source data from Table 36 (Furnas 2003, p.229) with notes interpreted from text (Furnas 2003, pp.225-26). All figures are per year and in tonnes. Percentages associated with pre 1850 figures are expressed as a percentage of current exports. Rainfall between 140 and 440 km3 per year at 100µg per L of N (100 t per km3) and 7 µg per L of P (7 t per km3). Sewage percentage is relative to river exports and based on sewage being discharged via ocean outlets or into coastal waterways. Sewage estimate does not take into account tertiary treatment and land based disposal so is an overestimate (based on 5kg N and 1.5kg P per person per year with modern secondary treatment). Aquaculture estimates based on daily discharge of 1kg N and 0.1 kg P per hectare of pond using 500 hectares of ponds. Aquaculture percentages are expressed as a proportion of river exports. More effluent is now being treated on site so figures may be higher than actual emissions. Proportionally higher increase in P reflects the increase in erosion and fine sediment losses from catchments.

3.5.2 Preliminary Assessment of Sediment and Nutrient Exports

In the early 1990s the issue of sediment and nutrient inputs to the coastal zone from agricultural lands was recognised and a quantitative assessment was undertaken jointly by the Queensland Department of Primary Industries (DPI) and the Department of Environment and Heritage (DEH). The resulting report titled *A Preliminary Assessment of Sediment and Nutrient Exports from Queensland Coastal Catchments* (Moss et al 1992) has some initial modelled estimates of the sediment and nutrient exports from the combined Ross and Black AWR River Basins. Point source inputs were calculated from DEH licence conditions for discharges. Inputs from urban diffuse sources and rural diffuse sources were calculated separately using different techniques and then combined to provide aggregate totals. Two models were used in the study. Results from the study for the combined Ross and Black Basins are summarised in the tables below.

Table 3.12 Ross-Black land use areas and other statistics

Land use areas (km^2)							Mean annual flow	Mean annual run-off
Pristine	Grazing			Cropping	Urban	Total		
	DPI estimate	Unallocated	Total grazing					
530	850	1,400	2,250	10	100	2,890	1,100	0.38

Source: Moss et al 1992 (p.12) Note: Mean annual flow (1000ML), Mean annual run-off (ML/km2)

Table 3.13 Ross-Black sediment export estimates

Export	Pristine	Grazing	Cropping	Urban	Total	Model 1	Belperio
Load (kilo tonnes)	13	223	2	4	242	265	550
Kilograms/hectare	247	990	2,474	[400]	838		

Source: Moss et al 1992 (pp.15-16) Note: Belperio (1983) estimates (Late Quaternary terrigenous sedimentation in the GBR lagoon in proceedings of the inaugural GBR Conference, Townsville (eds) Baker, J.T., Carter, R.M., Sammarco, P.W., and Stark, K.P. pp.71-76, JCU Press). Urban kg/ha estimate [in brackets] was not included in the report

Table 3.14 Ross-Black nutrient export estimates

Annual export		Pristine	Grazing	Cropping	Urban	Total	Model 1
Load (tonnes)	**N**	63	1,079	17	74	1,233	1,487
	P	9	154	3	7	173	212
Kilograms/hectare	**N**	1.2	4.8	17.3	[7.4]	4.3	
	P	0.17	0.69	2.57	[0.7]	0.6	

Source: Moss et al 1992 (pp.17-19)

Note: Urban kg/ha estimates [in brackets] were not included in the report

Overall, point sources of nutrients were found to be minor relative to diffuse sources, except in heavily urbanised catchments such as the Ross-Black (Townsville) and Barron (Cairns). Grazing land provided the greatest loads of sediment and nutrients based on the large areas devoted to this land use while cropping had the greatest export rate per unit area. Urban sediment and run-off rates used in the models have been included in the tables for comparison purposes but are an input to the study and not a result.

3.5.3 Sources of Sediment and Nutrient Exports to the GBR WHA

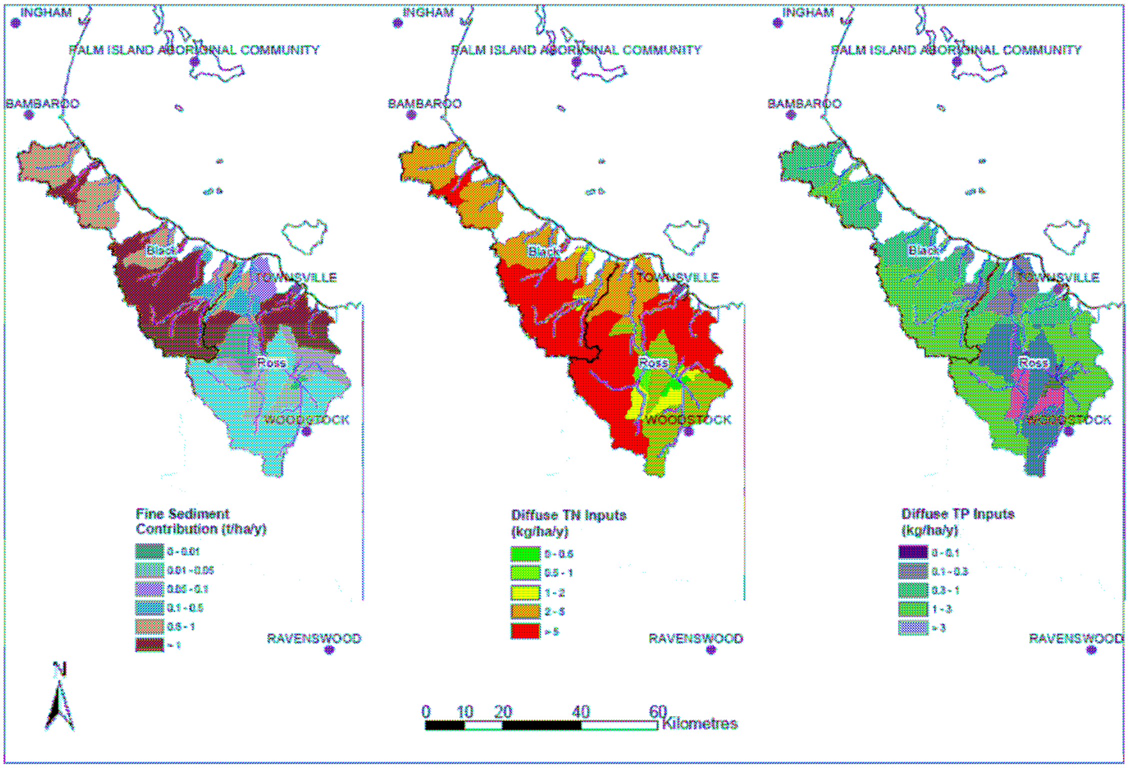
In their 2003 report Brodie et al estimated the current sediment and nutrient exports from the Black River and Ross River AWR Basins along with the pre-European export levels. The results are reproduced in Table 3.15.

Table 3.15 Current and natural exports from the Black and Ross River Basins

Export to coast	Black River Basin		Ross River Basin	
	Current	Natural	Current	Natural
SS (kt/yr)	161	30	80	20
DIN (t/yr)	53		63	
DON (t/yr)	65		32	
PN (t/yr)	452		212	
Total N (t/yr)	570	77	307	39
DOP (t/yr)	4		5	
FRP (t/yr)	3		1	
PP (t/yr)	92		38	
Total P (t/yr)	99	11	44	5

Estimated contributions of suspended sediment (SS) exported to the coast and diffuse total nitrogen (TN) and total phosphorus (TP) inputs to the Black and Ross River basins are shown in Figure 3.2.

Figure 3.2 Estimated pollutant contributions Black and Ross River Basins



Note: White areas were not modelled

The results were also compared to the results of previous studies. The comparison is provided in Table 3.16

Table 3.16 Comparison of modelled results to previous results

Study	Black River Basin			Ross River Basin		
	SS (kt/yr)	TN (t/yr)	TP (t/yr)	SS (kt/yr)	TN (t/yr)	TP (t/yr)
Current	161	571	99	80	307	44
Furnas (2003)	140	319	62	180	411	81
Belperio (1983)	250			250		
Horn et al (1998)	67					
NLWRA (2001)	80			60		

Contributions to the load of sediment and nutrients from different land uses was also calculated. The results of the land use calculations appear in Table 3.17 for the Black Basin and Table 3.18 for the Ross Basin.

Table 3.17 Contribution of pollutants from land uses in the Black Basin

Parameter	Forest	Grazing	Sugar	Crops	Other	Total	Export
Area (ha)	36,340	50,220	810	740	2,570	90,680	
Area (%)	40	55	1	1	3		
SS (t/yr)	51,000	106,000	1,000	1,000	3,000	162,000	162,000
DIN (t/yr)	25	25	1	1	3	55	53
DON (t/yr)	33	28	1	1	2	65	65
PN (t/yr)	144	374	2	2	10	532	452
Total N (t/yr)	202	427	4	4	15	652	570
DOP (t/yr)	2	2	0	0	0	4	4
FRP (t/yr)	4	5	0	0	0	9	3
PP (t/yr)	35	61	1	1	1	99	92
Total P (t/yr)	41	68	1	1	1	112	99

Notes: SS is delivery to the coast and nutrients is delivery to streams/waterways. Export is export from the basin. Forest includes savanna woodland

Table 3.18 Contribution of pollutants from land uses in the Ross Basin

	Forest	Grazing	Sugar	Crops	Other	Total	Export
Area (ha)	20,990	92,330	0	940	15,300	129,560	
Area (%)	16	71	0	1	12		
SS (t/yr)	12,000	57,000	0	1,000	11,000	81,000	81,000
DIN (t/yr)	11	34	0	0	18	63	63
DON (t/yr)	6	30	0	0	9	45	32
PN (t/yr)	91	548	0	5	37	681	212
Total N (t/yr)	108	612	0	5	64	789	307
DOP (t/yr)	0	2	0	0	0	2	5
FRP (t/yr)	2	6	0	0	2	10	1
PP (t/yr)	16	78	0	1	7	102	38
Total P (t/yr)	18	86	0	1	9	114	44

Note: Total Exports include point sources

In deriving the results for the export of sediment and nutrients from the Black and Ross Basins Brodie et al used mean annual flow figures of 352 GL/year for the Black Basin and 224 GL/year for the Ross Basin. Natural flow figures for the Black Basin were considered to be the same as the current figure while the natural flow figure for the Ross Basin was considered to be 60 GL/year less than the current figure based primarily on a higher run-off rate resulting from the relatively high volume of impervious surfaces associated with the urban area.

3.6 Urban Diffuse Pollutant Sources

The Cooperate Research Centre for Catchment Hydrology (Catchment CRC) has produced a number of reports relevant to urban stormwater pollutants and stormwater quality management options. Findings from key publications are summarized below.

3.6.1 A Review of Urban Stormwater Quality Processes

In this review Duncan (1995) describes the physical processes, which contribute to the contamination of urban stormwater runoff. Understanding of these processes and associated pollutant sources can assist with the development of management actions for reduction of stormwater pollutants.

Some of the processes discussed in the review include:

- Wet and dry deposition of contaminants from the atmosphere including interception on vegetation and artificial above-ground structures;
- Build-up of contaminants on impervious surfaces;
- Wash-off from surfaces into formed channels or pipes;
- Transport along channels and pipes;
- Quality changes during storage; and
- Receiving waters influence.

The review was based on literature, which was predominantly from temperate regions so the findings are not directly translatable to the Dry Tropics. Points made are therefore generalisations and not specific to the Townsville area.

Wet deposition (1) is a function of rainfall while dry deposition (2) occurs without rain i.e. wind and air currents are the vector. Wet deposition tends to be more uniform while dry deposition is much more reliant on conditions close to the ground and is generally more variable. Wet deposition is usually substantially greater than dry deposition. Deposition and rainfall quality are influenced by the land and human activities in the surrounding environment.

While atmospheric deposition can contribute as much nitrogen to stormwater contamination as is washed off in urban run off it is principally a component of air quality. If air quality is at acceptable levels then atmospheric deposition will be minimal and will not significantly impact water quality. Smaller quantities of suspended solids, phosphorus, COD, and heavy metals will also be present in atmospheric deposition.

Interception (3) is the interaction of rainfall with live plants and plant debris, and artificial structures before the rainfall reaches the ground. The main pollutant source of rainfall interception is accumulated dry deposition on roofs and plants, and solution of roof (e.g. zinc and copper) and plant materials. Lawn clippings and fallen leaves are a significant source of nitrogen and organic matter and may be a major source of phosphorus in urban run-off.

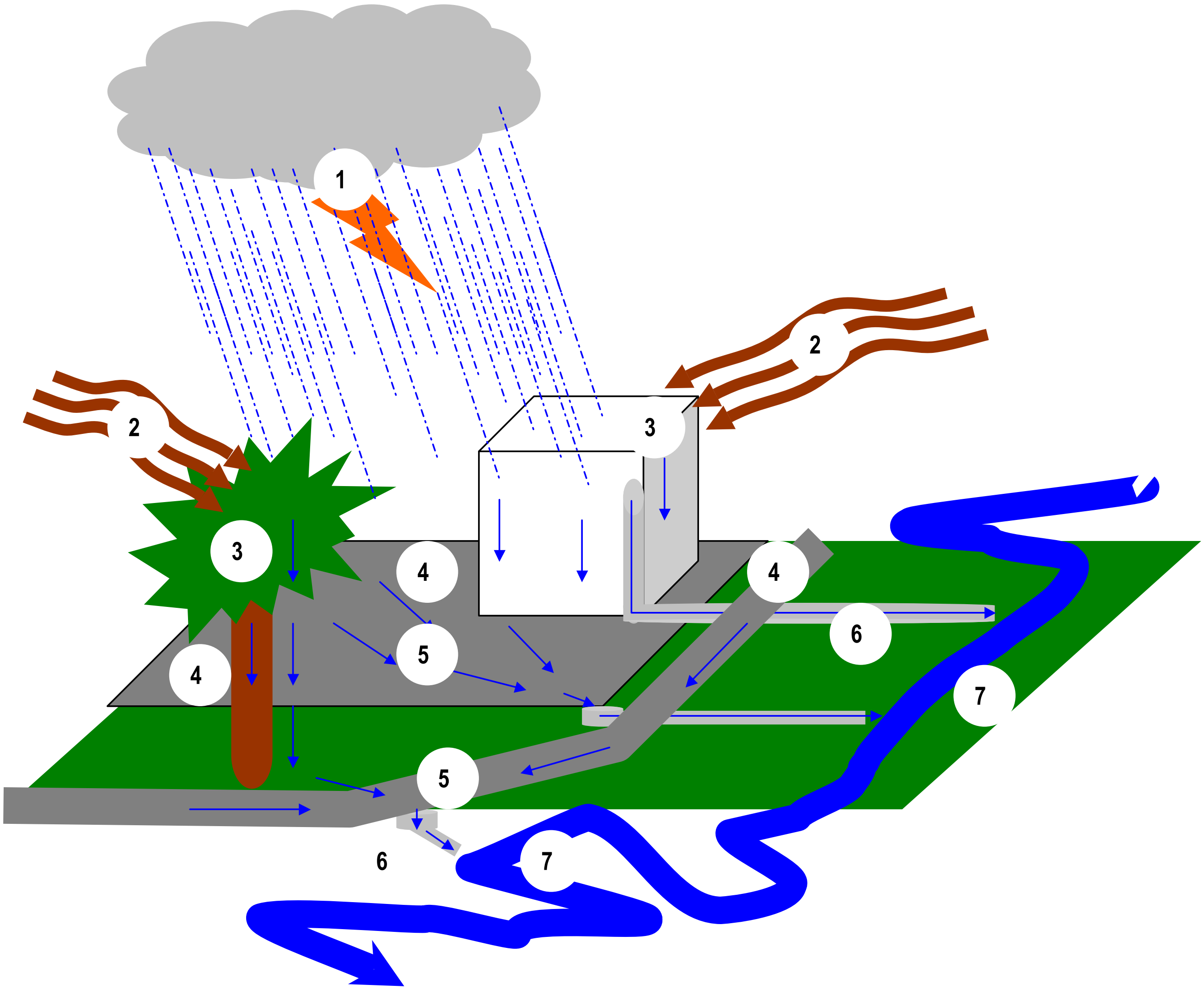
Buildup (4) is the accumulation on impervious surfaces of material from dry deposition. Roads are the main surface for buildup, with car parks and driveways also being significant buildup surfaces.

Wash-off (5) is the process where the accumulated dry deposition material is removed from impervious surfaces by rainfall and run-off and is added to the stormwater flow. The amount of material in wash-off is not directly correlated to the buildup material or to flow from a stormwater catchment. The amount of wash-off material in stormwater is most closely associated with rainfall intensity, which is particularly relevant to the Townsville region. The first flush phenomenon is where a high proportion of material i.e. sediment and dissolved nutrients, is mobilised early in a storm and is transported to receiving waters. First flush material is generated from both pervious and impervious surfaces, and like wash-off is most closely related to rainfall intensity. First flush is a characteristic of small catchments and is particularly noticeable in urban areas where soil is exposed during construction phases.

Transport (6), in the urban stormwater context, is the movement of contaminants through gutters, pipes and channels to receiving waters. Coarse sediment (bed load), suspended matter, litter (natural and artificial) and dissolved matter is transported through the stormwater system often as a drainage function rather than as part of a stormwater management process. The nutrient contribution of natural litter i.e. leaves, grass and other plant material, to receiving waters is often not measured in the short-term and may not be adequately addressed as a result (P content of leaves is about 0.2% of dry weight and N is about 1% with higher nutrient content for grasses).

Receiving waters (7) are the endpoint of the stormwater system, generally a natural system that the 'pipe' empties into. Receiving waters are often seen as the natural system that contaminated urban stormwater has the potential to degrade. To ensure an effective stormwater quality treatment train is designed the receiving waters need to be defined and their environmental values acknowledged. A conceptual model of the processes affecting urban stormwater quality is shown in Figure 3.3 with numerical reference to the processes described above.

Figure 3.3 Urban Stormwater Quality Processes Conceptual Diagram



Note: Numbers relate to the processes described in the text above and are: 1 Wet deposition, 2 Dry deposition, 3 Intercept, 4 Buildup, 5 Wash-off, 6 Transport and 7 Receiving waters

3.6.2 Urban Stormwater Pollution

Chiew et al (1997) discuss the impacts of urban development on the environment in terms of:

- Stormwater pollutants generated;
- Increased run-off; and
- Alteration of natural stream environments.

Principle pollutants of urban areas are; sediments, nutrients (principally nitrogen and phosphorus), oxygen demanding materials (biodegradable organic material), metals, toxic organic wastes (garden and household chemicals), pathogenic micro-organisms (bacteria, viruses etc), hydrocarbons and litter. Nutrient concentrations in urban stormwater are generally less than those from areas of intensive agriculture and significantly greater than from forested catchments (P is two to ten times greater) and undeveloped catchments (N is two to five times greater).

As identified by Duncan (1995) the main process of stormwater contamination is from the accumulation of pollutant material on impervious surfaces during dry weather (buildup) including:

- Settling of fine particles from the atmosphere;
- Accumulation of fine particles and gross pollutants from local sources; and
- Redistribution of surface pollutants by wind and traffic.

Some contaminants can be carried relatively long distances by wind and rain before being deposited (distributed sources) while others have a local origin. Some of the more significant local sources of pollutants are associated with motor vehicles and roadways. Local and distributed sources of urban stormwater pollutants as identified by Chiew et al (1995) are listed in Table 3.19.

Table 3.19 Common Urban Diffuse Stormwater Pollutants

Distributed Sources		Local Sources
Ash and smoke from bush fires		Leaf litter, grass clippings and other vegetation
Sea spray		Dog and other domesticated animal faeces
Swamp gases		Pesticides, herbicides and fertilisers
Windblown pollen, insects and micro-organisms		Sewer overflows
Dust from agricultural activities and roads		Sewer outlets illegally connected to stormwater systems
Dust, ashes and emissions from industry		Septic tank leakage
Agricultural pesticides, herbicides and chemicals		Leakage and spillage of materials from; vehicles, storage tanks and bins
		Seepage from land fill waste disposal sites
		Waste water from cleaning operations
		Corrosion of roofing and other metallic materials
		Industrial emissions
		Vehicle emissions
		Vehicle component wear e.g. tyres and brakes
		Wear of road surfaces
		Erosion from construction activity and vegetation removal
		Litter – plastic, glass and metal containers, plastic, foam etc

Levels and loads of urban stormwater pollution can be calculated relatively easily due to the small size of stormwater catchments and assumptions made which reduce the complexity and uncertainty associated with the calculations. Adequate water quality monitoring assists the process but calculations can also be made using models specifically designed for urban areas where key input information is the amount of impervious surface area in a catchment, local rainfall data and pollutant run-off coefficients for specific land uses.

3.6.3 Urban Pets

Leaving dog poo on streets, parks and beaches is smelly, unsightly and is a concern for local communities and councils. Dog poo is a serious litter issue with wide ranging impacts on amenity, health and the environment. Droppings contain harmful bacteria and nutrients, and some end up washing into natural waterways and Cleveland Bay through the stormwater system. This may contribute to excessive E. coli pollution readings and contributes to the overall nutrient load in waterways following heavy rainfalls.

Townsville has approximately 32,000 registered dogs and if we assume there are another 8,000 unregistered dogs we have approximately 40,000 dogs in the Black Ross WQIP area. From Victorian figures (http://www.litter.vic.gov.au/www/html/272-how-to-use-this-kit-.asp) on average each dog excretes 100g of poo per day. This is equivalent to 4,000 kg per day or 1,460 tonnes per annum. If we assume that cats add to this output and round the figure to 1,700 tonnes then we have an approximate figure for the contribution of pets to the diffuse source pollutant load for the Black Ross WQIP area. The majority of these animals would reside in the main urban catchments, in relative proportion to the human population, with the exception of high density and commercial areas i.e. CBD, high-rise and apartments. We can assume that this pollutant source would be most prominent in catchments dominated by traditional residential land use.

3.6.4 Stormwater Gross Pollutants

Allison et al (1997) examined gross pollutants as a specific contaminant group in the urban context. Gross pollutants are relatively "*large pieces of debris flushed through urban catchments and stormwater systems*". For the purpose of their report Allison et al (1997) describe gross pollutants as "*debris items larger than five millimeters*". Gross pollutants are typically human litter (mostly containers and packaging) as well 'natural' litter comprising vegetation (leaves, grass clippings and twigs). Gross pollutants can also include larger sediment particles that are likely to settle out of the water column given the right conditions.

"*In the CRC studies, organic material – leaves, twigs and grass clippings – constituted the largest proportion of gross pollutant load (by mass) carried by urban stormwater. Vegetation, however, is not a major source of nutrients compared to other sources*" (Allison et al 1997, p.3). However, if vegetation accumulates in waterways and is allowed to break down over time then the nutrient contribution may be more significant.

"*Results from the CRC monitoring program suggest that urban areas contribute about 20-40 kilograms (dry mass) per hectare per year of gross pollutants to stormwater*" (Allison et al 1997, p.2). For Townsville, (based on an urban footprint of 150 square kilometres) this is equivalent to approximately 300-600 tonnes per year (1200-2300 cubic metres) of gross pollutants.

3.6.5 Urban Stormwater Quality A Statistical Overview

A report prepared by Duncan (1999) titled *Urban Stormwater Quality: A Statistical Overview* is the result of a review of literature from around the world. It is used as the main reference document in Australia in the absence of adequate local data on stormwater quality. The report assesses the broad scale behaviour of urban run-off, the quality of stormwater and its interactions with land use and other catchment characteristics.

The water quality variables and catchment characteristics assessed in the review are listed in Table 3.20.

Duncan (1999) found that concentrations in urban stormwater are approximately log-normally distributed for all water quality parameters investigated. The exception was pH, which is approximately normally distributed. "*Concentrations of SS, TN and TP are on average highest for agricultural catchments, intermediate for urban catchments and lowest for forested catchments. Concentrations of lead, BOD, COD and microbiological parameters are higher on average from high urban catchments*"[1] (Duncan 1999, p.v).

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[1] High urban catchments have >65% urban landuse

Table 3.20 Water Quality Variables and Catchment Characteristics

Water Quality Variables		Catchment Characteristics	
pH	Metals:	% of:	Catchment area (ha)
Suspended solids (SS)	• Lead	• Residential	Impervious %
Turbidity	• Zinc	• Industrial	Urban %
Total phosphorus (TP)	• Copper	• Commercial	Population density (people/ha)
Total nitrogen (TN)	• Cadmium	• Institutional	Roads %
Chemical oxygen demand (COD)	• Chromium	• Urban open space	Traffic density (vehicles/day)
Biochemical oxygen demand (BOD)	• Nickel	• Other urban	Roofs %
Oil and grease	• Iron	• Agricultural	Mean annual rainfall (mm)
Total organic carbon (TOC)	• Manganese	• Forest	
Microbiological: • Total coliforms • Fecal coliforms • Fecal streptococci	• Mercury	• Other rural	

Note: Microbiological measurement used is number of organisms per 100mL, turbidity measured in NTU and other parameters in milligrams per litre (equivalent to parts per million).

Significant points from the Duncan (1999) study include:

- Elevated chemical oxygen demand (COD) appears to be associated with all kinds of roads and high urban land use. Industrial areas have the highest COD concentrations of the urban land uses (Duncan 1999, p.20).
- It appears that biochemical oxygen demand (BOD) increases with increasing urbanization. In conjunction with this there is an increase in BOD with increasing population density (Duncan 1999, p.23).
- As could be expected levels of oil and grease are highest from roads and in high urban areas (Duncan 1999, p.25).
- Mean turbidity from roofs is significantly lower than from other urban land uses suggesting that the sources of turbidity are concentrated at ground level (Duncan 1999, p.31).
- Traditionally the highest source of lead has been roads with higher vehicle densities giving higher concentrations. This is less relevant now following the removal of lead from petrol (Duncan 1999, p.36).
- The primary source of zinc is associated with roofs followed by roads (Duncan 1999, p.39).
- Copper concentrations are highest from roads and non-residential urban areas (Duncan 1999, p.43).
- It appears that the main source of cadmium is related to non-urban areas i.e. pervious surfaces (Duncan 1999, p.46)[2].
- Assessment of land use associations with chromium, nickel, iron, manganese and mercury are inconclusive due to lack of data (Duncan 1999, pp.48-55).
- Microbiological parameters are twenty times higher for high urban areas than for low urban areas[3] (Duncan 1999, pp.56-61). Within the urban environment residential areas tend to produce lower concentrations of metals and organic carbon, and higher concentrations of phosphorus and microbiological parameters (Duncan 1999, p.v);
- Urban sites with higher mean annual rainfall produce lower stormwater concentrations, on average, for most metal and non-metal parameters, but not for microbiological measures (Duncan 1999, p.v);
- Sites with higher population density produce higher stormwater concentrations on average for TN, BOD fecal coliforms, but not for metals (Duncan 1999, p.v).

Significant points with regard to suspended solids (see Table 3.21) include:

- Increasing the mean annual rainfall by 500mm approximately halves the most likely concentration of SS in runoff (Duncan 1999, p.v);

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[2] Possibly a function of fertiliser use

[3] Low urban areas have <35% urban land use

- The greatest mass of SS in urban runoff typically occurs in the 1 – 50 micro metre particle size range (Duncan 1999, p.5);
- Concentrations from roads are significantly related to mean annual rainfall (Duncan 1999, p.6);
- Dry weather redistribution by wind tends to concentrate dense particulate matter at lower elevations (Duncan 1999, p.8);
- In urban areas roofs produce the lowest concentrations of suspended solids followed by high urban sites with high urban roads having the highest average concentrations.

Table 3.21 Suspended Solids by Land Use

	Log transformed data		Untransformed data (mg/L)		
Subgroup	**Mean**	**Std. Dev.**	**Arith. Mean**	**Geo. Mean**	**Median**
High urban roads	2.41	0.46	779	257	232
Low urban roads	1.84	0.66	229	69	64
Roofs	1.55	0.38	47	35	41
High urban	2.19	0.48	294	155	152
Agricultural	2.27	0.47	311	186	133
Forest	1.90	0.30	99	79	71
From Figure 3					
All medium urban	2.248			180	
High Urban					
Residential	2.15			140	
Industrial	2.176			146	
Commercial	2.126			130	

Note: Primary information extracted from Table 1 (Duncan 1999, p.10) with additional median approximated from Figure 3 (Duncan 1999, p.6) No significant difference was found to exist between high urban categories. Arith. Mean is arithmetic mean and Geo. Mean is geometric mean.

Summary statistics for phosphorus are provided in Table 3.22. In urban areas the residential land use produces the highest average concentrations of phosphorus. Production of phosphorus from forest areas is significantly lower than from urban areas with agricultural areas having the highest concentrations of all the land uses.

Table 3.22 Phosphorus Summary Statistics

	Log transformed data		Untransformed data (mg/L)		
Subgroup	**Mean**	**Std. Dev.**	**Arith. Mean**	**Geo. Mean**	**Median**
Roads	-0.59	0.44	0.42	0.26	0.24
Roofs	-0.89	0.29	0.15	0.13	0.14
Residential	-0.40	0.34	0.56	0.40	0.39
High urban/non-res.	-0.50	0.40	0.46	0.32	0.36
Agricultural	-0.27	0.45	0.90	0.54	0.51
Forest	-1.14	0.34	0.095	0.072	0.07

Note: Information extracted from Table 2 (Duncan 1999, p.13)

Summary statistics for nitrogen are provided in Table 3.23. As with phosphorus the highest concentration of nitrogen is produced by agricultural land followed by urban areas with forest areas being significantly lower.

Table 3.23 Nitrogen Summary Statistics

	Log transformed data		Untransformed data (mg/L)		
Subgroup	**Mean**	**Std. Dev.**	**Arith. Mean**	**Geo. Mean**	**Median**
Roads	0.33	0.30	2.7	2.1	2.2
High urban	0.42	0. 82	3.4	2.6	2.5
Agricultural	0.59	0.39	5.3	3.9	4.4
Forest	-0.08	0.36	1.1	0.83	0.95

Note: Information extracted from Table 3 (Duncan 1999, p.18)

3.6.6 Heavy Metals

Moss and Costanzo (1998) present the results of a study between 1975 and 1992 of sediment concentrations of six heavy metals in Queensland freshwater streams, estuaries and coastal waters i.e. zinc (Zn), copper (Cu), cadmium (Cd), lead (Pb), nickel (Ni), and chromium (Cr). Concentrations of cobalt (Co) and mercury (Hg) were also measured but were excluded from the report results as "*cobalt has a low toxicity rating and was present at only very low values at all sites; while mercury results at most sites were below the limits of detection*" (Moss and Costanzo 1998, p.2).

Moss and Costanzo (1998) reported that urban runoff is normally a much more significant metals source than sewage discharges. A special survey carried out in Cleveland Bay, Townsville (Moss 1981), showed little elevation of metal concentrations around the Cleveland Bay STP outfall (Sandfly Creek) compared to local background values.

"*Zn values were in the 40–70mg/kg range. In contrast, Zn values in Townsville city foreshore areas that are affected by urban stormwater drains were in the 90–140mg/kg range. A similar pattern was observed for Pb and Cu. Again, urban runoff was clearly having a larger impact on sediment metals levels than the sewage discharge*" (Moss and Costanzo 1998, p.6). However, such contamination is usually relatively minor when compared to reference levels.

"*Queensland does not have a large industrial base and has few major secondary industry sources of heavy metals. None of Queensland's major east coast rivers or estuaries are significantly contaminated by heavy metals from industry*" (Moss and Costanzo 1998, p.2).

3.6.7 Metals in Sediment

In a study commissioned for the Black Ross WQIP, Butler (2008) investigated metal concentrations in benthic sediments of the lower Ross River basin. "*Samples were taken at 34 sites within the river or its tributaries, and at one estuarine control site situated on Cocoa Ck to the south of Ross River. Site locations included headwater streams, the Ross River weirs and Dam, Stuart Creek, Goondi Creek, Gordon Creek, the estuary, and several urban drains. Samples were analysed for the twelve most toxic metals that could potentially be associated with land uses and activities in the catchment area. These comprise antimony, arsenic, cadmium, chromium, cobalt, copper, lead, nickel, selenium, silver, zinc and thallium*" (Butler 2008, p.i).

"*The survey found no evidence of any significant existing or emerging metal contamination problems at any site in the Ross River catchment. Some very minor isolated anomalies were detected at a few sites but none of these were large enough to be considered ecologically significant or to warrant management attention*" (Butler 2008, p.ii).

While the study showed that metal concentrations are not an issue in the Ross River and Stuart Creek catchments there was a recommendation that a similar study be undertaken for the Bohle River catchment. It was also noted that there is pre-existing evidence showing metal contamination issues associated with Ross Creek and the Townsville Harbour area.

3.7 National Pollutant Inventory

"*Diffuse emissions to air include sources such as: smaller facilities that are not required to report [through the NPI], transport (e.g. motor vehicles) and non-industrial (e.g. barbeques). Diffuse emissions to water include nutrients (total nitrogen and total phosphorus) emissions from water catchments due to different land use types*."

"*Commonwealth, state and territory environment agencies have approved the techniques used to estimate emissions for the NPI. It is important to note that the accuracy of these techniques varies. For the diffuse data in particular, comparative analysis of the data may be misleading, because jurisdictions may have used different approved estimation techniques*."
(Source: http://www.npi.gov.au/database/data-explanation.html)

NPI diffuse data comprises emissions within airshed and water catchment study areas. There are 33 airshed and 32 water catchment regions, and they include urban and rural locations. The location and size of the regions are determined in line with stakeholder priorities. The regions do not cover the whole of Australia. Diffuse data provides a more comprehensive picture of pollution across Australia and provides context for facility emissions.
(Source: NPI 2005 Diffuse emissions data Fact Sheet)

Townsville is not included in the NPI airsheds or water catchment regions.

According to NPI figures the most significant diffuse source of emissions across Australia is motor vehicles (see Table 3.24).

Table 3.24 Top Ten Diffuse Source Emissions

Substance	Tonnes	Major diffuse source	% of total diffuse
Carbon monoxide	4,500,000	Motor vehicles	48%
Total volatile organic compounds	3,000,000	Biogenics (from living organisms)	80%
Oxides of nitrogen	660,000	Motor vehicles	56%
Particulate matter 10.0 um	610,000	Burning/wildfires	36%
Sulphur dioxide	71,000	Fuel combustion – sub reporting	58%
Ammonia (total)	35,000	Agriculture (livestock)	86%
Toluene	30,000	Motor vehicles	60%
Xylenes	22,000	Motor vehicles	64%
Benzene	15,000	Motor vehicles	67%
n-Hexane	7,500	Motor vehicles	43%

Note: Source data from NPI 2008, p.7. Diffuse data is not collected annually and may be from different years. Tonnes figures are totals from all airsheds. % is for the major source relative to total emissions for that substance.

The NPI provides a range of information on diffuse emissions including a range of Manuals. The Diffuse Emissions Manuals assist governments in estimating emissions from:

- Non-industrial activities such as transportation;
- Domestic activities such as lawn mowing;
- Commercial activities such as baking of bread in small bakeries;
- Industrial activities, which are not reported because the relevant thresholds are not exceeded or because the industries are exempt from reporting.

The manuals facilitate consistent reporting by jurisdictions. Diffuse emissions are also known as aggregated emissions data (AED). The twenty-one manuals listed in Table 3.25 are available for use by states and territories for estimating diffuse emissions. Relevance of the manuals to the Black Ross WQIP area is noted in the table.

Table 3.25 NPI Diffuse Emission Manuals

No.	Subject	Relevance to Black Ross WQIP
1	Aircraft	Townsville Airport and RAAF base are located in the Townsville urban area and may have local significance
2	Aquaculture - Temperate	Not applicable
3	Aquaculture - Tropical	Small aquaculture facilities are located in the study area and are included in point source emissions to water as licensed ERAs
4	Architectural Coating	Relevant but not considered significant and mainly VOCs in relatively small quantities
5	Barbeques	Relevant but not considered significant
6	Bushfires and Prescribed Burning	Seasonally relevant especially for particulate matter
7	Commercial Ships/Boats and	Townsville Port and significant recreational boating. Localised

	Recreational Boats	impacts in the vicinity of port and marina facilities
8	Cutback Bitumen	Relevant but not considered significant. Mainly VOCs at the time of application and relatively small amounts thereafter
9	Domestic/Commercial Solvents and Aerosol Use	Relevant but not considered significant as mainly VOCs in relatively small amounts dispersed throughout the area. May be more relevant to wastewater treatment plants and landfill facilities as waste
10	Dry Cleaning	Relevant but not considered significant as it mainly involves solvents and VOCs which are recovered and recycled
11	Fuel Combustion (Sub-Threshold)	Relevant but not considered to be significant for water quality in Townsville with the possible exception of industrial areas, however, emissions are generally above reportable levels and are allocated in point source emissions
12	Gaseous Fuel Burning - Domestic	Relevant but not considered significant for water quality. Gas usage levels are unknown but not as significant as for southern areas for heating and other applications where gas is available through a 'reticulated' supply
13	Industrial Solvents Use	Relevant but not considered significant for water quality
14	Lawn Mowing - Domestic	Relevant but not considered significant for water quality
15	Motor Vehicles	Relevant and potentially significant as atmospheric deposition
16	Motor Vehicle Refinishing	Relevant but not considered significant for water quality
17	Paved and Unpaved Roads	Relevant and potentially significant
18	Printing and Graphical Arts	Relevant but not considered significant for water quality
19	Railways	Relevant and potentially significant for local areas
20	Service Stations	Relevant but not considered significant for water quality
21	Solid Fuel Burning - Domestic	Not significant in the Townsville area

Note: Diffuse Emissions Source descriptions are provided at http://www.npi.gov.au/database/aed-sources.html.
(Source: http://www.npi.gov.au/handbooks/aedmanuals/index.html)

Information from the diffuse emissions manuals considered to be most relevant to the Black Ross WQIP area is provided below. Where appropriate, estimates have been made for emissions in the Townsville region i.e. Townsville City Council local government area.

3.7.1 Aircraft

Table 3.26 lists the NPI substances that are typically emitted from aircraft i.e. gas turbines (jet engines) and reciprocating engines (piston engines).

Table 3.26 Aircraft Emissions

Typical Pollutants Emitted		
Acetaldehyde	Chromium (III) compounds	Particulate matter ≤ 10 μm (PM10)
Acetone	Chromium (VI) compounds	Phenol
Arsenic and compounds	Ethylbenzene	Styrene
Benzene	Formaldehyde	Sulphur dioxide
1,3-Butadiene	Lead and compounds	Toluene
Cadmium and compounds	Nickel and compounds	Total volatile organic compounds (VOCs)
Carbon monoxide	Oxides of nitrogen	Xylenes

Calculation of emissions from aircraft for an airshed is based on a landing/takeoff (LTO) cycle i.e. all of the normal flight and ground operation modes associated with landing and take-off. Operations in the LTO cycle have been grouped into the four standard modes for which emission rate data are readily available. These modes are:

- The approach mode, for which emissions are estimated from 1,000 m above ground level (AGL) to ground level;

- The taxi/idle mode, which applies to both incoming and outgoing aircraft during taxiing and idling operations.
- The takeoff mode, which is defined as the period between commencement of acceleration on the tarmac and the aircraft reaching 200 m AGL, during which time the engine is operated at full throttle and fuel usage is at a maximum for any given engine; and
- The climb out mode, for which emissions are calculated for the period between 200 and 1,000 m AGL.

Data required for estimating aircraft emissions in an airshed is:

- The location of airports, runways, landing and approach flight paths, and associated ground movements, in the airshed;
- The number of landing/takeoff (LTO) cycles for each of the aircraft types operating at these airports;
- The prevalence of the different types of engines (and numbers of engines) and auxiliary power units (APUs) used by each aircraft type i.e. usually diesel powered generators;
- The time spent in each operating mode (approach, taxi/idle, takeoff and climbout) for the airport for estimating aircraft engine emissions; and
- The time spent operating the APU at the airport.

(Source: Environment Australia 2003, *Emissions Estimation Technique Manual for Aggregated Emissions from Aircraft*)

Potential water quality impacts

It is unlikely that any aircraft emissions in flight mode would have any noticeable effect on water quality as a result of emissions settling at ground level and being carried in stormwater run-off to nearby waterways. Emissions from the landing/takeoff (LTO) cycles, and especially the taxi/idle and takeoff modes, may have some impact on water quality in the vicinity of the airport. Monitoring of stormwater outlets collecting run-off from the airport would provide an indication of any water quality issues associated with aircraft and other emissions at the airport. Estimates for Townsville Airport and a commentary are included in Appendix D.

3.7.2 Barbeques

Table 3.27 shows the NPI substances that are typically emitted from domestic barbeques.

Table 3.27 Barbecue Emissions

Typical Pollutants Emitted		
Acetaldehyde	Cyanide compounds	Oxides of nitrogen
Acetone	Dichloromethane	Particulate matter ≤ 10 μm (PM10)
Antimony and compounds	Di-(2-Ethylexyl) phthalate (DEHP)	Phenol
Arsenic and compounds	Ethylbenzene	Polycyclic aromatic hydrocarbons
Benzene	Fluoride compounds	Selenium and compounds
Beryllium and compounds	Formaldehyde	Styrene
1,3-Butadiene	n-Hexane	Sulphur dioxide
Cadmium and compounds	Lead and compounds	Tetrachloroethylene
Carbon disulphide	Manganese and compounds	Toluene
Carbon monoxide	Mercury and compounds	Total volatile organic compounds (VOCs)
Chromium (VI) compounds	Methyl ethyl ketone	Xylenes
Cobalt and compounds	Nickel and compounds	Zinc and compounds

Barbeque use releases emissions from several sources, including the direct burning of fuel to provide heat for cooking, from the product being cooked and from the burning of dripping fats and oils. Depending on the fuel being used emission types and quantities will vary. Emissions from processes other than direct fuel burning are difficult to quantify and are not included in the modeling of the source document.

Estimates of the emissions released from barbeque fuel and briquettes are obtained by using emission factors for the burning of brown coal in 5 hand-fed stoves. Emissions calculations for wood fueled barbeques are based on the quantity of wood fuel consumed and use emission factors for open fireplaces.

Emissions released from barbeques currently have no controls in place to regulate them.

Emissions released from domestic barbeque use vary with season, day of the week and time of the day. In spite of this, bodies such as the NPI more frequently produce annual aggregated emissions reports. Such annual calculations have further inherent variations dependant on the household and population distribution of the target area as well as any sub-regional variations in solid fuel usage.

Data required to calculate aggregated emissions from domestic barbeques is:

- The amount of each type of fuel consumed in barbeques in the relevant jurisdiction or airshed; and
- The distribution of households or population by ABS Collection District.

The amount of each fuel type consumed in domestic barbeques in an airshed can be calculated using the equations found on pages 6-7 of the source document.
(Source: Environment Australia 1999, *Emissions Estimation Technique Manual for Aggregated Emissions from Barbeques*)

Potential water quality impacts
Clusters of barbeque facilities, such as in picnic areas or camping grounds, cause nuisance value to air quality but emissions are too small to have any impact on water quality through emissions settling on or near neighbouring water bodies. In terms of emissions released from wood burning, those emitted from barbeque use comprise a very small fraction of the total and are unlikely to have any significant impacts on water quality.

3.7.3 Aquaculture

Aquatic species are generally very susceptible to chemical pollution; hence, by its very nature the aquaculture industry is largely self-regulating as far as pollutants are concerned. In general, chemical use in aquaculture is kept to a minimum and effluent is usually comprised principally of nutrients and suspended solids.

Total nitrogen (N) and total phosphorus (P) are the main nutrients produced by any aquaculture farm. Initially, estimates are made of the effluent from the ponds, tanks or cages and not necessarily from the farm. These estimates may be viewed as a measure of the potential of the farm to discharge effluent into the environment. In a cage system all of the effluent from the cage will be carried into the surrounding water by currents.

Faeces and uneaten food are flushed out regularly and discharged with wastewater. In a pond system the nutrients will leave by a number of pathways. Suspended solids are considered a significant effluent component by the aquaculture industry and are reportable under Queensland Environmental Protection Agency (EPA) licencing rules. At the present time suspended solids are not included in NPI reporting.

Chemical use in aquaculture
There is a range of minor-use chemicals that are added for special purposes. These include:

- Antibiotics, which may be used to control outbreaks of disease. Use of these are regulated by veterinarians;
- 'Tea seed cake' containing the natural product saponin used to kill fish in prawn ponds;
- Colouring which may be added for final conditioning in prawns.

These are generally complex materials and may contain minor NPI substances, however, even under the most liberal use they will not reach reportable levels.

Chlorine (Cl), which is used for cleaning and sterilizing, may reach aggregate emission levels equal to reportable thresholds in larger facilities. This is especially true for some crocodile farms where there is regular use of chlorine for cleaning pens and abattoir facilities. There are reports of the use of Copper Sulphate ($CuSO_4$) for cleaning and the control of fungal diseases on crocodile farms, however this use is now very minor and appears to be largely discontinued on most farms. Similarly the use of Acetic Acid (ethanoic acid) in prepacking treatment of crocodile meat seems to be being phased out in favour of chlorine.

There may be sources of emissions associated with running a large aquaculture farm, but not directly resulting from aquaculture e.g. use of fuel for generators, outboard motors and other equipment.
(Source: Environment Australia 2000, *Aggregate Emission Data Estimation Technique Manual for the Aquaculture of Barramundi, Prawns, Crocodiles, Pearl Oysters, Red Claw, Tropical Abalone in Tropical Australia*)

Potential water quality impacts
As the main pollutants from aquaculture are nutrients and sediment which are often discharged directly to water the potential impact from this industry is tangible. The industry is licenced through the EPA and is therefore considered to be well regulated. Aquaculture is considered to be a point source pollutant emitter in this report and is included in the section on ERAs (see section 2.2.1).

3.7.4 Bushfires and Prescribed Burning

Prescribed burning and wildfires have a variety of emissions, which are listed in Table 3-4.

Table 3-4 Bushfire Emissions

Typical Pollutants Emitted		
Antimony and compounds	Cobalt and compounds	Oxides of nitrogen
Arsenic and compounds	Copper and compounds	Particulate matter ≤ 10 μm (PM10)
1,3-Butadiene	Lead and compounds	Selenium and compounds
Cadmium and compounds	Manganese and compounds	Total volatile organic compounds (VOCs)
Carbon monoxide	Mercury and compounds	Zinc and compounds
Chromium (VI) compounds	Nickel and compounds	

Note: Speciation profiles are not available to convert estimates of total VOC emissions from these types of sources to emissions of particular organic substances that are listed in the National Environment Protection Measure (NEPM).

Emissions estimation techniques
The data required to calculate aggregated emissions from prescribed burning and wildfires (excluding agricultural burning) are:

- The size of the area burned for each fire event;
- The fuel loading of that burn area; and
- The location of each fire event (for spatial allocation purposes).

Assumptions are made about the actual amount of fuel consumed (72% for wildfires, 42% for prescribed forest burns and 72% for temperate and savanna grasslands) or default fuel loadings for various vegetation types in different locations throughout Australia are used in the calculation. Default fuel loadings for Queensland are:

- 19.3 tonnes per hectare for forest wildfires;
- 3.91 tonnes per hectare for forest prescribed burning; and
- 2.16 tonnes per hectare for savanna burning.

Emission factors for each of the pollutants are required to enable calculations of the emission of each pollutant from a particular type of fire (see page 8 of source document for formula). With the exception of carbon monoxide, oxides of nitrogen, particulate matter and VOCs, which have emission factors measured in grams per kilogram, the other pollutants are measured in micrograms per kilogram (see page 11 of the source document).

Some emissions have been calculated for a 100 hectare fire for each fire type (see Table 3.28) to provide an indication of the quantity associated with selected pollutants. Emissions can also be calculated for agricultural burning i.e. crop residues.

Table 3.28 Calculated Emissions Vegetation Burning (100 hectares)

	Emissions in kilograms for fire types		
Pollutant	**Savanna**	**Forest wildfire**	**Forest prescribed**
Carbon monoxide	18,058	135,100	43,792
Oxides of Nitrogen	1,374	3,860	782
Particulate matter	2,160	14,436	4,692
VOCs	1,058	20,458	2,502
Cadmium and compounds	1.3	1	0.4
Lead and compounds	0.1	0.8	0.4
Mercury and compounds	0.03	0.2	0.09
Nickel and compounds	0.04	0.3	0.1
Zinc and compounds	0.2	1.4	0.06

(Source: Environment Australia 1999, *Emissions Estimation Technique Manual for Aggregated Emissions from Prescribed Burning and Wildfires*)

Potential water quality impacts

To determine the potential impact on water quality the actual fate of the emissions would have to be calculated using a dispersion model. It is assumed that only very large fires would have any significant impact on water quality as a result of the pollutants settling at ground level and subsequently being carried in rainfall run-off to waterways, or settling directly onto water bodies. The emissions that could have an impact on water quality in this situation are particulate matter and, to a lesser extent, oxides of nitrogen.

3.7.5 Commercial Ships/Boats and Recreational Boats

Table 3.29 shows the NPI substances that are typically emitted from commercial ships, commercial boats and recreational boats.

Table 3.29 Emissions from Shipping and Boats

Typical Pollutants Emitted		
Acetaldehyde	Cobalt and compounds	Particulate matter ≤ 10 μm (PM10)
Antimony and compounds	Copper and compounds	Polycyclic aromatic hydrocarbons
Arsenic and compounds	Cyclohexane	Selenium and compounds
Benzene	Ethylbenzene	Styrene
Beryllium and compounds	Formaldehyde	Sulphur dioxide
1,3-Butadiene	Lead and compounds	Toluene
Cadmium and compounds	Mercury and compounds	Total volatile organic compounds (VOCs)
Carbon monoxide	n-Hexane	Xylenes
Chromium (III) compounds	Nickel and compounds	Zinc and compounds
Chromium (VI) compounds	Oxides of nitrogen	

Sources of emissions

Commercial ships may emit air pollutants under two major modes of operation: while underway, and at berth under auxiliary power.

Emissions underway come from a ship's engine exhaust and are influenced by a great variety of factors including engine size, the fuel used (residual oil or diesel oil), operating speed and load.

A ship continues its emissions at berth. Power must be made available for the ship's lighting, heating, pumps, refrigeration, ventilation and so on. Ships normally use diesel-powered generators to furnish auxiliary power. Emissions from these generators may also be a source of underway emissions if they are used away from port.

In addition to engine exhaust emissions, there are fugitive emissions from the loading and ballasting of petroleum tankers in port. During fuel loading and the taking on of ballast, vapour within tankers is vented to atmosphere.

Ballasting operations are a major source of evaporative emissions associated with the unloading of petroleum liquids at marine terminals. Ballasting emissions occur as vapour-laden air in the empty cargo tank is displaced to the atmosphere by ballast water being pumped into the tank. Emissions from ballast operations may occur at dock or at some distance out to sea. The reason for taking on ballast at sea is because of quarantine concerns over the transport of marine life rather than air pollution issues. Little ballast is taken on at dockside, as it is only necessary for trimming the ship when partial cargoes are unloaded. The loading and unloading of certain cargoes (e.g. grain) may release particulate matter into the immediate area if conveyor belts are not enclosed.

The operation of shipboard incinerators is another emission source for some large ships, with the nature of the substances emitted varying with the matter burnt. These two sources of emissions are relatively small in relation to fuel related emissions.

Emissions from commercial and recreational boats arise from boat engines while the boats are travelling. Engines are usually shut down while at berth. While both inboard and outboard engines are used in commercial boats, most recreational boats use outboard engines. All outboard engines use petrol and most inboard engines use diesel as the fuel. Some outboards have underwater exhausts, however only emissions to air are considered in the source document.

Emissions estimation techniques

The data required for estimating emissions from commercial boats are:

- Annual registration of commercial boats by engine type (i.e. inboard and outboard) in an airshed;
- The annual fuel consumption in domestic water transport for a jurisdiction;
- The proportion of commercial boats used in the airshed;
- The proportion of leaded and unleaded petrol used in the airshed (or jurisdiction); and
- The areas where commercial boats carry out their activities.

The data required for estimating commercial ship exhaust emissions are:

- The location of ports in the relevant airshed;
- The number of ships visiting a port in a particular year in the following tonnage ranges:
    - Less than 1 000,
    - 1 000 to 5 000,
    - 5 000 to 10 000,
    - 10 000 to 50 000, and
    - Over 50 000 tonnes;
- The average number of hours at berth;
- The average speed of ships in shipping channels; and
- The locations and lengths of shipping channels in the airshed.

The following data are required for estimating loading and ballasting emissions:

- The volume of petrol or petroleum liquid loaded at port;
- The number of tankers - loading, unloading, and both;
- The average deadweight tonnage (DWT) of tankers; and
- The proportion of ballast emissions at berth.

(Source: Environment Australia 1999, *Emissions Estimation Technique Manual for Aggregated Emissions from Commercial Ships/Boats and Recreational Boats*)

Potential water quality impacts

Emissions from commercial ships and recreational boating may impact on water quality by settling directly onto water bodies from atmospheric emissions or leaching from vessels through corrosion or engine fuel leakages. These substances can be flushed through the area by river and ocean currents, thereby having potentially wider impacts depending on the volume of the emission. While emissions to air from fuel burning may have some localised impact on water quality in the vicinity of the port the wider impacts are unlikely to pose a significant threat to water quality.

The most serious potential impact on water quality would result from the leakage of hydrocarbons (fuel and oils) directly to water and the discharge of waste and ballast waters. However, such emissions are well regulated by the relevant authorities, including the port, and the transport industry and are more likely to be occasional mishaps than constant pollutant sources.

3.7.6 Lawn mowing

Table 3.30 shows the main NPI substances, which are emitted by lawn mowers.

Table 3.30 Emissions from Lawn Mowers

Typical Pollutants Emitted		
Benzene	Ethylbenzene	Polycyclic aromatic hydrocarbons
1,3-Butadiene	Formaldehyde	Styrene
Carbon monoxide	Lead and compounds	Sulphur dioxide
Chromium (III) compounds	n-Hexane	Toluene
Chromium (VI) compounds	Manganese and compounds	Total volatile organic compounds (VOCs)
Cobalt and compounds	Nickel and compounds	Xylenes
Copper and compounds	Oxides of nitrogen	Zinc and compounds
Cyclohexane	Particulate matter ≤ 10 µm	

Emission sources and related processes

There are four types of lawn mowers used in Australia: two-stroke engine mowers, four-stroke engine mowers, electric mowers and push mowers. Only the first two types emit pollutants to the atmosphere at the point of use (power utilities will report emissions from electricity generation for electric mowers). Four-stroke mowers have lower emissions of VOCs, CO and PM_{10} than two stroke mowers, but higher NOx emissions. Fuel type (leaded or unleaded petrol) can also affect emissions, especially for lead and SO_2. As lead petrol is no longer used in Australia this is no longer a factor.

Lawn mower usage can vary across a region. Important factors affecting local equipment usage include climate, land use, lot size, population demographics, and the availability of water in more arid regions (Heiken *et al*, 1997). Lawn mower usage also varies both seasonally and with day of the week. Emissions from spills during fuel transfer can be significant. Emissions can also be affected by combustion chamber temperature and air/fuel ratio (Priest, 1996).

Emissions estimation techniques

The estimation of aggregated emissions from domestic lawn mowing requires information on the following:

- Annual hours of lawn mower usage per household; and
- Mower type (two- or four-stroke).

Annual usage hours for different fuel types are only required for calculating emissions of lead and SO_2.
(Source: Environment Australia 1999, *Emissions Estimation Technique Manual for Aggregated Emissions from Domestic Lawn Mowing*)

Potential water quality impacts

Lawn mower emissions have the potential to impact on water quality but this is dependant on the proximity to water bodies and the magnitude of use. Leaded petrol lawnmowers are no longer a factor due to the removal of leaded petrol from the market. Emissions have the potential to affect water quality through direct settling or by being flushed in rainfall run-off. However, based on an estimation of lawnmower use and emissions in the Townsville region (see Text Box below and Appendix D), the magnitude of these potential impacts is such that lawn mower use should not be considered a threat to water quality.

Annual lawnmower emission calculations for Townsville

Emissions from lawn mowers have been calculated based on assumptions of 30,000 two stroke mowers and 30,000 four stroke mowers in the Townsville region and usage of 1 hour per mower per fortnight i.e. 780,000 two stroke lawn mower hours per year and 780,000 four stroke lawn mower hours per year.

If we assume that the mowing footprint is 150 square kilometres (same as for gross pollutants) and all of the oxides of nitrogen and particulate matter settles within the mowing footprint then we have a contribution from lawn mowers of 0.43 kg/ha per year of particulate matter and 0.33 kg/ha year of oxides of nitrogen. These quantities are not considered to be significant in terms of water quality impacts.

3.7.7 Motor vehicles

Table 3.31 lists the NPI substances that are typically emitted from motor vehicles.

Table 3.31 Motor Vehicle Emissions

Typical Pollutants Emitted		
Acetaldehyde	Copper and compounds	Particulate matter ≤ 10 µm
Acetone	Cyclohexane	Polycyclic aromatic hydrocarbons
Benzene	Ethylbenzene	Styrene
1,3-Butadiene	Formaldehyde	Sulphur dioxide
Cadmium and compounds	Lead and compounds	Toluene
Carbon monoxide	n-Hexane	Total volatile organic compounds (VOCs)
Chromium (III) compounds	Manganese and compounds	Xylenes
Chromium (VI) compounds	Nickel and compounds	Zinc and compounds
Cobalt and compounds	Oxides of nitrogen	

Emission sources and related processes

The energy to propel the vehicle comes from burning fuel in an engine. Pollution from vehicles arises from the by-products of the combustion process (emitted via the exhaust system) and from evaporation of the fuel itself. Particulate matter is also emitted from brakes and tyre wear.

Various types of pollutants are produced in the combustion process. A range of volatile organic compounds (VOCs) are produced because the fuel is not completely burnt (oxidised) during combustion. Oxides of nitrogen (NOx) result from the oxidation of nitrogen at high temperature and pressure in the combustion chamber. Carbon monoxide (CO) occurs when carbon in the fuel is partially oxidised rather than fully oxidised to carbon dioxide.

Sulphur dioxide (SO_2) and lead are derived from the sulphur and lead in fuels.

Particulate matter is produced from the incomplete combustion of fuels, additives in fuels and lubricants, and worn material that accumulates in the engine lubricant. These additives and worn materials also contain trace amounts of various metals and their compounds, which may be released as exhaust emissions.

Evaporative emissions come mainly from petrol (diesel fuel has a much lower vapour pressure) and consist of VOCs and small amounts of lead. These emissions may occur in several ways:

- Diurnal Losses: As the ambient air temperature rises during the day, the temperature of fuel in the vehicle's fuel system increases and increased vapour is produced.
- Running Losses: Heat from the engine and exhaust system can vaporize gasoline when the car is running.
- Hot Soak Losses: Because the engine and exhaust system remain hot for a period of time after the engine is turned off, gasoline evaporation continues when a car is parked.
- Resting Losses: Vapour may be lost from the fuel system or the evaporative emission control system as a result of permeation through rubber components and other leaks.

Another source of emission is the crankcase of early model (pre-1970) vehicles without positive crankcase ventilation systems. In such vehicles, losses occur directly from venting of the crankcase during engine operation.

Evaporative emissions also occur from vehicle refuelling at service stations or from fuel tanker loading and unloading. Emissions can occur when liquid fuel leaks or is spilt, but these emissions are also not considered in the manual. Another type of emission that arises from use of motor vehicles is dust emissions from roads.

Factors affecting vehicle emissions

The main factors affecting vehicle emissions are:

- The vehicle type;
- The type and composition of the fuel used by a vehicle;
- The age of a vehicle; and
- The types of roads on which a vehicle travels.

The emission control technologies employed by an in-service vehicle, the condition of its emission control equipment, and its state of maintenance and repair, have significant impacts on emissions. These factors are reflected in the emissions estimation techniques by considering the age of particular types of vehicles. In particular, the original emission quality and subsequent emission deterioration with time may be simulated by the use of deterioration factors based on the average distance travelled by vehicles of different ages.

Emissions also vary significantly with vehicle and engine operation, which in turn are strongly related to road types (selected on the basis of traffic flow conditions), and hence vehicle speeds and driving patterns. Reid Vapour Pressure (RVP), temperature and number of trips per day have important effects on evaporative emissions. Other factors affecting motor vehicle emissions, include road conditions and grade, weather conditions, the proportions of hot and cold starts, and the use of air conditioners.

Emissions estimation techniques

The following activity data and related information are required for estimating annual emissions from motor vehicles in an airshed:

- Traffic count data or spatially distributed vehicle kilometres travelled (VKT) data by road type in an airshed;
- Relative VKT by vehicle type on each road type in the airshed;
- VKT in a jurisdiction by vehicle/fuel type and year of manufacture;
- The number of vehicles in a jurisdiction by vehicle/fuel type and year of manufacture;
- The average fuel consumption rate of each vehicle/fuel type;
- The sulphur and lead contents of fuels and RVP of petrol used in an airshed; and
- The average temperature and average daily maximum and minimum temperatures (preferably for each month, otherwise for a year) in the airshed.

(Source: Environment Australia 2000, *Emissions Estimation Technique Manual for Aggregated Emissions from Motor Vehicles*)

Potential water quality impacts

Motor vehicles can have significant impacts on water quality through airborne emissions and particularly through particulate matter and chemicals in run-off from road surfaces. Exhaust fumes released into the atmosphere may settle on water surfaces or be washed out in rainfall and subsequently impact water quality. These events would require either extremely high concentrations of motor vehicles close to water bodies or high concentrations of pollutants in the airshed. Fugitive emissions from petrol stations and fuel storage facilities are less significant than the 'burnt' emissions from vehicle exhausts.

The main issues associated with motor vehicle emissions in the atmosphere are health related. Nitrogen dioxide is classified as harmful by inhalation at concentrations greater than 0.1% and very toxic by inhalation at concentrations greater than 10%. It is also irritating to the skin, eyes and respiratory system at concentrations greater than 0.5%.

More relevant in terms of water quality is the transport of particulate matter, oils and fuel from road surfaces into water bodies through stormwater systems as a component of rainfall run-off (see 3.7.8 below).

Calculations for motor vehicles for the Townsville region are included in Appendix D with a summary of annual emissions relevant to water quality listed in Table 3.32. On the basis of these calculations it is not considered that emissions to air are a significant water quality issue, although it is likely that there will be a contribution to nitrogen levels resulting from the wetfall deposition of oxides of nitrogen, and in particular nitrogen dioxide.

Table 3.32 Vehicle Emission Estimates Relevant to Water Quality

	Car	LCV	Bus	Truck	Motorcycle	Totals (tonnes)	Max Potential Deposition
NO_x	883	468	89	440	13	**1,893**	76 kg/ha
PM_{10}	67	41	3	17	2	**130**	5.2 kg/ha
SO_2	58	34	3	14	3	**112**	4.5 kg/ha

Note: LCV is light commercial vehicle. Figures exclude trailers, farming machinery and mobile campervans. Values are expressed as tonnes per year. Maximum potential deposition was calculated by assuming 100% deposition of material from the airshed over a 250 square kilometre area. This is a significant overestimation of actual deposition.

While there are implications for air quality and global warming associated with the vehicle emissions calculated for the Townsville region the immediate and localised impacts on water quality are less tangible.

3.7.8 Paved and Unpaved Roads

Table 3.33 lists the NPI substances that are typically emitted from paved and unpaved roads.

Table 3.33 Emissions from Paved and Unpaved Roads

Typical Pollutants Emitted		
Antimony and compounds	Copper and compounds	Nickel and compounds
Arsenic and compounds	Lead and compounds	Particulate Matter ≤10mm
Cadmium and compounds	Manganese and compounds	Selenium and compounds
Cobalt and compounds	Mercury and compounds	Zinc and compounds

Field studies have found that paved and unpaved roads are a major source of atmospheric particulate matter within an airshed (USEPA 1997). Road dusts emitted into the atmosphere may be categorised according to dust particle size as follows:

- Particulate matter less than or equal to 2.5 µm ($PM_{2.5}$);
- Particulate matter less than or equal to 10 µm (PM_{10}), which is a substance listed in Table 2 of Schedule A to the NEPM;
- Particulate matter less than or equal to 15 µm (PM_{15}); and
- Particulate matter less than or equal to 30 µm (PM_{30}), which is assumed to be equivalent to total suspended particulate matter (USEPA 1998).

A number of other NPI substances are found on roadways in trace amounts, and may form part of the particulate matter, which is emitted from paved and unpaved roads.

Paved roads

When a vehicle travels over a paved road, particulate emissions are generated by the suspension or resuspension of loose material on the road surface. The surface loading of this material is the main source of particulate emissions from roads, and is continually moved and removed. Deposition processes lead to a constant supply of loose material accumulating on the road surface. Particulate matter also arises from exhaust and other emissions directly associated with motor vehicles.

Unpaved roads

When a vehicle travels on an unpaved road the force of the wheels on the road surface pulverises the surface material into fine particles. Tests have shown that fine particles are continually removed by traffic through re-entrainment to the atmosphere, leaving a higher percentage of coarse particles on the road surface (USEPA 1998). These fine particles are lifted by and dropped from the rolling wheels of vehicles, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake that is left behind the vehicle continues to act on the road surface after the vehicle has passed, resulting in further particulate emissions.

(Source: Environment Australia 1999, *Emissions Estimation Technique Manual for Aggregated Emissions from Paved and Unpaved Roads*)

Potential water quality impacts

Paved and unpaved roads can have significant impacts on water quality through the collection and subsequent transfer of chemical or particulate matter to water bodies. Traffic use and environmental stressors degrade road condition, releasing particulate and chemical particles. These particles can be transferred to water bodies through aerial vectors or by rainfall run-off.

Fine particulate matter can affect the light penetration and turbidity of water bodies while chemical runoff can have significant impacts on local ecological processes. The magnitude of these effects depends on the proximity of roads to a water body, stormwater drainage pathways to receiving waters as well as the density of traffic.

3.7.9 Railways

Table 3.34 lists the NPI substances that are typically emitted from railway locomotives.

Table 3.34 Emissions from Rail Locomotives

Typical Pollutants Emitted		
Acetaldehyde	Copper and compounds	Particulate Matter ≤10mm
Antimony and compounds	Ethylbenzene	Polycyclic aromatic hydrocarbons
Arsenic and compounds	Formaldehyde	Selenium and compounds
Benzene	Lead and compounds	Sulphur dioxide
Cadmium and compounds	Manganese and compounds	Toluene
Carbon monoxide	Mercury and compounds	Total volatile organic compounds (VOCs)
Chromium (III) compounds	n-Hexane	Xylenes
Chromium (VI) compounds	Nickel and compounds	Zinc and compounds
Cobalt and compounds	Oxides of nitrogen	

Railway locomotives used in Australia are primarily of two types i.e. electric and diesel-electric. Electric locomotives are powered by electricity generated at stationary power plants and emissions are produced only at the electrical generation plant, which is considered a point source and therefore not considered in this section.

Diesel-electric locomotives, on the other hand, use a diesel engine and an alternator or generator to produce the electricity required to power its traction motors.

A third type, the steam locomotive, is used in very localised operations, primarily as tourist attractions. Emissions from these locomotives are insignificant and no emission factors have been developed for them. In addition, the particulates emitted from operating steam locomotives are so large that nearly all particles fall to the surface within 50 metres of the engine.

Other sources of emissions from railroad operations include small gasoline and diesel engines used on refrigerated and heated rail cars. These engines are thermostatically controlled, working independently of train motive power, and are not covered in the manual. Brake dust from trains can also be a source of PM_{10}, however, no emission factor is available for this parameter.

(Source: Environment Australia 1999, *Emissions Estimation Technique Manual for Aggregated Emissions from Railways*)

Potential water quality impacts

Locomotive infrastructure release emissions through the burning of diesel fuel and as chemical or particulate matter released from railways by traffic. Atmospheric emissions may settle on water bodies while aerial processes and rainfall run-off can transfer settled particulate matter to waterbodies. As rail traffic is limited to narrow corridors the influence of the main emissions is confined to a small area in the vicinity of the rail corridor. The overall impact on the Townsville region is not considered significant however there may be localised issues e.g. Stuart Creek catchment. Monitoring of storm water runoff near rail corridors could be used to determine the extent of influence such substances have on local water quality.

3.7.10 Landfills

Landfills are significant sources of methane (CH_4) and carbon dioxide (CO_2). In addition to CH_4 and CO_2, amounts of non-methane organic compounds (NMOC) are also produced. NMOCs include a number of NPI-listed reactive volatile organic compounds (VOCs) and speciated organic compounds.

Emissions to air

CH_4 and CO_2 are the primary constituents of landfill gas, and are produced during anaerobic decomposition of cellulose and proteins in the landfilled wastes. Although neither of these substances are NPI-listed, estimating emissions of these gases is important as they are indicators for emissions of other listed pollutants.

Decomposition is a complex process and requires certain environmental conditions. Environmental factors that affect the decomposition include moisture content of the waste, nutrient concentration, the presence and distribution of microorganisms, the particle size of the waste, water flux, pH, and temperature. Because of the complex set of conditions that must occur before landfill gas is generated, waste may be in place for a year or more before anaerobic decomposition begins and landfill gas is generated. Refuse in a landfill may produce landfill gas for 20 to 30 years, with an average of 25 years. On the other hand, aerobic decomposition results in CO_2 and water. Uncontrolled dumps, where waste is exposed to air, may be subject to aerobic decomposition.

Some emissions may also occur during the operation of the landfill site. Excavation and heavy machinery may be significant sources of emissions through both the combustion of fuel and the compaction of waste.

Emissions to land and water

Leachate is generally considered to be water that has entered a landfill site and become contaminated after diffusion through the waste or liquids within the waste. Leachate is likely to contain a number of NPI-listed substances. Its composition will vary from site-to-site, depending on many factors including; the nature of the waste in the landfill, the filling method, the level of compaction, the engineering design of the landfill, the rainfall of the region, and the stage of decomposition of the waste.

Emissions to land and waters from a landfill generally come from diffusion of leachate to the groundwater (emission to land), leaks to surface waters (emission to water), or run-off from the flow of water across the landfill site. The volume of leachate produced within a landfill will depend mainly on the rainfall of the area, how well the landfill is sealed and capped, and the original water content of the waste deposited.

Emissions of substances to land on-site include solid wastes, slurries, sediments, spills and leaks, and the use of chemicals to control various elements of the environment (such as pesticides and dust suppressants) where these emissions contain listed substances. These emission sources can be broadly categorised as;

- Surface impoundments of liquids and slurries;
- Application farming;
- Unintentional leaks and spills; and
- Emissions of leachate to land/groundwater.

Waste disposed into a landfill is not considered as an emission to land, only emissions from the landfill.

For the purposes of determining whether a landfill exceeds a threshold, the following factors need to be considered:

- Does the landfill accept or coincidentally produce any of the listed substances in excess of 10 tonnes during the reporting period;
- Does the landfill burn more than 400 tonnes of landfill gas, any other fuel or waste on-site during the reporting period; and
- Does the landfill emit more than 15 tonnes of nitrogen or 3 tonnes of phosphorus to a waterway during the reporting period.

Table 3.35 Landfill NPI Substance Typical Concentrations

NPI listed substance	Household waste a (mg/kg)	Waste paper b		Plastic c	
		mg/kg	%	mg/kg	% d
Cadmium & compounds	2.9	0.5	3.4	43.1	84.4
Chromium (VI) compounds	53	15	4.0	19.7	1.5
Chromium (VI) compounds	23	7	1.7	8.5	0.6
Copper & compounds	31	65	41.8	78	14.4
Fluoride compounds	71	104	29.2	14	1.1
Nickel & compounds	13	10.7	16.2	18.8	8.3
Lead & compounds	294	65.7	4.4	171.1	3.3
Zinc & compounds	310	108	6.9	402.3	7.4

Source: Bilitewski, et al, 1994 (translated 1997).

a 30% moisture content. **b** 8% moisture content. **c** 6% moisture content. **d** Percentage contribution of NPI-listed substance to the entire municipal solid waste (MSW) stream e.g. cadmium present in plastic makes up 84.4% of the total amount of cadmium in the MSW.

(Source: NPI 2005, *Emission Estimation Technique Manual for Municipal Solid Waste (MSW) Landfills Version 1.2*, Commonwealth of Australia)

The main landfills in Townsville (Vantassel Street and Harveys Range Road)) are not listed as NPI emitters and are therefore not considered to be a significant source of pollutants to surface water. Monitoring bores are located around the landfills to monitor any seepage to groundwater.

3.8 Diffuse Emissions Summary

A summary of the calculated emissions to air from the main diffuse sources in Townsville is provided in Table 3.36. This includes emissions to air from industry included in the NPI point source register.

Table 3.36 Summary of Main Diffuse Emissions to Air (tonnes per annum)

Type	NOx	PM10	SO2	Ammonia	CO2/CO
Aircraft/Airport	48	6.5	7		/ 220
Lawnmowers	5	6.5	0.4		/ 952
Vehicles	1,893	130	112		470,000 / 11,000
Industry (NPI)	4,300	1,500	13,000	1,200	/ 970
Bushfires (100ha)	2	5			/ 50
Total (tonnes/year)	6,250	1,650	13,120	1,200	470,000/ 13,190

Note: Industry figures include data for industrial facilities for the 2006 - 2007 NPI reporting year. Bushfire figures are based on an average of 100 hectares burnt per year. Totals are rounded. See Appendix D for diffuse source calculations and Appendix A for NPI point source emissions.

4. Atmospheric Deposition

4.1 What is Atmospheric Deposition

Atmospheric deposition results from material that is gaseous or suspended in the atmosphere that settles on water, land, vegetation or structures as dry deposition or as wash down by rain (wet deposition). Plants respond to rainfall as the wash down of nitrogen and traces of other elements provides a form of 'natural fertiliser'. Nitrogen is the main nutrient in natural atmospheric deposition.

4.2 Background Levels

Nutrient budget studies for tropical coastal ecosystems are rare hence data to determine background levels of atmospheric nutrient deposition for tropical Australia are very scarce in the literature. A proliferation of agricultural and industrial activity in northern Queensland mean that natural background levels of nutrient and sediment in the atmosphere have been obscured by human produced inputs to the atmosphere. Additionally most studies have been focused on the impacts of industrial activities and have concentrated on measuring the atmospheric levels associated with human activities e.g. industry and agriculture.

The most common pollutants associated with atmospheric deposition from natural sources are shown in Table 4.1.

Table 4.1 Natural Atmospheric Deposition Pollutants

Pollutant	Source/Pathway
Nitrogen	• Lightning (oxides) • Dissolved in rainfall (ammonia) • Soil release/denitrification/volatilisation • Fires
Phosphorus	• Wind erosion (attached to soil particles)
Particulate matter	• Wind erosion • Fires • Volcanic eruptions
Heavy metals	• Wind erosion (attached to soil particles) • Fires • Volcanic eruptions
Salt	• Windborne (on moist coastal breezes)
Volatile organic compounds	• Plant release • Carbon based fuels (especially liquid)
Sulphur dioxide	• Fires • Volcanic eruptions

In the Townsville airshed, the Environment Protection Agency (EPA) has established atmospheric monitoring stations at Pimlico, South Townsville, Garbutt, Stuart and the Townsville Port (see Figure 4.2). These stations were established after 1994 and therefore provide no data without human influences.

4.2.1 Data Limitations

While the direct measurement of atmospheric deposition of nutrients is technically and logistically challenging, wet deposition in rainfall is often easier to measure than dry deposition. As measuring dry deposition is more difficult it often means that it is measured less frequently and at fewer locations than wet deposition.

Using previous studies to model ambient atmospheric nutrient concentrations may introduce error due to differing population demographics, industrial configuration and geographic properties. Other features such as prevailing winds and the proximity of monitoring stations to industry can introduce error into deposition modelling.

4.2.2 Nitrogen Compounds

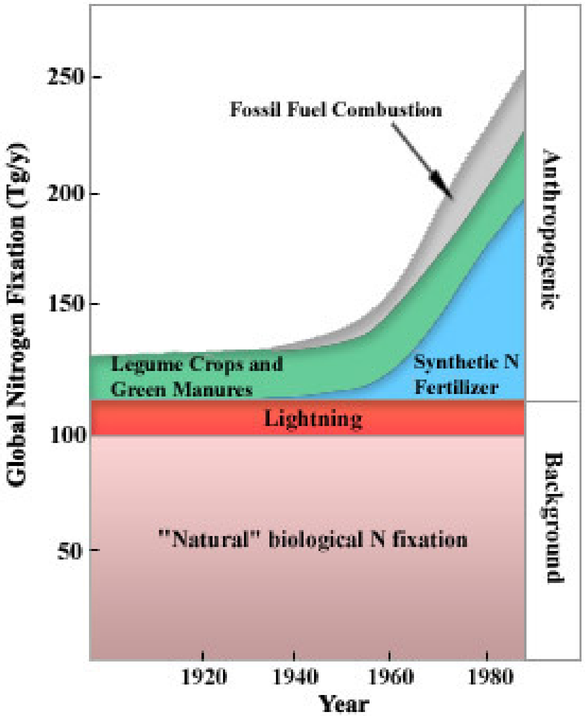
Atmospheric studies outside Australia have been conducted for longer periods of time and have more data to determine potential background atmospheric levels than Australian-based estimates. International research indicates that human activities such as the burning of fossil fuels and the production and application of fertiliser have resulted in an increase in the rate of atmospheric deposition of reactive nitrogen of between two and ten times pre-industrial levels (Clark and Tilman 2008; Bergstrom and Jansson 2006). Further, over 80% of global nitric oxide emissions and 70% of ammonia emissions are thought to be generated by anthropogenic sources (Vitousek et al).

Studies have found that the total dissolved nitrogen in rivers in the North Sea region have increased between six and twenty times pre-industrial levels while in temperate rivers around the North Atlantic Ocean Basin, levels have increased by two to twenty times (Vitousek et al). These increases are thought to be principally from two sources i.e. atmospheric deposition and the use of agricultural fertiliser. The ratio of atmospheric deposition to fertiliser use is not known.

Nitrogen fixation i.e. conversion from N_2 gas to bioavailable forms, occurs naturally in two main ways:

- N_2 is converted to ammonium by nitrogen fixing bacteria often associated with host plants. In the aquatic environments, blue-green algae (cyanobacteria) is an important nitrogen fixer, and
- High-energy events such as lightning; forest fires, volcanism and hot lava flows can cause the fixation of smaller, but significant amounts of nitrogen. The high energy of these natural phenomena can break the triple bonds of N_2 molecules, thereby making individual N atoms available for chemical transformation, often to NO or NO_2.

Figure 4.1 Relative Nitrogen Fixation Activities



(Source: http://www.visionlearning.com/library/module_viewer2.php?mid=98&l=&let1=Ear modified from Modified from Vitousek, P. M. and P. A. Matson 1993)

With an increase in nitrogen fixing activities (see Figure 4.1) there is a greater amount of available nitrogen in the atmosphere and biosphere and therefore greater potential for atmospheric deposition above background levels.

Several studies have monitored global emissions of nitrogen compounds, developing estimates for both pre-industrial and contemporary times (see Table 4.2 and Table 4.3).

Table 4.2 Global Emissions NOx Estimates

Source	Pre-Industrial (TgN/year)	Contemporary (TgN/year)
Fossil Fuel Combustion	0	20-24
Aircraft Emissions	0	0.23-0.6
Biomass Burning	0.25-7	3-13
Lightning	3-25	3-25
Soil NOx Emissions	3.59-18.2	4-21
• Natural	4-15.5	4-15.5
• Agricultural	Unknown	1.8-5.4
NH_4 Oxidation	0.2-0.6	0.5-3
Stratospheric Injection	0.1-0.6	0.1-0.6
Total	7.8-41	23-81

(From Holland et al 2001) Note: Tg is tera grams i.e. 10^{12} grams or 1 mega (million) tonne

Table 4.3 Global Emission NH_4 Estimates

Source	Pre-Industrial (TgN/year)	Contemporary (TgN/year)
Fossil Fuel Combustion	0	0.1 – 2.2
Industrial Process	0	0.2
Domestic Animal Excreta	-	20 – 43
Biomass Burning	-	2.0 – 8.0
Domestic Animals + Biomass Burning	8.95	-
Crops	-	3.6
Wild Animal Excreta	2.5	0.1 – 6.0
Synthetic Fertiliser Use	0	1.2 – 9.0
Oceans	-	8.2 – 13
Soils and Natural Vegetation	3.8	2.4 – 10
Humans and Pets	-	2.6 – 4
Total	15 – 21	45 – 83

(From Holland et al 2001)

Studies have found that pre-industrial atmospheric deposition of oxides of nitrogen (NO_x) and ammonia (NH_4) was greatest in tropical zones, due principally to climatic conditions, with emissions related to soil processes, burning of biomass and lightning activity. Today, the greatest atmospheric deposition of nitrogen occurs in temperate regions of the northern hemisphere. All temperate and tropical ecosystems now receive greater levels of nitrogen deposition than before industrialisation (see Table 4.4).

Table 4.4 Nitrogen Deposition (kg N/hectare/year)

Biome	Northern Hemisphere Temperate Latitudes	Tropical	Southern Hemisphere Temperate Latitudes
Pre-industrial			
Grasslands	0.5	1.42	0.63
Forests	1.02	1.85	0.76
Mixed	0.58	1.19	0.8
Life-forms wetlands and riparian zones	0.77	1.83	0.8
Ice	0.37	-	0.42
Contemporary			
Grasslands	2.81	2.26	1.49
Forests	4.94	3.58	1.43

Mixed	5.98	3.94	1.85
Life-forms wetlands and riparian zones	1.3	4.15	1.54
Ice	-	-	0.05

(From Holland et al 2001)

Hall and Matson (2003) estimated the global rate of atmospheric nitrogen deposition before industrialisation at 2 kilograms per hectare per year. A study by Bristow et al (1998) in the 1970s showed nitrogen loading in wet deposition to be approximately 2kg per hectare per year for Townsville. As wet deposition delivers the bulk of total nitrogen from the atmosphere it can be assumed that nitrogen deposition around Townsville in general has not significantly increased since pre-industrial times. As this data for Townsville is isolated it needs further testing to be accepted as accurate.

Green et al (2004) have estimated no change from pre-industrial to contemporary times in nitrogen deposition across the Australian continent. They also estimate that nitrogen deposition across the Pacific Ocean has increased by around 290% and the increase in total nitrogen deposition across the planet is between 260% and 370% (see Table 4.5).

Table 4.5 Global Nitrogen Mobilisation Estimates

Continent/Ocean	Deposition	Fixation	Fertiliser	Livestock	People	Total
Australia (pre ind.)	0.46	6.99	-	-	-	7.45
Australia (now)	0.46	5.70	0.19	1.48	0.09	7.91
Africa (pre ind.)	3.63	31.99				35.61
Africa (now)	6.58	25.02	0.94	6.43	2.25	41.22
Sth America (pre ind.)	2.75	20.16				22.91
Sth America (now.)	3.51	16.12	1.59	6.63	1.21	29.06
Asia (pre ind.)	3.29	25.45				28.73
Asia (now)	11.21	22.63	20.21	22.41	12.70	89.15
Oceania (pre ind.)	0.02	0.34				0.35
Oceania (now)	0.03	0.17	0.07	0.58	0.02	0.87
Nth America (pre ind.)	1.27	9.81				11.08
Nth America (now.)	6.16	8.76	5.48	5.85	1.95	28.21
Europe (pre ind.)	0.62	3.92				4.54
Europe (now)	4.40	3.06	5.48	10.13	3.09	26.16
Pacific Ocean (pre ind.)	1.91	14.89				16.80
Pacific Ocean (now)	5.48	12.01	13.78	10.67	7.18	49.11
Global totals (pre ind.)	12	99				111
Global totals	32 [44]	81 [112]	34 [71]	54	21	223

From Green et al 2004. Note: Figures are expressed as Tg/year. Not all oceans included in the table, which contribute to the global total. Global totals include second figures [in brackets] corrected for losses.

Conversion of the estimated nitrogen deposition rate for Australia (0.46 Tg/year) to kg/hectare/year gives a figure of 0.6 kilograms/hectare/year (0.46m tonnes or 460 million kilograms divided by the land area of Australia 769 million hectares).

Estimates by Furnas (2003) of annual nitrogen deposition in rainfall across the Great Barrier Reef lagoon were between 14,000 to 44,000 tonnes. This was derived from rainfall estimates of between 140 and 440 km^3 per year with a nitrogen concentration of 100µg per litre of nitrogen (equivalent to 100 t per km^3 rainfall).

4.2.3 Phosphorus

The phosphorus cycle does not contain any long-lived gaseous forms and as such contributes little to the atmosphere. The rate of atmospheric deposition of phosphorus from this source is therefore relatively low. It is assumed that any atmospheric deposition of phosphorus will be a result of wind erosion and in particulate form attached to fine soil particles. It is estimated that the global phosphorus flux as a result of wind erosion has increased as a result of human actions although the actual values are unclear i.e. <3 Mt/year to > 3 Mt/year (Smil 2000).

Estimates by Furnas (2003) of annual phosphorus deposition in rainfall across the Great Barrier Reef lagoon were between 1,000 to 3,000 tonnes. This was derived from rainfall estimates of between 140 and 440 km^3 per year with a phosphorus concentration of 7 µg per litre of phosphorus (equivalent to 7 t per km^3 of rainfall).

4.2.4 Heavy Metals

For toxic heavy metals, trends in atmospheric pollution are little known before 1980 when monitoring began in earnest. However, research in Greenland shows that atmospheric deposition of thallium, cadmium and lead increased by a factor of ten between pre-industrial times and the early twentieth century, after which time levels began to decrease (McConnell and Edwards 2008). It is assumed that atmospheric deposition of heavy metals follows a similar pathway to phosphorus and is associated primarily with wind erosion and attachment to soil particles.

4.3 Anthropogenic Sources

The compounds present in atmospheric deposition can originate from a variety of sources, including industrial and agricultural activity as well as vehicular emissions (see Table 3.24). Compounds most commonly found in atmospheric deposition include nitrogen, sulphur and particulate matter, all of which can have impacts on water quality if atmospheric concentrations are high.

"*Townsville is the third largest city in Queensland and the site of several large industrial facilities, including metals processing, cement production and a busy port. The port handles large quantities of mineral ores and concentrates, cement clinker and other cargo, all of which can contribute to elevated particulate matter levels. Townsville's dry climate also contributes to ambient particulate matter levels*" (Neale 2005, p.64).

4.3.1 Nitrogen and Industry

Results from published studies indicate a long-term increase in the rate of atmospheric nitrogen deposition during the 20th century. The increasing industrialisation of nations, particularly in the northern hemisphere, means that the atmospheric deposition of nitrogen in northern Europe and in the north eastern United States stand at 100kg and 30kg per hectare per year respectively. In comparison, the global rate of atmospheric nitrogen deposition before industrialisation is estimated at 2kg per hectare per year (Hall and Matson 2003).

Such increases in nitrogen deposition have the potential to considerably alter the nutrient balance of natural ecosystems and are further compounded by the accelerating production of nitrogen compounds by industry in developing nations.

The high concentration of heavy industry in the northern hemisphere means that atmospheric deposition of nitrogen compounds is significantly higher in the northern hemisphere than in the southern hemisphere, particularly in terms of nitrate concentration in wet deposition (Harris 2001). The mobile nature of nitrogen compounds in the atmosphere means that some of the atmospheric deposition monitored along the Queensland coast may originate from some distance away.

Limited studies have been undertaken in Australia and none specific to Townsville with the exception of an airshed study undertaken for the proposed Woodstock Industrial site. The study was not available for review and inclusion in this document.

From a study in South Australia by Wilkinson et al (2006) the overall nitrogen input into Adelaide coastal waters, wetfall and dryfall contributes approximately 33 tonnes per year, or less than 1% of the total input from all non-marine sources, which includes WWTP output. When this is compared to stormwater run off only, without the WWTP and other output, then the atmospheric deposition is equivalent to 24% of the total nitrogen input.

The wetfall nitrogen deposition was calculated to have a maximum loading of 8.1 kg N/ha/y, which equates to a maximum urban loading of 6.5 kg N/ha/y (assumed background ambient loading of 1.6 kg N/ha/y). Dryfall total Kjedhal nitrogen (TKN) was estimated at a mean deposition rate of 2.9 kg N/ha/y. South Australian EPA estimates used the TAPM air quality model, which gives a range of deposition rates ranging from approximately 0.3 kg N/ha/yr in the off-shore zone to 8 kg N/ha/y adjacent to major sources of NOx such as an electricity generation plant. Dryfall deposition rate was assumed to be approximately 0.5 kg N/ha/y NOx away from the immediate areas influenced by industrial activities.

Mean concentrations of total nitrogen in rainfall were calculated to be 0.403 mg/L. Nitrogen concentrations and other results from the automatic rainfall sampler are shown in Table 4.6.

Table 4.6 Concentrations of C, N and P in Rainfall at Adelaide

(Concentrations in mg/L)	TC	IC	TOC	TN	NO_3	NO_2	NH_4	TDP	SRP
Geometric mean	2.55	0.82	1.58	0.275	0.064	0.021	0.135	0.033	0.025
Mean	3.65	1.05	2.67	0.403	0.171	0.030	0.207	0.098	0.063
Maximum	19.39	11.56	11.49	2.518	2.166	0.261	1.326	1.558	0.732
95 percentile	11.05	1.84	9.70	1.092	0.707	0.099	0.574	0.433	0.375
5 percentile	0.69	0.298	0.27	0.073	0.013	0.013	0.013	0.013	0.013
Minimum	0.07	0.11	0.12	0.049	0.013	0.013	0.013	0.013	0.013

(Source: Wilkinson et al 2006, Table 1 - p.5) Note: TC isTotal carbon, IC is inorganic carbon, TOC is total organic carbon, TN is total nitrogen, NO_3 is nitrate, NO_2 is nitrite, NH_4 is ammoniacal nitrogen, TDP is total dissolved phosphorus, and SRP is soluble reactive phosphorus.

"*Summarising the wetfall nitrogen data into monthly mean concentrations and total loads demonstrates that, for the 2004-5 rainfall season, oxides of nitrogen are the dominant components of the total nitrogen concentration from March to the end of May. From June onwards into the wet season, the mean monthly total nitrogen concentration is significantly lower and ammonia nitrogen is the dominant form of nitrogen. An obvious interpretation of these results is that, during late summer and Autumn, air pollution sources of nitrogen are dominant. Then, with the wetting of soils and streams, microbial ammonia sources become dominant*" (Wilkinson et al 2006, p.6).

In a case study of Adelaide's Port waterways (Australian Government 2006) atmospheric deposition accounted for approximately 34% of nitrogen from land based diffuse sources but only contributed 2% of the overall load when point sources were added.

The amount of NO_2 in the exhaust stream as it is released from combustion sources is typically in the order of 5-10% of total NO_x. In the atmosphere, oxides of nitrogen are rapidly oxidised to nitrogen dioxide (half-life about 50 days), which dissolves in water to produce dilute nitric acid and precipitates in rain. An increased rate of formation of oxides of nitrogen therefore contributes to 'acid rain'.

In the Townsville region the use of motor vehicles and industrial activities burning fossil fuels needs to be taken into account when calculating the extent of atmospheric deposition of nitrogen above background levels.

An estimate of the atmospheric emissions from motor vehicles is provided in section 3.7.7.

Using results from the Pimlico air monitoring station and assuming a maximum NO_2 concentration of 0.04ppm gives a concentration of 82 µg / m^3. If we assume the concentration is uniform and multiply it by the volume of our airshed (250km^2 by 100m high = 25,000,000,000 m^3) we have 2,050,000 grams (2,050kg) of NO_2 in the airshed.

If we then assume that 10% of the NO_2 is deposited each day and the total amount of NO_2 is deposited during rainfall events this is equivalent to an annual deposition of 203,975 kg of NO_2 across our 250km² airshed footprint (295 days [365 days – 70 rain days] x 10% of 2,050kg [60,475kg] plus 70 rain days x 2,050kg [143,500kg] = 203,975 kg year). This is equivalent to a deposition rate of 8 kg NO_2/ha/yr. Of this deposition a background deposition rate of 2 kg NO_2/ha/yr is assumed with the remaining 6 kg NO_2/ha/yr assumed to be from human sources. The figure is an overestimation of the actual deposition rate and this can be seen when compared to the cumulative estimation of oxides of nitrogen emissions to air for the Townsville region in Table 3.36.

Dispersion modelling has been carried out by QNI (BHP Billiton) for the Yabulu nickel refinery and a summary of a recent report (Pacific Air and Environment 2007) is included in Appendix C. The results of the report show that emissions from the stack studied are well below the EPA's air quality guidelines for nitrate as well as for particulate matter, sulphur dioxide and a range of volatile organic carbons.

4.3.2 Nitrogen and Agriculture

The anthropogenic application of nitrogen-containing products is beginning to exceed the rate of nitrogen fixation in natural systems. This means that human use is the primary driver of increased levels of wet and dry nitrogen deposition.

Nitrogen compounds are most commonly found in fertiliser use, the cultivation of crops, manure and other organic material, and the burning of fossil fuels. Gases can be released to the atmosphere through processes such as denitrification and volatilization.

Denitrification often occurs when nitrate, carbohydrate and micro-organisms are present in anaerobic soil conditions, with nitrate compounds being converted to gaseous nitrogen products. Denitrification is encouraged when soils are warm and wet; conditions closely replicated when fertilisers are applied in spring prior to heavy rain events or in warm, waterlogged tropical soils. Modification of nitrogen compounds in this way can form acidic compounds and contribute to acid rain events. Losses of nitrogen through denitrification are mainly linked to the application of subsurface fertilisers.

Losses (volatilisation) of ammonia can occur from growing and senescent leaves, plant residues, soil surface litter, urine, dung, surface-applied N fertiliser and through burning of dried herbage. There is general agreement that ammonia losses can be large, particularly where animals are involved, as 60 to 90% (usually >80%) of the N ingested is excreted as urea and nitrosamines, which are rapidly hydrolysed to ammonia (Eckerd 1998).

Ammonia entering the atmosphere is often deposited in large volumes in rainfall or by dry deposition into natural ecosystems. The rate of volatilisation is thought to be encouraged by high soil pH, a characteristic lacking in many humid tropical soil environments. However, the accelerated application of nitrogen products to agricultural and farming land may negate the role of pH and allow for high rates of volatilisation. In intensive agriculture losses of nitrogen through volatilisation are mainly linked to the above ground application of fertilisers.

Losses of gaseous nitrogen vary from region to region and are affected by such factors as rates of plant growth and precipitation, type of mineralisation, and the timing and depth of nitrogen fertiliser application.

In terms of the overall nitrogen cycle the land based impacts of increased nitrogen input (see Table 4.5) through fertiliser and animal manure, and subsequent transport to waterways in stormwater, outweighs the impact of any small increase in atmospheric deposition (unmeasured).

In rainforest systems, wet deposition inputs of nitrogen range from approximately 2 to 21 kg per hectare per year. For northern Australia, the only published data are from Townsville, which records inputs of approximately 2 kg of nitrogen per hectare per year. Modelled projections of atmospheric deposition of nitrogen into the wet tropics agricultural areas are approximately 5-10 kg per hectare per year.

Given the relatively low amount of intensive agriculture in the Black Ross WQIP area the atmospheric inputs of nitrogen from agriculture are not expected to be significant. This is confirmed by the limited amount of water quality data from agricultural catchments (Mitchell et al 2007).

4.3.3 Phosphorus

Many of the anthropogenic inputs into the atmosphere are of a nitrogen, sulphur or carbon-based nature. Anthropogenic sources have, however, significantly altered the global phosphorus cycle outside the atmospheric reservoir. There may be some contribution at the time of fertiliser application as a result of wind drift.

Pollard et al (2001) investigated phosphorus deposition in Moreton Bay and showed an increase from an average of 25 and 18 tonnes per year in 1981 and 1982 respectively, to averages of 95 and 101 tonnes per year (5.5% of total phosphorus loading) from two studies in 1996. While these figures would suggest that atmospheric deposition of phosphorus increased during the period 1981-1996 the ranges were variable and the accuracy of the data to calculate the means is questionable.

Studies in Florida found that dry deposition of phosphorus was significantly higher than wet deposition, accounting for approximately 80% of the total atmospheric input of phosphorus into the study area. Atmospheric deposition of phosphorus was also found to be more highly concentrated in summer storms than winter storms.

Average atmospheric deposition of phosphorus over several sites in Florida was found to be 5 mg per square metre per year (50,000mg per hectare i.e. 0.05kg/ha/year) Similar studies on Lake Michigan measured rates of atmospheric deposition of phosphorus to be 22 to 36 mg per square metre per year (i.e. 0.22 to 0.36 kg/ha/year).

Estimates of atmospheric deposition of phosphorus to the Torrens Lake in South Australia are approximately 20 mg per square metre per year (i.e. 0.2 kg/ha/year). This magnitude of phosphorus input from atmospheric deposition is not significant in terms of water quality impacts. In a case study of Adelaide's Port waterways (Australian Government 2006) atmospheric deposition accounted for approximately 12% of phosphorus from land based diffuse sources but contributed less than 1% of the overall load when marine and point sources were added.

4.3.4 Particulate Matter

A study in Adelaide showed total suspended particulates and PM_{10} (particulate matter that passes through a 10 µm filter) collected by a high volume air sampler over eight years gave a low reading of 3.6 µg/m³, a high reading of 263 µg/m³, with an average of 57 µg/m³ (standard deviation of 49 µg/m³). The dust concentration data when analysed with the rainfall data illustrate the well-known process of washout of dust and aerosols by rainfall.

The annual load of atmospheric particulate matter deposited into the 10 km coastal strip was estimated at between 1,800 and 3,860 tonnes. The mean deposition rate over the entire 10 km coastal strip was 36 kg/ha/y (Wilkinson et al 2006, pp.9-10). The amount of material from natural sources and anthropogenic sources was not quantified but regardless of the source this volume of material is not significant as a water quality issue.

Deposition of particulate matter in the Townsville region is the main air quality issue although it is not chronic and is not considered to be a health issue (see section 4.4.2). While contributing to the amount of suspended solids in waterways, especially in urban areas, it is not in itself a major water quality issue in the Black Ross WQIP area.

An estimate of the amount of particulate matter can be made if we apply a daily average particulate matter concentration of 40 µg/m³ (overestimate of Townsville Port air monitoring station readings - see section 4.4.2) over the 250 square kilometre urban footprint to a height of 100 metres. Our adopted airshed therefore is 25,000,000,000 m³ multiplied by 40 µg / m³ to give 1,000,000 grams per day (1,000kg) of particulate matter in the airshed. If we assume that all of this material settles out onto the catchment each day then this amounts to approximately 365,000 kg/year. This is equivalent to a deposition of approximately 15 kilograms/hectare/year.

4.3.5 Heavy Metals

Industrial and agricultural development has introduced many heavy metals in natural ecosystems, including arsenic, cadmium, copper, zinc and nickel. These compounds are strongly attracted to particulate vectors, which often provide atmospheric transport into the environment and waterways.

Given the estimated atmospheric deposition of particulate matter it is unlikely that there are any significant water quality issues associated with the amount of attached heavy metals. The possible exceptions would be in the vicinity of materials handling facilities where metal ores are treated, loaded and unloaded e.g. Townsville Port, refineries and in the vicinity of roads, railways and airports.

4.3.6 Pesticides

Similarly, organochloride pesticides are often transported into the atmosphere by particulate matter, through direct spraying onto crop foliage and through volatilization of compounds. Given the low level of intensive agriculture in the Black Ross WQIP area it is unlikely that airborne pesticides are a water quality issue apart from a very minor contribution to plant and land based application levels.

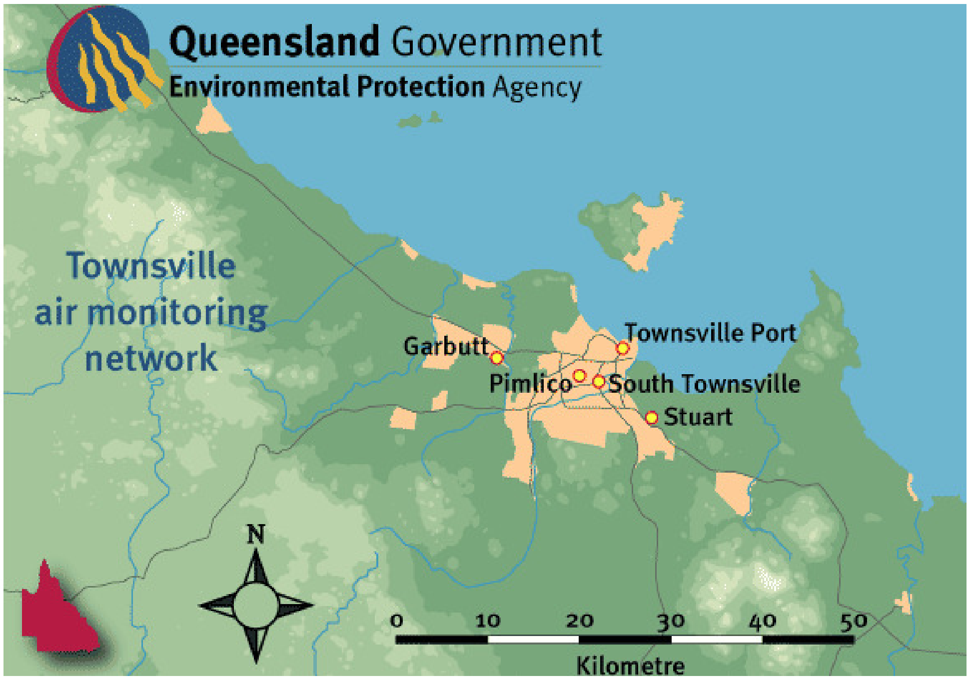
4.3.7 Sulphur Dioxide

Deposition models of sulphur released from industry in Mt Isa show dry deposition of sulphur dioxide and aerosol sulphate to be significantly higher than wet deposition of sulphate. The results of the modelling suggest that rainfall is a relatively inefficient pathway for the removal of sulphur compounds. However, dry deposition was also found to be relatively inefficient, with sulphur particles experiencing long atmospheric residence times and subsequent long-distance advection. Large sulphur particles are less likely to be subject to long distance atmospheric dispersion and can settle on nearby water bodies and soils. The addition of sulphur often results in increasing acidity and consequential environmental impacts. Relatively large emissions of sulphur are required before any adverse impacts are noticeable and such emission levels are not present in the Townsville region.

4.4 Townsville Air Quality Measurement

In the Townsville airshed, the Environment Protection Agency (EPA) has established atmospheric monitoring stations at Pimlico, South Townsville, Garbutt, Stuart and the Townsville Port (see Figure 4.2).

Figure 4.2 Townsville Air Monitoring Network Sites



(Source http://www.derm.qld.gov.au/environmental_management/air/air_quality_monitoring/air_monitoring_network/townsville _region.html) Note: EPA is now part of the Department of Environment and Resource Management (DERM)

A summary of relevant information associated with the Townsville atmospheric monitoring network is provided in Table 4.7.

Table 4.7 Atmospheric Monitoring Stations Summary

Parameter	Garbutt	Pimlico	Tvl Port	Sth Tvl	Stuart	Coastguard
Established	1994	2004	1994	1994	2001	2007
Closed	2004			2004		
Operator	EPA	EPA	TPA	EPA	Sunmetals	
Wind direction		Yes	Yes		Yes	
Wind speed		Yes	Yes		Yes	
Temperature		Yes			Yes	Yes
Humidity					Yes	
Rainfall					Yes	
Ozone		Yes				
Nitrogen oxides		Yes				
Sulphur dioxide		Yes			Yes	
PM10	Yes	Yes	Yes	Yes		
Visibilty		Yes				
TSP						Yes

(Source:http://www.epa.qld.gov.au/environmental_management/air/air_quality_monitoring/northern_queensland_monitoring_stations/) Note: TSP is total suspended particles, PM_{10} is particulate matter < 10 µm i.e. passes through a 10 µm filter.

Monitoring information from some of these stations is available on the DERM / EPA website (http://www.derm.qld.gov.au/environmental_management/air/air_quality_monitoring/search.php /).

DERM / EPA has developed a series of air pollutant standards that are used to assess the acceptability of atmospheric pollutant levels (see Table 4.8).

Table 4.8 EPA Air Pollutant Standards

Pollutant	EPA Standards	Averaging Time	NEPM Standard	Averaging Time
Nitrogen Dioxide	0.12 ppm	1 hour	0.12 ppm	1 hour
			0.03 ppm	1 year
Sulphur Dioxide	0.20 ppm	1 hour	0.20 ppm	1 hour
			0.08 ppm	1year
PM_{10}	50 µg/m3	24 hours	50 µg/m3	24 hours
$PM_{2.5}$	25 µg/m3	24 hours	25 µg/m3	24 hours
Ozone			0.10 ppm	1 hour
			0.08 ppm	4 hours
Carbon monoxide			9.0 ppm	8 hours
Lead			50 µg/m3	1 year

(Source: http://www.epa.qld.gov.au/)

Notes: ppm = parts per million µg/m3 = micrograms per cubic metre

The standards are based on the National Environment Protection Measure for Ambient Air Quality (also referred to as the Air NEPM) released in June 1998 by the National Environment Protection Council (NEPC). The desired environmental outcome of the Air NEPM for ambient air quality is the protection of human health and well-being. It sets air quality standards for six pollutants, together with the maximum exceedence levels of each standard (see Table 4.8).

(Source: http://www.epa.qld.gov.au/environmental_management/air/air_quality_monitoring/national_measures/). Note: This is an old web link and may not be the same following the inclusion of EPA with DERM.

4.4.1 Regional trends

The introduction of continuous PM_{10} monitoring equipment at Gladstone and Townsville in 2000 has contributed to the rise seen in these two regions in the last five years through the availability of more complete measurement data for this period.

The general trend in PM_{10} levels at sites in Gladstone, Rockhampton and Townsville has remained static or been downward since monitoring began in 1994 or later. Dry conditions and smoke particles from bushfires led to a rise in levels in the Gladstone region in 2001-2002. Similarly dry conditions were responsible for increases at Rockhampton and Townsville sites in 2001-2002. The extensive dust storm also contributed to higher PM_{10} levels in all three regions in 2002.

4.4.2 Townsville Air Quality

The Garbutt site in Townsville is located in an industrial area and levels at this site are predominantly influenced by dust-generating activities occurring at adjacent industrial premises rather than being indicative of ambient PM_{10} concentrations for the region (Neale 2005, p.100).

PM_{10} levels measured at the South Townsville site are influenced by loading and unloading activities at the Townsville Port and are more representative of exposure levels experienced by Townsville residents in the inner city area and surrounds. The Pimlico site measures a wider range of pollutants and provides a general indication of the air quality in the Townsville airshed.

As part of the monitoring program Sun Metals Corporation have been monitoring ambient sulphur dioxide levels at a site in Stuart approximately 4km from their metals processing plant and close to residential areas. Data shows that maximum sulphur dioxide levels at this site are very low (see Figure 4.5), rarely exceeding 10 percent of the EPP (Air) goals. Sulphur dioxide levels have been virtually unchanged over the period 2001-2004 (Neale 2005, p.87).

A summary of daily air quality in Townsville from 2004 is provided in Table 4.9.

Table 4.9 Townsville Air Quality Rating

Year	Air Quality Days		
	Poor	Fair	Good
2004 (from May)	0	6	214
2005	5	8	352
2006	2	4	359
2007	0	4	361
2008 (to July)	1	4	208

Notes: Poor - Number of days when at least one NEPM monitoring station did not meet one or more NEPM air quality standards, reflecting high pollution levels.
Fair - Number of days when all NEPM monitoring stations were within the NEPM standards but at least one station reached at least half the standard for one or more pollutants.
Good - Number of days when all NEPM monitoring stations were below half the NEPM air quality standards, reflecting good air quality.
Standards: (see Table 4.8) ozone (1-hour average), nitrogen dioxide (1-hour average), sulphur dioxide (1-hour average), carbon monoxide (8-hour average) and PM_{10} (24-hour average)
(Source: http://www.epa.qld.gov.au/environmental_management/air/air_quality_monitoring/regional_trends/). Note: This is an old web link and may not be the same following the inclusion of EPA with DERM.

Air quality in Townsville is generally good with Poor and Fair days usually resulting from higher levels of particulate matter being present in the air, usually emanating from industrial activities in the vicinity of the air monitoring stations. On occasion the particulate levels are raised as a result of extended dry conditions and the mobilisation of dust by strong winds (see section 4.4.1). Particles from bushfires can also raise levels.

Poor air quality days as a result of high levels of NO_3, SO_2, ozone, carbon monoxide or lead have not been measured to date through the Townsville air-monitoring network. Given that the air quality is relatively good in the Townsville airshed it is unlikely that there will be any adverse impacts on water quality as a result of atmospheric deposition in either wetfall or dryfall, although there is a potentially measurable contribution of particulate matter, albeit unquantified, to receiving waters as a result of atmospheric deposition. While not measured directly through the air-monitoring network it is assumed that some amount of nitrogen and phosphorus will be associated with the particulate matter as well as traces of organic material, other compounds and metals.

Examples of the data outputs from the Townsville air-monitoring network are included as Figure 4.3, Figure 4.4 and Figure 4.5.

Figure 4.3 Air Quality at Pimlico Monitoring Station (Nitrogen dioxide in 2007)

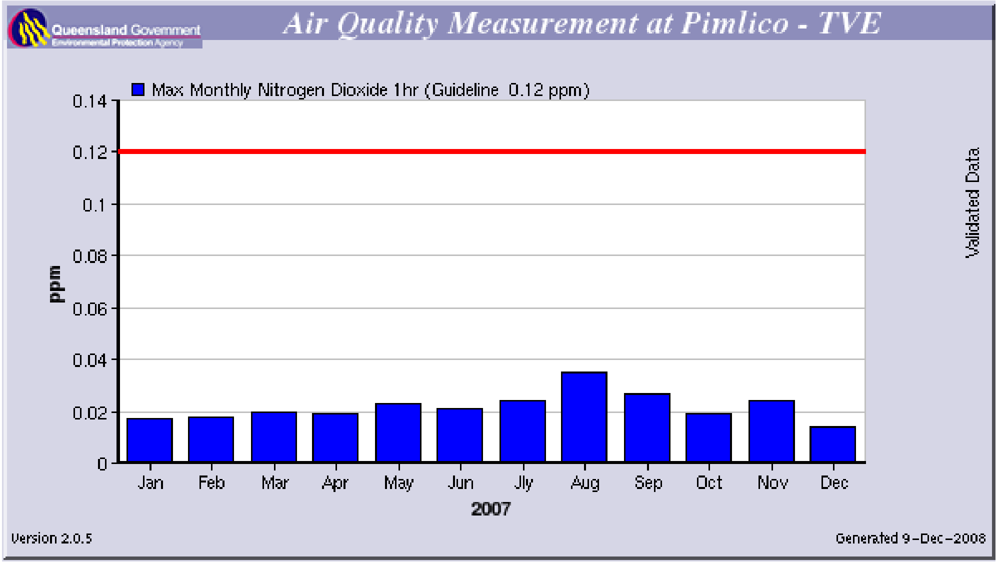


Figure 4.4 Townsville Port Air Quality by Month (PM_{10} in July 2007)

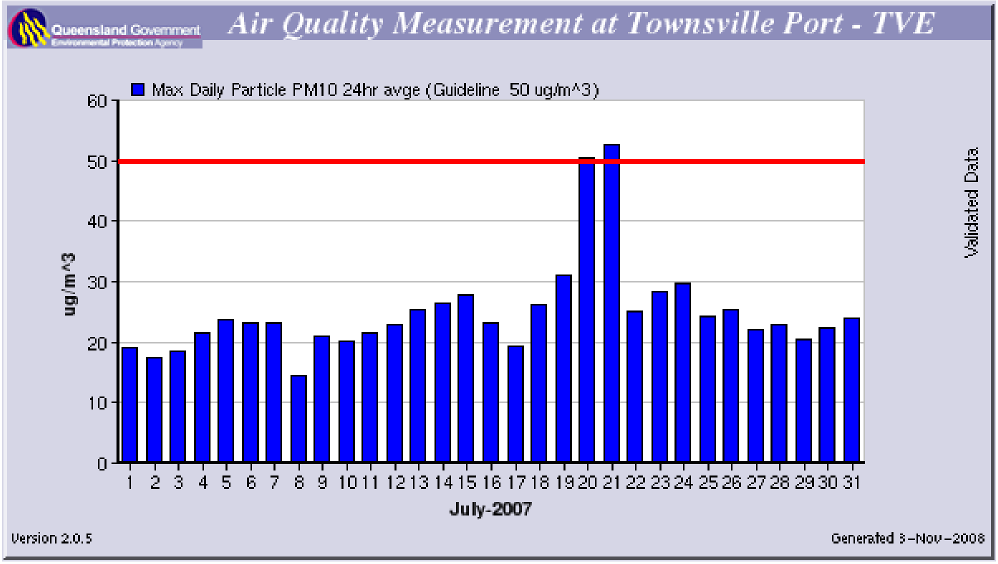
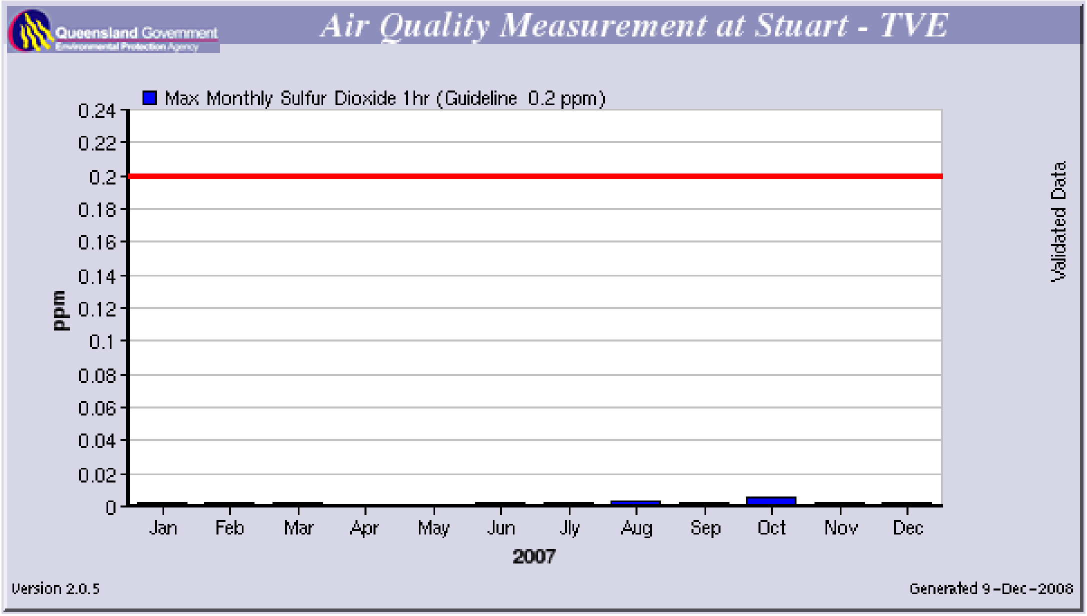


Figure 4.5 Stuart Air Quality Monitoring (Sulphur dioxide in 2007)



4.4.3 Future Air Studies

The Department of State Development and Innovation recognises the need to maintain air quality at the same time as promoting industrial development at the Townsville State Development Area (TSDA) at Stuart. The department has entered into an agreement with the EPA to develop an air quality model for the Townsville airshed. When fully developed the model will be used to assess the potential impact on air quality of current and future proposed industrial development in the TSDA and other sites around Townsville.

The application of the Townsville model will provide a consistent approach to air quality modeling including the assessment of cumulative impacts of new and expanding industries and the establishment of appropriate emission targets for ongoing air quality in the region.

Figure 4.6 Townsville Regional Air Quality is Generally Good

Source: J Gunn

5. Pollutant Profiles

5.1 Pollutants and Impacts

At the 2006 census, there were approximately 836,000 people living in the Great Barrier Reef Catchment with an average annual growth rate of 1.23 percent. This is approximately 21 percent of Queensland's resident population of almost 4 million. The infrastructure for supporting the growing regional population with associated manufacturing, agricultural and urban services represents a substantial modification of the Great Barrier Reef's coastal and catchment landscape. The effect of 68,000 personal watercraft, active commercial fisheries, 1.9 million tourist visits annually, defence activities and development of infrastructure to support visitors and residents accessing and enjoying the Great Barrier Reef combines to make an extensive ecological footprint. This will affect the Great Barrier Reef in far more complex forms than tropical marine ecosystems that are more isolated.
(Source: Johnson and Marshall (eds) 2007, pp.6-8)

It is in the context of expanding population and infrastructure, land use change and outdated land management practices that water quality pollutants become an issue i.e. increased beyond 'natural' levels. It is also recognised that extreme natural events contribute significant pollutant loads to receiving waters, however, it is the amount of ongoing additional material resulting from anthropogenic activities that we seek to reduce.

Potential impacts of pollutants on water quality are discussed below under the broad pollutant groupings:

- Particulate matter and sediment;
- Nitrogen and compounds (ammonia, oxides);
- Phosphorus;
- Hydrocarbon derivatives;
- Metals and compounds; and
- Sulphur compounds.

Principles sources of information for this section are Duncan 1999 and Chiew et al 1997.

5.1.1 Particulate matter and sediment

Particulate matter is the term used to describe particles that are suspended in the air. Particles may be solid or liquid and are one of the most obvious forms of pollution as they are visible in the hazes that cover a city or region.

Size is the main determinant of the behaviour of an atmospheric particle influencing the aerodynamic properties and falling speed. Larger particles (greater than 50µm) usually only remain in the air for a few minutes and settle near the source. Smaller particles (less than 10µm, known as PM_{10}) can remain in the air for several days and can be spread by winds over wide areas or long distances from the original source. Fine particles (between 0.1-2.5µm) may remain in the atmosphere indefinitely [Note: The average human hair has a diameter of 60µm].

Windblown dusts, pollens from plants and sea salts are natural sources of particles in the atmosphere. Bushfires, agricultural and forest hazard-reduction burning release smoke particles into the air. Combustion processes using coal and other fossil fuels, such as power generation, industrial operations and motor vehicle fuels, emit most of the particulate matter in urban areas. (Source: http://www.epa.qld.gov.au/environmental_management/air/air_ quality _monitoring/air_pollutants/airborne_particulates/)

The main issues associated with air borne particulate matter are health related with some environmental issues if other pollutants are attached e.g. oxides of nitrogen or sulphur dioxide.

Particulate matter can have multifaceted and often significant impacts on water quality if present in large enough quantities. Particulate matter in water is usually referred to as suspended solids or suspended sediment. The main source is usually from terrestrial run-off either through soil erosion or transport of built up material from impervious surfaces in urban areas. Impacts range from causing blockages in waterways, increasing turbidity and changing local hydrology. Secondary impacts include decreased light penetration in the water column due to increased sediment loads.

Further, particulate matter often acts as a vector for organic chemicals, inorganic nutrients, hydrocarbons and heavy metals. Changes in these features often result in corresponding changes to water quality.

Major sources of particulate matter relevant to this study include:

- Degradation of roads (paved and unpaved);
- Motor vehicular traffic;
- Wind and water erosion of pervious surfaces (principally soil);
- Construction and demolition operations; and
- Atmospheric deposition.

5.1.2 Nitrogen and compounds

Nitrogen is found in many forms, including organic nitrogen (N), ammonia (NH_3), ammonium (NH_4), nitrite (NO_{2-}), nitrate (NO_{3-}), and nitrogen gas (N_2). These different forms can be dissolved, however organic nitrogen is usually particulate and transported on sediment particles.

Organic nitrogen, ammonia and ammonium are often consolidated into a group known as total kjeldahl nitrogen while nitrite and nitrate are grouped as oxidized nitrogen (NO_x).

Major sources of nitrogen relevant to this study include:

- Combustion of fossil fuels;
- Fertilisers;
- Rainfall; and
- Aerial dust movement.

Nitrogen is an essential, and often a limiting, nutrient. As such, increasing levels of nitrogen in water bodies can often stimulate accelerated rates of growth in plants and algae and result in eutrophication.

The most common gaseous forms of nitrogen, apart from N_2, are:

NO_2 (nitrogen dioxide):
- Is a dark brown, fuming liquid or gas with a pungent, acrid odour detectable at 0.12 ppm.
- Is highly soluble in water, to form nitric acid (a strong acid).
- Is produced (by oxidation of nitrogen) for the manufacture of nitric acid (by its dissolution in water). Most nitric acid is used in the manufacture of fertilisers; some is used in the production of explosives.

NO (nitric oxide):
- Is a colourless gas with a sharp, sweet odour, brown at high concentrations in air.
- Is slightly soluble in water, to form nitrous acid (a weak acid).

N_2O (nitrous oxide):
- Is a colourless gas with a slight, sweetish odour.
- Is non-flammable and has anaesthetic properties.
- Has been used as an anaesthetic (known as 'laughing gas').

Excessive levels of the oxides of nitrogen, particularly nitrogen dioxide, can cause death in plants and roots and damage the leaves of many agricultural crops. Excessive levels increase the acidity of rain (i.e. lower the pH) and thus lower the pH of surface and groundwaters as well as soils. In turn, this lowered pH can have harmful effects, including death, on a variety of biota.
(Source: http://www.environment.gov.au/atmosphere/airquality/publications/sok/oxides.html)

5.1.3 Phosphorus

Phosphorous is an essential nutrient often found in limiting quantities in natural ecosystems. By increasing phosphorous levels in water bodies, growth rates of plants and algae can be stimulated and may result in eutrophication. Phosphorous can be found in either dissolved or particulate form.

Major sources of phosphorous include:

- Fertilisers;
- Industrial waste;
- Atmospheric deposition; and
- Detergents and lubricants.

5.1.4 Hydrocarbon derivatives

Major sources of hydrocarbon derivatives stem from oil and grease used in:

- Detergents;
- Lubrication;
- Combustion; and
- Protective coatings.

Spills of such oils can exceed recommended levels and result in short term toxicity. Further, surfactants found in detergents can impact on aquatic flora and fauna by damaging biological membranes.

5.1.5 Metals and compounds

Heavy metals are often found to be more highly concentrated in urban areas than in rural areas, as a result of higher densities of source emissions such as wear of tyres and brakes, vehicle emissions, road and pavement degradation, water pipe, roof corrosion and industrial activity. Metals and their compounds are therefore a pollutant issue in the Black Ross WQIP area.

Metals relevant to water quality investigations include: Lead, Zinc, Copper, Cadmium, Chromium, Nickel, Iron, Manganese and Mercury. Characteristics of these metals are summarized below.

Lead

Lead in urban storm water is most commonly measured in dissolved and particulate forms that create a stratum of suspended lead solids. These solids often exceed recommended environmental and drinking water levels.

The presence of lead poses serious threats to floral and faunal health due to its ability to bio-accumulate and reach toxic levels. Due to this characteristic, lead is often regarded as a primary contaminant of concern in water quality monitoring. The incidence of lead as a water quality contaminant in urban areas has reduced considerably since the removable of leaded petrol from the market.

Major sources of lead include:

- Petrol additives (no longer significant in Australia);
- Tyres;
- Leaded water pipes, paints and roofs; and
- Industrial emissions.

Zinc

Zinc is an essential element for all living organisms from bacteria to humans. However, too much or too little zinc can harm your health. The seriousness of health effects can be expected to increase with both level and length of exposure. Zinc and compounds emitted to land can remain in the environment for years and can bio-accumulate in fish if the substance reaches waterways. Zinc is most commonly measured in dissolved form and is often transported on other suspended sediments and particles. Excessive levels of zinc in drinking water yield an unpleasant taste and cloudy appearance.

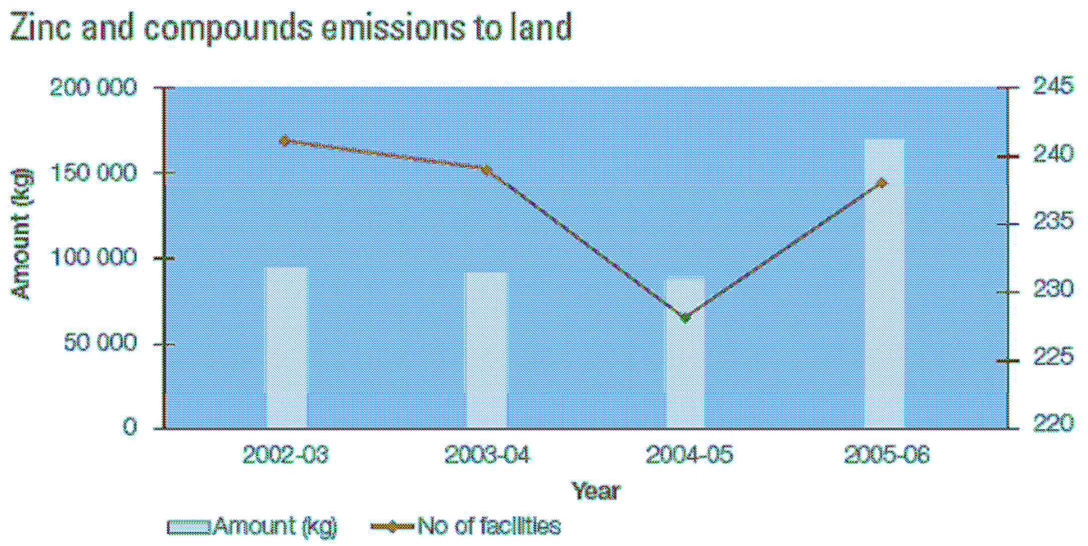
Major sources of zinc include:

- Corrosion of products such as galvanized roofs and metal piping;
- Wear of tyres and brake pads; and
- Combustion of lubricants.

"*The largest industry source of emissions of zinc and compounds to land is zinc smelting and refining. 238 facilities emitted 170,000 kilograms of zinc and compounds to land during the 2005-06 reporting year. Emissions increased by 95% compared to the previous year, chiefly due to an increase in production from a large mining facility.*"

Figure 5.1 shows the emissions of zinc and compounds to land for the reporting years 2002-03 to 2005-06 and the number of facilities reporting the substance to the NPI.

Figure 5.1 Zinc Emissions to Land



(Source NPI Report 2005-2006 pp.14-15)

Copper

While copper is essential to human metabolism, in large doses it has the potential to be a powerful irritant. While toxicity to humans is rare, high levels of copper can accumulate in plants and animals and become toxic to aquatic organisms. Environmental guidelines for copper in storm water and drinking water are frequently exceeded. High levels of copper in drinking water yield an unpleasant taste and tinted colour.

Major sources of copper include:

- Wear of tyres and brake pads;
- Combustion of lubricants;
- Industrial emissions;

- Corrosion of products such as galvanized roofs and metal piping;
- Pesticide use; and
- Wear of moving engine components.

Cadmium

Cadmium is most commonly measured in dissolved and particulate form and is often transported on other suspended sediments. Levels can become particularly concentrated in shellfish and can accumulate in organs such as the liver and kidneys of humans and animals. Cadmium has been shown to be highly toxic as well as having carcinogenic properties.

Major sources of cadmium include:

- Wear of tyres and brake pads;
- Combustion of lubricants;
- Industrial emissions;
- Leaching from land fill;
- Corrosion of galvanized products; and
- Pesticide and fertiliser use.

Chromium

Chromium is found in various forms, with differing impacts of each on water quality. Trivalent chromium is found commonly in chlorinated or aerated water, is essential for human metabolism and is not thought to be toxic. Hexavalent chromium is thought to be carcinogenic and can cause liver, kidney and gastrointestinal damage. In aquatic organisms, hexavalent chromium is toxic.

Major sources of chromium include:

- Pesticide and fertiliser use;
- Corrosion of metal plating;
- Wear of moving engine components;
- Dyes, paints, ceramics, paper; and
- Heating and cooling coils.

Nickel

Nickel is often found with suspended solids and organic matter in storm water. Nickel is not thought to be toxic to animals in elevated concentrations, does not bio-accumulate and in appropriate quantities is essential for adequate animal nutrition.

Major sources of nickel relevant to this study include:

- Corrosion of metal plating;
- Wear of engine components;
- Electroplating; and
- Alloying.

Iron

Iron is a naturally occurring element in the environment and is essential to human nutrition. However, high levels of iron in water produce an unpleasant taste and stained colour and may prove toxic to fish and invertebrates.

Major sources of iron include:

- Corrosion of motor vehicles;
- Combustion of coal;

- Emissions from the iron and steel industry;
- Leaching from land fill; and
- Corrosion of water pipes and fittings.

Manganese

Manganese is essential to human and animal nutrition and metabolism and is not considered to be highly toxic. In drinking water, manganese produces an unpleasant taste and can stain fixtures and products it comes into contact with. Manganese is found in both dissolved form and as suspended solids.

Major sources of manganese include:

- Wear of tyres and brake pads;
- Manufacture of paints and dyes;
- Manufacture of steel and steel products; and
- Fertilisers.

Mercury

Mercury is highly toxic to fish, mammals and invertebrates and can accumulate in concentrated doses along the food chain. There are no known benefits of mercury to animal physiology or metabolism. As such, mercury is a highly damaging substance in the aquatic environment.

Major sources of mercury include:

- Combustion of coal;
- Production of paint products;
- Run-off from gold mines; and
- Emissions from the clor-alkali industry.

5.1.6 Sulphur compounds

Sulphur compounds, particularly sulphur dioxide, can have damaging effects to human health including burns, headache, respiratory irritation and damage to the reproductive system.

In natural ecosystems, excessive amounts of sulphur are harmful to plants and can affect productivity of crops. Sulphur in water increases acidity and can have adverse effects on a range of features.

Sources of sulphur relevant to this study include:

- Combustion of fossil fuels (particularly in petroleum and metal refineries and smelting of sulfide containing ores such as lead, silver and zinc); and
- Vehicular emissions.

(Source:www.npi.gov.au/database/substance-info/profiles/77.html)

5.1.7 Gross pollutants

Gross pollutants refers to debris items larger than 5mm, but often includes smaller sediment particles. Gross pollutants include plastics and other packaging, garden waste (lawn clippings, leaves and other plant material) and coarse sediment. While the litter component of gross pollutants is an aesthetic water quality detractor there can also be deleterious impacts on aquatic animals from plastic litter in waterways through ingestion and entanglement. Organic material can lead to oxygen depletion during decomposition.

5.1.8 Impacts on Water Quality

Atmospheric nitrogen has been recognised as an important source of external nitrogen for a wide variety of marine and freshwater ecosystems. Despite the low deposition rates of nitrogen in Australia relative to the rest of the world, atmospheric deposition of nitrogen and nutrients into estuaries can influence primary production and biomass concentration.

Both nitrogen and phosphorus are essential nutrients often found in limiting quantities in natural ecosystems. As such, the introduction of external nutrient loads can rapidly alter natural water bodies. Accelerated rates of plant and algal growth can clog waterways and stimulate eutrophication. If present in large enough quantities, oxidised nitrogen and sulphur compounds can lower water pH levels and thereby increase acidity.

Elevating sediment loads can affect the turbidity and clarity of water, potentially impacting on integral processes such as photosynthesis and compromising natural aesthetics. Excessive sediment can alter environment conditions and habitat and biological functions of organisms.

Introduced heavy metals can bioaccumulate in flora and fauna, impacting growth rates, reproductive processes and mortality. This accumulation can be passed on through the natural food chain and eventually impact the ‘top’ of the chain predators, including humans.

Figure 5.2 The Lakes and Cleveland Bay

6. Load Estimates

6.1 Event Monitoring Results

Event monitoring was conducted by the Australian Centre for Tropical Freshwater Research (ACTFR) for the Black Ross WQIP over the 2006/07 and 2007/08 wet seasons. Load estimates from the subsequent report (Lewis et al 2008) are provided for sediment (see Table 6.1), nitrogen (see Table 6.2) and phosphorus (see Table 6.3).

Table 6.1 Sediment Load Main Catchments 2006-2008

	2006/07			2007/08			Comparison to model	
Catchment	Sediment load (tonnes)	Total flow volume ML	EMC mg/L	Sediment load (tonnes)	Total flow volume ML	EMC mg/L	Load adjusted to mean annual flow *	Sednet model ** (tonnes)
Alligator Creek	600	41,500	15				530	8,500
Black River	33,000	135,000	240	41,000	180,400	230	17,000	20,200
Bluewater Creek	2,700	63,500	40				1,600	12,500
Bohle River	22,000	147,000	150	35,100	154,200	230	39,000	59,000
Ross River	26,500	261,000	100	14,500	290,000	50	2,500	1,400

Notes: *As specified by the SedNet model. **Kinsey-Henderson et al. (2007).

Source: Table 3. Suspended sediment loads of the major catchments in the Black Ross WQIP Region over the 2006/07 and 2007/08 wet seasons. (Lewis et al 2008, p.17)

Table 6.2 Nitrogen Load Main Catchments 2006-2008

	2006/07			2007/08			Comparison to model	
Catchment	TN load (kilograms)	Total flow volume ML	EMC µg/L	TN load (kilograms)	Total flow volume ML	EMC µg/L	Load adjusted to mean annual flow *	Annex model ** (kilograms)
Alligator Creek	9,440	41,500	228				8,320	46,700
Black River	59,700	135,000	435	91,500	180,400	507	35,000	1,208,970
Bluewater Creek	17,630	63,500	275				10,240	89,700
Bohle River	71,200	147,000	481	83,400	154,200	547	105,600	475,700
Ross River	173,000	261,000	667	149,700	290,000	521	17,200	28,800

Note: *As specified by the SedNet model. **Kinsey-Henderson et al. (2007). Loads and EMC calculated by adding all data from N components tables (Lewis et al 2008, Tables 5, 9, 13, 15 and 16). DIN (Table 16) was used for Annex model and ammonia and NOx were used for monitored sites i.e. DIN = ammonia (Table 13) + NOx (Table 15)

Table 6.3 Phosphorus Load Main Catchments 2006-2008

	2006/07			2007/08			Comparison to model	
Catchment	TP load (kilograms)	Total flow volume ML	EMC µg/L	TP load (kilograms)	Total flow volume ML	EMC µg/L	Load adjusted to mean annual flow *	Annex model ** (kilograms)
Alligator Creek	1,540	41,500	38				1,360	12,200
Black River	15,200	135,000	112	17,900	180,400	100	7,800	23,500
Bluewater Creek	1,240	63,500	20				711	18,100
Bohle River	23,000	147,000	156	24,300	154,200	158	32,300	82,900
Ross River	20,800	261,000	79	22,300	290,000	78	2,290	6,700

Note: *As specified by the SedNet model. **Kinsey-Henderson et al. (2007). Loads and EMC calculated by adding all data from P components tables (Lewis et al 2008, Tables 6, 10 and 18)

6.2 Modelling

BMT WBM was commissioned to undertake catchment modelling to provide estimates of the sediment and nutrient discharge loads for the main catchments in the Black Ross WQIP area. Event mean concentrations (EMC) and data from the ACTFR event water quality monitoring was used as input to the model. The set of preliminary modelled results is provided in Appendix F.

After reviewing the preliminary modelled results some adjustments were made to EMC values for 'wet' and 'dry' catchments and the new figures used for additional runs of the model. Scenarios were also modelled based on predicted population growth coupled with known dwelling occupancy rates, known and anticipated urban expansion areas, planning scheme zonings, the Townsville-Thuringowa Strategy Plan and land use mapping. The resulting population and development growth maps were used for the following scenario horizons:

- 2005 (Base case),
- 2012 (Wastewater upgrades),
- 2021 (Achievable management practice adoption timeframe), and
- 2045 (Measurable water quality outcomes timeframe).

The following tables show the results of the modelled scenarios with no additional management action intervention for diffuse source pollutants. The base case (2005) and 2045 land use scenarios were modelled and the 2021 results were interpolated from those results.

Table 6.4 Base Case (2005) Modelled Load Summary by WQIP Sub Basin

Sub Basin		Area	Flow	TSS	TN	TP
	No.	Hectares	ML/year	kg/year	kg/year	kg/year
Crystal Creek	1	22,629	239,443	5,513,449	90,122	9,383
Rollingstone Creek	2	21,822	144,387	1,603,046	40,448	4,021
Bluewater Creek	3	28,872	145,698	2,806,946	92,700	4,641
Black River (no STP)	4	29,539	114,396	7,195,425	69,178	10,022
Black Basin total		102,861	643,925	17,118,866	292,448	28,067
Bohle River (no STP)	5	33,194	131,708	9,295,613	78,328	14,146
Lower Ross River	6	13,244	53,714	4,205,854	33,120	6,981
Upper Ross River	7	74,929	196,870	8,108,550	100,444	12,784
Stuart Creek (no STP)	8	11,024	47,483	1,650,930	18,956	2,959
Alligator Creek	9	27,490	104,834	2,104,936	42,716	4,811
Ross Basin total		159,882	534,608	25,365,882	273,565	41,680
Magnetic Island	10	4,815	27,390	342,217	6,286	944
Black Ross Total		267,559	1,205,923	42,826,965	572,299	70,690

Note: Updated using 9/6/09, 10/6/09 and 12/6/09 data. Does not include WWTP discharge contributions

Table 6.5 Interpolated Load Summary 2021

Sub Basin		Area	Flow	TSS	TN	TP
	No.	Hectares	ML/year	kg/year	kg/year	kg/year
Crystal Creek	1	22,629	239,283	6,515,695	97,966	10,352
Rollingstone Creek	2	21,822	144,635	2,168,745	45,643	4,572
Bluewater Creek	3	28,872	145,245	2,807,092	95,213	4,515
Black River (no STP)	4	29,539	114,411	7,408,731	70,669	10,246
Black Basin		102,861	643,574	18,900,263	309,491	29,686
Bohle River (no STPs)	5	33,194	132,384	9,494,820	78,326	14,225
Lower Ross River	6	13,244	54,146	5,081,431	36,718	7,766
Upper Ross River	7	74,929	196,578	10,153,950	110,232	14,741

Stuart Creek (no STP)	8	11,024	47,483	2,429,643	23,559	3,777
Alligator Creek	9	27,490	104,410	3,792,099	53,248	6,586
Ross Basin		159,882	535,001	30,951,942	302,083	47,094
Magnetic Island	10	4,815	27,430	399,459	6,383	1,000
Black Ross Total		267,559	1,206,004	50,251,665	617,957	77,780

Note: Updated using 9/6/09, 10/6/09 and 12/6/09 data. Does not include WWTP discharge contributions

Table 6.6 Modelled Loads Summary 2045

Sub Basin		Area	Flow	TSS	TN	TP
	No.	Hectares	ML/year	kg/year	kg/year	kg/year
Crystal Creek	1	22,629	239,042	8,019,064	109,732	11,806
Rollingstone Creek	2	21,822	14,5008	3,017,294	53,436	5,400
Bluewater Creek	3	28,872	144,566	2,807,312	98,983	4,327
Black River (no STP)	4	29,539	114,433	7,728,690	72,904	10,581
Black Basin		102,861	643,048	21,572,359	335,055	32,115
Bohle River (no STPs)	5	33,194	133,397	9,793,631	78,322	14,343
Lower Ross River	6	13,244	54,795	6,394,797	42,114	8,943
Upper Ross River	7	74,929	196,139	13,222,050	124,916	17,678
Stuart Creek (no STP)	8	11,024	47,483	3,597,713	30,462	5,004
Alligator Creek	9	27,490	103,775	6,322,843	69,047	9,248
Ross Basin		159,882	535,589	39,331,033	344,860	55,216
Magnetic Island	10	4,815	27,489	485,322	6,527	1,084
Black Ross Total		267,559	1,206,126	61,388,714	686,442	88,416

Note: Updated using 9/6/09, 10/6/09 and 12/6/09 data. Does not include WWTP discharge contributions

Estimated changes in load values over time with no management interventions are shown in Table 6.7 for total suspended solids, Table 6.8 for nitrogen and Table 6.9 for phosphorus.

Table 6.7 TSS Load Change 2005 to 2045

Catchment	2005	2021			2045		
	Load (kg/year)		Change from 2005		Load (kg/year)	Change from 2005	
			kg/year	%		kg/year	%
Crystal Creek SB	5,513,449	6,515,695	1,002,246	18	8,019,064	2,505,615	45
Rollingstone Creek SB	1,603,046	2,168,745	565,699	35	3,017,294	1,414,248	88
Bluewater Creek SB	2,806,946	2,807,092	146	0	2,807,312	365	0
Black River SB	7,195,425	7,408,731	213,306	3	7,728,690	533,265	7
Black Basin	17,118,866	18,900,263	1,781,397	10	21,572,359	4,453,493	26
Bohle River SB	9,295,613	9,494,820	199,207	2	9,793,631	498,018	5
Lower Ross River SB	4,205,854	5,081,431	875,577	21	6,394,797	2,188,943	52
Upper Ross River SB	8,108,550	10,153,950	2,045,400	25	13,222,050	5,113,500	63
Stuart Creek SB	1,650,930	2,429,643	778,713	47	3,597,713	1,946,783	118
Alligator Creek SB	2,104,936	3,792,099	1,687,163	80	6,322,843	4,217,907	200
Ross Basin	25,365,882	30,951,942	5,586,060	22	39,331,033	13,965,151	55
Magnetic Island SB	342,217	399,459	57,242	17	485,322	143,105	42
Black Ross WQIP area	42,826,965	50,251,665	7,424,700	17	61,388,714	18,561,749	43

Note: Diffuse sources only. Percentage is the change from the base case (2005) as a percentage of the 2005 load.

Table 6.8 TN Load Change 2005 to 2045

Catchment	2005	2021			2045		
	Load (kg/year)		Change from 2005		Load (kg/year)	Change from 2005	
			kg/year	%		kg/year	%
Crystal Creek SB	90,122	97,966	7,844	8.7	109,732	19,610	21.8
Rollingstone Creek SB	40,448	45,643	5,195	12.8	53,436	12,988	32.1
Bluewater Creek SB	92,700	95,213	2,513	2.7	98,983	6,282	6.8
Black River SB	69,178	70,669	1,490	2.2	72,904	3,726	5.4
Black Basin	292,448	309,491	17,043	5.8	335,055	42,606	14.6
Bohle River SB	78,328	78,326	-2	0.0	78,322	-6	0.0
Lower Ross River SB	33,120	36,718	3,598	10.9	42,114	8,994	27.2
Upper Ross River SB	100,444	110,232	9,789	9.7	124,916	24,472	24.4
Stuart Creek SB	18,956	23,559	4,602	24.3	30,462	11,505	60.7
Alligator Creek SB	42,716	53,248	10,532	24.7	69,047	26,331	61.6
Ross Basin	273,565	302,083	28,518	10.4	344,860	71,296	26.1
Magnetic Island SB	6,286	6,383	96	1.5	6,527	241	3.8
Black Ross WQIP area	572,299	617,957	45,657	8.0	686,442	114,143	19.9

Note: Diffuse sources only. Percentage is the change from the base case (2005) load as a percentage of the 2005 load.

Table 6.9 TP Load Change 2005 to 2045

Catchment	2005	2021			2045		
	Load (kg/year)		Change from 2005		Load (kg/year)	Change from 2005	
			kg/year	%		kg/year	%
Crystal Creek SB	9,383	10,352	969	10.3	11,806	2,423	25.8
Rollingstone Creek SB	4,021	4,572	552	13.7	5,400	1,380	34.3
Bluewater Creek SB	4,641	4,515	-125	-2.7	4,327	-313	-6.7
Black River SB	10,022	10,246	224	2.2	10,581	559	5.6
Black Basin	28,067	29,686	1,620	5.8	32,115	4,049	14.4
Bohle River SB	14,146	14,225	79	0.6	14,343	197	1.4
Lower Ross River SB	6,981	7,766	785	11.2	8,943	1,962	28.1
Upper Ross River SB	12,784	14,741	1,958	15.3	17,678	4,894	38.3
Stuart Creek SB	2,959	3,777	818	27.7	5,004	2,045	69.1
Alligator Creek SB	4,811	6,586	1,775	36.9	9,248	4,437	92.2
Ross Basin	41,680	47,094	5,415	13.0	55,216	13,536	32.5
Magnetic Island SB	944	1,000	56	6.0	1,084	141	14.9
Black Ross WQIP area	70,690	77,780	7,090	10.0	88,416	17,726	25.1

Note: Diffuse sources only. Percentage is the change from the base case (2005) load as a percentage of the 2005 load.

Table 6.10 Diffuse Source Loads Summary 1850 to 2045

		1850	1850	1850	1850	2005	2005	2005	2005	2021	2021	2021	2045	2045	2045	2045
Sub Basin	**Area**	**Flow**	**TSS**	**TN**	**TP**	**Flow**	**TSS**	**TN**	**TP**	**TSS**	**TN**	**TP**	**Flow**	**TSS**	**TN**	**TP**
	Hectare	**ML/year**	**kg/year**	**kg/year**	**kg/year**	**ML/year**	**kg/year**	**kg/year**	**kg/year**	**kg/year**	**kg/year**	**kg/year**	**ML/year**	**kg/year**	**kg/year**	**kg/year**
Crystal Creek	22,629	241,419	967,949	45,919	4,693	239,443	5,513,449	90,122	9,383	6,515,695	97,966	10,352	239,042	8,019,064	109,732	11,806
Rollingstone Creek	21,822	145,337	581,003	27,628	2,943	144,387	1,603,046	40,448	4,021	2,168,745	45,643	4,572	14,5008	3,017,294	53,436	5,400
Bluewater Creek	28,872	145,516	582,464	27,704	3,102	145,698	2,806,946	92,700	4,641	2,807,092	95,213	4,515	144,566	2,807,312	98,983	4,327
Black River	29,539	112,643	1,521,997	38,790	4,120	114,396	7,195,425	69,178	10,022	7,408,731	70,669	10,246	114,433	7,728,690	72,904	10,581
Black Basin	102,861	644,915	3,653,413	140,041	14,859	643,925	17,118,866	292,448	28,067	18,900,263	309,491	29,686	643,048	21,572,359	335,055	32,115
Bohle River	33,194	119,673	1,955,625	46,633	4,895	131,708	9,295,613	78,328	14,146	9,494,820	78,326	14,225	133,397	9,793,631	78,322	14,343
Lower Ross River	13,244	46,692	760,268	18,181	1,909	53,714	4,205,854	33,120	6,981	5,081,431	36,718	7,766	54,795	6,394,797	42,114	8,943
Upper Ross River	74,929	198,331	3,119,235	77,433	7,962	196,870	8,108,550	100,444	12,784	10,153,950	110,232	14,741	196,139	13,222,050	124,916	17,678
Stuart Creek	11,024	37,986	609,968	14,793	1,538	47,483	1,650,930	18,956	2,959	2,429,643	23,559	3,777	47,483	3,597,713	30,462	5,004
Alligator Creek	27,490	110,086	1,902,587	42,778	4,621	104,834	2,104,936	42,716	4,811	3,792,099	53,248	6,586	103,775	6,322,843	69,047	9,248
Ross Basin	159,882	512,769	8,347,683	199,817	20,925	534,608	25,365,882	273,565	41,680	30,951,942	302,083	47,094	535,589	39,331,033	344,860	55,216
Magnetic Island	4,815	26,755	107,077	5,088	518	27,390	342,217	6,286	944	399,459	6,383	1,000	27,489	485,322	6,527	1,084
Black Ross Total	267,559	1,184,438	12,108,173	344,945	36,302	1,205,923	42,826,965	572,299	70,690	50,251,665	617,957	77,780	1,206,126	61,388,714	686,442	88,416
Change from 2005		-21485	-30,718,792	-227,354	-34,388	0	0	0	0	7,424,700	45,657	7,090	202	18,561,749	114,143	17,726
% change from 2005		-1.8	-72	-39.7	-48.6					17	8	10	0.0	43	19.9	25.1
Change from 1850		0	0	0	0	21,485	30,718,792	227,354	34,388	38,143,492	273,011	41,478	21,688	49,280,542	341,497	52,114
% change from 1850						1.8	254	66	95	315	79	114	1.8	407	99	144

Note: Diffuse sources only. Updated using 9/6/09, 10/6/09 and 12/6/09 data

Management intervention scenarios were subsequently modelled for:

- Water sensitive urban design (WSUD) applied to new (Greenfield) developments;
- WSUD retrofit of all urban areas; and
- Rural best management practice.

Results of the modelled scenarios and implications for the Black Ross WQIP can be found in the *Black Ross Water Quality Improvement Plan Options, Costs and Benefits Report* (Gunn and Manning 2009).

7. Relative Contributions

7.1 Determining Relative Contributions

Determining the relative contributions of pollutants to receiving waters is an imprecise process due to a high dependence on the availability of reliable monitoring information. In general the information required is not available for the Black and Ross Basins. Determining relative contributions of pollutants to receiving waters for Townsville is therefore based on a number of assumptions and indirect measurements using tools such as catchment and water quality models.

As a starting point the receiving waters are important to define as different processes operate in different receiving waters. For example nutrient sources and cycling are different in the marine environment compared to estuaries and freshwater. Along with nutrient inputs from terrestrial sources the Great Barrier Reef marine environment also receives nutrients from; upwelling from the Coral Sea, rainfall; and nitrogen fixation by cyanobacteria. As we are principally concerned with the contribution to the marine environment from the terrestrial environment the cycling of pollutants in the marine environment will not be considered in this report.

For Townsville the main consideration is the relative contribution of various land uses to sediment and nutrient loads at the end of the catchment i.e. the material that is exported to the marine environment (receiving waters). Various other sources are also taken into consideration e.g. point sources (see section 2) and atmospheric deposition (see section 4). In the context of the urban environment the export of heavy metals, hydrocarbons, pesticides and gross pollutants is also an important consideration for water quality.

7.2 Land Use

Land use is the key parameter for determining the relative contribution of pollutants from the terrestrial environment to receiving waters. In reality it is not just the land use that determines the contribution of pollutants, as the management activities associated with the land use are also a significant factor. Land use is chosen as the initial indicator as it is relatively easy to measure and place in a geographic context relative to the receiving waters. Determining variations associated with management practices is a more difficult task and requires monitoring at the ‘paddock’ scale to detect the differences between paddock scale management practices.

Assumptions and generalisations are made about the generic management practices associated with a land use that results in characteristic pollutant run-off profiles for the land use. Obviously there will be differences at the paddock scale between ‘good’, ‘average’ and ‘bad’ land management practices that will affect the amount of pollutants in run-off. For the purposes of modelling, average profiles are used for various land uses to reflect the ‘normal’ management practices associated with the land use across a catchment.

Relative diffuse source contributions of pollutants from different land uses were discussed in section 3. Summaries of the findings from various studies are included in Table 7.1 in terms of broad land use categories and in Table 7.2 with respect to urban land uses.

Table 7.1 Broad Land Use Group Pollutant Contributions

Black Ross Combined	Forest	Grazing	Sugar	Crops	Other	Total	Export
Area (ha)	57,330	142,550	810	1,680	17,870	220,240	
SS (t/yr)	63,000	163,000	1,000	2,000	14,000	243,000	243,000
SS kg/ha/yr	1,099	1,143	1,235	1,190	783	1,103	
Total N (t/yr)	310	1,039	4	9	79	1,441	877
TN kg/ha/yr	5.4	7.3	4.9	5.4	4.4	6.5	
Total P (t/yr)	59	154	1	2	10	226	143
TP kg/ha/yr	1.0	1.1	1.2	1.2	0.6	1.0	
Black Ross Export	**Pristine**	**Grazing**		**Cropping**	**Urban**	**Total**	**Export**
Area (ha)	53,000	225,000		1,000	10,000	289,000	
Sediment (t/yr)	13,000	223,000		2,000	4,000		242,000

Sediment (kg/ha/yr)	247	990		2,474	400	833	
Total N (t/yr)	63	1,079		17	74		1,233
TN kg/ha/yr	1.2	4.8		17.3	[7.4]	4.3	
Total P (t/yr)	9	154		3	7		173
TP kg/ha/yr	0.17	0.69		2.57	[0.7]	0.6	

Source: Brodie et al 2003 (top of table) and Moss et al 1992 (bottom of table). Figures in [square brackets] are interpreted from a graph.

Note: Annual flow from Moss 1,100,000ML with 0.38 ML/km² run-off.

Table 7.2 Urban Land Use Pollutant Contributions

	SS (mg/L)		Nitrogen (mg/L)		Phosphorus (mg/L)	
Land use subgroup	**Mean**	**Median**	**Mean**	**Median**	**Mean**	**Median**
High urban roads	779	232				
Low urban roads	229	64				
Roads			2.7	2.2	0.42	0.24
Roofs	47	41			0.15	0.14
Residential					0.56	0.39
Industrial						
Commercial						
High urban/non-res.	294	152	3.4	2.5	0.46	0.36
Agricultural	311	133	5.3	4.4	0.90	0.51
Forest	99	71	1.1	0.95	0.095	0.07

Source: Information extracted from Duncan 1999 (p.10, p.13, p.18)

7.2.1 Event Monitoring Results

Along with the information derived from other studies additional work has also been undertaken for the Black Ross WQIP area by the ACTFR through the design and implementation of event based water quality monitoring during the 2006/07 and 2007/08 wet seasons.

Subsequent interpretation of the results, in a 2008 report (Lewis et al), confirmed the strong water quality ‘signals’ associated with catchments draining different land uses, which were indicated in the 2006/07 wet season monitoring.. The EMC values calculated from the event monitoring have been used as input to the catchment modelling study to provide more locally relevant data. A summary of the results from the event monitoring report (Lewis et al 2008) is provided below

The main points (see Table 7.3) associated with total suspended solids (TSS) and land use are:

- Waterways draining the developing urban sites contained elevated TSS concentrations,
- A developing urban hillslope site had a peak TSS concentration of 20,000 mg/L,
- Comparison undeveloped hillslope samples were all consistently below 100 mg/L,
- The developing urban sites on the coastal plain (Kern Drain and Gordon Creek) had considerably higher TSS concentrations compared to the established urban site,
- TSS event mean concentration (EMC) calculated for the established urban sites (20 mg/L) is similar to the conservation land use (19 mg/L),
- Minimal use, rural residential, urban industrial (Stuart C. d/s site) and the light industrial sites had slightly elevated TSS EMCs,
- Developing urban sites all had considerably higher TSS EMCs,
- The large difference between the TSS EMC for the two urban industrial sites reflects the difference in catchment area and land use i.e. Stuart Creek (ds) larger grazing catchment and Louisa Creek smaller urban catchment.

(Source: Lewis et al 2008, pp.13-15)

Table 7.3 Event Monitoring Suspended Solids Data 2006-2008

Dominant land use	Site	Year	Mean (all data)	Median (all data)	Rise (mean)	Peak (mean)	Fall (mean)	Mean rise, peak and fall	Mean EMC mg/L
Established urban	Woolcock St drain	06/07	22	24	20	29	22	24	20
		07/08	15	10	51	17	8.8	26	
	Captain Ck	06/07	15	15	25	12	7.4	15	
Developing urban (Coastal plain)	Kern drain	06/07	339	278	612	284	185	360	795
		07/08	502	445	637	770	389	599	
	Gordon Ck	06/07	409	351	783	444	184	470	
		07/08	662	130	4,600	500	123	1741	
Dev. urban (hillslope) *	Riverview Ck		11,142	4,975					11,140
Light industrial	Hill St drain	07/08	49	43	100	46	26	57	57
Urban industrial	Stuart Ck (ds)	06/07	237	200	257	305	169	244	130
	Louisa Ck	06/07	14	12	21	15	7.8	15	
Rural residential	Sachs Ck	06/07	29	7.1	139	21	5.6	55	35
	Bluewater Ck (ds)	06/07	27	8.3	40	45	4.4	30	
	Alligator Ck (ds)	06/07	20	19	20	14	24	19	
Minimal use	Stuart Ck (us)	06/07	96	63	41	224	49	105	56
	Hencamp Ck	06/07	27	9.3	46	47	14	36	
	Campus Ck	06/07	14	3.5	10	49	1.9	20	
	Bluewater Ck (us)	06/07	55	18	130	48	9	62	
Conservation	Alligator Ck (us)	06/07	12	7	34	19	4.6	19	19

Source: Table 2. Summary of TSS concentrations (mg/L) for the different land uses in the Black Ross WQIP Region over the 2006/07 and 2007/08 wet seasons (Lewis et al 2008, p.16)

Note: * This land use was not fully sampled over the hydrograph and most samples were collected over the rise and peak stages. Therefore this mean is probably an overestimation.

In terms of nutrients, water samples were analysed for total nitrogen (TN) and phosphorus (TP), particulate nitrogen (PN), particulate phosphorus (PP), total filterable nitrogen (TFN) and total filterable phosphorus (TFP), ammonia, NO_x (nitrate and nitrite) and filterable reactive phosphorus (FRP). TN and TP results were not included in the Lewis et al (2008) report so TN and TP were calculated by Creek to Coral by aggregating the four nitrogen components and three phosphorus components. Medians were calculated from TN and TP raw data.

Lewis et al (2008) base their commentary on the nitrogen and phosphorus components rather than TN (see Table 7.4) and TP (see Table 7.5) and this is reflected in the summary comments on nutrients below.

The main points associated with nitrogen and land use in the sampled waterways are:

- Summary EMC for PN show there is little variability in PN across the different land uses,
- Established urban sites had higher PN EMC compared to the developing urban sites indicating runoff from more fertile (or fertilised) soils in the established urban lands,
- Waterways draining the urban and light industrial lands contained elevated concentrations of DON,
- All sites displayed a higher DON EMC than the conservation land use,
- On average, ammonia concentrations were relatively higher at Woolcock St Drain,
- Ammonia EMC were higher for all land uses compared to the conservation land use,
- Highest ammonia EMCs were in the established and developing urban sites,
- NO_x EMC was higher in all land uses compared to the conservation land use,
- NO_x EMC was particularly elevated for the established urban, developing urban and rural residential sites.

(Source: Lewis et al 2008, pp.18-26)

Table 7.4 Event Monitoring Total Nitrogen Data 2006-2008

Dominant land use	**Site**	**Year**	**Mean (all data)**	**Median (all data)**	**Rise (mean)**	**Peak (mean)**	**Fall (mean)**	**Mean rise, peak and fall**	**Mean EMC mg/L**
Established urban	Woolcock St drain	06/07	716	643	653	724	798	725	**744**
		07/08	793	826	770	684	825	760	
	Captain Ck	06/07	740	642	632	570	1020	740	
Developing urban (Coastal plain)	Kern drain	06/07	767	806	695	625	869	729	**748**
		07/08	830	666	744	987	832	854	
	Gordon Ck	06/07	746	694	758	555	794	702	
Light industrial	Hill St drain	07/08	858	648	684	821	973	826	**822**
Urban industrial	Stuart Ck (ds)	06/07	674	642	772	698	587	685	**626**
	Louisa Ck	06/07	572	533	542	526	611	560	
Rural residential	Sachs Ck	06/07	568	564	801	487	537	608	**510**
	Bluewater Ck (ds)	06/07	403	368	498	436	311	414	
	Alligator Ck (ds)	06/07	432	363	392	680	368	480	
Minimal use	Stuart Ck (us)	06/07	632	644	498	729	603	611	**482**
	Hencamp Ck	06/07	400	397	402	219	444	354	
	Campus Ck	06/07	447	327	552	305	363	407	
	Bluewater Ck (us)	06/07	529	421	672	429	497	533	
Conservation	Alligator Ck (us)	06/07	331	254	699	270	253	407	**404**

Source: Lewis et al 2008 total nitrogen compiled from N components in Tables 4, 8, 12 and 14.

Note: Means were calculated by adding all data from N components tables while the Median figure was calculated from TN raw data

The main points associated with phosphorus and land use in the sampled waterways are:

- Elevated PP was measured in the developing urban land use,
- PP typically follows the TSS EMC with the highest concentrations in the developing urban land,
- Urban and light industrial lands contained elevated concentrations of DOP,
- EMC for DOP in the different land uses were all higher than the conservation land use,
- DOP EMC at the light industrial site was twice that of any other land use,
- Waterways draining the urban and industrial lands had considerably elevated FRP EMC,
- The highest FRP EMC was found at the light industrial site.

(Source: Lewis et al 2008, pp.18-26)

Table 7.5 Event Monitoring Total Phosphorus Data 2006-2008

Dominant land use	**Site**	**Year**	**Mean (all data)**	**Median (all data)**	**Rise (mean)**	**Peak (mean)**	**Fall (mean)**	**Mean rise, peak and fall**	**Mean EMC mg/L**
Established urban	Woolcock St drain	06/07	314	297/285	308	268	353	309	**279**
		07/08	357	329/330	312	365	363	346	
	Captain Ck	06/07	236	202/245	279	230	196.2	235	
Developing urban (Coastal plain)	Kern drain	06/07	353	321/362	394	386	317	366	**279**
		07/08	338	328/340	363	386	321	357	
	Gordon Ck	06/07	213	217/197	230	207	205	213	
Light industrial	Hill St drain	07/08	465	224/209	360	455	526	447	**445**
Urban industrial	Stuart Ck (ds)	06/07	282	219/204	288	315	252	286	**229**
	Louisa Ck	06/07	179	187/175	163	172	193	176	
	Sachs Ck	06/07	65.4	51.9/50	133	68.6	49.6	83	**56**

Rural residential	Sachs Ck	06/07	65.4	51.9/50	133	68.6	49.6	83	
	Alligator Ck (ds)	06/07	66	50.6/50	81	34	60	58	
	Stuart Ck (us)	06/07	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	Hencamp Ck	06/07	25.5	23.6/26	20.2	22.6	27.5	23.8	
	Campus Ck	06/07	102	89/90	117	94.3	84	98	
	Bluewater Ck (us)	06/07	79.6	48/50	101.2	77.8	67.4	81.8	
Conservation	Alligator Ck (us)	06/07	31.2	28.5/30	21.4	54	28.8	34.2	**34.2**

Source: Lewis et al 2008 total phosphorus compiled from P components in Tables 6, 10 and 17.

Note: Means were calculated by adding all data from P components tables while the Median figure was calculated from TP data

"*The results from the 2007/08 water quality monitoring program further support the conclusions drawn from the 2006/07 results and strengthen the water quality dataset available for urban and industrial land uses in dry tropical environments*."

"*The latest data from 2007/08 show two of the key water quality concerns identified in the previous 2006/07, namely suspended sediment in the developing urban sites and FRP in the urban and industrial land uses, are consistent over the two monitored wet seasons. The addition of the light industrial site in the 2007/08 monitoring program showed very high levels of FRP and DOP from this land use and helped to highlight the possible main sources of dissolved phosphorus in the Black Ross WQIP Region*."

(Source: Lewis et al 2008, p.39)

Water Sensitive Urban Design (WSUD) literature supports the Townsville monitoring results with regard to sediment exported from developing catchments. Annual sediment discharge rates from developing catchments are one to two orders of magnitude higher than for developed catchments (i.e. 50 m^3/ha and 200 m^3/ha of sediment each year compared to 1.6 m^3/ha).

7.2.2 Preliminary MUSIC Model Land Use Contributions

Initial input data was required to test the Bayesian Belief Network (BBN) model being developed to factor in changes in management practices and impacts on water quality. This information was provided by BMT WBM, who were commissioned to provide the modelled catchment loads for the Black Ross WQIP area. The preliminary areal pollutant export rates and event mean concentrations for the BBN were extracted from a MUSIC model prior to the broader catchment modelling study. The preliminary pollutant export rates are listed in Table 7.21.

7.2.3 Monitoring modified modelling

After a review of the draft outputs from the BMT WBM catchment modelling it was decided that the northern catchments of the Black Basin should be treated differently to the drier southern catchments of the Ross Basin due to the difference in rainfall regime, vegetation and run-off and erosion characteristics. The Paluma Ranges in the northern catchments more closely resemble the conditions found in the wet tropics than the drier Hervey Range of the Ross Basin. This is partly due to the closer proximity of the ranges to coast resulting in greater orographic rainfall.

To account for these differences data from the Black Ross event monitoring was combined with event monitoring data from the Tully catchment to provide a set of 'dry' and 'wet' catchment EMC values for grazing and green space. The 'new' figures (replacing Minimal Use and Conservation in Table 7.3, Table 7.4 and Table 7.5) are provided in Table 7.6 for TSS, Table 7.7 for nitrogen and Table 7.8 for phosphorus.

The modified EMC values, and other data from the event water quality monitoring, were subsequently used as input to the final catchment and water quality modelling used to determine diffuse source end of catchment pollutant loads discharging to the receiving waters of the Great Barrier Reef (see section 6.2).

Table 7.6 Wet and Dry Catchment TSS EMC values

Dominant land use	Site	Year	Mean (all data)	Median (all data)	Rise (mean)	Peak (mean)	Fall (mean)	Mean rise, peak and fall	Mean EMC mg/L
Dry savanna grazing	Stuart Ck (us)	06/07	96	63	41	224	49	105	**130**
	Black River	06/07						240	
	Black River	07/08						230	
	Bluewater Ck (us)	06/07	55	18	130	48	9	62	
Green space (dry)	Alligator Ck (us)	06/07	12	7	34	19	4.6	19	**25**
	Campus Creek	06/07	14	3.5	10	49	1.9	20	
	Hencamp Ck	06/07	27	9.3	46	47	14	36	
Wet Tropics grazing	Davidson Ck	05-07	29	12					**25**
	Warrami Creek	05-07	25	13					
Green space (wet)	Murray Falls	05-07	1	0.35					**4**
	Tully Gorge	05-08	7	4					
	North Hull River	05-07	10	4					

Note: (us) is upstream

Table 7.7 Wet and Dry Catchment Nitrogen EMC values

Dominant land use	Site	Year	Mean (all data)	Median (all data)	Rise (mean)	Peak (mean)	Fall (mean)	Mean rise, peak and fall	Mean EMC µg/L
Dry savanna grazing	Stuart Ck (us)	06/07	632	558	498	729	603	610	**535**
	Black River	06/07						435	
	Black River	07/08						507	
	Bluewater Ck (us)	06/07	529	447	672	429	497	533	
Green space (dry)	Alligator Ck (us)	06/07	331	261	699	270	253	407	**383**
	Campus Creek	06/07	447	347	552	305	363	407	
	Hencamp Ck	06/07	400	329	402	219	444	355	
Wet Tropics grazing	Davidson Ck	05-07	493	452					**768**
	Warrami Creek	05-07	1489	1323					
Green space (wet)	Murray Falls	05-07	131	106					**193**
	Tully Gorge	05-08	233	155					
	North Hull River	05-07	241	168					

Note: Figures calculated by adding DON, PN, NOx and ammonia values provided by ACTFR (see Appendix E).

Table 7.8 Wet and Dry Catchment Phosphorus EMC values

Dominant land use	Site	Year	Mean (all data)	Median (all data)	Rise (mean)	Peak (mean)	Fall (mean)	Mean rise, peak and fall	Mean EMC µg/L
Dry savanna grazing	Stuart Ck (us)	06/07	142	135	117	190	126	144	**110**
	Black River	06/07						112	
	Black River	07/08						100	
	Bluewater Ck (us)	06/07	80	48	101	78	67	82	
Green space (dry)	Alligator Ck (us)	06/07	31.2	28.5	21.4	54.0	28.8	34.7	**51**
	Campus Creek	06/07	102.0	89.0	117.0	94.3	84.0	98.4	
	Hencamp Ck	06/07	25.5	23.6	20.2	22.7	27.5	23.5	
Wet Tropics grazing	Davidson Ck	05-07	24.5	21.0					**27**
	Warrami Creek	05-07	30.0	27.0					
Green space (wet)	Murray Falls	05-07	13.0	12.0					**15**
	Tully Gorge	05-08	16.0	13.0					
	North Hull River	05-07	17.0	14.0					

Note: Figures calculated by adding FRP, PP, and DOP values provided by ACTFR (see Appendix E). (us) is upstream

7.3 Point Sources

Point source facilities that discharge to air have been included in the section on atmospheric deposition as a diffuse source contribution. Point source facilities that discharge to land have not been included in contributions as it is assumed that the licensing conditions associated with the activities and facilities preclude constant discharge to water. Accidental or intentional discharges, which contravene licence conditions, have not been considered as these are intermittent contributions at the most and are dealt with through legislative means.

The main point sources considered as pollutant contributors are the wastewater treatment plants as they discharge directly to water and contribute significant amounts of nutrients. They are also the subject of major upgrade operations and discharge concentrations of nutrients will be reduced in the near future (2012).

Contributions from point sources have been derived from catchment modelling and from calculations associated with the event monitoring undertaken by the ACTFR (Lewis et al 2008). The ACTFR results are summarised below by catchment.

7.3.1 Bohle River Catchment

Three wastewater treatment plants (WWTP) discharge into the Bohle River (Condon, Deeragun and Mt St John WWTPs) either directly or to tributaries. The discharge from Deeragun (Saunders Creek) and Mt St John WWTP (a drain entering the lower reaches) enters the Bohle River below the water quality monitoring site. Discharge data was obtained from Townsville City Council and load estimates calculated and compared to a previous report prepared by GHD (2007) (see Table 7.9).

Table 7.9 Bohle River WWTP Load Estimates

Water year	Condon WWTP (kg)		Deeragun WWTP (kg)		Mt St John WWTP (kg)	
	TN	TP	TN	TP	TN	TP
1998/99	2,110	1,920	1,300	1,490		
1999/2000	1,980	1,740	1,560	1,350		
2000/01	1,320	2,090	1,400	1,460		
2001/02	2,150	2,640	1,550	1,710		
2002/03	2,480	2,620	1,890	1,920		
2003/04	1,190	2,470	2,250	2,050		
2004/05	1,760	2,590	2,590	1,700	107,000	22,800
2005/06	950	2,310	3,250	1,680	136,000	21,900
2006/07	1,550	2,710	1,370	1,560	136,000	18,200
2007/08					139,000	14,200
ACTFR average	**1,721**	**2,343**	**1,907**	**1,658**	**129,500**	**19,275**
GHD 2007	**4,380**	**2,920**	**2,847**	**1,971**	**68,255**	**12,045**

Source: Lewis et al 2008, Table 19 and Table 20, p.34.

Load estimates for the Mt St John WWTP were considered to be more accurate than for the Condon and Deeragun WWTPs due to the higher resolution dataset and the greater consistency in the concentration data over time. ACTFR calculations suggest that the previous GHD load estimates for all three WWTPs may be too high.

Mt St John WWTP data show that high proportions of the TN and TP load consist of the dissolved inorganic fractions including DIN (~85% of TN) and phosphate (~75% of TP). This is also expected for the Condon and Deeragun WWTPs.

Estimated nutrient load contributions from the Condon WWTP at the event water quality monitoring site are indicated in Table 7.10.

Table 7.10 Condon WWTP Nutrient Load Contributions

Period	Monitoring Site		Condon WWTP			
	TN (kg)	TP (kg)	TN (kg)	TP (kg)	TN (%)	TP (%)
2006/07	70,600	23,000	1,700	2,300	2	10
2007/08	83,400	24,300	1,700	2,300	2	9.5

Source: Lewis et al 2008, p.33

The Mt St John WWTP is a much larger facility and when combined with the Deeragun WWTP the two have the potential to contribute another 131,000 kilograms of TN and 21,000 kilograms of TP to the annual end of catchment load of the Bohle River.

The estimated contributions to the end of catchment nutrient load of the Bohle River from the WWTPs are shown in Table 7.11. Collectively the three WWTPs contribute up to ~61% of TN and ~50% of TP to the total end of catchment load of the Bohle River.

Table 7.11 Bohle End of Catchment WWTP Nutrient Contributions

	Condon WWTP		Deeragun WWTP		Mt St John WWTP	
	TN	TP	TN	TP	TN	TP
Discharge (kg)	1,700	2,300	1,900	1,700	129,500	19,300
EoC contribution	1%	5%	1%	4%	59%	41%

Source: Lewis et al 2008, p.33. Bohle River end of catchment loads are approximately 218,300 kg TN and 46,700 kg TP

The WWTPs may contribute up to 90% of the total DIN load and 60% of the total phosphate load from the Bohle River. These are the more bioavailable forms of nutrients and have the potential for greater water quality impacts in terms of biological activity and eutrophication.

7.3.2 Black River Catchment

The Mt Low WWTP discharges into the lower reaches of the Black River below the monitoring site. As such a direct measurement of the contribution of the Mt Low WWTP by water quality monitoring is not possible. The contribution of TN and TP from the Mt Low WWTP to the end-of-catchment discharge is assumed as a ratio of the average annual WWTP discharge (see Table 7.12) to the annual discharge from the Black River (see Table 7.13).

Table 7.12 Mt Low WWTP Discharge Loads

Water year	TN (kg)	TP (kg)	Water year	TN (kg)	TP (kg)
1998/99	1,160	1,000	2003/04	1,620	1,590
1999/2000	2,290	1,460	2004/05	1,430	1,600
2000/01	2,770	1,270	2005/06	2,400	1,090
2001/02	1,800	1,640	2006/07	1,520	1,020
2002/03	1,850	1,410	Average	**1,871**	**1,342**

Source: Lewis et al 2008, Table 19, p.34.

Table 7.13 Mt Low WWTP Nutrient Contribution to Black River Load

Year	Total nitrogen (kilograms)			Total phosphorus (kilograms)		
	Black River	STP	%	Black River	STP	%
2006/07	59,700	1,520	2.5	15,200	1,020	6.7
2007/08	91,500	1,870	2.0	17,900	1,340	7.5

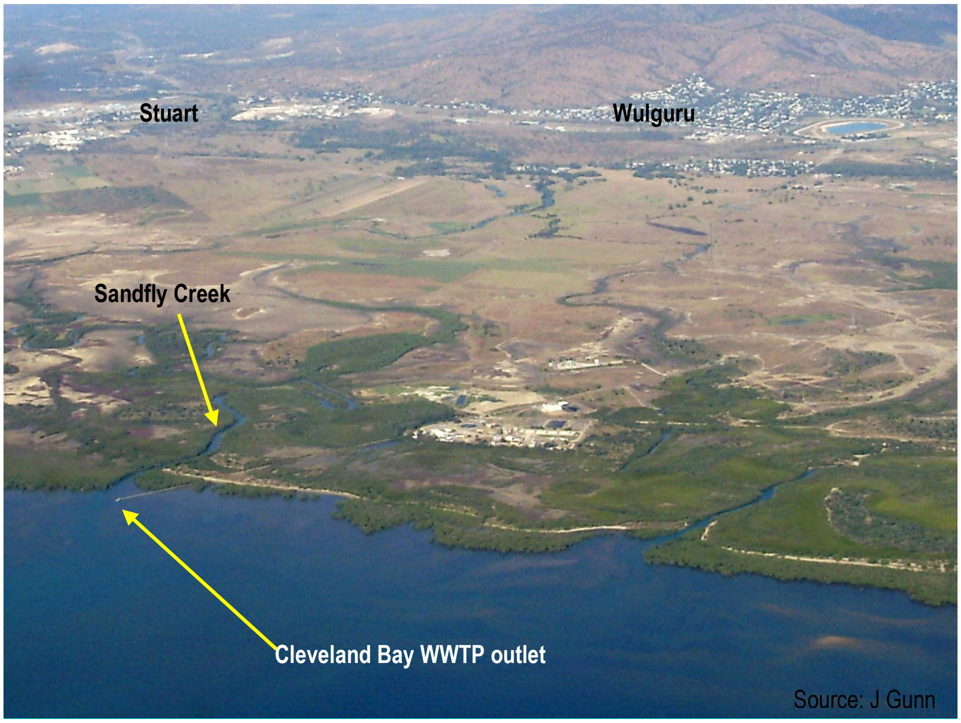
Note: Mt Low discharge figures were used for 2006/07 and average discharge figures were used for 2007/08.

Notes: Estimated (from Lewis et al 2008) discharge for 2006/07 and 2007/08 were 59,700kg and 91,500kg N and 15,200kg and 17,900 kg P.

7.3.3 Sandfly Creek Catchment

The Cleveland Bay WWTP discharges directly into the near coastal waters just beyond the mouth of Sandfly Creek at high tide (see Figure 7.1Table 7.14). At low tide the discharge point is into the intertidal channel of Sandfly Creek (see Figure 7.2). As the discharge point is so close to the mouth of Sandfly Creek the Cleveland Bay WWTP has been included as a point source discharge for the Sandfly Creek catchment, within the Stuart Creek sub basin.

Figure 7.1 Cleveland Bay WWTP Outfall High Tide



Source: J Gunn

Figure 7.2 Cleveland Bay WWTP Outfall Low Tide

Source: J Gunn

The Cleveland Bay WWTP is the largest facility in the Townsville region and has historically contributed considerable amounts of bioavailable nitrogen and phosphorus to Cleveland Bay. There would have been water quality impacts on the estuarine and near coastal environments in the vicinity of the outfall, including the Sandfly Creek estuary, Stuart Creek estuary and, to a lesser extent, the Ross River estuary.

It should be noted that the water quality issues associated with event flow conditions are different to the constant discharge of the WWTP throughout the year during low flow conditions. Event flows effectively dilute and flush the nutrients away from near shore areas as opposed to low flow conditions where tidal influences and estuarine processes see nutrient rich water remaining relatively close to the coast and cycling in and out of the estuaries.

The Cleveland Bay WWTP has been upgraded (2006) and this showed as a marked reduction in the loads of nitrogen and phosphorus discharged in the 2007/08 event monitoring results (see Table 7.14).

"*Loads from the sewerage treatment plants show that they may contribute a high proportion of bioavailable nitrogen and phosphorus exported from the Black Ross Region. However, plant upgrades have the potential to considerably reduce the loads of N and P*."
(Source: Lewis et al 2008, p.39)

Table 7.14 Cleveland Bay WWTP Discharge Loads

Water Year	Ammonia-N	Nitrate-N	Total N	Phosphate-P	Total P
2004/05	69,600	33,500	125,000	2,900	41,000
2005/06	73,500	26,900	126,000	2,600	39,200
2007/08	620	16,700	27,300	460	5,900
Average 2004-06	**71,550**	**30,200**	**125,500**	**2,750**	**40,100**

Source: Lewis et al 2008, Table 20, p.34. Note: Loads are in kilograms

Estimates of load contributions from catchment modelling results for the Cleveland Bay plant are shown by sub basin, basin and Black Ross WQIP area in Table 7.16.

A summary of proposed upgrade works to Townsville's wastewater treatment network is provided in Appendix B and the Options, Costs and Benefits background report (Gunn and Manning 2009).

Cleveland Bay WWTP discharge was initially treated as a direct input to Cleveland Bay rather than an end of catchment load. The load contribution to Cleveland Bay was calculated by adding the discharge loads for the Ross River, Stuart / Sandfly Creeks (estimate) and Alligator Creek and expressing the point source input as a proportion of the aggregated loads i.e. point source load divided by the combined waterway loads plus the point source load, to give a Cleveland Bay receiving waters load contribution.

Calculations were based on 2004 to 2006 discharge figures. Post upgrade contributions to Cleveland Bay were calculated using the same discharge rate and the nutrient concentrations measured after the upgrade. Results of the pre and post-upgrade calculations are displayed in Table 7.15.

Table 7.15 Alternate Cleveland Bay Load Calculations

Nutrient/Year	Alligator	Stuart	Ross	CBay WWTP	Total	Percentage
TN 2006/07 (Pre)	9,440	6,560	173,000	126,000	315,000	40
TN 2007/08 (Post)	9,440	4,300	149,700	27,300	190,740	14
TP 2006/07 (Pre)	1,540	960	20,800	40,000	63,300	63
TP 2007/08 (Post)	1,540	940	22,300	5,900	30,680	19

Source: Lewis et al 2008 and BMT WBM initial catchment modelling results

7.3.4 Modelled WWTP Contributions

As wastewater treatment plants (WWTP) are a significant point source contributor to end of catchment pollutant loads catchment modelling was also used to calculate the relative contribution from point sources. This is particularly relevant given the upgrades to WWTPs underway. Pre and post upgrade scenarios were modelled with the final upgrade scenario (2012) modelled based on the 2008 report prepared for Townsville City Council (Maunsell 2008). The base case (2007) modelling results for sub basins with contributions from WWTPs are shown in Table 7.16 along with total modelled loads for the Black and Ross Basins and the WQIP area. All other sub basins do not have any WWTP discharge and their load figures are therefore unchanged (see Table 6.4).

Table 7.16 2007 Modelled Load Summary by WQIP Sub Basin With WWTPs

Sub Basin		Area	Flow	TSS	TN	TP
	No.	Hectares	ML/Year	kg/Year	kg/Year	kg/Year
Black River	4	29,539	114,396	7,190,500	70,591	11,063
Black Basin total		102,861	643,925	17,107,149	293,708	29,095
Bohle River	5	33,194	131,708	9,289,250	191,753	29,795
Stuart Creek	8	11,024	47,483	1,649,800	61,320	20,039
Ross Basin total		159,882	534,608	25,348,520	429,232	74,391
Black Ross Total		267,559	1,205,923	42,797,652	729,223	104,429

Note: These figures include the upgrade to Cleveland Bay WWTP and are therefore post 2006/07 wet season. The Black Ross total includes the total for Magnetic Island sub basin. For pre upgrade loads see Appendix F

A comparison of sub basin loads with and without WWTPs is provided in Table 7.18 along with pre and post upgrade values for the Cleveland Bay WWTP.

Based on the proposed upgrades in the *Wastewater Upgrade Program Planning Report* (Maunsell Australia 2008), population growth figures and projected resulting pollutant discharge rates over time, estimates of the discharge loads of nitrogen and phosphorus from all WWTPs in the Black Ross WQIP area were made using catchment modelling (WaterCAST). Point source load change over time associated with WWTPs is shown in Table 7.17.

Table 7.17 Point Source Loads Over Time

Years	Total Flows (ML/day)	Total TSS loads (t/yr)	Total TN loads (t/yr)	Total TP loads (t/yr)
Pre 2006	41.54	91.03	296.32	72.08
2008 [1]	41.54	91.03	157.41	33.83
2010	43.24	94.77	163.29	36.68
2012 [2]	48.43	106.14	70.02	23.92
2021 [3]	55.65	121.97	92.10	28.67
2045	74.43	163.12	124.64	37.06

Note: Loads are in tonnes per year. Flows are daily discharge flows based on expected population growth. [1]Cleveland Bay WWTP upgrades are in place by 2008. [2]All other WWTP upgrades are assumed to be in place by 2012. Upgrades are based on reduction of nutrient concentrations. [3] Nutrient discharge increases after 2012 due to population increase

Increasing population and subsequent increase in point source discharge means that the relative contribution from point sources will increase over time (post 2012) if no other reduction measures are introduced.

Table 7.18 Load Comparisons With and Without WWTPs

Sub Basin	Flow	TSS	TN	TP
	ML/Year	kg/Year	kg/Year	kg/Year
Crystal Creek	239,279	5,509,675	90,060	9,376
Rollingstone Creek	144,288	1,601,949	40,420	4,018
Bluewater Creek	145,599	2,805,025	92,637	4,637
Black River (with WWTP)	114,318	7,190,500	70,591	11,063
Black River (no WWTP)	114,318	7,190,500	69,131	10,016
		Difference	1,460 (2.1%)	1,047 (9.5%)
Black Basin	643,484	17,107,149	293,708	29,095
Black Basin	643,484	17,107,149	292,248	28,047
		Difference	1,460 (0.5%)	1,047 (3.6%)
Bohle River (with WWTP)	131,618	9,289,250	191,753	29,795
Bohle River (no WWTP)	131,618	9,289,250	78,275	14,136
		Difference	113,478 (59.2%)	15,659 (52.6%)
Lower Ross River	53,677	4,202,975	33,097	6,976
Upper Ross River	196,735	8,103,000	100,375	12,775
Stuart Creek (with WWTP)	47,450	1,649,800	61,320	20,039
Stuart Creek (no WWTP)	47,450	1,649,800	18,944	2,957
		Difference	42,376 (69%)	17,082 (85%)
Alligator Creek	104,762	2,103,495	42,687	4,807
(with WWTP) **Ross Basin**	534,242	25,348,520	429,232	74,391
(no WWTP) **Ross Basin**	534,242	25,348,520	273,378	41,651
		Difference	155,854 (36.3%)	32,740 (44%)
Magnetic Island	27,371	341,983	6,282	943
(with WWTP) **Black Ross Total**	1,205,098	42,797,652	729,223	104,429
(no WWTP) **Black Ross Total**	1,205,098	42,797,652	571,908	70,641
		Difference	157,315 (21.6%)	33,788 (32.5%)
Pre Cleveland Bay WWTP Upgrade				
Stuart Creek	47,450	1,649,800	100,375	58,400
		Difference	39,055 (38.9%)	38,461 (65.9%)
		Difference	81,431 (81.1%)	55,443 (94.9%)
Ross Basin	534,242	25,348,520	567,932	112,753
		Difference	39,055 (6.9%)	38,461 (34.1%)
		Difference	81,431 (19%)	55,443 (74.5%)
Black Ross Total	1,205,098	42,797,652	867,922	142,791
			39,055 (4.5%)	38,461 (26.9%)
		Difference	81,431 (11.2%)	55,443 (53.1%)

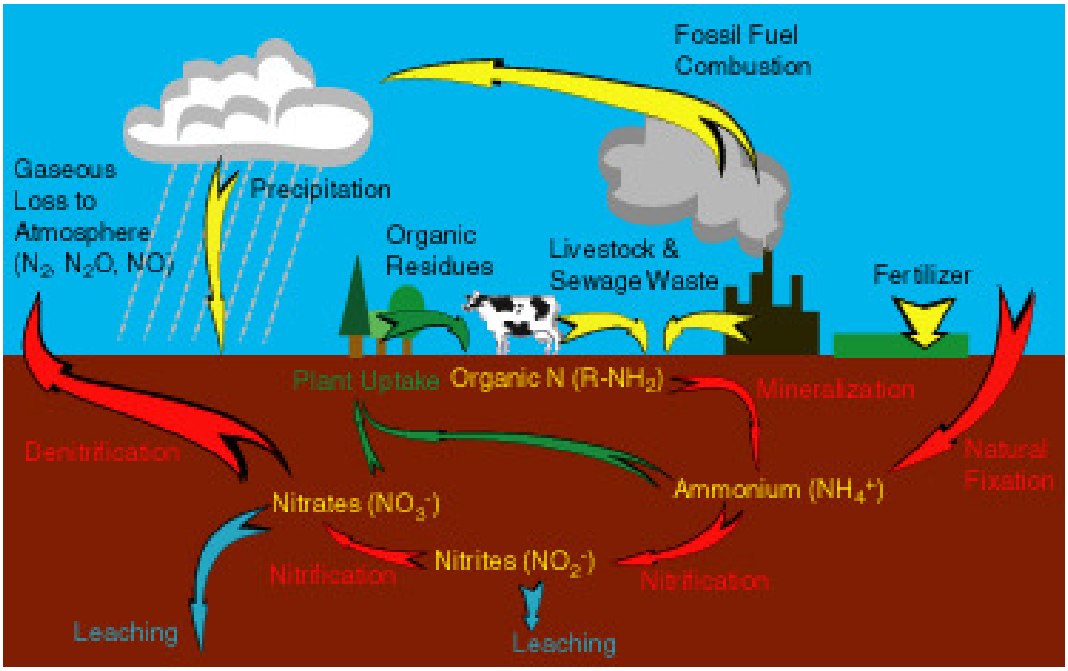
Notes: Uncoloured rows are load estimates for 2007 with WWTPs i.e. with Cleveland Bay upgrade. Tan shading are figures without WWTP loads and the difference relates to the 2007 load estimates. Blue rows are loads prior to Cleveland Bay WWTP upgrade and only relate to the Stuart Creek sub basin. Differences are from pre upgrade to post upgrade (2007 with WWTPs). Yellow difference is between pre Cleveland Bay upgrade and no WWTPs and again is only relevant for the Stuart Creek sub basin.

Further information on modelled point source pollutants can be found in the *Black Ross Water Quality Improvement Plan Options, Costs and Benefits Report* (Gunn and Manning 2009).

7.4 Atmospheric Deposition

The principal pollutants by volume associated with atmospheric deposition are particulate matter and oxides of nitrogen. Background levels of both these pollutants are not known specifically for the Townsville area and current air quality monitoring is principally associated with airborne concentrations as a function of human health. Contributions from atmospheric deposition of both particulate matter and oxides of nitrogen are a combination of natural background levels and any additional contributions from human sources. This is illustrated for the nitrogen cycle in Figure 7.3 (see section 4 for more detail on potential sources of atmospheric deposition).

Figure 7.3 The Human Modified Nitrogen Cycle



(Source: http://www.visionlearning.com/library/module_viewer2.php?mid=98&l=&let1=Ear)

Notes: Yellow arrows indicate human sources of nitrogen to the environment. Red arrows indicate microbial transformations of nitrogen. Blue arrows indicate physical forces acting on nitrogen. And green arrows indicate natural, non-microbial processes affecting the form and fate of nitrogen.

The main sources of particulate matter in Townsville, above background levels, are industrial facilities loading and unloading metal ores and quarry products, industrial facilities burning fossil fuels, motor vehicles, roadways, and construction sites. Dispersion and deposition of particulate matter is generally confined to the area around the generation site with finer particles drifting greater distances.

An estimate of average atmospheric deposition of particulate matter from all sources for the Townsville urban footprint (250 square kilometres) is 15 kg/ha/year (see section 4.3.4). This is equivalent to a depth of 0.0015 millimetres. The average annual contribution of particulate matter from atmospheric deposition to the sediment load of waterways in the Black Ross WQIP area is considered to be minimal across the region although it may be locally significant at Townsville Port and in close proximity to quarrying and earthmoving operations.

The main nitrogen dioxide (NO_2) source is a by-product of the combustion of fossil fuels from industrial facilities and motor vehicles. Background levels of atmospheric nitrogen deposition are in the order of 2-3 kg/ha/year (see section 4.2.2). Maximum potential deposition of NO_2 from human sources is estimated to be approximately 5-6 kg/ha/year to give a total NO_2 deposition of 8 kg/ha/yr (see 4.3.1). This is considered to be a significant overestimate and a more realistic figure of 2 kg/ha/year has been adopted for calculating the human induced contribution of atmospheric deposition of nitrogen in the urban footprint.

Atmospheric deposition of phosphorus, heavy metals, pesticides and sulphur dioxide is not considered to contribute significantly to water quality issues (see sections 4.3.3, 4.3.5, 4.3.6 and 4.3.7).

7.5 Relative Contributions Summary

Relative contributions of sediment and nutrients to the end of catchment and receiving waters loads from the Black Ross WQIP area are summarised below.

7.5.1 Point Sources

According to the results from event monitoring (Lewis et al 2008) and subsequent calculations by the authors of this report, point sources are significant contributors of nutrient loads to Halifax Bay from the Bohle and Black catchments, and to Cleveland Bay from Stuart Creek sub basin, as a result of discharges to water from wastewater treatment plants.

The estimated contributions from point sources to the end of catchment nutrient loads based on ACTFR event monitoring and calculations are:

- Black River - (from Mt Low WWTP) ~3% of TN (1.9 tonnes) and ~8% of TP (1.3 tonnes);
- Bohle River - (from Condon, Deeragun and Mt St John WWTPs) ~60% of TN (131 tonnes) and ~50% of TP (21 tonnes);
- Sandfly Creek (Stuart Creek sub basin) / Cleveland Bay - (Cleveland Bay WWTP) 126 tonnes of total nitrogen and 40 tonnes of total phosphorus (these figures are pre-upgrade and results cannot be considered as an indicative current contribution).

Results from catchment modelling are displayed in Table 7.19. Estimated contributions from point sources to the end of catchment nutrient loads based on the modelled results are:

- Black River - (from Mt Low WWTP) ~2% of TN (1.4 tonnes) and ~9% of TP (1.0 tonnes);
- Bohle River - (from Condon, Deeragun and Mt St John WWTPs) ~59% of TN (113 tonnes) and ~53% of TP (16 tonnes);
- Sandfly Creek / Stuart Creek - (Cleveland Bay WWTP) ~69% TN (42 tonnes) and ~85% of TP (17 tonnes)

Table 7.19 WWTP Contributions from Modelled Results

Sub Basin	Total N (kg/yr)		Difference		Total P (kg/yr)		Difference	
	With	Without	kg/yr	%	With	Without	kg/yr	%
Black River	70,591	69,178	1,413	2.0	11,063	10,022	1,041	9.4
Black Basin total	293,861	292,448	1,413	0.5	29,108	28,067	1,041	3.6
Bohle River	191,753	78,328	113,425	59.2	29,795	14,146	15,649	52.5
Stuart Creek	61,320	18,956	42,364	69.1	20,039	2,959	17,080	85.2
Ross Basin total	429,353	273,565	155,788	36.3	74,409	41,680	32,729	44.0
Black Ross Total	729,500	572,299	157,201	21.5	104,461	70,690	33,771	32.3

Note: Nutrient load contribution totals for basins and the Black Ross WQIP area are from all sources (point source and diffuse) and all sub basins. Only the sub basins with contributions from WWTPs have been included in the table. "With" is the total for sub basins with WWTP discharge figures included and "Without" is diffuse source loads only. Percentage difference is the kilogram difference as a percentage of the total end of catchment load with WWTP discharge.

Relative contributions for the Black River and Bohle River catchments are similar for the ACTFR and modelled results while the results for the Cleveland Bay WWTP cannot be readily compared due to the ACTFR results being pre-upgrade. In reality the Cleveland Bay WWTP discharges directly into Cleveland Bay and is not a true contributor to the Stuart Creek sub basin end of catchment loads.

7.5.2 Atmospheric Deposition

There are two components to atmospheric deposition i.e. direct deposition to water and deposition to land.

Atmospheric deposition to land as a water quality issue is not directly measurable as the processes associated with nutrient uptake and cycling as well as intra catchment erosion and sedimentation make the estimation of a contribution to catchment loads extremely difficult and potentially redundant. Atmospheric deposition to land is therefore treated as an integral component of the terrestrial run-off contribution and is accounted for through the pollutant coefficients of the different land uses.

Deposition to water is a direct contribution and has been calculated by determining the area of water in each catchment and multiplying this by the deposition rate to give a load that can be used to determine the overall contribution in terms of end of catchment loads.

The sub basins have been divided into urban and non-urban and separate deposition rates applied to reflect the assumed level of atmospheric deposition i.e. background levels only for non-urban areas. In Table 7.20 the modelled end of catchment loads have been used to calculate the atmospheric deposition contribution for each sub basin.

Table 7.20 Atmospheric Deposition

Sub basin	Area (ha)	Water (ha)	PM_{10} (kg)	%	TN (kg)	%	TP (kg)	%
Crystal Creek	22,629	268 [1]	2,144	0.04	536	0.59	54	0.58
Rollingstone Ck	21,822	110 [0.5]	880	0.05	220	0.54	22	0.55
Bluewater Ck	28,872	426 [1.5]	3,408	0.12	852	0.92	85	1.83
Black River	29,539	513 [1.7]	4,104	0.06	1,026	1.48	103	1.03
Bohle River	33,194	532 [1.7]	7,980	0.09	2,128	2.72	213	1.51
Ross River (btd)	13,244	754 [5.6]	11,310	0.27	3,016	9.11	302	4.33
Ross River (atd)	74,929	4,372 [5.8]	34,976	0.43	8,744	8.71	874	6.84
Stuart Creek	11,024	1,047 [10]	15,705	0.95	4,188	22.09	419	14.16
Alligator Creek	27,490	1,798 [6.8]	14,384	0.68	3,596	8.42	360	7.48
Magnetic Island	4,815	0	0		0		0	
Totals	267,558	9,820 [3.7]	94,891	0.22	24,306	4.25	2,432	3.44

Notes: Atmospheric deposition rates used: Urban footprint (Bohle River, Lower Ross River, and Stuart Creek sub basins) - PM_{10} 15 kg/ha/year, N 4kg/ha/yr (2kg/ha/yr background and 2kg/ha/yr anthropogenic), and P 0.4 kg/ha/year (equivalent to double the figure from a South Australian study). Non-urban (all other sub basins) footprint - PM_{10} 8 kg/ha/year, N 2kg/ha/yr and P 0.2 kg/ha/year. End of river load figures to calculate % contributions were sourced from BMT WBM modelled results. Figures in [brackets] in the Water column are the percentage of the sub basin defined as water through land use categories. Totals are for the Black Ross WQIP area

As can be seen the percentage contribution of atmospheric deposition for the modelled end of catchment loads is variable across the region and directly related to the area of water defined for the sub basin. It should be noted that the contribution assigned to atmospheric deposition is an estimate only and there is no monitoring information available to confirm the estimate.

It should be noted also that the there was considerable variation between the estimations obtained using ACTFR event monitoring data and the catchment modelling. It appears that the main difference was associated with the end of catchment load estimates, which were in turn dependent on estimations of flow volume. This is not an indication that the modelling is more accurate but rather a reflection on the need to obtain better volumetric data associated with water quality monitoring to enable improved calculation of end of catchment loads that are being discharged to the marine environment.

7.5.3 Land Use Contributions

Pollutant contributions from land use are often expressed as an areal load i.e. kilograms per hectare per year. This is useful for determining relative contributions from different land uses and providing input figures for catchment models however it does not necessarily reflect actual catchment condition and health.

The most influential factors in pollutant export to waterways from terrestrial sources are percentage ground cover, soil/land disturbance, soil type, slope and proximity to waterways. It is important to note that erosion is the main initial mobiliser of water pollutants from terrestrial sources however the transport of sediment and nutrients in run-off is another associated function, which determines the actual amount of pollutants that enter receiving waters.

Figure 7.4 Expanding Urban Areas are Sediment Sources

Source: J Gunn (CCI\Images\20080703 tvl air\enhanced\fairfield waters widesmall)

In the urban context it is the developing areas that contribute the greatest sediment pollutant loads to waterways while the developed urban areas contribute greater relative contributions of nutrients. In the rural context grazing lands contribute greater relative amounts of sediment while intensive agriculture contributes greater relative loads of nutrients.

Land use contributions in the Black Ross WQIP area have been investigated through the event water quality monitoring program undertaken in 2006/07 and 2007/08 by the ACTFR. The results showed the significance of land use classification and the development stage associated with the land use. The relative contributions from the various land uses used for the initial run of Bayesian Belief Network model for the Bohle River catchment are listed in Table 7.21. These figures were adopted for the WaterCAST catchment model as derived from ACTFR event water quality monitoring data.

After a review of the draft outputs from the catchment modelling it was decided that the northern catchments of the Black Basin should be treated differently to the drier southern catchments of the Ross Basin due to the difference in rainfall regime, vegetation and run-off and erosion characteristics. The Paluma Ranges of northern catchments more closely resemble the conditions found in the wet tropics than in the drier Hervey Range of the Ross Basin.

Table 7.21 Relative Pollutant Contribution by Land Use

Landuse	Run-off coefficient	Export rate (kg/ha/yr)			Adopted EMC (mg/L)		
		TSS	TP	TN	TSS	TP	TN
Formal parks	0.32	42.4	0.21	1.29	9	0.05	0.33
Rural residential	0.35	55.9	0.18	1.74	11	0.04	0.43
Traditional residential	0.40	823.0	1.31	3.01	152	0.26	0.64
High density residential	0.44	954.0	1.49	3.29	152	0.26	0.64
Commercial/light industrial	0.51	984.0	1.17	3.75	143	0.19	0.62
Heavy industrial	0.66	1330.0	1.57	4.75	143	0.19	0.62
Bare ground	0.33	4340.0	1.29	7.60	1000	0.32	1.95
Natural areas	0.32	43.3	0.21	1.24	9	0.05	0.33
Forestry	0.32	37.8	0.19	1.30	9	0.05	0.33
Grazing	0.32	1180.0	0.62	3.09	260	0.15	0.80
Intensive agriculture	0.32	1390.0	1.30	7.11	300	0.32	1.95
Mining	0.35	692.0	0.83	2.52	143	0.19	0.62

Source: BMT WBM Internal memo 13 November 2008. Note: Bare ground is the default landuse applied to developing areas.

Data from the Black Ross event monitoring was combined with event monitoring data from the Tully catchment to provide a set of ‘dry’ and ‘wet’ catchment EMC values (event mean concentrations) for grazing and green space. The EMCs for the other main land use categories delineated during the event monitoring were also recalculated and nitrogen and phosphorus species were separated. The amended EMC values are shown in Table 7.22.

Table 7.22 Recalculated EMC Values

Landuse	TSS	NH_4	NOx	PN	DON	TN	FRP	PP	DOP	TP
	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Dry savanna grazing	130	15	105	175	240	535	29	70	11	110
Green space (dry)	25	8	50	125	200	383	25	20	6	51
Wet Tropics grazing	25	18	500	90	160	268	7	14	6	27
Green space (wet)	4	8	50	45	90	193	3	8	4	15
Urban/peri-urban										
Rural residential	35	10	149	114	228	501	26	20	10	56
Established urban	20	29	127	221	364	741	152	69	60	281
Light industrial	57	17	102	313	394	826	195	123	129	447
Urban industrial	129	7	94	210	313	624	104	111	15	230
Developing urban¹	793	38	122	190	397	747	130	128	19	277
Developing urban²	11,142									

Source: Unpublished data (Stephen Lewis (ACTFR) 2009). Notes: ¹ is coastal plains and ² is hillslopes. Highest values are highlighted with the exception of Developing urban² which is an anomalous value and not considered to be a ‘typical’ average figure.

7.5.4 Overall contributions

Relative land use contribution figures were used in catchment and water quality modelling to obtain end of catchment loads. The end of catchment loads were then used as the base figures to calculate contributions from atmospheric deposition and were combined with discharge data from wastewater treatment plants to calculate contributions from point sources. The overall relative contribution of pollutants from all sources to end of catchment loads for the Black Ross WQIP area are displayed in Table 7.23.

Table 7.23 Relative Pollutant Contributions

Sub Basin Pollutant Source	TSS	TN	TP
	kg/year	kg/year	kg/year
Crystal Creek-atmospheric deposition	2,144	536	54
Crystal Creek- atmospheric deposition %	0.04	0.59	0.58
Crystal Creek-terrestrial run off	5,511,305	89,586	9,329
Crystal Creek- terrestrial run off %	99.96	99.41	99.42
Crystal Creek-diffuse total	5,513,449	90,122	9,383
Rollingstone Creek- atmospheric deposition	880	220	22
Rollingstone Creek- atmospheric deposition %	0.05	0.54	0.55
Rollingstone Creek-terrestrial run off	1,602,166	40,228	3,999
Rollingstone Creek- terrestrial run off %	99.95	99.46	99.45
Rollingstone Creek-diffuse total	1,603,046	40,448	4,021
Bluewater Creek- atmospheric deposition	3,408	852	85
Bluewater Creek- atmospheric deposition %	0.12	0.92	1.83
Bluewater Creek-terrestrial run off	2,803,538	91,848	4,556
Bluewater Creek- terrestrial run off %	99.88	99.08	98.17
Bluewater Creek-diffuse total	2,806,946	92,700	4,641
Black River- atmospheric deposition	4,104	1,026	103
Black River- atmospheric deposition %	0.06	1.45	0.93
Black River-terrestrial run off	7,191,321	68,152	9,919
Black River- terrestrial run off %	99.94	96.48	89.61
Black River-diffuse total	7,195,425	69,178	10,022
Black River-wastewater treatment plant		1,460	1,047
Black River- wastewater treatment plant %		2.07	9.46
Black River-diffuse and point sources	7,195,425	70,638	11,069
Black Basin atmospheric deposition **total**	10,536	2,634	264
Black Basin atmospheric deposition **%**	0.06	0.90	0.91
Black Basin terrestrial run off total	17,108,330	289,814	27,803
Black Basin terrestrial run off %	99.94	98.61	95.50
Black Basin diffuse total	17,118,866	292,448	28,067
Black Basin wastewater treatment plant **total**		1,460	1,047
Black Basin wastewater treatment plant **%**		0.50	3.60
Black Basin diffuse and point sources	17,118,866	293,908	29,114
Bohle River- atmospheric deposition	7,980	2,128	213
Bohle River- atmospheric deposition %	0.09	1.11	0.71
Bohle River-terrestrial run off	9,287,633	76,200	13,933
Bohle River- terrestrial run off %	99.91	39.73	46.75
Bohle River-diffuse total	9,295,613	78,328	14,146
Bohle River- wastewater treatment plant		113,478	15,659
Bohle River- wastewater treatment plant %		59.16	52.54
Bohle River-diffuse and point sources		191,806	29,805
Lower Ross River- atmospheric deposition	11,310	3,016	302
Lower Ross River- atmospheric deposition %	0.27	9.11	4.33
Lower Ross River-terrestrial run off	4,194,544	30,104	6,679
Lower Ross River- terrestrial run off %	99.73	90.89	95.67
Lower Ross River-diffuse total	4,205,854	33,120	6,981

Upper Ross River- atmospheric deposition	34,976	8,744	874
Upper Ross River- atmospheric deposition %	0.43	8.71	6.84
Upper Ross River-terrestrial run off	8,073,574	91,700	11,910
Upper Ross River- terrestrial run off %	99.57	91.29	93.16
Upper Ross River-diffuse total	8,108,550	100,444	12,784
Stuart Creek- atmospheric deposition	15,704	4,188	419
Stuart Creek- atmospheric deposition %	0.95	6.83	2.09
Stuart Creek-terrestrial run off	1,635,226	14,768	2,540
Stuart Creek- terrestrial run off %	99.05	24.08	12.67
Stuart Creek- wastewater treatment plant		42,376	17,082
Stuart Creek- wastewater treatment plant %		69.09	85.24
Stuart Creek-diffuse total		18,956	2,959
Stuart Creek-diffuse and point sources	1,650,930	61,332	20,041
Alligator Creek- atmospheric deposition	14,384	3,596	360
Alligator Creek- atmospheric deposition %	0.68	8.42	7.48
Alligator Creek-terrestrial run off	2,090,552	39,120	4,451
Alligator Creek- terrestrial run off %	99.32	91.58	92.52
Alligator Creek-diffuse total	2,104,936	42,716	4,811
Ross Basin atmospheric deposition **total**	84,354	21,672	2,168
Ross Basin atmospheric deposition **%**	0.33	5.05	2.91
Ross Basin terrestrial run off total	25,281,529	251,892	39,513
Ross Basin terrestrial run off %	99.67	58.66	53.09
Ross Basin diffuse total		273,565	41,680
Ross Basin wastewater treatment plant **total**		155,854	32,741
Ross Basin wastewater treatment plant **%**		36.29	43.99
Ross Basin diffuse and point sources total	25,365,882	429,419	74,421
Magnetic Island-diffuse total	342,217	6,286	944
Black Ross atmospheric deposition **total**	94,890	24,306	2,432
Black Ross atmospheric deposition **%**	0.22	3.33	2.33
Black Ross terrestrial run off **total**	42,389,859	541,706	67,316
Black Ross terrestrial run off **%**	98.98	74.25	64.43
Black Ross diffuse **total**		572,299	70,690
Black Ross wastewater treatment plant **total**		157,314	33,788
Black Ross wastewater treatment plant **%**		21.56	32.34
Black Ross Diffuse and Point Sources Total	42,826,965	729,613	104,478

Note: Based on an annual average discharge of 1,205,923 ML. Diffuse total is the sum of terrestrial run off and atmospheric deposition. WWTP is the contribution from wastewater treatment plants and is applicable to the Black River, Bohle River and Stuart Creek sub basins only.

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Appendix A

NPI Extracts

Appendix A - NPI Extracts

General information

Emissions are for all destinations i.e. air, land and water. All emissions have been rounded to two significant figures. Note that totals may differ from the sum of the individual amounts because of this rounding. Substance emissions are ranked on a scale of 1-100: 1=lowest; 100=highest. Rankings are shown as: ◔ =0-25; ◑ =26-50; ◕ =51-75; ● =76-100. Actual rankings are shown in brackets [ ].

The NPI reports on emissions of chemical substances and where and from what sources they are generated. The ultimate fate of these substances and therefore exposure to humans and the environment as pollution cannot be determined from the NPI. Numerous factors such as height of emission (high stacks versus ground level vehicle exhausts), nature of receiving environment, chemical reactivity of the substance and prevailing meteorological conditions determine whether an emission is felt as ground level pollution. Since NPI does not attempt to collect these parameters, the data can only reflect pollutant generation at source.

Facility Ranking: Individual substance emissions from each facility are compared against the maximum emission of that substance from all of the facilities reported on the NPI, on a scale of 1-100 (from lowest to highest) - if the total emission of a substance is 10% of the maximum reported to the NPI, the emission ranking would be **10**; if the total emission is 95% of the maximum, the ranking would be **95**. A score of 100 means that the facility is the highest facility emitter of that substance - in some cases many facilities may score 100, due to rounding. Top substances are those substance emissions that are ranked highest for any individual facility.

For example, a small rural sewage treatment plant may report a very small Total Nitrogen emission in comparison with a large metropolitan facility. If the rural facility reported an emission that is 7% of the maximum Total Nitrogen emission in Australia it would attract a ranking of 7. This ranking tells you that there are many other facilities that have much larger emissions of Total nitrogen. On the other hand a metropolitan sewage treatment plant may have a very large Total Nitrogen emission and therefore attracts a ranking of 100 for this substance. This only means that this particular facility has approximately the largest individual emission of that substance in Australia.

List of facilities, emission pathway/s and NPI report years

Facility	**Condon Sewage Treatment Plant p.6**
Address	Lot 52 Bowhunters Road Condon Qld 4815
Main activities	Sewage treatment by activated sludge (extended aeration) to a secondary standard
Emissions to	Water and Land
NPI Report Years	2005/2006, 2002/2003 and 1999/2000

Facility	**Deeragun Sewage Treatment Plant p.7**
Address	Kayleen Court Deeragun Qld 4818
Main activities	Sewage treatment by activated sludge (extended aeration) to a secondary standard
Emissions to	Land and water
NPI Report Years	2005/2006, 2002/2003 and 1999/2000

Facility	**Mt Low Sewage Treatment Plant p.8**
Address	Brabon Road Mt Low Qld 4818
Main activities	Sewage treatment by activated sludge (extended aeration) to a secondary standard
Emissions to	Land and water
NPI Report Years	2005/2006, 2002/2003 and 1999/2000

Facility	**Cleveland Bay Sewage Treatment Plant p.9**
Address	Cleveland Bay Townsville Qld 4810
Main activities	Treatment of wastewater as part of wastewater service provided to TCC declared sewage treatment areas.
Emissions to	Air, Land and water
NPI Report Years	2005/2006, 2003/2004 and 2001/2002

Facility	**Mt St John Sewage Treatment Plant p.10**
Address	Mt St John Road Townsville Qld 4818
Main activities	Treatment of wastewater as part of wastewater service provided to TCC declared sewage treatment areas.
Emissions to	Air, Land and water
NPI Report Years	2005/2006, 2003/2004 and 2001/2002

Facility	**Douglas Water Treatment Plant p.11**
Address	Upper Ross River Road Douglas Qld 4814
Main activities	Treatment of water for municipal purposes.
Emissions to	Air
NPI Report Years	2005/2006

Facility	Townsville Power Station pp.12-13
Address	Lot 1 Greenvale Street Yabulu QLD 4818
Main activities	Power generation
Emissions to	Air
NPI Report Years	2005/2006, 2003/2004 and 2001/2002

Facility	Townsville Terminal (Shell Co of Aust Ltd) pp.14-15
Address	Hubert Street Townsville Qld 4810
Main activities	Hydrocarbon storage and distribution Bitumen Blowing
Emissions to	Air
NPI Report Years	2005/2006, 2002/2003 and 1999/2000

Facility	Townsville Airport Fuelling Service (Shell) p.16
Address	Stinson Avenue Garbutt Qld 4814
Main activities	Aircraft refuelling
Emissions to	Air
NPI Report Years	2005/2006

Facility	Sun Metals Zinc Refinery pp.17-18
Address	1 Zinc Avenue Stuart QLD 4811
Main activities	Zinc refinery processing up to 400,000 tonnes per annum of zinc concentrates to produce 190,000 tonnes zinc metal and 350,000 tonnes sulphuric acid.
Emissions to	Air and Land
NPI Report Years	2005/2006, 2003/2004 and 2001/2002

Facility	Southern Cross Fertilisers - Townsville Port Facility p.19
Address	Centenary Drive Port of Townsville Qld 4810
Main activities	Fertiliser and sulphur storage
Emissions to	Air
NPI Report Years	2005/2006

Facility	Queensland Terminals p.20
Address	Benwell Road South Townsville Qld 4810
Main activities	Sulphuric Acid Storage and Transfers
Emissions to	Air
NPI Report Years	2005/2006

Facility	Stuart Railway Facility p.21
Address	Jurekey Street Stuart Qld 4811
Main activities	Railway rollingstock maintenance, servicing and fuelling
Emissions to	Air
NPI Report Years	2005/2006

Facility	QNI Yabulu Refinery - Materials Handing Facility p.22
Address	Berth 2 Port of Townsville Qld 4810
Main activities	Unloading of nickel ore from vessels to train carriages for transport to the QNI Yabulu Refinery
Emissions to	Air and water
NPI Report Years	2005/2006, 2002/2003 and 1999/2000

Facility	**QNI Townsville Port Bulk Fuel Facility p.23**
Address	Herbert Street South Townsville Qld 4810
Main activities	Storage & handling of bulk petroleum fuel
Emissions to	Air
NPI Report Years	2005/2006

Facility	**QNI - Yabulu Refinery pp. 24-26**
Address	1 Greenvale Street Yabulu QLD 4818
Main activities	Processing of ore through roasting, ammonia leach and solvent extraction processes to produce high grade nickel and cobalt products.
Emissions to	Air and water
NPI Report Years	2005/2006, 2002/2003 and 1999/2000

Facility	**Northern shipping and Stevedoring - Townsville Port p.27**
Address	Suter Pier Wharf Townsville 4810
Main activities	Stevedoring, i.e. unloading or loading ships. Products are handled in containers, bulk bags and in bulk form. Equipment used in the operation includes shore cranes, ships cranes, forklifts, excavators, skid steer loaders, end loaders and hoppers
Emissions to	Air
NPI Report Years	2005/2006

Facility	**Hanson Townsville Quarry p.28**
Address	Flinders Highway Townsville 4810
Main activities	Quarrying
Emissions to	Air
NPI Report Years	2005/2006

Facility	**Bohle Quarry p.29**
Address	Ingham Road Bohle 4818
Main activities	Quarry materials sand and gravel producers
Emissions to	Air
NPI Report Years	2005/2006

Facility	**Xstrata Copper - Townsville Port Operations pp.30-31**
Address	Berth 7 Lennon Drive Townsville 4810
Main activities	Stockpilig and shiploading of mineral concentrates
Emissions to	Air and water
NPI Report Years	2005/2006, 2002/2003 and 1999/2000

Facility	**Xstrata Copper - Townsville Operations pp.32-34**
Address	Hunter Street Stuart 4811
Main activities	Electro-refining of copper
Emissions to	Air, Land and water
NPI Report Years	2005/2006, 2002/2003 and 1999/2000

Facility	**BP Australia - Townsville Terminal pp.35-36**
Address	Hubert Street South Townsville Qld 4810
Main activities	Bulk Petroleum Storage Facility
Emissions to	Air, Land and water
NPI Report Years	2005/2006, 2002/2003 and 1999/2000

Facility	**Air BP Townsville p.37**
Address	Airside GA Area Townsville Airport 4810
Main activities	Bulk petroleum storage facility
Emissions to	Air
NPI Report Years	2005/2006

Facility	**BOC Townsville p.38**
Address	384 Ingham Road Garbutt 4814
Main activities	Stores gas, fills cylinders and distributes product.
Emissions to	Air
NPI Report Years	2005/2006

Facility	**Cannington Port Facility pp. 39-40**
Address	Townsville Port Townsville 4810
Main activities	Storage and Loading of Lead and Zinc Concentrates
Emissions to	Air and water
NPI Report Years	2005/2006, 2002/2003 and 1999/2000

Facility	**Townsville Abattoir pp. 41-44**
Address	Bruce Highway Aitkenvale via Townsville 4814
Main activities	Meat Processing
Emissions to	Air
NPI Report Years	2005/2006, 2002/2003 and 1999/2000

Facility	**Industrial Galvanizers North Queensland p.45**
Address	9 Commercial Avenue Bohle 4818
Main activities	Hot Dip Galvanizing
Emissions to	Air
NPI Report Years	2005/2006

Facility	**Origin Energy Mt Stuart p.46**
Address	Cnr Hunter Street and Bruce Highway Stuart 4811
Main activities	Peak Power Generation from Fossil Fuels
Emissions to	Air
NPI Report Years	2005/2006

Townsville NPI Point Source Emissions – Summary by facility

Facility Details

Facility	**Condon Sewage Treatment Plant**
Address	Lot 52 Bowhunters Road Condon Qld 4815
Main activities	Sewage treatment by activated sludge (extended aeration) to a secondary standard
Primary ANZSIC Industry Class	Sewerage and Drainage Services
ANZSIC Industry Group	Water Supply, Sewerage and Drainage Services
Cleaner production activities	A4. Modified process, equipment, layout, or piping

Emissions (2005/06)

		Air		Land		Water		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**kg**	**%**	**Ranking**
Chlorine	1,400	5.9	0.4	940	67	410	29	Low -2
Total Nitrogen	4,900			3400	69	1500	31	Low –1
Total Phosphorus	9,600			6600	69	3000	31	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=5082

Emissions (2002/03)

		Land		Water		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**Ranking**
Ammonia (total)	28,000	20,000	71.4	6,200	22.1	Low - 1
Chlorine	1,200	860	71.7	360	30	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;loc_type=state;loc_state=QLD;year=2003; jur_fac_id=5082#Emissions

Emissions (1999/2000)

		Water		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Total Nitrogen	3,400	3,400	100	Low –1
Total Phosphorus	2,700	2,700	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;loc_type=state;loc_state=QLD;year=2000;jur_fac_id=5082#Emissions

Facility Details

Facility	Deeragun Sewage Treatment Plant
Address	Kayleen Court Deeragun Qld 4818
Main activities	Sewage treatment by activated sludge (extended aeration) to a secondary standard
Primary ANZSIC Industry Class	Sewerage and Drainage Services
ANZSIC Industry Group	Water Supply, Sewerage and Drainage Services
Cleaner production activities	None reported

Emissions (2005/06)

		Land		Water		
Substance	**Total (kg)**	**Kg**	**%**	**kg**	**%**	**Ranking**
Chlorine	300	7	2.3	300	100	Low -1
Total Nitrogen	4,300	160	3.7	4,100	95.3	Low –1
Total Phosphorus	2,000	43	2.2	1,900	95	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=5083

Emissions (2002/03)

		Land		Water		
Substance	**Total (kg)**	**Kg**	**%**	**kg**	**%**	**Ranking**
Chlorine	210	29	13.8	190	90.5	Low -1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;loc_type=state;loc_state=QLD;year=2003;jur_fac_id=5083#Emissions

Emissions (1999/2000)

		Land		Water		
Substance	**Total (kg)**	**Kg**	**%**	**kg**	**%**	**Ranking**
Total Nitrogen	1,700			1,700	100	Low –1
Total Phosphorus	1,400			1,400	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;loc_type=state;loc_state=QLD;year=2000;jur_fac_id=5083#Emissions

Facility Details

Facility	**Mt Low Sewage Treatment Plant**
Address	Brabon Road Mt Low Qld 4818
Main activities	Sewage treatment by activated sludge (extended aeration) to a secondary standard
Primary ANZSIC Industry Class	Sewerage and Drainage Services
ANZSIC Industry Group	Water Supply, Sewerage and Drainage Services
Cleaner production activities	None reported

Emissions (2005/06)

		Land		**Water**		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**Ranking**
Chlorine	1,100	1,000	90.9	47	4.3	Low -1
Total Nitrogen	920	420	45.6	500	54.3	Low –1
Total Phosphorus	250			250	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=5084

Emissions (2002/03)

		Land		**Water**		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**Ranking**
Chlorine	110	110	100			Low -1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;loc_type=state;loc_state=QLD;year=2003;jur_fac_id=5084#Emissions

Emissions (1999/2000)

		Land		**Water**		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**Ranking**
Total Nitrogen	1,100			1,100	100	Low –1
Total Phosphorus	450			450	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;loc_type=state;loc_state=QLD;year=2000;jur_fac_id=5084#Emissions

Facility Details

Facility	**Cleveland Bay Sewage Treatment Plant**
Address	Cleveland Bay Townsville Qld 4810
Main activities	Treatment of wastewater as part of wastewater service provided to TCC declared sewage treatment areas.
Primary ANZSIC Industry Class	Sewerage and Drainage Services
ANZSIC Industry Group	Water Supply, Sewerage and Drainage Services
Cleaner production activities	Modified process, equipment, layout, or piping

Emissions (2005/06)

		Land		**Water**		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**Ranking**
Ammonia (total)	110,000	21,000	19.1	92,000	83.6	Low - 3
Hydrogen sulphide	26,000	4,800	18.5	22,000	84.6	Low – 14
Total Nitrogen	140,000			140,000	100	Low – 3
Total Phosphorus	42,000			42,000	100	Low - 4

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=33011

Emissions (2003/04)

		Air		**Land**		**Water**		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**kg**	**%**	**Ranking**
Ammonia (total)	80,000			24,000	30	56,000	70	Low – 2
Hydrogen sulphide	21,000	21,000	100					Low – 10
Total Nitrogen	84,000					84,000	100	Low – 2
Total Phosphorus	29,000					29,000	100	Low - 3

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;loc_type=state;loc_state=QLD;year=2004;jur_fac_id=33011

Emissions (2001/02)

		Water		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Ammonia (total)	89,000	89,000	100	Low – 2
Boron and compounds	2,100	2,100	100	Low – 2
Chlorophenols (di, tri, tetra)	5,200	5,200	100	Low – 18
Hydrogen sulfide	26,000	26,000	100	Low - 2
Manganese and compounds	1,300	1,300	100	Low – 1
Total nitrogen	150,000	150,000	100	Low – 3
Total phosphorous	43,000	43,000	100	Low – 4
Total volatile organic compounds	14,000	14,000	100	Low - 1
Zinc and compounds	2,000	2,000	100	Low - 1

Facility Details

Facility	**Mt St John Sewage Treatment Plant**
Address	Mt St John Road Townsville Qld 4818
Main activities	Treatment of wastewater as part of wastewater service provided to TCC declared sewage treatment areas.
Primary ANZSIC Industry Class	Sewerage and Drainage Services
ANZSIC Industry Group	Water Supply, Sewerage and Drainage Services
Cleaner production activities	Modified process, equipment, layout, or piping

Emissions (2005/06)

		Air		**Land**		**Water**		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**kg**	**%**	**Ranking**
Ammonia (total)	54,000	0.1	<0.1	5,900	10.9	48,000	88.9	Low - 2
Hydrogen sulphide	13,000			1,400	10.8	11,000	84.6	Low – 7
Total Nitrogen	130,000					130,000	100	Low – 3
Total Phosphorus	24,000					24,000	100	Low - 2

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=32872

Emissions (2003/04)

		Air		**Land**		**Water**		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**kg**	**%**	**Ranking**
Ammonia (total)	40,000			6,000	15	34,000	85	Low - 1
Hydrogen sulphide	23,000	12,000	52.2	1,800	7.8	9,900	43	Low – 11
Total Nitrogen	100,000					100,000	100	Low – 2
Total Phosphorus	18,000					18,000	100	Low - 2

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;loc_type=state;loc_state=QLD;year=2004;jur_fac_id=32872

Emissions (2001/02)

		Water		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Ammonia (total)	37,000	37,000	100	Low - 1
Boron and compounds	800	800	100	Low – 1
Chlorophenols (di, tri, tetra)	2,000	2,000	100	Low – 7
Hydrogen sulfide	10,000	10,000	100	Low - 1
Manganese and compounds	500	500	100	Low – 1
Total Nitrogen	120,000	120,000	100	Low – 2
Total Phosphorous	30,000	30,000	100	Low – 3
Total Volatile Organic Compounds	5,300	5,300	100	Low - 1
Zinc and compounds	800	800	100	Low – 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;loc_type=state;loc_state=QLD;year=2002;jur_fac_id=32872

Facility Details

Facility	Douglas Water Treatment Plant
Address	Upper Ross River Road Douglas Qld 4814
Main activities	Treatment of water for municipal purposes.
Primary ANZSIC Industry Class	Water Supply
ANZSIC Industry Group	Water Supply, Sewerage and Drainage Services
Cleaner production activities	None reported

Emissions (2005/06)

		Air		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Chlorine	31,000	31,000	100	Low - 25

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=32994

Facility Details

Facility	Townsville Power Station
Address	Lot 1 Greenvale Street Yabulu QLD 4818
Main activities	Power generation
Primary ANZSIC Industry Class	Electricity Supply
ANZSIC Industry Group	Electricity Supply
Cleaner production activities	Change to coal seam methane during NPI year
Installation of Pollution Control Equipment	E9. Low NOx burner

Emissions (2005/06)

		Air		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Arsenic & compounds	1	1.1	100	Low - 1
Beryllium & compounds	0.065	0.065	100	Low - 1
Cadmium & compounds	5.9	5.9	100	Low - 1
Carbon monoxide	450,000	450,000	100	Low - 1
Chlorine	0.00	0.00	100	Low - 0
Chromium (III) compounds	7.2	7.2	100	Low - 1
Chromium (VI) compounds	0.38	0.38	100	Low - 1
Copper and compounds	4.6	4.6	100	Low - 1
Lead and compounds	3.1	3.1	100	Low - 1
Mercury and compounds	1.4	1.4	100	Low - 1
Nickel and compounds	11	11	100	Low - 1
Oxides of nitrogen	1,800,000	1,800,000	100	Low - 4
Particulate matter 10.0um	41,000	41,000	100	Low - 1
Polychlorinated dioxins and furans	0.00010	0.00010	100	Low - 1
Polycyclic aromatic hydrocarbons	12	12	100	Low - 1
Sulphur dioxide	3,200	3,200	100	Low - 1
Total volatile organic compounds	12,000	12,000	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=32939

Emissions (2003/04)

		Air		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Antimony and compounds	0.3	0.3	100	Low – 1
Arsenic & compounds	0.1	0.1	100	Low – 1
Boron and compounds	0.9	0.9	100	Low – 1
Cadmium & compounds	0.1	0.1	100	Low - 1
Carbon monoxide	650	650	100	Low - 1
Chromium (III) compounds	0.6	0.6	100	Low – 1
Cobalt and compounds	0.1	0.1	100	Low – 1
Copper and compounds	18	18	100	Low - 1
Lead and compounds	0.8	0.8	100	Low - 1
Magnesium oxide fume	3.1	3.1	100	Low - 0
Manganese and compounds	4.7	4.7	100	Low - 1
Nickel and compounds	16	16	100	Low - 1
Oxides of nitrogen	2,600	2,600	100	Low - 1
Particulate matter 10.0um	410	410	100	Low - 1
Selenium and compounds	0.1	0.1	100	Low - 1

Sulphur dioxide	150	150	100	Low - 1
Total volatile organic compounds	230	230	100	Low – 1
Zinc and compounds	9.1	9.1	100	Low – 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2004;loc_type=state;loc_state=QLD;jur_fac_id=32939

Emissions (2001/02)

		Air		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Antimony and compounds	3	3	100	Low – 1
Arsenic & compounds	0.7	0.7	100	Low – 1
Boron and compounds	8.9	8.9	100	Low – 1
Cadmium & compounds	0.6	0.6	100	Low - 1
Carbon monoxide	6,500	6,500	100	Low - 1
Chromium (III) compounds	6.4	6.4	100	Low – 1
Cobalt and compounds	1.2	1.2	100	Low – 1
Copper and compounds	180	180	100	Low – 1
Lead and compounds	7.9	7.9	100	Low - 1
Magnesium oxide fume	32	32	100	Low - 1
Manganese and compounds	48	48	100	Low – 1
Mercury and compounds	0.1	0.1	100	Low – 1
Nickel and compounds	170	170	100	Low – 1
Oxides of nitrogen	27,000	27,000	100	Low - 1
Particulate matter 10.0um	4,200	4,200	100	Low - 1
Selenium and compounds	0.7	0.7	100	Low - 1
Sulphur dioxide	1,500	1,500	100	Low - 1
Total volatile organic compounds	2,300	2,300	100	Low – 1
Zinc and compounds	92	92	100	Low – 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2002;loc_type=state;loc_state=QLD;jur_fac_id=32939

Facility Details

Facility	Townsville Terminal (Shell Co of Aust Ltd)
Address	Hubert Street Townsville Qld 4810
Main activities	Hydrocarbon storage and distribution Bitumen Blowing
Primary ANZSIC Industry Class	Petroleum Product Wholesaling
ANZSIC Industry Group	Mineral, Metal and Chemical Wholesaling
Cleaner production activities	None reported

Emissions (2005/06)

		Air		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Benzene	850	850	100	Low - 1
Carbon monoxide	890	890	100	Low - 1
Cumene (1-methylethylbenzene)	150	150	100	Low - 1
Cyclohexane	8	8	100	Low - 1
Ethylbenzene	170	170	100	Low - 1
Formaldehyde (methyl aldehyde)	8.6	8.6	100	Low - 1
n-Hexane	920	920	100	Low - 1
Oxides of nitrogen	1,800	1,800	100	Low - 1
Particulate matter 10.0um	180	180	100	Low - 1
Polycyclic aromatic hydrocarbons	0.21	0.21	100	Low - 1
Sulphur dioxide	3,300	3,300	100	Low - 1
Toluene (methylbenzene)	1,300	1,300	100	Low - 1
Total volatile organic compounds	110,000	110,000	100	Low - 1
Xylenes (individual or mixed isomers)	690	690	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=5154

Emissions (2002/03)

		Air		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Benzene	840	840	100	Low - 1
Carbon monoxide	1,100	1,100	100	Low - 1
Cumene (1-methylethylbenzene)	43	43	100	Low - 1
Cyclohexane	5	5	100	Low - 1
Ethylbenzene	85	85	100	Low - 1
Formaldehyde (methyl aldehyde)	12	12	100	Low - 1
n-Hexane	1,100	1,100	100	Low - 1
Oxides of nitrogen	4,500	4,500	100	Low - 1
Particulate matter 10.0um	250	250	100	Low - 1
Polycyclic aromatic hydrocarbons	0.26	0.26	100	Low - 1
Sulphur dioxide	4,000	4,000	100	Low - 1
Toluene (methylbenzene)	1,100	1,100	100	Low - 1
Total volatile organic compounds	100,000	100,000	100	Low - 1
Xylenes (individual or mixed isomers)	390	390	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2003;loc_type=state;loc_state=QLD;jur_fac_id=5154

Emissions (1999/00)

		Air		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Benzene	1,600	1,600	100	Low - 1
Carbon monoxide	720	720	100	Low - 1
Cumene (1-methylethylbenzene)	31	31	100	Low - 2
Cyclohexane	8	8	100	Low - 1
Ethylbenzene	130	130	100	Low - 4
n-Hexane	2,300	2,300	100	Low - 2
Oxides of nitrogen	3,000	3,000	100	Low - 1
Particulate matter 10.0um	180	180	100	Low - 1
Sulphur dioxide	3,100	3,100	100	Low - 1
Toluene (methylbenzene)	2,000	2,000	100	Low - 1
Total volatile organic compounds	200,000	200,000	100	Low - 3
Xylenes (individual or mixed isomers)	660	660	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2000;loc_type=state;loc_state=QLD;jur_fac_id=5154

Facility Details

Facility	**Townsville Airport Fuelling Service (Shell)**
Address	Stinson Avenue Garbutt Qld 4814
Main activities	Aircraft refuelling
Primary ANZSIC Industry Class	Petroleum Product Wholesaling
ANZSIC Industry Group	Mineral, Metal and Chemical Wholesaling
Cleaner production activities	None reported

Emissions (2005/06)

		Air		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Benzene	3.9	3.9	100	Low - 1
Cumene (1-methylethylbenzene)	0.06	0.06	100	Low - 1
Cyclohexane	4.1	4.1	100	Low - 1
Ethylbenzene	0.70	0.70	100	Low - 1
n-Hexane	17	17	100	Low - 1
Oxides of nitrogen	1,800	1,800	100	Low - 1
Particulate matter 10.0um	180	180	100	Low - 1
Polycyclic aromatic hydrocarbons	0.21	0.21	100	Low - 1
Sulphur dioxide	3,300	3,300	100	Low - 1
Toluene (methylbenzene)	2.3	2.3	100	Low - 1
Total volatile organic compounds	77	77	100	Low - 1
Xylenes (individual or mixed isomers)	4.5	4.5	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=25159

Facility Details

Facility	Sun Metals Zinc Refinery
Address	1 Zinc Avenue Stuart QLD 4811
Main activities	Zinc refinery processing up to 400,000 tonnes per annum of zinc concentrates to produce 190,000 tonnes zinc metal and 350,000 tonnes sulphuric acid.
Primary ANZSIC Industry Class	Copper, Silver, Lead and Zinc Smelting, Refining
ANZSIC Industry Group	Basic Non-Ferrous Metal Manufacturing
Cleaner production activities	None reported

Emissions (2005/06)

		Air		Land		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**Ranking**
Arsenic & compounds	6.3	6.3	99.8	0.01	0.2	Low - 1
Cadmium & compounds	71	71	99.9	0.1	0.1	Low - 1
Carbon monoxide	23,000	23,000	100			Low - 1
Cobalt and compounds	1.1	1.1	100			Low - 1
Copper and compounds	260	260	99.996	0.01	<0.1	Low - 1
Fluoride compounds	2.8	1.7	61	1.1	39	Low - 1
Lead and compounds	890	890	99.994	0.05	<0.1	Low - 1
Mercury and compounds	0.84	0.84	100			Low - 1
Nickel and compounds	0.67	0.66	98.5	0.01	1.5	Low - 1
Oxides of nitrogen	100,000	100,000	100			Low - 1
Particulate matter 10.0um	38,000	38,000	100			Low - 1
Polycyclic aromatic hydrocarbons	0.1	0.1	100			Low - 1
Sulphur dioxide	280,000	280,000	100			Low - 1
Sulphuric acid	19,000	19,000	100			Low - 2
Total volatile organic compounds	29	29	100			Low - 1
Zinc and compounds	22,000	22,000	99.96	8.1	0.04	Low - 7

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=25204

Emissions (2003/04)

		Air		Land		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**Ranking**
Arsenic & compounds	11	9.2	83.6	2.2	20	Low - 1
Cadmium & compounds	180	76	42.2	100	55.6	Low – 5
Carbon monoxide	36,000	36,000	100			Low - 1
Cobalt and compounds	2.7	2.3	85.2	0.37	13.7	Low - 1
Copper and compounds	200	200	100	1.2	0.6	Low - 1
Fluoride compounds	1.7	1.7	100			Low – 1
Lead and compounds	870	870	100	1.1	0.1	Low - 1
Mercury and compounds	1.1	0.72	65.5	0.39	35.5	Low - 1
Nickel and compounds	1.4	1	71.4	0.36	25.7	Low - 1
Oxides of nitrogen	97,000	97,000	100			Low - 1
Particulate matter 10.0um	39,000	39,000	100			Low - 1
Polycyclic aromatic hydrocarbons	0.1	0.1	100			Low - 1
Sulphur dioxide	410,000	410,000	100			Low - 1
Sulphuric acid	25,000	25,000	100			Low - 2
Total volatile organic compounds	27	27	100			Low - 1

Zinc and compounds	23,000	23,000	100	490	2.1	Low - 7

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2004;loc_type=state;
loc_state=QLD;jur_fac_id=25204

Emissions (2001/02)

		Air		Land		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**Ranking**
Arsenic & compounds	5.1	3	58.8	2.1	42	Low - 1
Cadmium & compounds	140	39	27.8	98	70	Low – 2
Carbon monoxide	28,000	28,000	100			Low - 1
Cobalt and compounds	7.4	1.5	20.3	5.9	79.7	Low - 1
Copper and compounds	39	37	94.8	1.8	4.6	Low - 1
Fluoride compounds	51	1.2	2.4	50	98	Low – 1
Lead and compounds	540	540	99.4	3.5	0.6	Low - 1
Mercury and compounds	1	0.52	52	0.52	52	Low - 1
Nickel and compounds	2.3	0.55	23.9	1.7	73.9	Low - 1
Oxides of nitrogen	74,000	74,000	100			Low - 1
Particulate matter 10.0um	27,000	27,000	100			Low - 1
Sulphur dioxide	300,000	300,000	100			Low - 1
Sulphuric acid	46,000	45,000	97.8	560	1.2	Low - 1
Zinc and compounds	19,000	19,000	100	240	<0.1	Low - 7

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2002;loc_type=state;
loc_state=QLD;jur_fac_id=25204

Facility Details

Facility	Southern Cross Fertilisers - Townsville Port Facility
Address	Centenary Drive Port of Townsville Qld 4810
Main activities	Fertiliser and sulphur storage
Primary ANZSIC Industry Class	Storage n.e.c.
ANZSIC Industry Group	Storage
Cleaner production activities	None reported

Emissions (2005/06)

		Air		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Chromium (III) compounds	0.24	0.24	100	Low - 1
Copper and compounds	0.39	0.39	100	Low - 1
Fluoride compounds	43	43	100	Low - 1
Manganese and compounds	5.7	5.7	100	Low - 1
Nickel and compounds	0.21	0.21	100	Low - 1
Zinc and compounds	1.2	1.2	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;
loc_state=QLD;jur_fac_id=25196

Facility Details

Facility	Queensland Terminals
Address	Benwell Road South Townsville Qld 4810
Main activities	Sulphuric Acid Storage and Transfers
Primary ANZSIC Industry Class	Inorganic Industrial Chemical Manufacturing n.e.c.
ANZSIC Industry Group	Basic Chemical Manufacturing
Cleaner production activities	None reported

Emissions (2005/06)

		Air		
Substance	Total (kg)	kg	%	Ranking
Sulphuric acid	100	100	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=25196

Facility Details

Facility	Stuart Railway Facility
Address	Jurekey Street Stuart Qld 4811
Main activities	Railway rollingstock maintenance, servicing and fuelling
Primary ANZSIC Industry Class	Rail Transport
ANZSIC Industry Group	Rail Transport
Cleaner production activities	None reported

Emissions (2005/06)

		Air		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Benzene	0.19	0.19	100	Low - 1
Ethylbenzene	0.32	0.32	100	Low - 1
Polycyclic aromatic hydrocarbons	0.13	0.13	100	Low - 1
Toluene (methylbenzene)	2.3	2.3	100	Low - 1
Total volatile organic compounds	2,300	2,300	100	Low - 1
Xylenes (individual or mixed isomers)	5.9	5.9	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=25235

Facility Details

Facility	**QNI Yabulu Refinery - Materials Handing Facility**
Address	Berth 2 Port of Townsville Qld 4810
Main activities	Unloading of nickel ore from vessels to train carriages for transport to the QNI Yabulu Refinery
Primary ANZSIC Industry Class	Basic Non-Ferrous Metal Manufacturing n.e.c.
ANZSIC Industry Group	Basic Non-Ferrous Metal Manufacturing
Cleaner production activities	None reported

Emissions (2005/06)

		Air		**Water**		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**Ranking**
Arsenic & compounds	0.79	0.79	100			Low - 1
Boron & compounds	0.27	0.27	100			Low - 1
Cadmium & compounds	0.8	0.79	98.8	0.0089	1.1	Low - 1
Chromuim (III) compounds	370	370	99.7	1.8	0.3	Low - 1
Cobalt and compounds	50	50	100	0.010	0.02	Low - 1
Copper and compounds	4.1	4.1	99.7	0.012	0.3	Low - 1
Fluoride compounds	110	110	100			Low - 1
Manganese and compounds	220	220	100	0.0050	0.002	Low - 1
Nickel and compounds	560	560	100	0.45	0.08	Low - 1
Selenium and compounds	0.82	0.82	100			Low - 1
Zinc and compounds	11	11	99.7	0.037	0.3	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=14841

Emissions (2002/03)

		Air		**Water**		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**Ranking**
Cadmium & compounds	0.001			0.001	100	Low - 1
Chromuim (III) compounds	470	470	100			Low - 1
Cobalt and compounds	0.018			0.018	100	Low - 1
Copper and compounds	0.0032			0.0032	100	Low - 1
Manganese and compounds	330	330	100	0.0081	<0.1	Low - 1
Nickel and compounds	570	570	100	0.19	<0.1	Low - 1
Zinc and compounds	0.022			0.022	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2003;loc_type=state;loc_state=QLD;jur_fac_id=14841

Emissions (1999/2000)

		Air		**Water**		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**Ranking**
Cobalt and compounds	2.4	2.4	100			Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2000;loc_type=state;loc_state=QLD;jur_fac_id=14841

Facility Details

Facility	QNI Townsville Port Bulk Fuel Facility
Address	Herbert Street South Townsville Qld 4810
Main activities	Storage & handling of bulk petroleum fuel
Primary ANZSIC Industry Class	Petroleum Product Wholesaling
ANZSIC Industry Group	Mineral, Metal and Chemical Wholesaling
Cleaner production activities	None reported

Emissions (2005/06)

		Air		
Substance	Total (kg)	kg	%	Ranking
Benzene	0.23	0.23	100	Low - 1
Carbon monoxide	510	510	100	Low - 1
Cumene (1-methylethylbenzene)	1.6	1.6	100	Low - 1
Fluoride compounds	3.8	3.8	100	Low – 1
n-Hexane	0.0006	0.0006	100	Low - 1
Hydrochloric acid	35	35	100	Low - 0
Oxides of Nitrogen	5,600	5,600	100	Low - 1
Particulate matter 10.0um	4.2	4.2	100	Low - 1
Polycyclic aromatic hydrocarbons	12	12	100	Low - 1
Sulphur dioxide	40	40	100	Low - 1
Total volatile organic compounds	550	550	100	Low - 1
Xylenes (individual or mixed isomers)	0.17	0.17	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=25186

Facility Details

Facility	**QNI - Yabulu Refinery**
Address	1 Greenvale Street Yabulu QLD 4818
Main activities	Processing of ore through roasting, ammonia leach and solvent extraction processes to produce high grade nickel and cobalt products.
Primary ANZSIC Industry Class	Basic Non-Ferrous Metal Manufacturing n.e.c.
ANZSIC Industry Group	Basic Non-Ferrous Metal Manufacturing
Cleaner production activities	The Yabulu site has recently undergone a project that converted the Synthesis Gas Plant and Final Nickel Calciner from utilising liquid fuel (naphtha) to Coal Seam Methane gas. This has facilitated a reduction in greenhouse gas emissions

Emissions (2005/06)

		Air		**Water**		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**Ranking**
Ammonia (total)	1,300,000	880,000	67.7	400,000	30.8	Low - 25
Arsenic & compounds	140	140	100			Low - 1
Benzene	540	540	100			Low - 1
Beryllium & compounds	14	14	100			Low - 1
Boron & compounds	30	30	100			Low - 1
Cadmium & compounds	97	97	100	0.07	<0.1	Low - 2
Carbon monoxide	520,000	520,000	100			Low - 1
Chromium (III) compounds	40,000	40,000	100	2.1	<0.1	Med - 45
Chromium (VI) compounds	9.4	9.4	100			Low - 1
Cobalt and compounds	5,400	5,400	100			Med - 31
Copper and compounds	960	960	100			Low - 1
Cumene (1-methylethylbenzene)	3.2	3.2	100			Low - 1
Fluoride compounds	37,000	37,000	100			Low - 2
n-Hexane	120	120	100			Low - 1
Hydrochloric acid	200,000	200,000	100			Low - 1
Lead and compounds	62	60	96.8	1.7	2.7	Low - 1
Manganese and compounds	23,000	23,000	100			Low - 3
Mercury and compounds	18	18	100			Low - 1
Nickel and compounds	61,000	60,000	98.4	780	1.3	Med - 69
Oxides of nitrogen	2,700,000	2,700,000	100			Low - 6
Particulate matter 10.0um	2,800,000	2,800,000	100			Low - 13
Polychlorinated dioxins and furans	0.0003	0.0003	100			Low - 1
Polycyclic aromatic hydrocarbons	42	42	100			Low - 1
Selenium and compounds	320	320	100			Low - 4
Sulphur dioxide	3,800,000	3,800,000	100			Low - 2
Sulphuric acid	21,000	21,000	100			Low - 3
Total volatile organic compounds	30,000	30,000	100			Low - 1
Xylenes (individuals or mixed isomers)	5.5	5.5	100			Low - 1
Zinc and compounds	1,800	1,800	100	17	0.94	Low - 1

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Emissions (2002/03)

		Air		Water		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**Ranking**
Ammonia (total)	790,000	790,000	100			Low - 16
Arsenic & compounds	51,000	51,000	100			Low - 1
Benzene	130	130	100			Low - 1
Beryllium & compounds	15	15	100			Low - 1
Boron & compounds	27	27	100			Low - 1
Cadmium & compounds	12	12	100	0.001	<0.1	Low - 2
Carbon monoxide	460,000	460,000	100			Low - 1
Chromium (III) compounds	35,000	35,000	100	0.45	<0.1	Med - 63
Chromium (VI) compounds	9.2	9.2	100			Low - 1
Cobalt and compounds	4,600	4,600	100	0.018	<0.1	Med - 26
Copper and compounds	100	100	100	0.0032	<0.1	Low - 1
Cumene (1-methylethylbenzene)	3.8	3.8	100			Low - 1
Fluoride compounds	26,000	26,000	100			Low - 5
n-Hexane	20	20	100			Low - 1
Hydrochloric acid	210,000	210,000	100			Low – 3
Lead and compounds	59	59	100	0.001	<0.1	Low - 1
Manganese and compounds	25,000	25,000	100	0.0081	<0.1	Low - 3
Mercury and compounds	18	18	100			Low – 2
Nickel and compounds	44,000	44,000	100	0.19	<0.1	Med - 55
Oxides of nitrogen	2,400,000	2,400,000	100			Low - 6
Particulate matter 10.0um	2,600,000	2,600,000	100			Low - 12
Polychlorinated dioxins and furans	0.0004	0.0004	100			Low - 1
Polycyclic aromatic hydrocarbons	46	46	100			Low - 1
Sulphur dioxide	3,900,000	3,900,000	100			Low - 2
Sulphuric acid	22,000	22,000	100			Low – 1
Total volatile organic compounds	23,000	23,000	100			Low - 1
Xylenes (individuals or mixed isomers)	5.5	5.5	100			Low - 1
Zinc and compounds	0.022			0.022	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2003;loc_type=state;loc_state=QLD;jur_fac_id=14736

Emissions (1999/00)

		Air		Water		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**Ranking**
Arsenic & compounds	99	99	100			Low - 1
Benzene	120	120	100			Low - 1
Cadmium & compounds	19	19	100			Low - 1
Carbon monoxide	200,000	200,000	100			Low - 1
Chromium (VI) compounds	9.3	9.3	100			Low - 1
Cobalt and compounds	2,800	2,700	96.4	110	3.9	Low - 15
Fluoride compounds	28,000	28,000	100			Low - 4
Lead and compounds	110	110	100			Low - 1
Mercury and compounds	17	17	100			Low – 1
Oxides of nitrogen	6,100,000	6,100,000	100			Low - 16
Particulate matter 10.0um	450,000	450,000	100			Low - 2
Polycyclic aromatic hydrocarbons	30	30	100			Low - 1

Sulphur dioxide	5,800,000	5,800,000	100			Low – 1
Total Nitrogen	1,200,000	1,200,000	100			Low - 5
Xylenes (individuals or mixed isomers)	0.3	0.3	100			Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2000;loc_type=state;loc_state=QLD;jur_fac_id=14736

Facility Details

Facility	**Northern Shipping and Stevedoring - Townsville Port**
Address	Suter Pier Wharf Townsville 4810
Main activities	Stevedoring, i.e. unloading or loading ships. Products are handled in containers, bulk bags and in bulk form. Equipment used in the operation includes shore cranes, ships cranes, forklifts, excavators, skid steer loaders, end loaders and hoppers
Primary ANZSIC Industry Class	Stevedoring
ANZSIC Industry Group	Services to Water Transport
Cleaner production activities	• Improved procedures for loading, unloading and transfer operations • Dust suppression - water sprays / chemical suppression • Dust suppression - wind breaks / covered / enclosed stockpiles

Emissions (2005/06)

		Air		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Carbon monoxide	62,000	62,000	100	Low - 1
Fluoride compounds	0.98	0.98	100	Low - 1
Oxides of nitrogen	340,000	340,000	100	Low - 1
Particulate matter 10.0um	4,000	4,000	100	Low - 1
Polycyclic aromatic hydrocarbons	0.12	0.12	100	Low - 1
Sulphur dioxide	69,000	69,000	100	Low - 1
Total volatile organic compounds	19,000	19,000	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=14839

Facility Details

Facility	**Hanson Townsville Quarry**
Address	Flinders Highway Townsville 4810
Main activities	Quarrying
Primary ANZSIC Industry Class	Gravel and Sand Quarrying
ANZSIC Industry Group	Construction Material Mining
Cleaner production activities	

Emissions (2005/06)

		Air		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Carbon monoxide	8,100	8,100	100	Low - 1
Oxides of nitrogen	13,000	13,000	100	Low - 1
Particulate matter 10.0um	15,000	15,000	100	Low - 1
Polycyclic aromatic hydrocarbons	0.64	0.64	100	Low - 1
Sulphur dioxide	1,200	1,200	100	Low - 1
Total volatile organic compounds	1,100	1,100	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=25143

Facility Details

Facility	**Bohle Quarry**
Address	Ingham Road Bohle 4818
Main activities	Quarry materials sand and gravel producers
Primary ANZSIC Industry Class	Gravel and Sand Quarrying
ANZSIC Industry Group	Construction Material Mining
Cleaner production activities	

Emissions (2005/06)

		Air		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Carbon monoxide	12,000	12,000	100	Low - 1
Oxides of nitrogen	25,000	25,000	100	Low - 1
Particulate matter 10.0um	47,000	47,000	100	Low - 1
Polycyclic aromatic hydrocarbons	0.037	0.037	100	Low - 1
Sulphur dioxide	2,300	2,300	100	Low - 1
Total volatile organic compounds	3,000	3,000	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=25210

Facility Details

Facility	Xstrata Copper - Townsville Port Operations
Address	Berth 7 Lennon Drive Townsville 4810
Main activities	Stockpilig and shiploading of mineral concentrates
Primary ANZSIC Industry Class	Port Operators
ANZSIC Industry Group	Services to Water Transport
Cleaner production activities	The Yabulu site has recently undergone a project that converted the Synthesis Gas Plant and Final Nickel Calciner from utilising liquid fuel (naphtha) to Coal Seam Methane gas. This has facilitated a reduction in greenhouse gas emissions

Emissions (2005/06)

		Air		Water		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**Ranking**
Antimony and compounds	5	5	100	0.04	0.8	Low - 1
Arsenic & compounds	27	27	100	0.06	0.2	Low - 1
Cadmium & compounds	9.9	9.3	93.9	0.61	6.1	Low - 1
Carbon monoxide	12,000	12,000	100			Low - 1
Chlorine	0.19	0.19	100			Low - 1
Chromium (III) compounds	0.62	0.37	59.7	0.25	40.3	Low - 1
Cobalt and compounds	8.5	8.1	95.3	0.33	3.9	Low - 1
Copper and compounds	2,600	2,600	100	43	1.7	Low - 1
Cumene (1-methylethylbenzene)	3.2	3.2	100			Low - 1
Fluoride compounds	5.7	5.7	100			Low - 1
Lead and compounds	590	580	98.3	14	2.4	Low - 1
Manganese and compounds	9.6	3.1	32.3	6.5	67.7	Low - 1
Mercury and compounds	0.19	0.18	94.7	0.015	7.9	Low - 1
Nickel and compounds	5.3	1.5	28.3	3.8	71.7	Low - 1
Oxides of nitrogen	64,000	64,000	100			Low - 1
Particulate matter 10.0um	1,200	1,200	100			Low - 1
Polycyclic aromatic hydrocarbons	0.28	0.28	100			Low - 1
Selenium and compounds	1.5	0.27	18	1.2	80	Low - 1
Sulphur dioxide	13,000	13,000	100			Low - 1
Total volatile organic compounds	4,400	4,400	100			Low - 1
Zinc and compounds	3,200	3,000	93.8	140	4.4	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=14838

Emissions (2002/03)

		Air		Water		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**Ranking**
Acetaldehyde	120	120	100			Low - 1
Antimony and compounds	2.1	2	95.2	0.024	1.1	Low - 1
Arsenic & compounds	9.2	9.2	100	0.041	0.5	Low - 1
Benzene and compounds	67	67	100			Low – 1
Cadmium & compounds	5.2	4.9	94.2	0.027	0.5	Low – 1
Carbon monoxide	13,000	13,000	100			Low – 1
Chlorine	0.26	0.26	100			Low – 1
Cobalt and compounds	8.2	8.1	98.8	0.14	1.7	Low – 1
Copper and compounds	2,500	2,500	100	14	0.6	Low – 1

Ethylbenzene	0.011	0.011	100			Low – 1
Fluoride compounds	54	54	100			Low - 1
Formaldehyde (methyl aldehyde)	430	430	100			Low – 1
n-hexane	55	55	100			Low – 1
Lead and compounds	180	180	100	1.9	1	Low - 1
Manganese and compounds	6.5	1.7	26.2	4.8	73.8	Low - 1
Mercury and compounds	0.1	0.1	100	0.0037	3.7	Low - 1
Nickel and compounds	3.4	1.2	35.3	2.2	64.7	Low - 1
Oxides of nitrogen	69,000	69,000	100			Low - 1
Particulate matter 10.0um	1,000	1,000	100			Low - 1
Polycyclic aromatic hydrocarbons	0.0044	0.0044	100			Low - 1
Selenium and compounds	1.3	0.32	0.99			Low - 1
Sulphur dioxide	14,000	14,000	100			Low – 1
Toluene (methyl benzene)	68	68	100			Low – 1
Total volatile organic compounds	4,400	4,400	100			Low - 1
Zinc and compounds	1,700	1,600	94.1	75	4.4	Low - 1

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Emissions (1999/2000)

		Air		Water		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**Ranking**
Arsenic & compounds	1.3	1.3	100	0.044	3.4	Low - 1
Cadmium & compounds	1.1	1	90.9	0.14	12.7	Low – 1
Cobalt and compounds	1.3	1.2	92.3	0.11	8.5	Low – 1
Fluoride compounds	3.5	3.5	100			Low - 1
Lead and compounds	31	23	74.2	8.2	26.5	Low - 1
Mercury and compounds	0.023	0.022	95.6	0.001	4.3	Low - 1

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Facility	**Xstrata Copper - Townsville Operations**
Address	Hunter Street Stuart 4811
Main activities	Electro-refining of copper
Primary ANZSIC Industry Class	Copper, Silver, Lead and Zinc Smelting, Refining
ANZSIC Industry Group	Basic Non-Ferrous Metal Manufacturing
Cleaner production activities	

Emissions (2005/06)

		Air		**Land**		**Water**		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**kg**	**%**	**Ranking**
Arsenic & compounds	120	0.83	0.7	14	11.7	110	91.7	Low - 1
Benzene	72	72	100					Low - 1
Beryllium & compounds	0.0089	0.0089	100					Low - 1
Cadmium & compounds	0.26	0.26	100					Low - 1
Carbon monoxide	6,700	6,700	100					Low - 1
Chromium (III) compounds	0.1	0.1	100					Low - 1
Copper and compounds	570	64	11.2	4.5	0.8	500	87.7	Low - 1
Ethylbenzene	6.5	6.5	100					Low - 1
Fluoride compounds	0.74	0.74	100					Low - 1
n-Hexane	94	94	100					Low - 1
Lead and compounds	3.2	3.2	100					Low - 1
Mercury and compounds	0.027	0.027	100					Low - 1
Nickel and compounds	40	1.6	4	4.6	11.5	34	85	Low - 1
Oxides of nitrogen	9,400	9,400	100					Low - 1
Particulate matter 10.0um	700	700	100					Low - 1
Polychlorinated dioxins and furans	0.00000006	0.00000006	100					Low - 1
Polycyclic aromatic hydrocarbons	0.073	0.073	100					Low - 1
Sulphur dioxide	1,600	1,600	100					Low - 1
Sulphuric acid	210	210	100					Low - 1
Toluene (methylbenzene)	93	93	100					Low - 1
Total volatile organic compounds	7,900	7,900	100					Low - 1
Xylenes (individuals or mixed isomers)	50	50	100					Low - 1

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Emissions (2002/03)

		Air		**Land**		**Water**		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**kg**	**%**	**Ranking**
Acetone	8.9	8.9	100					Low - 1
Ammonia (total)	8.9	8.9	100					Low – 1
Antimony and compounds	15			13	86.7	2	13.3	Low – 1
Arsenic & compounds	0.016	0.016	100					Low - 1
Benzene	18	12	66.7	5.8	32.2	0.0028	<0.1	Low - 1
Beryllium & compounds	0.2	0.2	100					Low - 1
Biphenyl (1,1-biphenyl)	0.001	0.001	100					

Cadmium & compounds	0.42	0.42	100					Low - 1
Carbon monoxide	150,000	150,000	100					Low - 1
Chromium (III) compounds	0.2	0.2	100					Low - 1
Copper and compounds	16	13	81.2	2.6	16.25	0.0081	<0.1	Low - 1
Cumene (1-methylethylbenzene)	5.9	5.9	100					Low – 1
Cyclohexane	29	29	100					Low - 1
Ethyl acetate	14	14	100					Low - 1
Ethylbenzene	42	42	100					Low - 1
Formaldehyde (methyl aldehyde)	41	41	100					Low - 1
n-Hexane	260	260	100					Low - 1
Lead and compounds	0.95		100					Low - 1
Manganese and compounds	0.4	0.4	100					Low – 1
Mercury and compounds	0.2	0.2	100					Low - 1
Methyl ethyl ketone	3.8	3.8	100					Low – 1
Methyl isobutyl ketone	2.5	2.5	100					Low – 1
Nickel and compounds	7.8	5.4	69.2	2.3	3	0.14	1.8	Low - 1
Oxides of nitrogen	13,000	13,000	100					Low - 1
Particulate matter 10.0um	680	680	100					Low - 1
Polycyclic aromatic hydrocarbons	1.9	1.9	100					Low - 1
Sulphur dioxide	34,000	34,000	100					Low - 1
Sulphuric acid	1,800	1,800	100					Low - 1
Toluene (methylbenzene)	400	400	100					Low - 1
Total volatile organic compounds	9,600	9,600	100					Low - 1
Xylenes (individuals or mixed isomers)	260	260	100					Low – 1
Zinc and compounds	0.26	0.26	100					Low - 1

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Emissions (1999/2000)

		Air		Land		Water		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**kg**	**%**	**Ranking**
Arsenic & compounds	170	4.6	2.7	14	8.2	150	88	Low - 1
Benzene	16	16	100					Low - 1
Cadmium & compounds	0.63	0.63	100					Low - 1
Carbon monoxide	150,000	150,000	100					Low - 1
Lead and compounds	1.7	1.7	100					Low - 1
Mercury and compounds	0.26	0.26	100					Low - 1
Oxides of nitrogen	17,000	17,000	100					Low - 1
Particulate matter 10.0um	870	870	100					Low - 1
Sulphur dioxide	45,000	45,000	100					Low - 1
Sulphuric acid	900	900	100					Low - 1
Toluene (methylbenzene)	51	51	100					Low - 1
Total volatile organic compounds	1,900	1,900	100					Low - 1

Xylenes (individuals or mixed isomers)	49	49	100					Low – 1

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Facility Details

Facility	BP Australia - Townsville Terminal
Address	Hubert Street South Townsville Qld 4810
Main activities	Bulk Petroleum Storage Facility
Primary ANZSIC Industry Class	Petroleum Product Wholesaling
ANZSIC Industry Group	Mineral, Metal and Chemical Wholesaling
Cleaner production activities	None reported

Emissions (2005/06)

		Air		Land		Water		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**kg**	**%**	**Ranking**
Benzene	630	630	100	0.12	<0.1	6.5	1	Low - 1
Cumene (1-methylethylbenzene)	25	3.3	13.2	0.02	<0.1	22	88	Low - 1
Cyclohexane	1,100	1,100	100	0.17	<0.1	22	2	Low - 1
Ethylbenzene	170	160	94.1	0.32	0.19	3.1	1.8	Low - 1
n-Hexane	1,600	1,600	100	0.22	<0.1	22	1.4	Low - 1
Styrene (ethenylbenzene)	23	1.3	5.7	0.01	<0.1	22	95.6	Low - 1
Toluene (methylbenzene)	1,800	1,800	100	1.6	<0.1	6.5	0.36	Low - 1
Total volatile organic compounds	200,000	200,000	100	16	<0.1	110	<0.1	Low - 1
Xylenes (individual or mixed isomers)	720	710	98.6	1.7	0.24	8.3	1.2	Low - 1

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loc_state=QLD;jur_fac_id=5265

Emissions (2002/03)

		Air		Land		Water		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**kg**	**%**	**Ranking**
Benzene	3,100	3,100	100	0.54	<0.1	6.5	0.2	Low - 1
Cumene (1-methylethylbenzene)	42	19	45.2	0.94	2.2	22	52.4	Low - 1
Cyclohexane	680	660	97.1	0.072	<0.1	22	3.2	Low - 1
Ethylbenzene	150	150	100	0.41	0.3	3.1	2.1	Low - 1
n-Hexane	3,600	3,600	100	0.34	<0.1	22	0.6	Low - 1
Styrene (ethenylbenzene)	2,900	2,900	100	1.7	<0.1	6.5	0.2	Low - 1
Total volatile organic compounds	300,000	300,000	100	44	<0.1	110	<0.1	Low - 1
Xylenes (individual or mixed isomers)	1,100	1,100	100	2.6	0.2	8.3	0.8	Low - 1

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loc_state=QLD;jur_fac_id=5265

Emissions (1999/2000)

		Air		Water		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**Ranking**
Benzene	1,300	1,300	100	6.5	0.5	Low - 1
Cumene (1-methylethylbenzene)	46	26	56.5	20	43.5	Low - 3

Cyclohexane	160	140	87.5	20	12.5	Low - 1
Ethylbenzene	58	58	100	3	5.2	Low - 2
n-Hexane	1,200	1,200	100	20	1.7	Low - 1
Toluene (methylbenzene)	1,100	1,100	100	6.5	0.6	Low - 1
Total volatile organic compounds	120,000	120,000	100	110	<0.1	Low - 2
Xylenes (individual or mixed isomers)	460	450	97.8	8	1.7	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2000;loc_type=state;loc_state=QLD;jur_fac_id=5265

Facility Details

Facility	**Air BP Townsville**
Address	Airside GA Area Townsville Airport 4810
Main activities	Bulk petroleum storage facility
Primary ANZSIC Industry Class	Petroleum Product Wholesaling
ANZSIC Industry Group	Mineral, Metal and Chemical Wholesaling
Cleaner production activities	None reported

Emissions (2005/06)

		Air		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Benzene	14	14	100	Low - 1
Ethylbenzene	5.5	5.5	100	Low - 1
Toluene (methylbenzene)	15	15	100	Low - 1
Total volatile organic compounds	1,300	1,300	100	Low - 1
Xylenes (individual or mixed isomers)	19	19	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=32911

Facility Details

Facility	BOC Townsville
Address	384 Ingham Road Garbutt 4814
Main activities	Stores gas, fills cylinders and distributes product.
Primary ANZSIC Industry Class	Industrial Gas Manufacturing
ANZSIC Industry Group	Basic Chemical Manufacturing
Cleaner production activities	None reported

Emissions (2005/06)

		Air		
Substance	Total (kg)	kg	%	Ranking
Acetone	310	310	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=25294

Facility Details

Facility	Cannington Port Facility
Address	Townsville Port Townsville 4810
Main activities	Storage and Loading of Lead and Zinc Concentrates
Primary ANZSIC Industry Class	Water Transport Terminals
ANZSIC Industry Group	Services to Water Transport
Cleaner production activities	

Emissions (2005/06)

		Air		Water		
Substance	**Total (kg)**	**kg**	**%**	**kg**	**%**	**Ranking**
Antimony and compounds	0.49	0.49	100	0.0033	0.7	Low - 1
Arsenic & compounds	0.18	0.18	100	0.0003	0.17	Low - 1
Benzene	0.0012	0.0012	100			Low - 1
Beryllium and compounds	0.0023	0.0023	100			Low - 1
Cadmium & compounds	0.018	0.0023	12.8	0.016	88.9	Low - 1
Carbon monoxide	27	27	100			Low - 1
Chromium (III) compounds	0.0016	0.0016	100			Low - 1
Chromium (IV) compounds	0.0007	0.0007	100			Low - 1
Copper and compounds	0.006	0.0046	76.7	0.0014	23.3	Low - 1
Ethylbenzene	0.0003	0.0003	100			Low - 1
Fluoride compounds	0.52	0.16	30.8	0.36	69.2	Low - 1
Formaldehyde (methyl aldehyde)	0.26	0.26	100			
Lead and compounds	160	180	100	1.6	1	Low - 1
Manganese and compounds	0.33	0.0046	1.4	0.33	100	Low - 1
Mercury and compounds	0.0023	0.0023	100			Low - 1
Nickel and compounds	0.0023	0.0023	100			Low - 1
Oxides of nitrogen	110	110	100			Low - 1
Particulate matter 10.0um	140	140	100			Low - 1
Polychlorinated dioxins and furans	0.000000017	0.000000017	100			Low - 1
Polycyclic aromatic hydrocarbons	0.0065	0.0065	100			Low - 1
Selenium and compounds	0.014	0.012	85.7	0.0015	10.7	Low - 1
Sulphur dioxide	100	100	100			Low - 1
Toluene (methylbenzene)	0.034	0.034	100			Low - 1
Total volatile organic compounds	1.8	1.8	100			Low - 1
Xylenes (individual or mixed isomers)	0.0006	0.0006	100			Low - 1
Zinc and compounds	47	43	91.5	4.2	8.9	Low - 1

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Emissions (2002/03)

		Air		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Arsenic & compounds	0.31	0.31	100	Low - 1
Benzene	0.47	0.47	100	Low - 1
Cadmium & compounds	1.4	1.4	100	Low - 1
Carbon monoxide	570	570	100	Low - 1
Copper and compounds	4.1	4.1	100	Low - 1
Fluoride compounds	0.76	0.76	100	Low - 1
Lead and compounds	760	760	100	Low - 1

Mercury and compounds	4.3	4.3	100	Low - 1
Nickel and compounds	2.4	2.4	100	Low - 1
Oxides of nitrogen	1,800	1,800	100	Low - 1
Particulate matter 10.0um	1,100	1,100	100	Low - 1
Sulphur dioxide	90	90	100	Low - 1
Toluene (methylbenzene)	5.7	5.7	100	Low - 1
Total volatile organic compounds	250	250	100	Low - 1
Xylenes (individual or mixed isomers)	15	15	100	Low - 1
Zinc and compounds	260	260	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2003;loc_type=state;loc_state=QLD;jur_fac_id=5752

Emissions (1999/2000)

		Air		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Arsenic & compounds	0.003	0.003	100	Low - 1
Cadmium & compounds	0.00024	0.00024	100	Low - 1
Carbon monoxide	2,400	2,400	100	Low - 1
Fluoride compounds	0.024	0.024	100	Low - 1
Lead and compounds	0.6	0.6	100	Low - 1
Mercury and compounds	0.00012	0.00012	100	Low - 1
Oxides of nitrogen	3,900	3,900	100	Low - 1
Particulate matter 10.0um	420	420	100	Low - 1
Polycyclic aromatic hydrocarbons	0.17	0.17	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2000;loc_type=state;loc_state=QLD;jur_fac_id=5752

Facility Details

Facility	Townsville Abattoir
Address	Bruce Highway Aitkenvale via Townsville 4814
Main activities	Meat Processing
Primary ANZSIC Industry Class	Meat Processing
ANZSIC Industry Group	Meat and Meat Product Manufacturing
Cleaner production activities	A1. Improved maintenance scheduling, record keeping, or procedures A7. Installed overflow alarms or automatic shut-off valves A11. Implemented inspection or monitoring program for potential spill or leak sources A14. Dust suppression - wind breaks/covered/enclosed stockpiles Recycle water
Installation of Pollution Control Equipment	E5. Scrubber E7. Cyclone Wastewater treatment Effluent irrigation

Emissions (2005/06)

		Air		
Substance	Total (kg)	kg	%	Ranking
Acetaldehyde	1.5	1.5	100	Low - 1
Ammonia (total)	3,500	3,500	100	Low - 1
Antimony & compounds	0.15	0.15	100	Low - 1
Arsenic & compounds	18	18	100	Low - 1
Benzene	3	3	100	Low - 1
Beryllium & compounds	3.1	3.1	100	Low - 1
Cadmium & compounds	1.8	1.8	100	Low - 1
Carbon disulfide	0.29	0.29	100	Low - 1
Carbon monoxide	13,000	13,000	100	Low - 1
Chloroform (trichloromethane)	0.23	0.23	100	Low - 1
Chromium (III) compounds	54	54	100	Low - 1
Chromium (VI) compounds	0.18	0.18	100	Low - 1
Cobalt and compounds	0.36	0.36	100	Low - 1
Copper and compounds	0.45	0.45	100	Low - 1
Cumene (1-methylethylbenzene)	0.01	0.01	100	Low - 1
Cyanide (inorganic) compounds	5.9	5.9	100	Low - 1
Dichloromethane	0.68	0.68	100	Low - 1
Ethylbenzene	0.21	0.21	100	Low - 1
Fluoride compounds	340	340	100	Low - 1
Formaldehyde (methyl aldehyde)	1.4	1.4	100	Low - 1
n-Hexane	0.15	0.15	100	Low - 1
Hydrochloric acid	2,700	2,700	100	Low - 1
Lead and compounds	22	22	100	Low - 1
Magnesium oxide fume	25	25	100	Low - 1
Manganese and compounds	95	95	100	Low - 1
Mercury and compounds	0.68	0.68	100	Low - 1
Methyl ethyl ketone	0.91	0.91	100	Low - 1
Methyl methacrylate	0.05	0.05	100	Low - 1
Nickel and compounds	46	46	100	Low - 1

Oxides of nitrogen	21,000	21,000	100	Low - 1
Particulate matter 10.0um	18,000	18,000	100	Low - 1
Phenol	0.04	0.04	100	Low - 1
Polychlorinated dioxins and furans	0.0000004	0.0000004	100	Low - 1
Polycyclic aromatic hydrocarbons	0.09	0.09	100	Low - 1
Selenium & compounds	2.9	2.9	100	Low - 1
Styrene (ethenylbenzene)	0.06	0.06	100	Low - 1
Sulphur dioxide	82,000	82,000	100	Low - 1
Sulphuric acid	3,100	3,100	100	Low - 1
Tetrachloroethylene	0.1	0.1	100	Low - 1
Toluene (methylbenzene)	0.72	0.72	100	Low - 1
Total volatile organic compounds	270	270	100	Low - 1
Xylenes (individual or mixed isomers)	0.13	0.13	100	Low - 1
Zinc and compounds	430	430	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=14755

Emissions (2002/03)

		Air		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Acetaldehyde	2	2	100	Low - 1
Ammonia (total)	5,100	5,100	100	Low - 1
Antimony & compounds	0.16	0.16	100	Low - 1
Arsenic & compounds	21	21	100	Low - 1
Benzene	3.8	3.8	100	Low - 1
Beryllium & compounds	3.7	3.7	100	Low - 1
Cadmium & compounds	1.6	1.6	100	Low - 1
Carbon disulfide	0.35	0.35	100	Low - 1
Carbon monoxide	15,000	15,000	100	Low - 1
Chloroform (trichloromethane)	0.16	0.16	100	Low - 1
Chromium (III) compounds	64	64	100	Low - 1
Chromium (VI) compounds	0.21	0.21	100	Low - 1
Cobalt and compounds	0.4	0.4	100	Low - 1
Copper and compounds	0.53	0.53	100	Low - 1
Cumene (1-methylethylbenzene)	0.01	0.01	100	Low - 1
Cyanide (inorganic) compounds	6.9	6.9	100	Low - 1
Dichloromethane	0.8	0.8	100	Low - 1
Ethylbenzene	0.25	0.25	100	Low - 1
Fluoride compounds	400	400	100	Low - 1
Formaldehyde (methyl aldehyde)	1.8	1.8	100	Low - 1
n-Hexane	0.18	0.18	100	Low - 1
Hydrochloric acid	3,200	3,200	100	Low - 1
Lead and compounds	26	26	100	Low - 1
Magnesium oxide fume	29	29	100	Low - 1
Manganese and compounds	110	110	100	Low - 1
Mercury and compounds	0.8	0.8	100	Low - 1
Methyl ethyl ketone	1.1	1.1	100	Low - 1
Methyl methacrylate	0.05	0.05	100	Low - 1
Nickel and compounds	54	54	100	Low - 1
Oxides of nitrogen	26,000	26,000	100	Low - 1

Particulate matter 10.0um	21,000	21,000	100	Low - 1
Phenol	0.04	0.04	100	Low - 1
Polychlorinated dioxins and furans	0.0000048	0.0000048	100	Low - 1
Polycyclic aromatic hydrocarbons	0.14	0.14	100	Low - 1
Selenium & compounds	3.5	3.5	100	Low - 1
Styrene (ethenylbenzene)	0.07	0.07	100	Low - 1
Sulphur dioxide	96,000	96,000	100	Low - 1
Sulphuric acid	3,700	3,700	100	Low - 1
Tetrachloroethylene	0.12	0.12	100	Low - 1
Toluene (methylbenzene)	0.92	0.92	100	Low - 1
Total volatile organic compounds	380	380	100	Low - 1
Xylenes (individual or mixed isomers)	0.21	0.21	100	Low - 1
Zinc and compounds	500	500	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;loc_type=state;
loc_state=QLD;year=2003;jur_fac_id=14755

Emissions (1999/2000)

		Air		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Acetaldehyde	1.1	1.1	100	Low - 1
Ammonia (total)	5,900	5,900	100	Low - 1
Antimony & compounds	0.03	0.03	100	Low - 1
Arsenic & compounds	14	14	100	Low - 1
Benzene	2.4	2.4	100	Low - 1
Beryllium & compounds	2.5	2.5	100	Low - 3
Cadmium & compounds	1.1	1.1	100	Low - 1
Carbon disulfide	0.2	0.2	100	Low - 1
Carbon monoxide	9,200	9,200	100	Low - 1
Chloroform (trichloromethane)	0.1	0.1	100	Low - 1
Chromium (III) compounds	44	44	100	Low - 1
Chromium (VI) compounds	0.1	0.1	100	Low - 1
Cumene (1-methylethylbenzene)	0.01	0.01	100	Low - 1
Cyanide (inorganic) compounds	4.8	4.8	100	Low - 1
Dichloromethane	0.6	0.6	100	Low - 1
Ethylbenzene	0.2	0.2	100	Low - 1
Fluoride compounds	270	270	100	Low - 1
Formaldehyde (methyl aldehyde)	0.4	0.4	100	Low - 1
n-Hexane	0.1	0.1	100	Low - 1
Hydrochloric acid	2,200	2,200	100	Low - 1
Lead and compounds	18	18	100	Low - 1
Magnesium oxide fume	20	20	100	Low - 2
Manganese and compounds	77	77	100	Low - 1
Mercury and compounds	0.6	0.6	100	Low - 1
Methyl ethyl ketone	0.7	0.7	100	Low - 1
Methyl methacrylate	0.04	0.04	100	Low - 1
Nickel and compounds	36	36	100	Low - 0
Oxides of nitrogen	16,000	16,000	100	Low - 1
Particulate matter 10.0um	14,000	14,000	100	Low - 1
Phenol	0.03	0.03	100	Low - 1
Polychlorinated dioxins and furans	0.000003	0.000003	100	Low - 1
Polycyclic aromatic hydrocarbons	0.16	0.16	100	Low - 1

Selenium & compounds	2.4	2.4	100	Low - 1
Styrene (ethenylbenzene)	0.05	0.05	100	Low - 1
Sulphur dioxide	65,000	65,000	100	Low - 1
Tetrachloroethylene	0.08	0.08	100	Low - 1
Toluene (methylbenzene)	0.4	0.4	100	Low - 1
Total volatile organic compounds	97	97	100	Low - 1
Xylenes (individual or mixed isomers)	0.07	0.07	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2000;jur_fac_id=14755;loc_type=state;loc_state=QLD

Facility Details

Facility	Industrial Galvanizers North Queensland
Address	9 Commercial Avenue Bohle 4818
Main activities	Hot Dip Galvanizing
Primary ANZSIC Industry Class	Metal Coating and Finishing
ANZSIC Industry Group	Fabricated Metal Product Manufacturing
Cleaner production activities	

Emissions (2005/06)

		Air		
Substance	**Total (kg)**	**kg**	**%**	**Ranking**
Particulate matter 10.0um	120	120	100	Low - 1
Zinc and compounds	95	95	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=32964

Facility Details

Facility	Origin Energy Mt Stuart
Address	Cnr Hunter Street and Bruce Highway Stuart 4811
Main activities	Peak Power Generation from Fossil Fuels
Primary ANZSIC Industry Class	Electricity Supply
ANZSIC Industry Group	Electricity Supply
Cleaner production activities	

Emissions (2005/06)

		Air		
Substance	Total (kg)	kg	%	Ranking
Arsenic & compounds	1.5	1.5	100	Low - 1
Benzene	0.95	0.95	100	Low - 1
Beryllium & compounds	0.042	0.042	100	Low - 1
Cadmium & compounds	0.67	0.67	100	Low - 1
Carbon monoxide	1,600	1,600	100	Low - 1
Chromium (III) compounds	1.1	1.1	100	Low - 1
Chromium (VI) compounds	0.45	0.45	100	Low - 1
Ethylbenzene	3.2	3.2	100	Low - 1
n-Hexane	1.9	1.9	100	Low - 1
Lead and compounds	1.9	1.9	100	Low - 1
Mercury and compounds	0.17	0.17	100	Low - 1
Nickel and compounds	0.64	0.64	100	Low - 1
Oxides of nitrogen	22,000	22,000	100	Low - 1
Particulate matter 10.0um	1,700	1,700	100	Low - 1
Polychlorinated dioxins and furans	0.0000027	0.0000027	100	Low - 1
Polycyclic aromatic hydrocarbons	5.4	5.4	100	Low - 1
Sulphur dioxide	3,200	3,200	100	Low - 1
Toluene (methylbenzene)	9.5	9.5	100	Low - 1
Total volatile organic compounds	200	200	100	Low - 1
Xylenes (individual or mixed isomers)	6.3	6.3	100	Low - 1

http://www.npi.gov.au/cgi-bin/npireport.pl?proc=facility_report;instance=public;year=2006;loc_type=state;loc_state=QLD;jur_fac_id=14700

Appendix B

Sewage Treatment Plant

Appendix B Sewage Treatment Plant (STPs)

Condon

Facility	**Condon Sewage Treatment Plant (see Appendix A, p.2)**
Address	Lot 52 Bowhunters Road Condon Qld 4815
Main activities	Sewage treatment by activated sludge (extended aeration) to a secondary standard
Emissions to	Air, Land and water
NPI Report Years	2005/2006, 2002/2003 and 1999/2000

Condon STP Location

Deeragun

Facility	**Deeragun Sewage Treatment Plant (see Appendix A, p.3)**
Address	Kayleen Court Deeragun Qld 4818
Main activities	Sewage treatment by activated sludge (extended aeration) to a secondary standard
Emissions to	Land and water
NPI Report Years	2005/2006, 2002/2003 and 1999/2000

Deeragun STP location

Mt Low

Facility	**Mt Low Sewage Treatment Plant (see Appendix A, p.4)**
Address	Brabon Road Mt Low Qld 4818
Main activities	Sewage treatment by activated sludge (extended aeration) to a secondary standard
Emissions to	Land and water
NPI Report Years	2005/2006, 2002/2003 and 1999/2000

Mt Low STP location

Cleveland Bay STP

Facility	**Cleveland Bay Sewage Treatment Plant (see Appendix A, p.5)**
Address	Cleveland Bay Townsville Qld 4810
Main activities	Treatment of wastewater as part of wastewater service provided to TCC declared sewage treatment areas.
Emissions to	Air, Land and water
NPI Report Years	2005/2006, 2003/2004 and 2001/2002

Source: J Gunn

Source: J Gunn

Cleveland Bay STP location

The Cleveland Bay Wastewater Purification Plant (CBPP) is receiving a $65 million upgrade in order to meet more stringent Environmental Protection Agency (EPA) licence conditions that come into force in January 2008. Over 16 months, the plant will be completely rebuilt. When finished, the Cleveland Bay facility will be the largest membrane bioreactor wastewater treatment plant of its type in the southern hemisphere, recycling about 20 megalitres of treated effluent each day.

The membrane bioreactor technology allows the effluent to be treated to a very high standard by significantly reducing the level of nitrogen and phosphorous.

As part of the upgrade, a $9 million Biosolids Dewatering Facility has also been constructed which turns sewage sludge into a soil conditioner, suitable for the agricultural sector. This has further enhanced the environmental sustainability of the plant.

(Formerly available online at http://www.townsville.qld.gov.au/citiwater/cleveland.asp)

Mt St John

Facility	**Mt St John Sewage Treatment Plant (see Appendix A, p.6)**
Address	Mt St John Road Townsville Qld 4818
Main activities	Treatment of wastewater as part of wastewater service provided to TCC declared sewage treatment areas.
Emissions to	Air, Land and water
NPI Report Years	2005/2006, 2003/2004 and 2001/2002

Mt St John STP location

Mt St John Wastewater Treatment Plant (MSJ) is one of Townsville's major wastewater treatment plants. It started operations in 1972 and has been continually upgraded since then to meet the demands of an ever increasing population.

MSJ Wastewater Treatment Plant consists of a primary screen, aerated grit tank, primary clarifiers, biofilters, secondary clarifiers, sludge digestion tanks, sludge drying beds and UV disinfection. Sewage at this plant goes to primary and secondary levels of treatment.

MSJ receives between 11 and 13 million litres of raw sewage every day. Some treated effluent is reused to irrigate the plant grounds, the RAAF Base, Rowes Bay Golf Course, and Pallarenda foreshore.

Operation conditions for MSJ comply with the International Quality Management System ISO 9001 and effluent treatment and release is in accordance with EPA licensing agreements.

(Formerly available online at http://www.townsville.qld.gov.au/citiwater/mtstjohn.asp)

Magnetic Island

Nelly Bay

The Nelly Bay facility is now ownly utilised by a a small number of households in the vicinity of the plant and accepts trade waste from around the island. The predominant use it to treat the trade waste as it is problematic for the newer facilities at Picnic Bay and Horseshoe Bay. There is no discharge from the plant as the treatment volume is low and evaporation is equivalent to the input volume.

Picnic Bay

Magnetic Island Water Recycling (MIWR) was successfully commissioned in October 2002. It is the first use in Australia of a membrane biological reactor in a wastewater treatment facility. The facility treats wastewater to one of the highest levels achieved in the world, with a 100% re-use target of the final product for irrigation purposes.

The key points regarding Magnetic Island Water Recycling are:

- MIWR is built to world best practice;
- It is the first use of a new technology in Australia;
- MIWR has world significance, as it the first use in the world of nutrient removal processes ahead of membrane technology;
- MIWR provides a sustainable solution for the use of scarce resource water on Magnetic Island, with the treatment of wastewater to one of the highest levels achieved in the world and the development of 100% recycling of water;
- Nutrients such as nitrogen and phosphorous are reduced to the lowest levels possible in terms of world best practice.

MIWR is environmentally sensitive in other ways:

- The treatment facility has NO OUTFALL to the Great Barrier Reef Marine Park;
- The minimal sludge produced is re-used on the Island;
- Recycled water is stored during wet weather;
- A wetland system further filters any recycled water, released in the aftermath of tropical storms, before it reaches the ocean.

(Formerly available online at http://www.townsville.qld.gov.au/citiwater/MIWR.asp)

Horseshoe Bay

The wastewater treatment plant at Horseshoe Bay forms the heart of an innovative water recycling scheme that provides greater protection to the Great Barrier Reef Marine Park.

The facility was commissioned in September 2006 and uses advanced membrane bioreactor technology (MBR) - a technology also used at the treatment plant at Picnic Bay.

This technology has many benefits including its ability to produce high quality treated effluent by filtering out small particles that would not be removed during conventional treatment, and its vastly reduced reliance on chemicals such as chlorine.

By using this recycled water to irrigate some of Magnetic Island's local recreational areas, Citiwater is ensuring there is no discharge into Horseshoe Bay.

Dry Tropics Rainforest
This rainforest was purpose-built to receive the water from the treatment plant. It covers 2.5 hectares and consists of more than 8000 plants from 86 different species. These plants are flourishing, in part because of some of the nutrients that remain in the water.

Planted with the assistance of the Magnetic Island community, the park has become a sanctuary for native birds while greatly improving the area's biodiversity.

(Formerly available at http://www.townsville.qld.gov.au/citiwater/horseshoebay.asp

Maunsell 2008, *Wastewater Upgrade Program Planning Report*, Townsville City Council, Townsville.

Executive Summary

The Townsville region is undergoing significant population growth and this is placing pressure on the region's wastewater infrastructure. Table 1 below shows the projected population growth till 2025 and the corresponding capacities at each of the region's wastewater purification plants (WPP).

Table 1 – Population Projections

2008 2009 2010 2015 2025Available plant capacity

	Projected population (EP) for various end of calendar years					
	2008	2009	2010	2015	2025	Available plant capacity (EP)
Cleveland Bay WPP Catchment						
Eastern /Western/Southern	102,000	103,050	104,100	109,358	120,799	
Sub-Total Cleveland Bay	102,000	103,050	104,100	109,358	120,799	126,000
Mt St John WPP Catchment						
Mt Louisa	5,200	5,460	5,730	7,310	11,920	
Mather St PS Balance Area	18,400	18,400	18,400	18,400	18,400	
Kirwan	27,200	27,600	28,000	30,000	32,100	
Sub-Total Mt St John	50,800	51,460	52,130	55,710	62,420	45,000
Condon WPP Catchment						
Condon/Kelso/Rasmussen	17,000	17,600	18,200	20,600	24,200	
Bohle Plains	1,500	2,000	2,600	8,100	14,700	
Sub-Total Condon	18,500	19,600	20,800	28,700	38,900	23,000
Mt Low WPP Catchment						
Mt Low/ Bushland Beach	4,000	4,900	5,800	9,250	13,790	
Sub-Total Mt Low	4,000	4,900	5,800	9,250	29,340	3,000
Deeragun WPP Catchment						
Deeragun/ Burdell	3,550	4,520	5,870	9,120	15,550	
Sub-Total Deeragun	3,550	4,420	5,870	9,120	15,550	4,300
Overall Total All Catchments	178,850	183,430	188,700	212,138	267,009	201,300

The figures highlight that there is only a small amount of capacity remaining in existing wastewater treatment infrastructure. A number of existing treatment plants have reached or will soon reach their maximum treatment capacity and hence there is an imperative that the new Townsville City Council (TCC) ensures the timely delivery of additional treatment infrastructure to meet the ongoing growth needs of the Townsville community.

Submissions for Pre-Amalgamation Projects

Prior to the amalgamation of Townsville City Council and the City of Thuringowa (COT) Council in March 2008 to form the New Townsville City Council, each entity was responsible for their own catchments and infrastructure. The MCU applications were made by the new Townsville City Council for the previous City of Thuringowa projects for the following works:

- Interim plant upgrades to Mt Low and Deeragun WPP's to provide sufficient capacity and treatment capability to meet the load requirements till 2010.
- Upgrades to Mt Low WPP and Condon WPP's. Deeragun WPP was to be decommissioned.

In addition to the MCU applications, the new TCC had also submitted applications for subsidy for the upgrades required to the three plants (both the interim and major upgrades at Mt Low were applied for). TCC had recently upgraded their Cleveland Bay WPP, and were considering a quality upgrade to their Mt St John WPP to meet EPA discharge limits.

Environmental Constraints

Subsequent to the MCU applications for Mt Low and Condon, the EPA had revised their discharge limits for discharges from Condon (which discharges into the upper freshwater reaches of the Bohle River) and for Mount Low (which discharges into the mouth of the Black River). These revised limits were much more stringent and were based on the receiving waters for both these discharges being not suitable to receive the proposed nutrient loads.

For Condon, the EPA has indicated previously that they would prefer that no additional flows should be discharged to the Bohle River as it is an Ephemeral Stream at the discharge location of Condon WPP.

Also for the Mt Low discharge to the Black River, EPA's position was that the assimilation capacities of the Black River were not well understood.

To comply with these new limits required significantly more capital infrastructure. That is capital estimates went from $152.9M to $267.7M, an increase of $114.8M.

Post Amalgamation - A Regional Strategy

The amalgamation of the two councils provided a previously unrealisable opportunity to review the strategies in a more regional context. At the same time the New Townsville City Council was reviewing their potable water regional strategy with a view to looking at potable water replacement opportunities as a means of deferring a potable water upgrade to their Toonpan WTP. The new TCC asked the project design team to develop and review a number of regional strategies for wastewater treatment against the existing approach to ensure the best long-term approach is adopted.

After investigating a wide range of potential scenarios, the project team settled on two broad strategies to conduct an in depth comparison, a decentralised and a centralised option. The pre-amalgamation approach detailed above was considered a decentralised approach with upgrades to three of the WPPs (ie. Mt St John, Condon, and Mt Low). This was compared to a single large upgrade at the Mt St John WPP and the diversion of the major growth areas to this plant, referred to as the centralised approach.

A combination of cost (capital, operating and lifecycle (NPV)) and non-financial criteria were used to assess the two options including:

1) Capital Cost
2) Operating & Maintenance (O&M) Cost implications.
3) Environmental Considerations including GHG considerations and immediate and long term impacts on receiving waters.
4) Opportunity of the option for generating future reuse opportunities.
5) Social Considerations including potential odour, noise and visual impacts.
6) That the infrastructure provides a sound long term base for the future.
7) Project Timing

Table 2 shows the cost summary for the two options (from the report titled, Regional Strategy Review & Preliminary Business Case, June 2008):

Table 2 – Capital Cost Comparison

	Decentralised	**Centralised**
Overall Capital Cost	$264m	$189m#
Operations & Maintenance at 2025	$5m	$4m
Life Cycle Cost (Total Present Value over at 7% over 15 years to 2025)	$306m	$236m

Note: # includes costs only estimated for items in the Business Case Report.

On the basis of the of the approximate $75M capital cost saving, net present value, and the non financial analysis, the business case for the centralised option was compelling and was endorsed by council on 22 July, 2008.

Integrated Water Management

TCC recognise the importance of considering the WPP upgrades in light of any future integrated water management strategy developed for the region. Potable water replacement initiatives for recycling effluent have real and tangible benefits in deferring water infrastructure requirements for the Townsville region and this was considered in the regional strategy developed.

TCC have commenced an investigation into the feasibility of deferring capital for the upgrade to Toonpan WTP through the introduction of both two tiered water pricing and potable water replacement strategies. However, this is only the first phase of this study. Council is likely to require some time (more than 2-3 years) to develop a market for reuse. This is because there is a need to align the current price of potable water to represent the margin cost of providing future potable capacity. A full understanding of the future costs of both potable and recycled water in Townsville needs to be attained before a plan for future recycling in the region can be developed and assessed. As a result effluent re-use and potable water replacement does not form part of this planning report.

A Three Stage Approach

The new Townsville City Council has undertaken a thorough re-evaluation of wastewater upgrade options from a regional perspective. Given the population growth pressures and time constraints a staged approach is required to ensure infrastructure can meet short and long terms needs of the community. Three stages are proposed:

1. Stage One will involve interim upgrades at the existing Deeragun and Mt Low sites to allow these plants to meet EPA requirements until new infrastructure can be provided around 2010 to meet the region's longer term needs. Both these sites will be decommissioned once Stage Two works are fully operational.

2. Stage Two is focused on providing the necessary wastewater treatment infrastructure to meet the requirements to 2025 and is the main focus of this planning report.

3. Stage Three is focused on providing the additional infrastructure required to further reduce nutrient discharge from all discharge locations. The focus will be on developing a regional water management plan. The aim of this plan is to consider water supply in Townsville in an integrated way. It is likely from this plan that effluent reuse can be used to offset the need or defer the next potable replacement upgrade. This will also reduce the nutrient discharges to the environment resulting in a "win win" outcome. TCC intend to seek additional Federal funding to assist with the implementation of Stage Three infrastructure and will be the subject of a separate planning report.

Stage 1 – Interim Upgrades

The objective of the interim upgrades to Mount Low and Deeragun WPP's is to provide sufficient short term capacity to enable the design, construction and commissioning of the major upgrade to Mt St John WPP to be completed without failure of the plant's licence conditions.

Improvements to the plant capacity are to be achieved through minor plant changes such as:

- Bypassing of wet weather flows in excess of 3 x ADWF;
- Upgrades to disinfection systems;
- Additional aeration capacity to the oxidation ditches;
- Aerobic digestion of the sludge.

The interim upgrade works will be issued for tender in September, with works expected to commence late November 2008. The estimated capital requirement for these works (both plants) is $3.2M.

Stage 2 – Centralised Strategy
A summary of the capital works includes the following:

- Construction of a 106,500EP BNR upgrade to Mt St John WPP;
- Diversion of sewer flows from Bushland Beach/Deeragun to Mt St John WPP;
- Diversion of sewer flows from Kirwan/Bohle Plains to Mt St John WPP;
- Transfer of Bohle Industrial WPP effluent to Mount St John WPP;
- Decommissioning of Mt Low / Deeragun WPPs.

The existing plant at Condon would remain and provide treatment to the Upper Ross catchment only (Condon/Kelso/Rasmussen) avoiding the need for a capacity upgrade to Condon until 2025.

Conclusion & Recommendation
TCC has developed a systematic and logical three stage strategic approach to address the population growth on Townsville's wastewater treatment infrastructure. The three stage approach prioritises action given the timing imperative to deliver the overall wastewater upgrade program.

The adopted strategy is the correct investment decision for the following reasons [part only]:

- It reduces the loads and environmental impact to the sensitive receiving waterways of the upper freshwater reaches of the Bohle.
- It eliminates discharge to the sensitive receiving waterways of the Black River.
- It upgrades the existing Mt St John WPP leading to significant load reduction to the estuary of the Bohle River (70% nitrogen, 62% phosphorus and >98% ammonia). These levels can be further improved by increased effluent reuse.

It is therefore recommended that the three stage strategy implemented by TCC be endorsed and funding be assessed on the full capital works value of $206.9 M.

Appendix C

Atmospheric Emission Dispersion Modelling

Appendix C Atmospheric Emission Dispersion Modelling

Yabulu Dispersion Modelling

Dispersion modeling is generally carried out prior to the construction of industrial facilities to determine the potential pollutant levels associated with atmospheric emissions, generally from chimney stacks. Follow up studies are often undertaken to check the known emissions from a stack and calibrate models with monitored outputs.

A recent modeling study was commissioned by BHP Billiton Yabulu Refinery for one of the stacks at the Yabulu nickel refinery. A summary of the results from the report is provided below. Creek to Coral would like to acknowledge BHP Billiton Yabulua for making the report available (Pacific Air and Environment 2007, *QNI Air Quality and Health Risk Assessment Report*, Queensland Nickel Industries Limited).

The stacks at Yabulu are listed in Table A. The subject of the report was stack 330.

Table A Stacks at Yabulu

Stack	Height
330 Stack	77m
320 Stack	77m
380/514	92m
380 line 2 stack (new)	65m
514 stack (new)	92m

The scope of the study was to predict ground level concentrations for particulates (PM_{10}), NO_2, SO_2, benzene, toluene, ethylbenzene, xylenes and odour.

"*Dispersion modelling was performed using the CALPUFF dispersion model utilizing three-dimensional output from the CALMET meteorological pre-processor.*

The results of the dispersion modelling indicate that pollutant concentrations surrounding the Yabulu Refinery due to emissions from Stack 330 remain within the relevant state and federal air quality criteria."
(PAE, p.iii)

The concentrations of pollutants in ambient air are essential in characterising the airborne exposure pathway and in the overall risk assessment process. The modelling output for the study is reported as a concentration of pollutants in the air column in micro grams per cubic metre for all pollutants.

Pollutant concentrations are used to estimate the health risk or hazards associated with the emissions from industrial facilities. Concentrations and dispersion patterns of atmospheric pollutants can also be used to provide an indication of potential issues for water quality.

As with most situations monitoring is the most accurate way to determine pollutant concentrations. With air quality monitoring "*it is time consuming, costly and is typically limited to a few receptor locations. Air dispersion modelling, by contrast, is relatively inexpensive, is less time consuming, and also provides greater flexibility in terms of receptor locations, assessment of individual and cumulative source contributions, and characterisation of concentration over greater spatial extents.*

Models have therefore become a primary analytical tool in most air quality assessments. However, monitoring can be used in a complementary manner to dispersion models, and is particularly useful in assessing the accuracy of model estimates, especially when the relevant authority's air quality guidelines are approached."
(PAE, p.1)

The main factors in determining the fate of atmospheric emissions from stacks are weather related. This includes wind speed and direction, atmospheric turbulence and mixing height.

"*Wind direction dictates the direction in which the plume travels. Thus, over a long period, the temporal variation of wind directions determines the spatial pattern of average ground level concentrations. Wind speed influences the initial dilution of the plume as it leaves the source and also affects plume rise, with higher wind speeds resulting in smaller plume rise. Broadly, higher wind speeds result in lower ground level concentrations*." (PAE, p.5)

"*An important aspect of plume dispersion is the level of turbulence in the atmospheric boundary layer. Turbulence acts to dilute or diffuse a plume by increasing the cross-sectional area of the plume due to random motions. As turbulence increases, the rate of plume dilution, or diffusion, increases. Weak turbulence limits diffusion and is a critical factor in causing high plume concentrations downwind of a source.*

Turbulence is related to the vertical temperature gradient, the condition of which determines what is known as stability, or thermal stability". (PAE, p.6)

"*Mixing height is variable in space and time, and typically increases during fair-weather daytime over land from tens to hundreds of metres around sunrise up to one to four kilometres in the mid-afternoon, depending on the location, season and day-to-day weather conditions.*

Two different types of temperature inversion frequently develop and may lead to air pollution episodes. These are:

- *Radiation or surface inversions that form overnight through rapid cooling of the ground and surface air layers; and*
- *Subsidence inversions that form at various heights above the ground due to subsiding air associated with the anticyclone.*

Radiation inversions are usually short-lived and rarely persist beyond mid-morning. Subsidence inversions may persist for up to six days while the associated anticyclone is in the vicinity. Short periods of severe air pollution can occur with radiation inversions but sustained pollution events result from subsidence inversions.

Average mixing heights during the night and early morning hours are generally lower than 150 m, increasing after sunrise to an average maximum of 900 m (90th percentile of 1300 m) by mid-afternoon in response to convective mixing that results from solar heating of the earth's surface." (PAE, p.8)

The model calculated concentration or deposition for each point on the grid, and then used a suitable interpolation method to draw a continuous contour line (see Figure A).

"*Ground level concentrations were calculated over a grid of uniformly spaced receptor points 250 m apart over an area of 15 km by 15 km. In addition to this, concentrations over eight sensitive receptors, representing populated areas, were also calculated.*" (PAE, p.16)

For PM_{10} there were no incidences of exceedance over the entire domain.

For NO_2 there were no incidences of exceedance over the entire domain for any of the averaging periods assessed.

For SO_2 there were no incidences of exceedance over the entire domain for any of the averaging periods assessed.

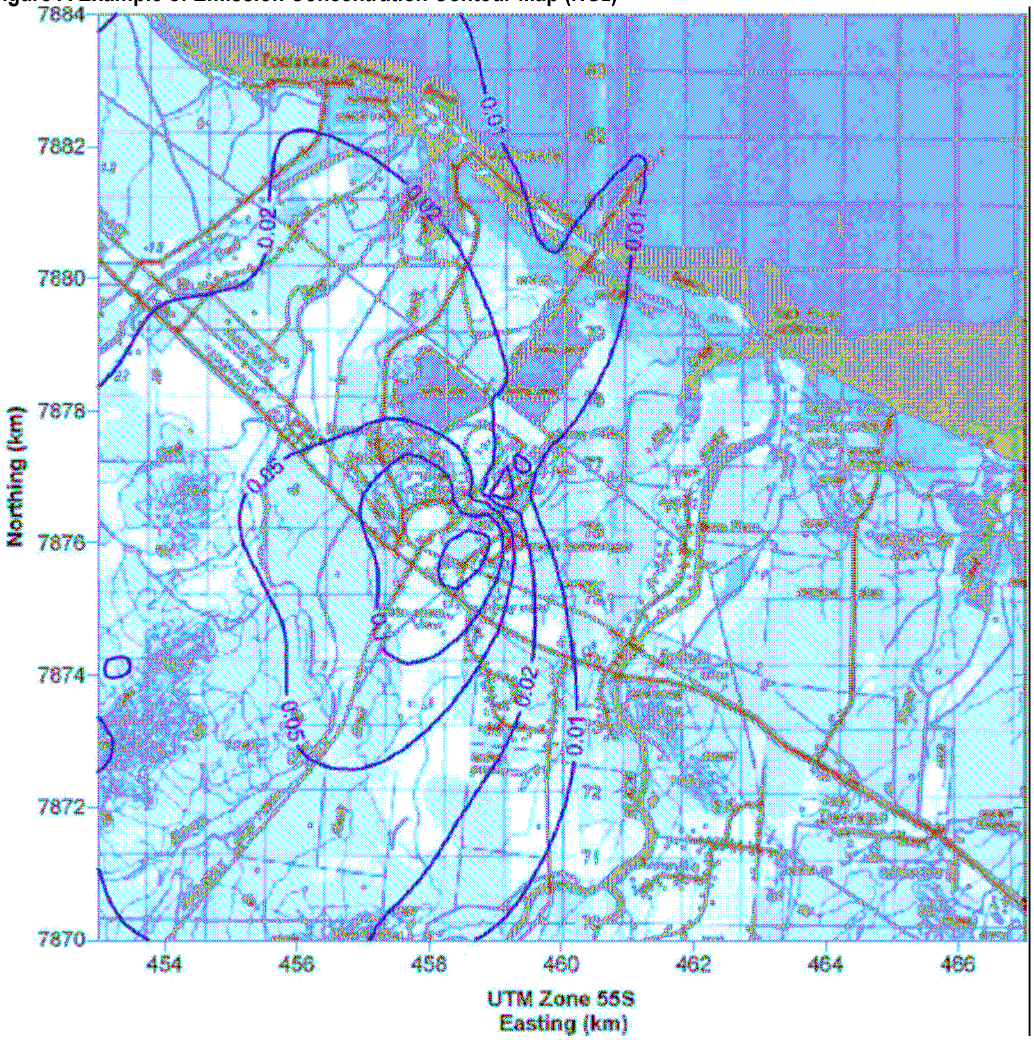
Similarly there were no incidences of exceedance for Benzene, Toluene, Xylenes or Ethyl Benzene. Results are listed in Table B.

Table B Summary Results from Dispersion Modelling

Pollutant	Emission rates (g/s)	Annual Ave	Guideline	Hour	Guideline
PM_{10}	16.87	1	50	5 (24 hr)	150
NO_2	2.94	<1	30	10 (1 hr)	320
SO_2	22	1	60	50 (1 hr)	570
Benzene	11.77	1	10.4		
Toluene	1.68			0.5 (24 hr)	8,000
Xylenes	0.8			0.2 (24 hr)	947
Ethyl benzene	0.21			1 (3 minute)	14,500

Source: PAE, p.14 Notes: Emission rates are those leaving the stack. Concentrations of pollutants are expressed in micro grams per cubic metre. Annual Ave (average) and Hour columns are results of the modeling study with guideline values for the pollutant in the column on the right. Maximum concentrations over various time frames are measured for different pollutants and this is expressed in the Hout column with the actual time period expressed in brackets.

Figure A Example of Emission Concentration Contour Map (NO_2)



Source Figure 5.4 (PAE, p.21) Average Annual Concentration of NO_2

Appendix D

Diffuse Emission Calculations for Townsville

Aircraft and Airport Emissions

Data below is sourced from *Townsville International Airport - Environment Strategy 2004* (Australian Airports (Townsville) Pty Ltd (AAL)) available at http://www.townsvilleairport.com.au/environment.php

Total emissions from airport operations for 1999 were calculated for inclusion in the Environment Strategy for Townsville Airport (see Table A).

Table A Total Emissions released from Townsville Airport operations for 1999

Pollutant	Total Emissions	
	Kilograms	Tonnes
Hydrocarbons (HC)/Volatile Organic Compounds (**VOC**s)	82,694	82.5
Carbon monoxide (**CO**)	220,109	220
Oxides of nitrogen (**NOx**)	47,675	47.5
Sulphur dioxide (**SO**$_2$)	6,535	6.5
Particulate matter (**PM**)	7,332	7

Source: (AAL 2004, p.125 [undertaken by Air Noise Environment Pty Ltd])

In addition to the substances listed in Table A there are unquantified emissions of:

- Ozone (O3);
- Chlorofluorocarbons (CFCs); and
- Other greenhouse gases.

The figures presented above should be used only as a baseline of air emissions from Townsville Airport. Nevertheless, estimates of air emissions from the airport are relatively low and were assessed as having a negligible impact on the airshed. There was no mention of potential water quality impacts associated with emissions to air.

The major sources of these air emissions at Townsville airport are:

- Combustion of aviation fuels during landing, take off and engine idling;
- Exhaust emissions from non-aircraft vehicles and ground service equipment;
- Refuelling of aircraft and other vehicles;
- Storage of fuel;
- Lawn mowing;
- Ground operation of helicopters;
- Maintenance of aircraft;
- Maintenance of ground service equipment.

Additional minor sources of air emissions include:

- Air conditioning;
- The use of generators and pumps;
- Venting of aircraft fuel;
- Surface painting and paint stripping;
- Fumigation; and
- Fire fighting exercises and operations.

Water bodies adjacent to the Townsville airport include:

- Louisa Creek;
- Rowes Bay Canal; and
- Bohle River estuary.

Drainage from the airport flows to the Rowes Bay Canal. Rowes Bay Canal is the third largest drainage basin in urban Townsville. The western arm of the canal drains the airport environs bounded to the west by the airport runway 01/19 embankment, combined with the drainage of the Garbutt area in the north. The catchment area is approximately 334 hectares, and drains into Rowes Bay, which is a part of the Great Barrier Reef World Heritage Area. (AAL 2004, p.33)

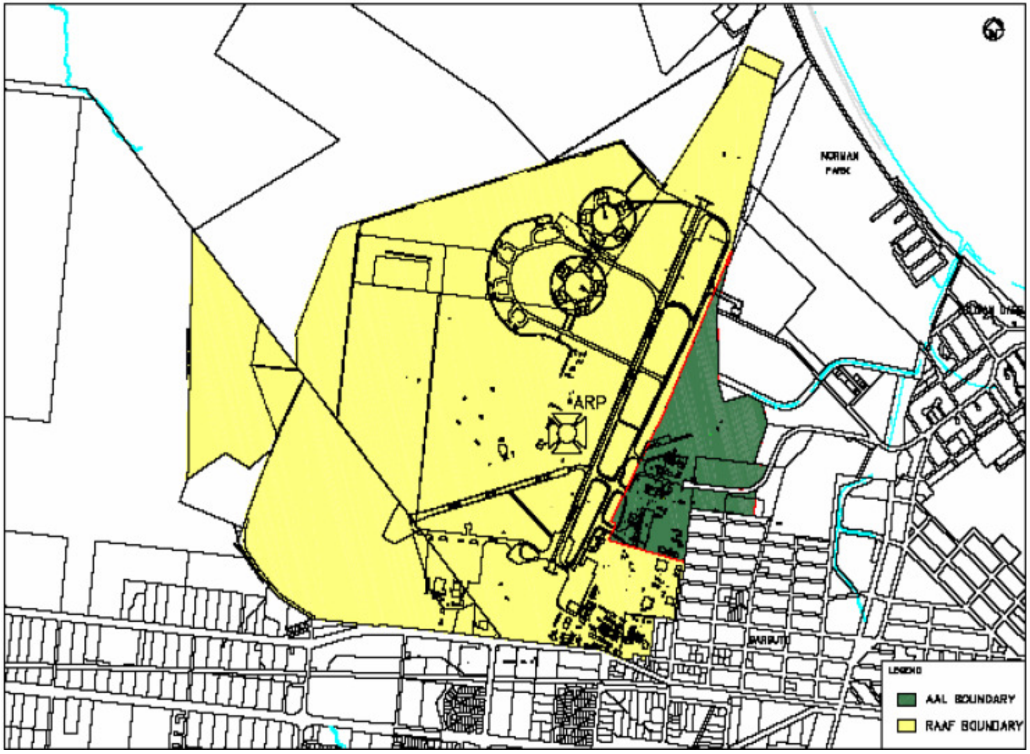
Activities associated with airport operations that have the potential to impact on water quality include:

- Increased erosion and sedimentation;
- Oil, lubricant and fuel leakage spills;
- Untreated oil, grease and detergents being released into water systems;
- Venting of fuel from aircraft;
- Runoff of herbicides and pesticides around airport grounds; and
- Untreated sewage being released into water systems.

(AAL 2004, pp.125-127)

The civil aviation section of the Townsville Airport is leased and operated by AAL and covers an area of 82 hectares. The remainder of the airport, including the runways, is controlled and operated by the RAAF (approximately 800 hectares). The RAAF Base Townsville has its own Environment Management System (EMS) certified to the international best practice standard for Environmental Management Systems ISO 14001. (AAL 2004, pp.27-31)

Figure A Townsville Airport



(AAL 2004, p.30)

Airport Stormwater Drainage System

Run-off from the international and domestic terminal areas flows via an underground system of pipe work into the open lined drain running along the eastern boundary of the airport. Another piped system drains the developed section of the northern building area. Stormwater samples are routinely taken downstream from these outlets. The northern part of the AAL leased area drains into an open eastern drain, north of the Airport Access Road, which in turn also drains into the western arm of the Rowes Bay Canal (which is part of the Great Barrier Reef World Heritage Area).

The Airport Drainage Canal flows in a generally northeasterly direction until it meets the western arm of the Rowes Bay Canal. This combined canal flows through Old Common Road until it meets the Rowes Bay Canal 170m upstream of the Townsville City Council Tide Gates. These Tide Gates are situated near Evans Street, Belgian Gardens, and some 700m from the outlet. The canal outlets onto the beach at Rowes Bay approximately 730m northwest of the Bundock Street/Heatley's Parade intersection.
(AAL 2004,pp.33-36)

Stormwater quality is important due to its eventual discharge into downstream estuarine environments. Investigations into sources of stormwater contamination and sources at the airport had been commenced in 1999. Stormwater monitoring undertaken by AAL during the period between 1999 and 2004 has indicated the presence of potential contaminants in low levels including metals, petroleum hydrocarbons, detergents, nutrients, oils, grease and BTEX in stormwater samples. AAL has implemented a range of measures to improve the stormwater quality within the airport.

Based on earlier full scans of potential contaminants, monitoring is targeted towards contaminants of concerns including metals and TPH. Such monitoring focuses on representative samples at four rising stage samplers across the wet season (December – March) each year, including first flush samples when quality is prone to be poor. (AAL 2004, p.36)

The Draft Townsville International Airport Environment Strategy identified the discharge of contaminated stormwater as one of the high-risk environmental issues for Townsville International Airport (AAL 2004, pp.131-134).

Annual Air Traffic Movement

Data associated with Townsville air traffic movement (see Table B and Table C) shows trends, which indicate that emissions associated with the Townsville Airport may have decreased from 1998 to 2004 before air traffic started to increase again. Estimates of air emissions made in 1999 are likely to be greater than for 2008 and would be well within one order of magnitude variation giving confidence that calculations made using these figures will be an overestimate of current emissions.

Table B Aircraft movements at Townsville Airport 1998 to 2007

Year	>136 tonne	7-136 tonne	< 7 tonne	Helicopter	Unknown	Military	Total
1998	4	24,116	35,028	3,280	1,076	14,360	77,864
1999	68	22,580	35,782	1,790	94	9,214	69,528
2000	56	24,722	32,842	1,938	278	9,802	69,638
2001	134	20,676	31,152	2,110	190	11,302	65,564
2002	124	16,756	25,522	1,938	332	9,622	54,294
2003	60	18,818	23,428	1,866	138	8,364	52,674
2004	10	20,046	18,690	1,424	24	6,760	46,954
2005	38	21,518	19,020	1,498	282	5,744	48,100
2006	76	25,248	23,110	1,564	-	6,162	56,160
2007	46	25,290	28,052	1,620	-	5,020	60,028

Note: 1998 figures extrapolated from six months data July to December. 1998 to 2005 derived from AVCHARGES data by Airservices Australia. 2006 and 2007 data sourced from the Operational Data Warehouse by Airservices Australia (Source: http://www.airservices.gov.au/projectsservices/reports/default.asp)

Table C Ratio of aircraft movements by type at Townsville Airport 1998 to 2007

Year	>136 tonne	7-136 tonne	< 7 tonne	Helicopter	Unknown	Military
1998	0.01	30.97	44.99	4.21	1.38	18.44
1999	0.10	32.48	51.46	2.57	0.14	13.25
2000	0.08	35.56	47.24	2.79	0.40	14.10
2001	0.20	31.54	47.51	3.22	0.29	17.24
2002	0.23	30.86	47.01	3.57	0.61	17.72
2003	0.11	35.73	44.48	3.54	0.26	15.88
2004	0.02	42.69	39.80	3.03	0.05	14.40
2005	0.08	44.74	39.54	3.11	0.59	11.94
2006	0.14	44.96	41.15	2.78		10.97
2007	0.08	42.13	46.73	2.70		8.36

Assuming a potential settling area for the air emissions of 700 hectares i.e. approximate area of the airport. Particulate matter - 7 tonnes per annum / 700 hectares is 0.01 tonne per hectare, which is roughly equivalent to a thickness of 0.001 mm. Oxides of nitrogen – 47 tonnes per annum / 700 hectares is 0.07 tonnes per hectare or 70 kg per hectare. It is unlikely that this quantity of NO_x would settle out in the vicinity of the airport as it is by nature more mobile than particulate matter and would be dispersed throughout the airshed. If 10% (7kg per hectare) of the NO_x emissions settled within the 700 hectare catchment the quantity is not significant and would not constitute a risk to water quality. In comparison cane farms apply approximately 180 kg/hectare per annum of nitrogen to crops.

Similarly sulphur dioxide, at 7 tonnes per annum, is not a significant quantity and would not constitute a risk to water quality.

Passenger Numbers

While aircraft movements have decreased the number of passengers has increased steadily (see Table D) reflecting the increase in capacity of aircraft and higher utilisation rates. The increase in utilisation rates was triggered by the introduction of lower priced airfares after the demise of Ansett and the entry of Virgin Blue into the domestic market in 2000.

Table D Passenger numbers at Townsville Airport

Year	Domestic	Regional	International	Total
1990/91	316,828	82,112	11,311	410,251
1991/92	350,899	102,023	-	452,922
1992/93	446,276	105,934	2,874	555,084
1993/94	389,140	119,391	5,557	514,358
1994/95	435,518	139,558	1,611	576,687
1995/96	454,567	143,548	-	598,115
1996/97	463,585	143,474	94	607,426
1997/98	478,228	149,528	146	627,902
1998/99	492,584	159,622	658	652,864
1999/2000	509,439	172,199	-	681,638
2003/04				920,000
2004/05				980,000
2005/06				1,150,000
2006/07				1,385,000
2007/08				1,485,000

Notes: Regional airline data is known to be incomplete. Domestic airline data was affected by a change in definition following 1991/92 and data from 1992/93 may include passengers in transit. Source of data for 1990 to 2000 was the Department of Transport and Regional Development 2001 (http://previous.townsville.qld.gov.au/atlas/economic_6.asp). 2003 to 2008 data interpreted from http://www.townsvilleairport.com.au/statistics.php

Townsville Airport handled 1,485,000 passengers to 30 June 2008, with most passengers originating from domestic sources, particularly within Queensland. Between 06/07 and 07/08 Townsville Airport experienced a 7.2% growth in passengers. Over the past six years the Airport has seen an 11.6% Average Annual Growth Rate (Source: http://www.townsvilleairport.com.au/ statistics.php).

Updated Flight Info for Townsville Airport

Analysis of flight information from the airlines operating into and out of Townsville International Airport show that approximately 500 flights operate in the region each week (see Table C). The airlines of interest are QANTAS, Jetstar, Virgin Blue, MacAir and SkyTrans as well as occasional flights by the tourist airplane the Red Baron.

Table E Breakdown of Townsville International Airport flight activity

	Small Inbound	Small Outbound	Large Inbound	Large Outbound	Red Baron	TOTAL
Monday	18	18	17	17	5	**75**
Tuesday	16	16	18	18	5	**73**
Wednesday	16	16	20	20	5	**77**
Thursday	17	17	18	18	5	**75**
Friday	17	17	20	20	5	**79**
Saturday	15	15	11	11	5	**57**
Sunday	12	12	16	16	5	**61**
Weekly Total	**111**	**111**	**120**	**120**	**35**	**497**
Annual Total	5,772	5,772	6,240	6,240	1,820	25,844

Note: The annual total is based on multiplying the weekly totals by 52. This may not be a true reflection of the actual number of flights

The busiest day of the week is Friday (79 flights in total), while Saturday has the least activity (57 flights in total). The predominant flight type was large incoming and outbound flights, mainly operated by QANTAS, Jetstar and Virgin Blue.

Large inbound and outbound flights most often used Boeing 737 and Airbus Industrie A320 aircraft. Smaller flights were mostly operated on De Havilland DHC-8 Series aircraft.

The Red Baron is a Grumman Sea-Cat tourist charter plane and as such does not have a fixed flight schedule. Management of the Red Baron estimate the plane to operate approximately 5 times each day depending on demand and local weather conditions.

This breakdown of flights into and out of Townsville has taken into account all available information. However, a large portion of aircraft activity in the Townsville air shed is operated by the Australian military and updated information was not publicly available. Similarly, information on charter flights operated by Alliance Airlines and other operators was not available. Consequently the listed activity relates to general commercial aircraft only. The flight activity listed above was compiled in late October 2008.

Lawnmower Emissions

Emissions from lawn mowers have been calculated based on assumptions of 30,000 two stroke mowers and 30,000 four stroke mowers in the Townsville region and usage of 1 hour per mower per fortnight i.e. 780,000 two stroke lawn mower hours per year and 780,000 four stroke lawn mower hours per year.

If we assume that the mowing footprint is 150 square kilometres (the same as for gross pollutants) and all of the oxides of nitrogen and particulate matter settles within the mowing footprint then we have a contribution from lawn mowers of 0.43 kg/ha per year of particulate matter and 0.33 kg/ha year of oxides of nitrogen.

Table F Estimate of Lawnmower Emissions for Townsville

Emission type	2 stroke EF	Kg/year	4 stroke EF	Kg/year	Total/year	
					Kg	Tonne
Benzene	17	13260	2.3	1794	15054	15
1,3-Butadiene	2.16	1684.8	0.292	227.76	1912.56	1.9
Carbon monoxide	731	570180	489	381420	951600	952
Chromium (III) compounds	0.00332	2.5896	0.000219	0.17082	2.76042	0.003
Chromium (VI) compounds	0.00138	1.0764	0.000091	0.07098	1.14738	0.001
Cobalt and compounds	0.0047	3.666	0.00031	0.2418	3.9078	0.004
Copper and compounds	0.0047	3.666	0.00031	0.2418	3.9078	0.004
Cyclohexane	0.517	403.26	0.07	54.6	457.86	0.5
Ethylbenzene	3.96	3088.8	0.534	416.52	3505.32	3.5
Formaldehyde	2.8	2184	0.68	530.4	2714.4	2.7
Lead and compounds	0.0002	0.156	0.001	0.78	0.936	0.001
n-Hexane	0.548	427.44	0.74	577.2	1004.64	1
Manganese and compounds	0.0047	3.666	0.00031	0.2418	3.9078	0.004
Nickel and compounds	0.0047	3.666	0.00031	0.2418	3.9078	0.004
Oxides of nitrogen	1.45	1131	4.85	3783	4914	4.9
Particulate matter ≤ 10 µm	7.8	6084	0.515	401.7	6485.7	6.5
Polycyclic aromatic hydrocarbons	0.895	698.1	0.121	94.38	792.48	0.8
Styrene	0.304	237.12	0.041	31.98	269.1	0.3
Sulphur dioxide	0.3	234	0.206	160.68	394.68	0.4
Toluene	28.6	22308	3.87	3018.6	25326.6	25
Total volatile organic compounds (VOCs)	304	237120	41.1	32058	269178	269
Xylenes	21	16380	2.83	2207.4	18587.4	18.6
Zinc and compounds	0.0047	3.666	0.00031	0.2418	3.9078	0.004

Notes: EF is the emission factor for each substance for lawn mowers in grams per hour.

A comparison of calculated emissions for Townsville to emissions from Australia as calculated by the NPI is provided in Table G.

Table G Lawn Mower Emissions Australia 2006/2007

	Kilograms per year emissions to air		
Substance	**Australia**	**Townsville 1**	**Townsville 2**
Benzene	910,000	9,100	15,000
Biphenyl (1,1-biphenyl)	63	0.63	
1,3-Butadiene (vinyl ethylene)	110,000	1,100	1,900
Carbon disulfide	570	5.7	
Carbon monoxide	86,000,000	860,000	952,000
Chloroethane (ethyl chloride)	1,800	18	
Chloroform (trichloromethane)	3,200	32	
Chromium (III) compounds	120	1.2	2.8
Chromium (VI) compounds	80	0.8	1.1
Cobalt & compounds	200	2	3.9
Copper & compounds	330	3.3	3.9
Cumene (1-methylethylbenzene)	82	0.82	
Cyanide (inorganic) compounds	2.6	0.03	
Cyclohexane	90,000	900	458
1,2-Dibromoethane	2,700	27	
Dibutyl phthalate	250	2.5	
1,2-Dichloroethane	3,700	37	
Dichloromethane	4,800	48	
Ethanol	8,600		
2-Ethoxyethanol	2,300	23	
2-Ethoxyethanol acetate	2,300	23	
Ethyl acetate	2,800	28	
Ethylbenzene	310,000	3,100	3,500
Ethylene glycol (1,2-ethanediol)	2,300	23	
Ethylene oxide	2,400	24	
Formaldehyde (methyl aldehyde)	210,000	2,100	2,717
n-Hexane	200,000	2,000	1,004
Hydrogen sulfide	0.020	-	
Lead & compounds	690	6.9	1
Manganese & compounds	240	2.4	4
Methanol	8,900	89	
2-Methoxyethanol	2,500	25	
Methyl ethyl ketone	7,700	77	
Methyl isobutyl ketone	3,600	36	
Methyl methacrylate	2,900	29	
Nickel & compounds	200	2	4
Oxides of Nitrogen	390,000	3,900	4,900
Particulate Matter 10.0 um	540,000	5,400	6,486
Phenol	2,800	28	
Polychlorinated dioxins and furans	0.00000067	-	
Polycyclic aromatic hydrocarbons	35,000	350	792
Styrene (ethenylbenzene)	28,000	280	269
Sulphur dioxide	88,000	880	395
Tetrachloroethylene	4,400	44	
Toluene (methylbenzene)	1,800,000	18,000	25,236
Total Volatile Organic Compounds	19,000,000	190,000	269,178
1,1,2-Trichloroethane	2,200	22	
Trichloroethylene	2,700	27	

Vinyl Chloride Monomer	2,700	27	
Xylenes (individual or mixed isomers)	1,500,000	15,000	18,587
Zinc and compounds	350	3.5	3.9

Source: http://www.npi.gov.au/cgi-bin/npireport.pl?proc=source;instance=public;year=2007;source=6;loc_type=national

Note: Townsville 1 calculations are based on the assumption that emissions are related to population and that Townsville population is approximately 1% of Australia's population. Townsville 2 calculations are translated from Table F.

Vehicle Emissions

The Townsville region displays a growing industrial sector and booming population. With permanent infrastructure such as a major Australian Defence Force Base (Lavarack Barracks), regional facilities such as James Cook University and the Townsville General Hospital, the Townsville population will only continue to grow.

With relatively limited public transport services and expanding urban and peri-urban land uses, private vehicular traffic has been and continues to be the predominant mode of transport. The urban road network is well developed and is being continually expanded to account for the growing population and driver demand.

Table D Registered Motor Vehicles in the Townsville and Thuringowa areas

Area	1997	2001	2008	Change % (1997-2001)	Change % (2001-2008)	Change % (1997-2008)
Townsville	51,248	58,209	-	13.6%	-	-
Thuringowa	20,108	29,343	-	46.0%	-	-
Townsville Region	71,356	87,552	122,976	22.7%	40.4%	72.3%

Note: Figures are exclusive of registered motorbikes and trailers.

Figures from the Queensland Department of Transport show that with a growing population (a 9.9% increase between 1996 and 2001), the number of registered vehicles is also increasing (see Table D). In the Townsville region, the number of registered vehicles, excluding registered motorbikes and trailers, rose by 22.7% between 1997 and 2001. This was mirrored between 2001 and 2008 with a rise of 40.4%.

Calculations from data provided by the QLD Department of Transport show that significant levels of emissions are released from road traffic each year (see Table E).

These emissions were calculated using three components:

- The number of registered vehicles in Townsville (information provided by Qld Department of Transport, Townsville) (including information on the fuel type, year of manufacture and vehicle type),
- EPA emissions factors (information provided by the Environment Protection Agency); and
- The number of vehicle kilometres travelled (VKT).

VKT was calculated by dividing the total 2006 QLD VKT (44,373,000,000) by the total number of registered QLD vehicles (excluding trailers) to give the VKT per individual QLD vehicle. This was then multiplied by the number of Townsville registered vehicles to give a final VKT value of 1,739,306,120.

The final emissions estimate was calculated as follows:

- Registered vehicles were divided into types of manufacture, petrol types and years of manufacture,
- These categories were used to calculate specific VKT values for each vehicle/year/fuel combination,
- Specific emissions values and VKT values were fed into the calculation for vehicular emissions,
- These results were tabulated to find overall emissions.

The final emissions calculations may be underestimated due to several factors.

- A constant speed of 60km/hr was assumed for all vehicles. As many of Townsville's roads are limited to lower speed limits and others allow higher speed limits, 60km/hr was adopted as an intermediate value to provide consistency to the calculations. This may introduce small inaccuracies into the final emissions.
- Calculations do not account for the multiple stops involved in urban driving (lights, traffic, intersections etc). This will result in lower emissions calculations.

- The emissions factors used were developed for southeast Queensland. The higher ambient temperatures experienced in Townsville increase fuel evaporation rates and mean that total hydrocarbon emission calculations will be underestimated.
- As emissions factors were unavailable for some vehicle types the closest available fuel emissions were used (this occurred particularly for petrol-fueled trucks and buses).

Nevertheless, this estimation demonstrates that vehicle pollution is a measurable process and provides an indication of the magnitude and type of emissions for inclusion in environmental assessment.

Table E Vehicular emissions (tonnes per year) in the Townsville City Council area

	Car	**LCV**	**Bus**	**Truck**	**Motorcycle**	**Totals**
NOx	883	468	89	440	13	**1,893**
CO	5,773	2,098	11	87	2,911	**10,881**
THC	391	134	3	17	227	**771**
PM10	67	41	3	17	2	**130**
SO_2	58	34	3	14	3	**112**
CO_2	283,616	124,651	9,281	43,811	8,788	**470,147**
CH4	43	14	0	2	23	**83**
N_20	55	12	0	1	0	**69**
Totals	**290,886**	**127,453**	**9,391**	**44,390**	**11,967**	**484,086**

Note: LCV is light commercial vehicle. Figures exclude trailers, farming machinery and mobile campervans. Values are expressed as tonnes per year. Assumed potential deposition area for the pollutants is 250 square kilometres.

Assuming all the NO_x is translated to land and water through rainfall then 1,900 tonnes of NO_2 divided by the assumed area of the airshed i.e. 250 square kilometres would give 7.6 tonnes per square kilometre or 0.076 tonnes per hectare (76 kg/ha). Similarly for particulate matter 0.52 tonnes per square kilometre, 0.0052 tonnes per hectare (5.2 kg/ha) and sulphur dioxide 0.45 tonnes per square kilometre, 0.0045 tonnes per hectare (4.5 kg/ha).

The majority of the emissions released from vehicles in Townsville compromised of carbon dioxide and carbon monoxide.

When examined by vehicle type, the majority of emissions are released by cars and light commercial vehicles (see Figures 3), which is a reflection of the number of those vehicle types on the road.

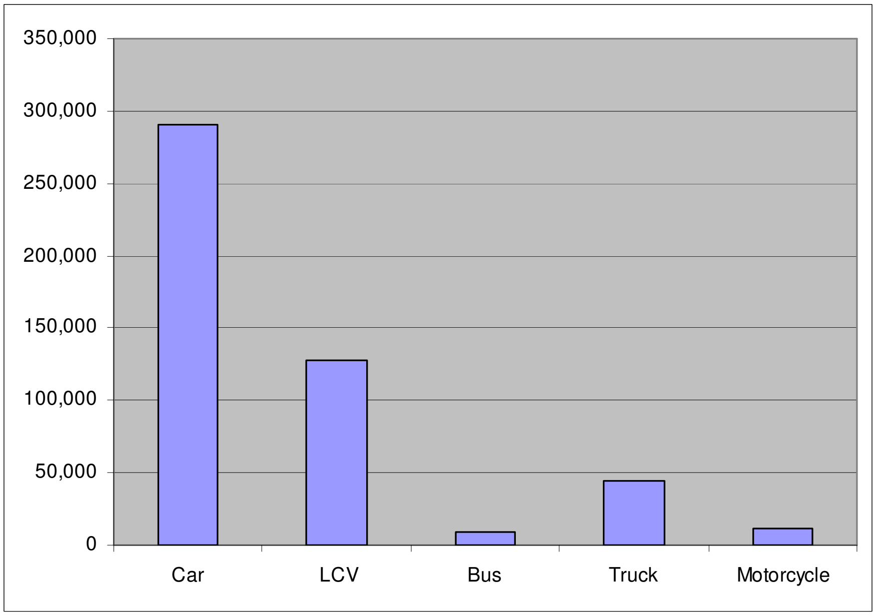


Figure 3. Magnitude of emissions by vehicle type.

The calculations show that almost half a million tonnes of emissions are released from vehicles in Townsville each year. If the greenhouse gases (carbon dioxide, methane and nitrous oxide) are adjusted by their global warming potential (by a factor of 21 for methane and 270 for nitrous oxide), total CO_{2e} emissions amount to approximately 490, 512 tonnes per year.

While there are implications for air quality and global warming associated with the vehicle emissions calculated for the Townsville region the immediate and localised impacts on water quality are less tangible.

Emissions from motor vehicles have been documented to have significant impacts on the environment, including on water quality. Contributions to the atmospheric reservoir as well as residues on road surfaces increase the amount of potential for atmospheric deposition and transport of pollutants in urban stormwater runoff to receiving water bodies.

Benthic Sediment sampling sites (Butler 2008, p.6)

Site	Description	Latitude	Longitude	Site Type
S1	Landsdowne Creek	S19°35'34.20"	E146°48'48.84"	Freshwater Control Sites
S2	Antill Plains Creek	S19°26'02.94"	E146°51'19.92"	
S3	Stonehouse Ck (Toonpan)	S19°28'19.01"	E146°51'26.26"	
S4	Central Creek	S19°28'54.69"	E146°38'47.56"	
S5	Sachs Creek (Oak Valley)	S19°26'36.10"	E146°48'46.30"	Freshwater Monitoring Sites
S6	Central Creek	S19°27'24.30"	E146°43'45.00"	
S7	Black Weir (below dam)	S19°23'45.97"	E146°43'48.79"	
S8	Palmetum drain (Aplins)	S19°18' 35.35"	E146°45' 52.83"	
S9	Black Weir (Rasmussen)	S19°21' 28.17"	E146°44' 00.68"	
S10	Condon drain (Black Weir)	S19°20' 03.59"	E146°43' 39.65"	
S11	Lower end Black Weir	S19°19' 07.51"	E146°44' 05.93"	
S12	Riverside drain (Black Weir)	S19°19' 16.32"	E146°44' 00.34"	
S13	Drain mouth (Gleesons)	S19°19' 05.04"	E146°44' 41.87"	
S14	Riverside drain (Aplins Weir)	S19°19' 05.42"	E146°44' 55.00"	
S15	Douglas drain (Aplins Weir)	S19°18' 43.35"	E146°45' 26.80"	
S16	Aplins Weir (Cranbrook side)	S19°18' 51.59"	E146°45' 9.97"	
S17	Aplins Weir (Aitkenvale side)	S19°18' 15.08"	E146°46' 46.93"	
S18	Annandale drain (Aplins Weir)	S19°18' 31.94"	E146°46' 33.19"	
S19	Lavarack Creek (Annandale)	S19°19' 02.11"	E146°47' 11.56"	
S20	Stuart Creek (Upstream)	S19°22'06.54"	E146°50'43.54"	
S21	Stuart Creek (Cluden)	S19°19'03.96"	E146°50'13.14"	
S22	Stuart Creek (upper estuary)	S19°17'37.50"	E146°49'58.50"	Estuarine Monitoring Sites
S23	Ross R (Bowen Road bridge)	S19°18'14.94"	E146°48'4.80"	
S24	Ross R (below Fairfield W)	S19°17'13.68"	E146°48'15.05"	
S25	Lavarack Creek (tidal end)	S19°18'25.44"	E146°47'54.48"	
S26	Ross R (below Rooneys Br)	S19°17'12.48"	E146°49'14.46"	
S27	Gordon Creek (near Ross R)	S19°17'30.00"	E146°49'33.12"	
S28	Ross R (above NP ramp)	S19°16'56.34"	E146°49'29.28"	
S29	Ross R (near Goondi)	S19°16'40.14"	E146°49'51.90"	
S30	Goondi Creek (mouth)	S19°16'28.92"	E146°49'42.00"	
S31	Gordon Creek (near tidal limit)	S19°18'35.96"	E146°49'24.44"	
S32	Ross R (Flying Fox Ck mouth)	S19°16'17.34"	E146°50'4.86"	
S33	Ross R (mouth reclaim)	S19°15'47.70"	E146°50'13.92"	
S34	Tidal drain (Benwell Rd)	S19°15'41.82"	E146°50'11.58"	
S35	Cocoa Creek	S19°17'17.43"	E146°50'11.58"	Estuarine Control

	Silver	Arsenic	Cadmium	Chromium	Copper	Nickel	Lead	Antimony	Zinc
ISQG low	1	20	1.5	80	65	21	50	2	200
ISQG high	3.7	70	10	370	270	52	220	25	410

Appendix E

Event Monitoring Calculations EMC

TSS (Combined old and new values)

Dominant land use	Site	Year	Mean (all data)	Median (all data)	Rise (mean)	Peak (mean)	Fall (mean)	Mean rise, peak and fall	Mean EMC mg/L
Established urban	Woolcock St drain	06/07	22	24	20	29	22	24	20
		07/08	15	10	51	17	8.8	26	
	Captain Creek	06/07	15	15	25	12	7.4	15	
Developing urban (Coastal plain)	Kern drain	06/07	339	278	612	284	185	360	795
		07/08	502	445	637	770	389	599	
	Gordon Creek	06/07	409	351	783	444	184	470	
		07/08	662	130	4600	500	123	1741	
Dev. urban (hillslope) *	Riverview Creek		11142	4975					11140
Light industrial	Hill St drain	07/08	49	43	100	46	26	57	57
Urban / industrial	Stuart Ck (ds)	06/07	237	200	257	305	169	244	129
	Louisa Creek	06/07	14	12	21	15	7.8	15	
Rural residential	Sachs Creek	06/07	29	7.1	139	21	5.6	55	35
	Bluewater Ck (ds)	06/07	27	8.3	40	45	4.4	30	
	Alligator Ck (ds)	06/07	20	19	20	14	24	19	
Minimal use	Stuart Ck (us)	06/07	96	63	41	224	49	105	56
	Hencamp Ck	06/07	27	9.3	46	47	14	36	
	Campus Ck	06/07	14	3.5	10	49	1.9	20	
	Bluewater Ck (us)	06/07	55	18	130	48	9	62	
Conservation	Alligator Ck (us)	06/07	12	7	34	19	4.6	19	19
Dry savanna grazing	Stuart Ck (us)	06/07	96	63	41	224	49	105	130
	Black River	06/07						240	
	Black River	07/08						230	
	Bluewater Ck (us)	06/07	55	18	130	48	9	62	
Green space (dry)	Alligator Ck (us)	06/07	12	7	34	19	4.6	19	25
	Campus Creek	06/07	14	3.5	10	49	1.9	20	
	Hencamp Ck	06/07	27	9.3	46	47	14	36	
Wet Tropics grazing	Davidson Ck	05-07	29	12					25
	Warrami Creek	05-07	25	13					
Green space (wet)	Murray Falls	05-07	1	0.35					4
	Tully Gorge	05-08	7	4					
	North Hull River	05-07	10	4					

Note: Minimal Use and Conservation replaced with grazing and green space, wet and dry categories (shaded)

Nitrogen

Initial TN calculations

Dominant land use	Site	Year	Mean (all data)	Median (all data)	Rise (mean)	Peak (mean)	Fall (mean)	Mean rise, peak and fall	Mean EMC mg/L
Established urban	Woolcock St drain	06/07	716	643	653	724	798	725	**744**
		07/08	793	826	770	684	825	760	
	Captain Ck	06/07	740	642	632	570	1020	740	
Developing urban (Coastal plain)	Kern drain	06/07	767	806	695	625	869	729	**748**
		07/08	830	666	744	987	832	854	
	Gordon Ck	06/07	746	694	758	555	794	702	
Light industrial	Hill St drain	07/08	858	648	684	821	973	826	**822**
Urban industrial	Stuart Ck (ds)	06/07	674	642	772	698	587	685	**626**
	Louisa Ck	06/07	572	533	542	526	611	560	
Rural residential	Sachs Ck	06/07	568	564	801	487	537	608	**510**
	Bluewater Ck (ds)	06/07	403	368	498	436	311	414	
	Alligator Ck (ds)	06/07	432	363	392	680	368	480	
Minimal use	Stuart Ck (us)	06/07	632	644	498	729	603	611	**482**
	Hencamp Ck	06/07	400	397	402	219	444	354	
	Campus Ck	06/07	447	327	552	305	363	407	
	Bluewater Ck (us)	06/07	529	421	672	429	497	533	
Conservation	Alligator Ck (us)	06/07	331	254	699	270	253	407	**404**

Established Urban

Parameter	Site	Year	Mean (all data)	Median (all data)	Rise (mean)	Peak (mean)	Fall (mean)	Mean rise, peak and fall	Mean EMC mg/L
DON	Woolcock St drain	06/07	419	426	437	208	537	394	**364**
		07/08	369	334	229	252	422	301	
	Captain Ck	06/07	380	359	403	369	369	380	
PN	Woolcock St drain	06/07	144	61	89	419	34	181	**221**
		07/08	256	303	392	261	234	296	
	Captain Ck	06/07	204	169	150	97	366	204	
NOx	Woolcock St drain	06/07	114	114	106	82	146	111	**127**
		07/08	135	115	110	145	135	130	
	Captain Ck	06/07	134	72	62	97	242	134	
Ammonia	Woolcock St drain	06/07	39	24	21	15	81	39	**29**
		07/08	33	32	39	26	34	33	
	Captain Ck	06/07	22	16	17	7.0	43	22	
TN	Woolcock St drain	06/07	716	625	653	724	798	725	**741**
		07/08	793	784	770	684	825	760	
	Captain Ck	06/07	740	616	632	570	1020	741	

Developing urban (Coastal plain)

Parameter	Site	Year	Mean (all data)	Median (all data)	Rise (mean)	Peak (mean)	Fall (mean)	Mean rise, peak and fall	Mean EMC mg/L
DON	Kern drain	06/07	449	399	448	391	475	438	**397**
		07/08	457	417	357	412	498	422	
	Gordon Ck	06/07	382	402	404	294	395	364	

PN	Kern drain	06/07	175	135	132	79	240	150	**190**
		07/08	264	196	244	483	234	320	
	Gordon Ck	06/07	154	140	209	79	145	144	
NOx	Kern drain	06/07	103	87	78	101	119	99	**122**
		07/08	84	81	109	81	76	89	
	Gordon Ck	06/07	161	140	113	147	192	151	
Ammonia	Kern drain	06/07	40	36	37	54	35	42	**38**
		07/08	25	16	34	11	24	23	
	Gordon Ck	06/07	49	42	32	35	62	43	
TN	Kern drain	06/07	767	657	695	625	869	730	**747**
		07/08	830	710	744	987	832	854	
	Gordon Ck	06/07	746	724	758	555	794	702	

Light Industrial

Parameter	**Site**	**Year**	**Mean (all data)**	**Median (all data)**	**Rise (mean)**	**Peak (mean)**	**Fall (mean)**	**Mean rise, peak and fall**	**Mean EMC mg/L**
DON	Hill St drain	07/08	415	318	301	386	495	394	**394**
PN	Hill St drain	07/08	324	215	259	319	360	313	**313**
NOx	Hill St drain	07/08	102	89	99	107	100	102	**102**
Ammonia	Hill St drain	07/08	17	18	25	9.0	18	17	**17**
TN	Hill St drain	07/08	858	640	684	821	973	826	**826**

Urban industrial

Parameter	**Site**	**Year**	**Mean (all data)**	**Median (all data)**	**Rise (mean)**	**Peak (mean)**	**Fall (mean)**	**Mean rise, peak and fall**	**Mean EMC mg/L**
DON	Stuart Ck (ds)	06/07	281	226	309	308	242	286	**313**
	Louisa Ck	06/07	362	343	362	273	381	339	
PN	Stuart Ck (ds)	06/07	309	265	382	304	260	315	**210**
	Louisa Ck	06/07	108	95	75	100	136	104	
NOx	Stuart Ck (ds)	06/07	81	95	79	78	84	80	**94**
	Louisa Ck	06/07	90	92	96	146	80	107	
Ammonia	Stuart Ck (ds)	06/07	3.4	<0.2	2.0	8.4	0.7	3.7	**6.9**
	Louisa Ck	06/07	12	5.5	9.3	7.0	14	10	
TN	Stuart Ck (ds)	06/07	674	586	772	698	587	686	**623**
	Louisa Ck	06/07	572	536	542	526	611	560	

Rural Residential

Parameter	**Site**	**Year**	**Mean (all data)**	**Median (all data)**	**Rise (mean)**	**Peak (mean)**	**Fall (mean)**	**Mean rise, peak and fall**	**Mean EMC mg/L**
Rural residential	Sachs Ck	06/07	257	248	286	320	237	281	**228**
	Bluewater Ck (ds)	06/07	183	170	225	199	141	188	
	Alligator Ck (ds)	06/07	203	224	192	269	187	216	
Rural residential	Sachs Ck	06/07	121	69	303	123	81	169	**114**
	Bluewater Ck (ds)	06/07	64	40	68	84	47	66	
	Alligator Ck (ds)	06/07	110	113	123	107	93	108	
Rural residential	Sachs Ck	06/07	188	181	204	41	218	154	**149**
	Bluewater Ck (ds)	06/07	152	142	196	148	122	155	
	Alligator Ck (ds)	06/07	92	55	30	297	82	136	
Rural residential	Sachs Ck	06/07	2.4	2.0	8.0	2.5	1.1	3.9	**9.6**
	Bluewater Ck (ds)	06/07	4.4	1.7	9.0	4.8	0.8	4.9	

	Alligator Ck (ds)	06/07	27	7.0	47	7.0	6.0	20	
Rural residential	Sachs Ck	06/07	568	500	801	487	537	608	**501**
	Bluewater Ck (ds)	06/07	403	354	498	436	311	415	
	Alligator Ck (ds)	06/07	432	399	392	680	368	480	

Dry savanna grazing

Parameter	**Site**	**Year**	**Mean (all data)**	**Median (all data)**	**Rise (mean)**	**Peak (mean)**	**Fall (mean)**	**Mean rise, peak and fall**	**Mean EMC mg/L**
DON	Stuart Ck (us)	06/07	270	284	255	298	259	271	**240**
	Black River	06/07						300	
	Black River	07/08						210	
	Bluewater Ck (us)	06/07	210	206	147	169	278	198	
PN	Stuart Ck (us)	06/07	175	138	124	270	136	177	**175**
	Black River	06/07						22	
	Black River	07/08						230	
	Bluewater Ck (us)	06/07	211	152	409	95	156	220	
NOx	Stuart Ck (us)	06/07	165	131	75	136	191	134	**105**
	Black River	06/07						100	
	Black River	07/08						59	
	Bluewater Ck (us)	06/07	104	87	107	164	61	111	
Ammonia	Stuart Ck (us)	06/07	22	5.0	44	25	17	29	**15**
	Black River	06/07						13	
	Black River	07/08						8	
	Bluewater Ck (us)	06/07	3.9	2.0	9.0	1.0	2.3	4.1	
TN	Stuart Ck (us)	06/07	632	558	498	729	603	610	**535**
	Black River	06/07						435	
	Black River	07/08						507	
	Bluewater Ck (us)	06/07	529	447	672	429	497	533	

Greenspace (dry)

Parameter	**Site**	**Year**	**Mean (all data)**	**Median (all data)**	**Rise (mean)**	**Peak (mean)**	**Fall (mean)**	**Mean rise, peak and fall**	**Mean EMC mg/L**
DON	Alligator Ck (us)	06/07	171	174	164	184	169	172	**200**
	Campus Creek	06/07	245	200	271	199	229	233	
	Hencamp Ck	06/07	240	211	198	145	269	204	
PN	Alligator Ck (us)	06/07	128	58	500	50	54	201	**125**
	Campus Creek	06/07	92	91	149	92	7.8	83	
	Hencamp Ck	06/07	93	63	124	50	100	91	
NOx	Alligator Ck (us)	06/07	28	28	33	30	26	30	**50**
	Campus Creek	06/07	107	54	127	12	125	88	
	Hencamp Ck	06/07	57	52	38	22	67	42	
Ammonia	Alligator Ck (us)	06/07	4.0	1.0	2.0	6.0	4.0	4.0	**8.0**
	Campus Creek	06/07	3.3	2.0	5.3	2.0	1.0	2.8	
	Hencamp Ck	06/07	9.7	3.0	42	1.5	7.8	17	
TN	Alligator Ck (us)	06/07	331.0	261.0	699.0	270.0	253.0	407.3	**383.0**
	Campus Creek	06/07	447.3	347.0	552.3	305.0	362.8	406.7	
	Hencamp Ck	06/07	399.7	329.0	402.0	218.5	443.8	354.8	

Wet Tropics grazing

Parameter	**Site**	**Year**	**Mean (all data)**	**Median (all data)**	**Rise (mean)**	**Peak (mean)**	**Fall (mean)**	**Mean rise, peak and fall**	**Mean EMC mg/L**
DON	Davidson Ck	05-07	115	90					**160**
	Warrami Creek	05-07	210	137					
PN	Davidson Ck	05-07	60	48					**90**
	Warrami Creek	05-07	123	70					

NOx	Davidson Ck	05-07	306	307					**500**
	Warrami Creek	05-07	1132	1090					
Ammonia	Davidson Ck	05-07	12	7.0					**18**
	Warrami Creek	05-07	24	26.0					
TN	Davidson Ck	05-07	493	452					**768**
	Warrami Creek	05-07	1489	1323					

Greenspace (wet)

Parameter	**Site**	**Year**	**Mean (all data)**	**Median (all data)**	**Rise (mean)**	**Peak (mean)**	**Fall (mean)**	**Mean rise, peak and fall**	**Mean EMC mg/L**
DON	Murray Falls	05-07	87	66					**90**
	Tully Gorge	05-08	93	92					
	North Hull River	05-07	96	82					
PN	Murray Falls	05-07	34	31					**45**
	Tully Gorge	05-08	40	24					
	North Hull River	05-07	61	40					
NOx	Murray Falls	05-07	8	7					**50**
	Tully Gorge	05-08	94	35					
	North Hull River	05-07	66	28					
Ammonia	Murray Falls	05-07	2	2.0					**8**
	Tully Gorge	05-08	5.5	4.0					
	North Hull River	05-07	18	18.0					
TN	Murray Falls	05-07	131	106					**193**
	Tully Gorge	05-08	233	155					
	North Hull River	05-07	241	168					

Phosphorus

Established Urban

Parameter	Site	Year	Mean (all data)	Median (all data)	Rise (mean)	Peak (mean)	Fall (mean)	Mean rise, peak and fall	Mean EMC mg/L
FRP	Woolcock St drain	06/07	226	214	241	149	258	216	**152**
		07/08	173	155	91	116	202	136	
	Captain Ck	06/07	129	138	131	134	121	129	
PP	Woolcock St drain	06/07	53	58	52	71	43	55	**69**
		07/08	79	86	135	91	68	98	
	Captain Ck	06/07	61	46	93	23	67	61	
DOP	Woolcock St drain	06/07	35	25	15	48	52	38	**60**
		07/08	105	88	86	158	93	112	
	Captain Ck	06/07	46	18	55	73	8.2	45	
TP	Woolcock St drain	06/07	314	297	308	268	353	310	**281**
		07/08	357	329	312	365	363	347	
	Captain Ck	06/07	236	202	279	230	196	235	

Developing urban (Coastal plain)

Parameter	Site	Year	Mean (all data)	Median (all data)	Rise (mean)	Peak (mean)	Fall (mean)	Mean rise, peak and fall	Mean EMC mg/L
FRP	Kern drain	06/07	203	186	191	217	204	204	**130**
		07/08	130	88	90	85	151	109	
	Gordon Ck	06/07	102	124	96	117	100	104	
PP	Kern drain	06/07	123	117	161	141	94	132	**128**
		07/08	158	185	188	257	131	192	
	Gordon Ck	06/07	93	84	124	80	79	94	
DOP	Kern drain	06/07	27	18	42	28	19	30	**19**
		07/08	50	55	85	44	39	56	
	Gordon Ck	06/07	18	9	10	10	26	15	
TP	Kern drain	06/07	353	321	394	386	317	366	**277**
		07/08	338	328	363	386	321	357	
	Gordon Ck	06/07	213	217	230	207	205	214	

Light Industrial

Parameter	Site	Year	Mean (all data)	Median (all data)	Rise (mean)	Peak (mean)	Fall (mean)	Mean rise, peak and fall	Mean EMC mg/L
FRP	Hill St drain	07/08	219	89	50	265	270	195	**195**
PP	Hill St drain	07/08	124	99	137	93	140	123	**123**
DOP	Hill St drain	07/08	122	36	173	97	116	129	**129**
TP	Hill St drain	07/08	465	224	360	455	526	447	**447**

Urban industrial

Parameter	Site	Year	Mean (all data)	Median (all data)	Rise (mean)	Peak (mean)	Fall (mean)	Mean rise, peak and fall	Mean EMC mg/L
FRP	Stuart Ck (ds)	06/07	87	83	79	85	93	86	**104**
	Louisa Ck	06/07	117	134	106	142	121	123	
PP	Stuart Ck (ds)	06/07	181	122	196	214	147	186	**111**
	Louisa Ck	06/07	42	36	29	27	54	37	
DOP	Stuart Ck (ds)	06/07	14	14	13	16	12	14	**15**

	Louisa Ck	06/07	20	17	28	3.0	18	16	
TP	Stuart Ck (ds)	06/07	282	219	288	315	252	285	**231**
	Louisa Ck	06/07	179	187	163	172	193	176	

Rural Residential

Parameter	**Site**	**Year**	**Mean (all data)**	**Median (all data)**	**Rise (mean)**	**Peak (mean)**	**Fall (mean)**	**Mean rise, peak and fall**	**Mean EMC mg/L**
FRP	Sachs Ck	06/07	34	29	72	39	25	45	**26**
	Bluewater Ck (ds)	06/07	6.4	6.1	6.2	6.7	6.4	6.4	
	Alligator Ck (ds)	06/07	28	20	31	14	31	25	
PP	Sachs Ck	06/07	22	19	33	21	19	24	**20**
	Bluewater Ck (ds)	06/07	12	11	14	21	5.4	13	
	Alligator Ck (ds)	06/07	27	22	39	13	15	22	
DOP	Sachs Ck	06/07	9.4	3.9	28	8.6	5.6	14	**10**
	Bluewater Ck (ds)	06/07	4.9	4.4	8.4	2.9	3.7	5.0	
	Alligator Ck (ds)	06/07	11	8.6	11	7	14	11	
TP	Sachs Ck	06/07	65.4	51.9	133.0	68.6	49.6	83.7	**56**
	Bluewater Ck (ds)	06/07	23.3	21.5	28.6	30.6	15.5	24.9	
	Alligator Ck (ds)	06/07	66.0	50.6	81.0	33.9	60.0	58.3	

Dry savanna grazing

Parameter	**Site**	**Year**	**Mean (all data)**	**Median (all data)**	**Rise (mean)**	**Peak (mean)**	**Fall (mean)**	**Mean rise, peak and fall**	**Mean EMC mg/L**
FRP	Stuart Ck (us)	06/07	53	55	55	74	44	58	**29**
	Black River	06/07						31	
	Black River	07/08						13	
	Bluewater Ck (us)	06/07	6.3	5.1	8.2	2.8	7.3	6.1	
PP	Stuart Ck (us)	06/07	70	69	53	100	60	71	**70**
	Black River	06/07						68	
	Black River	07/08						73	
	Bluewater Ck (us)	06/07	68	38	87	67	57	70	
DOP	Stuart Ck (us)	06/07	19	11	9	16	22	16	**11.0**
	Black River	06/07						13	
	Black River	07/08						14	
	Bluewater Ck (us)	06/07	5.3	4.9	6.0	8.0	3.1	5.7	
PP	Stuart Ck (us)	06/07	142	135	117	190	126	144	**110.0**
	Black River	06/07						112	
	Black River	07/08						100	
	Bluewater Ck (us)	06/07	80	48	101	78	67	82	

Greenspace (dry)

Parameter	**Site**	**Year**	**Mean (all data)**	**Median (all data)**	**Rise (mean)**	**Peak (mean)**	**Fall (mean)**	**Mean rise, peak and fall**	**Mean EMC mg/L**
FRP	Alligator Ck (us)	06/07	17	15	3.0	31	18	17	**25**
	Campus Creek	06/07	59.0	54.0	74.0	25.0	54.0	51.0	
	Hencamp Ck	06/07	7.3	5.1	4.9	9.9	7.0	7.3	
PP	Alligator Ck (us)	06/07	11	10	12	23	7.6	14	**20**
	Campus Creek	06/07	31	23	29	60	19	36	
	Hencamp Ck	06/07	13	13	12	8	15	12	
DOP	Alligator Ck (us)	06/07	3.2	3.5	6.4	0.0	3.2	3.2	**6.0**
	Campus Creek	06/07	12	12	14	9.3	11	11	
	Hencamp Ck	06/07	5.2	5.5	3.3	4.7	5.5	4.5	
TP	Alligator Ck (us)	06/07	31.2	28.5	21.4	54.0	28.8	34.7	**51.0**
	Campus Creek	06/07	102.0	89.0	117.0	94.3	84.0	98.4	
	Hencamp Ck	06/07	25.5	23.6	20.2	22.7	27.5	23.5	

Wet Tropics grazing

Parameter	**Site**	**Year**	**Mean (all data)**	**Median (all data)**	**Rise (mean)**	**Peak (mean)**	**Fall (mean)**	**Mean rise, peak and fall**	**Mean EMC mg/L**
FRP	Davidson Ck	05-07	7.5	6.0					**7**
	Warrami Creek	05-07	7.0	6.0					
PP	Davidson Ck	05-07	11	10					**14**
	Warrami Creek	05-07	16	15					
DOP	Davidson Ck	05-07	6.0	5.0					**6**
	Warrami Creek	05-07	7.0	6.0					
TP	Davidson Ck	05-07	24.5	21.0					**27**
	Warrami Creek	05-07	30.0	27.0					

Greenspace (wet)

Parameter	**Site**	**Year**	**Mean (all data)**	**Median (all data)**	**Rise (mean)**	**Peak (mean)**	**Fall (mean)**	**Mean rise, peak and fall**	**Mean EMC mg/L**
FRP	Murray Falls	05-07	3.0	3.0					**3**
	Tully Gorge	05-08	5.0	5.0					
	North Hull River	05-07	2.0	2.0					
PP	Murray Falls	05-07	4	3					**8**
	Tully Gorge	05-08	8	6					
	North Hull River	05-07	11	8					
DOP	Murray Falls	05-07	6.0	6.0					**4**
	Tully Gorge	05-08	3.0	2.0					
	North Hull River	05-07	4.0	4.0					
TP	Murray Falls	05-07	13.0	12.0					**15**
	Tully Gorge	05-08	16.0	13.0					
	North Hull River	05-07	17.0	14.0					

Appendix F

Catchment Modelling Load Calculations

Preliminary results by modelled catchments (17/02/09)

Sub catchment	Area (Ha)	Area (km2)	Flow ML/yr	TSS kg/yr	TN kg/yr	TP kg/yr
SC #1 Bohle River	13	0.1	49.5	6181.1	44.2	6.3
SC #2 Bohle River 2	5,214	52.1	17944.0	2254824.0	13781.2	1974.2
SC #3 Picnic Bay MI	147	1.5	1009.2	56764.8	523.5	119.8
SC #4 Pallarenda	1,753	17.5	7600.2	148849.9	3342.8	410.0
SC #5 Esplanade	281	2.8	1403.4	131820.5	1065.9	244.1
SC #6 Bohle River	976	9.8	5108.8	542419.2	4415.0	1059.6
SC #7 Stuart Creek (SB)	11,158	111.6	41942.9	1813320.0	21255.3	3115.8
SC #8 Crocodile Creek	9,062	90.6	32797.4	267740.6	12299.0	1296.1
SC #9 Ross River (btdam)	2,149	21.5	8010.1	391046.4	5045.8	706.4
SC #10 Bohle River	134	1.3	555.0	4415.0	203.4	22.0
SC #11 Bohle River 2	464	4.6	1807.0	197415.4	1242.5	175.7
SC #12 Ross River (btdam)	394	3.9	1387.6	91139.0	1037.5	143.2
SC #13 Alligator Ck (L)	7,966	79.7	28666.2	372124.8	12645.9	1352.9
SC #14 Lorna Ck/Ollera Ck	1,202	12.0	12551.3	1501113.6	11132.2	1602.0
SC #15 Nelly Bay MI	766	7.7	5329.6	180385.9	2349.4	441.5
SC #16 Bohle River	1,647	16.5	7253.3	290446.6	3752.8	618.1
SC #17 Esplanade	91	0.9	476.2	46042.6	381.6	90.8
SC #18 Ross River (btdam)	633	6.3	3721.2	394200.0	2595.4	630.7
SC #19 Ross Creek	1,486	14.9	7915.5	857779.2	6370.3	1570.5
SC #20 Bohle River	1,201	12.0	6086.4	611798.4	4951.2	1182.6
SC #21 Rollingstone Ck	7,611	76.1	68433.1	1879545.6	28950.0	3942.0
SC #22 Arcadia MI	256	2.6	1769.2	62441.3	791.6	154.2
SC #23 Mundy Creek	763	7.6	3563.6	283193.3	2671.1	517.2
SC #24 Ross Creek	443	4.4	2418.8	250711.2	1813.3	457.3
SC #25 Cocoa Creek	1,830	18.3	7158.7	58972.3	2642.7	280.4
SC #26 Bohle River 2	10,523	105.2	37212.5	4478112.0	29265.4	4635.8
SC #27 Bohle River	1,198	12.0	6528.0	700099.2	5140.4	1252.0
SC #28 Bohle River	2,981	29.8	13276.7	1542110.4	10943.0	1753.4
SC #29 Ross River (btdam)	4,733	47.3	20340.7	1472731.2	14380.4	2661.6
SC #30 Ross River (btdam)	755	7.5	3626.6	318513.6	2806.7	621.3
SC #31 Bohle River	6,369	63.7	27594.0	3099988.8	19930.8	3216.7
SC #32 Bohle River	2,435	24.4	10438.4	82939.7	3815.9	413.1
SC #33 Sleeper Log Ck	7,020	70.2	37212.5	3910464.0	25607.2	3595.1
SC #34 Station Creek	884	8.8	7379.4	85777.9	2721.6	350.0
SC #35 Wild Boar Creek	382	3.8	3342.8	28161.6	1160.5	148.5
SC #36 Hencamp Creek	3,703	37.0	38789.3	1356048.0	18858.5	2749.9
SC #37Scrubby Creek	1,584	15.8	13812.8	1050148.8	8483.2	1144.8
SC #38 Ollera Creek SC	704	7.0	7284.8	618105.6	4888.1	674.9
SC #39 Lorna Creek	415	4.1	4352.0	567648.0	3216.7	469.9
SC #40 Crystal Creek	1,1890	118.9	160202.9	6685632.0	77578.6	11100.7
SC #41 Ollera Creek	4,577	45.8	51719.0	1854316.8	21759.8	3049.5
SC #42 Two Mile Creek	1,588	15.9	8325.5	990230.4	6023.4	857.8
SC #43 Bluewater Ck (L)	1,688	16.9	9050.8	649641.6	5708.0	750.6
SC #44 Deep Creek	9,781	97.8	45411.8	5108832.0	32166.7	4730.4
SC #45 Black River (L)	5,409	54.1	27499.4	2497651.2	18732.4	3144.1
SC #46 Cape Cleveland	621	6.2	3405.9	30968.4	1207.8	151.1
SC #47 Alligator Ck (U)	6,727	67.3	37843.2	378432.0	14159.7	1712.4

SC #48 Black River (U)	2,4850	248.5	88931.5	10028448.0	63387.4	8987.8
SC #49 Ross River (U)						
SC #50 Leichhardt Creek	5,138	51.4	28256.3	1280361.6	13907.4	1731.3
SC #51 Saltwater Creek	5,605	56.1	44465.8	542419.2	16493.3	2141.3
SC #52 Bluewater Ck (U)	8,897	89.0	55188.0	7095600.0	35951.0	5550.3
SC #53 Unnamed RollCk	575	5.8	4856.5	239042.9	2743.6	438.4
SC #54 Surveyors Creek	1,791	17.9	13055.9	482500.8	6212.6	763.2
SC #55 Rollingstone Bay MI	164	1.6	1091.1	9208.5	381.6	48.3
SC #56 Five Bch Bay MI	437	4.4	2970.7	25039.6	1040.7	131.5
SC #57 Horseshoe Bay MI	1,298	13.0	8924.7	124882.6	3374.4	466.7
SC #58 Radical Bay MI	342	3.4	2330.5	19678.5	816.8	103.1
SC #59 West Coast MI	1,514	15.1	9807.7	88931.5	3469.0	441.5
SC #60 Cape Cleveland	1,160	11.6	6717.2	56449.4	2365.2	295.5
Totals	195,369	1,954	1,116,203	70,193,806	624,001	92,396
Totals (tonne/year)				70,194	624	92

Note: U is upper and L is lower. SB is sub basin. MI is Magnetic Island. Upper Ross River (SC#49) has no t been included in the modelling as the dam is considered as a sediment trap and flow over the spillway is not a regular feature of catchment flow. Pollutant loads delivered to the dam will be calculated and a component of pollutant load will be added to the end of catchment loads for the Ross River.

Preliminary Results by WQIP Sub Basin and Catchment (17/02/09)

Model SC	**Hectares**	**Catchment**	**No.**	**Flow**	**TSS**	**TN**	**TP**
		Crystal Creek SB	**1**	**ML/yr**	**t/yr**	**kg/yr**	**kg/yr**
40	11,890	Crystal Creek	1-1	160,203	6,686	77,579	11,101
39	415	Lorna Creek	1-2	4,352	568	3,217	470
14	1,202	Lorna/Ollera Ck	1-2	12,551	1,501	11,132	1,602
38	704	Ollera Creek	1-3	7,285	618	4,888	675
41	4,577	Ollera Creek	1-3	51,719	1,854	21,760	3,050
37	1,584	Scrubby Creek	1-4	13,813	1,050	8,483	1,145
36	3,702	Hencamp Creek	1-5	38,789	1,356	18,859	2,750
SB total	24,074			288,712	13,633	145,917	20,792
		Rollingstone Creek SB	**2**	**Flow**	**TSS**	**TN**	**TP**
21	7,611	Rollingstone Creek	2-1	68,433	1,880	28,950	3,942
53	575	Unnamed	2-2	4,857	239	2,744	438
54	1,791	Surveyors Creek	2-3	13,056	483	6,213	763
35	382	Wild Boar Creek	2-4	3,343	28	1,161	149
34	884	Station Creek	2-5	7,379	86	2,722	350
51	5,605	Saltwater Creek	2-6	44,466	542	16,493	2,141
51		Cassowary Creek	2-7				
50	5,138	Leichhardt Creek	2-8	28,256	1,280	13,907	1,731
SB total	21,986			169,790	4,538	72,189	9,515
		Bluewater Creek SB	**3**	**Flow**	**TSS**	**TN**	**TP**
33	7,020	Sleeper Log Creek	3-1	37,212	3,910	25,607	3,595
42	1,588	Two Mile Creek	3-2	8,326	990	6,023	858
52	8,897	Bluewater Creek (U)	3-3	55,188	7,096	35,951	5,550
43	1,688	Bluewater Creek (L)	3-3	9,051	650	5,708	751
44	9,781	Deep Creek	3-4	45,412	5,109	32,167	4,730
SB total	28,974			155,189	17,755	105,456	15,484
		Black River SB	**4**	**Flow**	**TSS**	**TN**	**TP**
48	24,850	Black River (Upper)	4-1	88,932	10,028	63,387	8,988
45	5,409	Black River (Lower)	4-1	27,499	2,498	18,732	3,144
		Alice River	4-2				
SB total	30,258			116,431	12,526	82,120	12,132
		Bohle River SB	**5**	**Flow**	**TSS**	**TN**	**TP**
1,6,10,16,20, 27,28,32,31	16,954	Bohle River	5-1	76,890	6,880	53,197	9,524
2,11, 26	16,201	Bohle River 2	5-2	56,963	6,930	44,289	6,786
4		Shelly Beach	5-3				
SB total	33,155			133,854	13,811	97,486	16,309
		Lower Ross River SB	**6**	**Flow**	**TSS**	**TN**	**TP**
4	1,753	Pallarenda	6-1	7,600	149	3,343	410
23	763	Mundy Creek	6-2	3,564	283	2,671	517
5 and 17	371	Esplanade	6-3	1,880	178	1,448	335
19 and 24	1,929	Ross Creek	6-4	10,334	1,108	8,184	2,028
9,12,18, 29,30	8,663	Ross River (btdam)	6-5	37,086	2,668	25,866	4,763
SB total	13,478			60,464	4,386	41,511	8,053
		Upper Ross River SB	**7**	**Flow**	**TSS**	**TN**	**TP**
49		Ross River (atd)	7-1				
49		Six Mile Creek	7-2				

49		Toonpan Lagoon	7-3				
49		Antill Plains Creek	7-4				
49		Sachs Creek	7-5				
49		Mt Stuart	7-6				
SB total							
		Stuart Creek SB	**8**	**Flow**	**TSS**	**TN**	**TP**
7	11,158	Stuart Creek	8-1				
7		Sandfly Creek	8-2				
SB total	11,158			41,943	1,813	21,255	3,116
		Alligator Creek SB	**9**	**Flow**	**TSS**	**TN**	**TP**
13	7,966	Alligator Creek	9-1	28,666	372	12,646	1,353
47	6,727	Alligator Creek	9-1	37,843	378	14,160	1,712
8	9,062	Crocodile Creek	9-2	32,797	268	12,299	1,296
25	1,830	Cocoa Creek	9-3	7,159	59	2,643	280
46	621	Cape Cleveland	9-4	3,406	31	1,208	151
60	1,160	Cape Cleveland	9-4	6,717	56	2,365	295
SB total	27,366			116,589	1,165	45,320	5,088
		Magnetic Island	**10**	**Flow**	**TSS**	**TN**	**TP**
59	1,514	West Coast	10-1	9,808	89	3,469	442
3	147	Picnic Bay	10-2	1,009	57	523	120
15	766	Nelly Bay	10-3	5,330	180	2,349	442
22	256	Arcadia	10-4	1,769	62	792	154
58	342	Radical Bay	10-5	2,331	20	817	103
57	1,298	Horseshoe Bay	10-6	8,925	125	3,374	467
56	437	Five Beach Bay	10-7	2,971	25	1,041	132
55	163	Rollingstone Bay	10-8	1,091	9	382	48
SB total	4,923			33,233	567	12,747	1,907

Preliminary Summary by WQIP Sub Basin (17/02/09)

Sub Basin	**No.**	**Area**	**Flow**	**TSS**	**TN**	**TP**
		Hectares	**ML/yr**	**t/yr**	**kg/yr**	**kg/yr**
Crystal Creek SB	1	24,074	288,712	13,633	145,917	20,792
Rollingstone Creek SB	2	21,986	169,790	4,538	72,189	9,515
Bluewater Creek SB	3	28,973	155,189	17,755	105,456	15,484
Black River SB	4	30,258	116,431	12,526	82,120	12,132
Black Basin Sub total		105,291	730,121	48,452	405,682	57,922
Bohle River SB	5	33,155	133,854	13,811	97,486	16,309
Lower Ross River SB	6	13,478	60,464	4,386	41,511	8,053
Upper Ross River SB	7					
Stuart Creek SB	8	11,158	41,943	1,813	21,255	3,116
Alligator Creek SB	9	27,365	116,589	1,165	45,320	5,088
Ross Basin Sub total		85,155	352,849	21,175	205,572	32,567
Magnetic Island	10	4,923	33,233	567	12,747	1,907
Total		195,369	1,116,203	70,194	624,001	92,396

Recalculated Base Case with STPs (pre Cleveland Bay upgrade) WQIP Sub Basin Summary (4/06/2009)

Catchment	Flow	TSS	TN	TP
	ML/Year	kg/Year	kg/Year	kg/Year
Crystal Creek SB	239,279	5,509,675	90,060	9,376
Rollingstone Creek SB	144,288	1,601,949	40,420	4,018
Bluewater Creek SB	145,599	2,805,025	92,637	4,637
Black River SB	114,318	7,190,500	70,591	11,063
Black Basin	643,484	17,107,149	293,708	29,095
Bohle River SB	131,618	9,289,250	191,753	29,795
Lower Ross River SB	53,677	4,202,975	33,097	6,976
Upper Ross River SB	196,735	8,103,000	100,375	12,775
Stuart Creek SB	47,450	1,649,800	200,020	58,400
Alligator Creek SB	104,762	2,103,495	42,687	4,807
Ross Basin	534,242	25,348,520	567,932	112,753
Magnetic Island SB	27,371	341,983	6,282	943
Black Ross WQIP area	1,205,098	42,797,652	867,922	142,791

Note: Black Ross WQIP is the sum of Black Basin, Ross Basin and Magnetic Island. Does not include upgraded figures for Cleveland Bay STP in Stuart Creek sub basin i.e. relates to 2005 base case

Recalculated Base Case with STPs (post Cleveland Bay upgrade) WQIP Sub Basin Summary (29/05/2009)

Sub Basin	Flow	TSS	TN	TP
	ML/Year	kg/Year	kg/Year	kg/Year
Crystal Creek	239,279	5,509,675	90,060	9,376
Rollingstone Creek	144,288	1,601,949	40,420	4,018
Bluewater Creek	145,599	2,805,025	92,637	4,637
Black River	114,318	7,190,500	70,591	11,063
Black Basin	643,484	17,107,149	293,708	29,095
Bohle River	131,618	9,289,250	191,753	29,795
Lower Ross River	53,677	4,202,975	33,097	6,976
Upper Ross River	196,735	8,103,000	100,375	12,775
Stuart Creek	47,450	1,649,800	61,320	20,039
Alligator Creek	104,762	2,103,495	42,687	4,807
Ross Basin	534,242	25,348,520	429,232	74,391
Magnetic Island	27,371	341,983	6,282	943
Black Ross Total	1,205,098	42,797,652	729,223	104,429

Note: Black Ross WQIP is the sum of Black Basin, Ross Basin and Magnetic Island. Includes upgraded figures for Cleveland Bay STP in Stuart Creek sub basin i.e. relates to 2007 not 2005 base case

Recalculated Base Case with STPs by WQIP Sub Basin and Catchment (29/05/2009)

Model SC No.	WQIP No.	Catchment	Flow	TSS	TN	TP
			ML/Year	kg/Year	kg/Year	kg/Year
40	1-1	Crystal Creek	134320	3069650	47085	5146.5
39	1-2	Lorna Creek	3233.9	59130	2317.75	91.615
14	1-2	Lorna Ck /Ollera Ck	9417	613200	8066.5	821.25
38 and 41	1-3	Ollera Creek	49421	579620	15691.35	1302.32
37	1-4	Scrubby Creek	10621.5	220825	5621	390.55
36	1-5	Hencamp Creek	32266	967250	11278.5	1624.25
		Crystal Creek SB	239279.4	5509675	90060.1	9376.485
21	2-1	Rollingstone Creek	58035	784750	16206	1722.8
53	2-2	Unnamed	3905.5	113515	1565.85	260.245
54	2-3	Surveyors Creek	10475.5	123735	3547.8	307.695
35	2-4	Wild Boar Creek	2814.15	11278.5	536.55	54.02
34	2-5	Station Creek	6314.5	45625	1335.9	143.81
51	2-6	Saltwater Creek	38325	300395	8249	919.8
51	2-7	Cassowary Creek				
50	2-8	Leichhardt Creek	24418.5	222650	8979	609.55
		Rollingstone Creek SB	144288.15	1601948.5	40420.1	4017.92
33	3-1	Sleeper Log Creek	33288	620500	21608	1025.65
42	3-2	Two Mile Creek	7592	129575	5292.5	206.225
52 and 43	3-3	Bluewater Creek		1084050	35441.5	1777.55
44	3-4	Deep Creek	44895	970900	30295	1627.9
		Bluewater Creek SB	145598.5	2805025	92637	4637.325
48 and 45	4-1	Black River				
	4-2	Alice River				
		Black River SB	114318	7190500	70591	11063.15
10, 32, 16, 6, 27, 20, 1, 28, 31	5-1	Bohle River	77616.52	5166940	154574.215	21386.9195
2, 26, 11	5-2	Bohle River 2	54001.75	4122310	37178.9	8407.775
4	5-3	Shelly Beach				
		Bohle River SB	131618.27	9289250	191753.115	29794.6945
4	6-1	Pallarenda	6716	186515	3051.4	372.3
23	6-2	Mundy Creek	3044.1	241995	2011.15	427.05
5, 17	6-3	Esplanade	1565.85	175930	959.22	266.085
19, 24	6-4	Ross Creek	9106.75	927100	5821.75	1681.92
9, 29, 30, 18, 12	6-5	Ross River (btdam)	33244.2	2671435	21253.95	4228.525
		Lower Ross River SB	53676.9	4202975	33097.47	6975.88
49	7-1	Ross River (atd)				
49	7-2	Six Mile Creek				

49	7-3	Toonpan Lagoon				
49	7-4	Antill Plains Creek				
49	7-5	Sachs Creek				
49	7-6	Mt Stuart				
		Upper Ross River SB	196735	8103000	100375	12775
7	8-1	Stuart Creek				
7	8-2	Sandfly Creek				
		Stuart Creek SB	47450	1649800	61320	20038.5
13 and 47	9-1	Alligator Creek	60882	1365100	25477	2978.4
8	9-2	Crocodile Creek	28871.5	467200	11388	1186.25
25	9-3	Cocoa Creek	6205	98185	2427.25	249.66
46 and 60	9-4	Cape Cleveland	8803.8	173010	3394.5	393.105
		Alligator Creek SB	104762.3	2103495	42686.75	4807.415
59	10-1	West Coast	8139.5	37595	1562.2	166.075
3	10-2	Picnic Bay	832.2	39055	302.585	80.665
15	10-3	Nelly Bay	4380	121545	1273.85	271.56
22	10-4	Arcadia	1452.7	40880	419.75	91.615
58	10-5	Radical Bay	1905.3	8066.5	368.65	37.595
57	10-6	Horseshoe Bay	2456.45	81395	1715.5	230.68
56	10-7	Five Beach Bay	7300	9818.5	467.2	47.45
55	10-8	Rollingstone Bay	905.2	3628.1	172.28	17.4835
		Magnetic Island SB	27,371	341,983	6,282	943
		Black Basin	643,484	17,107,149	293,708	29,095
		Ross Basin	534,242	25,348,520	429,232	74,391
		Black Ross WQIP area	1,205,098	42,797,652	729,223	104,429

Note: Black Ross WQIP is the sum of Black Basin, Ross Basin and Magnetic Island.

1/06/2009 No STPs

Sub Basin	**Flow**	**TSS**	**TN**	**TP**
	ML/Year	**kg/Year**	**kg/Year**	**kg/Year**
Crystal Creek	239,279	5,509,675	90,060	9,376
Rollingstone Creek	144,288	1,601,949	40,420	4,018
Bluewater Creek	145,599	2,805,025	92,637	4,637
Black River (no STP)	114,318	7,190,500	69,131	10,016
Black Basin	643,484	17,107,149	292,248	28,047
Bohle River	131,618	9,289,250	78,275	14,136
Lower Ross River	53,677	4,202,975	33,097	6,976
Upper Ross River	196,735	8,103,000	100,375	12,775
Stuart Creek	47,450	1,649,800	18,944	2,957
Alligator Creek	104,762	2,103,495	42,687	4,807
Ross Basin	534,242	25,348,520	273,378	41,651
Magnetic Island	27,371	341,983	6,282	943
Black Ross Total	1,205,098	42,797,652	571,908	70,641

With and No STPs comparison

Sub Basin	Flow	TSS	TN	TP
	ML/Year	kg/Year	kg/Year	kg/Year
Crystal Creek	239,279	5,509,675	90,060	9,376
Rollingstone Creek	144,288	1,601,949	40,420	4,018
Bluewater Creek	145,599	2,805,025	92,637	4,637
Black River (with STP)	114,318	7,190,500	70,591	11,063
Black River (no STP)	114,318	7,190,500	69,131	10,016
		Difference	1,460	1,047
		% difference	2.1%	9.5%
Black Basin	643,484	17,107,149	293,708	29,095
Black Basin	643,484	17,107,149	292,248	28,047
		Difference	1,460	1,047
		% difference	0.5%	3.6%
Bohle River (with STP)	131,618	9,289,250	191,753	29,795
Bohle River (no STP)	131,618	9,289,250	78,275	14,136
		Difference	113,478	15,659
		% difference	59.2%	52.6%
Lower Ross River	53,677	4,202,975	33,097	6,976
Upper Ross River	196,735	8,103,000	100,375	12,775
Stuart Creek (with STP)	47,450	1,649,800	61,320	20,039
Stuart Creek (no STP)	47,450	1,649,800	18,944	2,957
		Difference	42,376	17,082
		% difference	69%	85%
Alligator Creek	104,762	2,103,495	42,687	4,807
(with STP) **Ross Basin**	534,242	25,348,520	429,232	74,391
(no STP) **Ross Basin**	534,242	25,348,520	273,378	41,651
		Difference	155,854	32,740
		% difference	36.3%	44%
Magnetic Island	27,371	341,983	6,282	943
(with STP) **Black Ross Total**	1,205,098	42,797,652	729,223	104,429
(no STP) **Black Ross Total**	1,205,098	42,797,652	571,908	70,641
		Difference	157,315	33,788
		% difference	21.6	32.5

Note: Black Ross WQIP is the sum of Black Basin, Ross Basin and Magnetic Island.

Changes to modelled sub catchments

Modelled areas	**TN**	**TN**	**Difference**	**TP**	**TP**	**Difference**
STP	With	Without		With	Without	
Bohle sub basin						
SC #28	9526.5	9526.5		1627.9	1627.9	
SC #2	11351.5	11351.5		1657.1	1657.1	
SC #11	1007.4	1007.4		144.175	144.175	
SC #26	24,820	22,740	2,081	6,607	3,833	2,774
SC #1	39.055	39.055		5.7305	5.7305	
SC #20	3431	3431		1018.35	1018.35	
SC #6	3007.6	3007.6		916.15	916.15	
SC #16	3171.85	3171.85		551.15	551.15	
SC #31	18,287	16,389	1,898	5,001	2,862	2,139
SC #32	113,150	3,650	109,500	11,133	387	10,746
SC #10	202.21	202.21		21.389	21.389	
SC #27	3759.5	3759.5		1113.25	1113.25	
Bohle totals	191,753	78,275	113,479	29,795	14,136	15,659
Black sub basin						
SC #48	52560	52560		7592	7,592	
SC #45	18,031	16,571	1,460	3471	2,424	1,047
Black totals	70,591	69,131	1,460	11,063	10,016	1,047
Stuart sub basin						
SC #7	61,320	18,944	42,377	20,039	2,957	17,082
Black Ross total change			158,775			34,835

Notes: Shaded rows are modelled sub catchments where changes occur from STP removal
Units are kg/year

2045 no STPs

Model SC No.	WQIP No.	Catchment	TSS	TN	TP
			kg/Year	kg/Year	kg/Year
40	1-1	Crystal Creek	2922000	45656	5004
39	1-2	Lorna Creek	75242	2349	112
14	1-2	Lorna Ck /Ollera Ck	683018	8839	891
38	1-3	Ollera Creek	246909	4456	339
41	1-3	Ollera Creek	642840	16582	1224
37	1-4	Scrubby Creek	275033	6721	438
36	1-5	Hencamp Creek	3174023	25129	3799
		Crystal Creek SB	8019064	109732	11806
21	2-1	Rollingstone Creek	1723980	24800	2648
53	2-2	Unnamed	202349	2444	333
54	2-3	Surveyors Creek	286356	5077	442
35	2-4	Wild Boar Creek	11286	537	54
34	2-5	Station Creek	37621	1256	145
51	2-6	Saltwater Creek	511350	9606	1158
51	2-7	Cassowary Creek			
50	2-8	Leichhardt Creek	244352	9716	621
		Rollingstone Creek SB	3017294	53436	5400
33	3-1	Sleeper Log Creek	606315	22207	983
42	3-2	Two Mile Creek	129664	5296	206
52	3-3	Bluewater Creek	1037310	35575	1479
43	3-3	Bluewater Creek	175685	4894	301
44	3-4	Deep Creek	858338	31010	1359
		Bluewater Creek SB	2807312	98983	4327
48	4-1	Black River (upper and Alice)	6209250	54057	8036
45	4-1	Black River (lower)	1519440	18847	2546
		Black River SB	7728690	72904	10581
10	5-1	Bohle River	8620	202	21
32	5-1	Bohle River	278686	4127	508
16	5-1	Bohle River	515003	4018	782
6	5-1	Bohle River	456563	3002	917
27	5-1	Bohle River	617273	4127	1107
20	5-1	Bohle River	555180	3499	1070
1	5-1	Bohle River	4346	37	6
28	5-1	Bohle River	1161495	8620	1567
31	5-1	Bohle River	2217068	15888	2823
2	5-2	Bohle River 2	1256460	11286	1633
26	5-2	Bohle River 2	2607885	22499	3762
11	5-2	Bohle River 2	115054	1015	148
4	5-3	Shelly Beach			
		Bohle River SB	9793631	78322	14343
4	6-1	Pallarenda	242891	2867	413
23	6-2	Mundy Creek	302792	2301	486
5	6-3	Esplanade	169111	712	217
17	6-3	Esplanade	54788	256	81
19	6-4	Ross Creek	770678	4785	1399

24	6-4	Ross Creek	216593	1304	376
9	6-5	Ross River (btdam)	1077488	9058	1392
29	6-5	Ross River (btdam)	2761290	15267	3346
30	6-5	Ross River (btdam)	359771	2118	606
18	6-5	Ross River (btdam)	258597	1925	402
12	6-5	Ross River (btdam)	180799	1519	226
		Lower Ross River SB	6394797	42114	8943
49	7-1	Ross River (atd)			
49	7-2	Six Mile Creek			
49	7-3	Toonpan Lagoon			
49	7-4	Antill Plains Creek			
49	7-5	Sachs Creek			
49	7-6	Mt Stuart			
		Upper Ross River SB	13222050	124916	17678
7	8-1	Stuart Creek			
7	8-2	Sandfly Creek			
		Stuart Creek SB	3597713	30462	5004
47	9-1	Alligator Creek	2337600	23887	3298
13	9-1	Alligator Creek	2801468	25823	3689
8	9-2	Crocodile Creek	913125	13514	1618
25	9-3	Cocoa Creek	98252	2429	250
46	9-4	Cape Cleveland	58075	1143	133
60	9-4	Cape Cleveland	114323	2250	260
		Alligator Creek SB	6322843	69047	9248
59	10-1	West Coast	42734	1589	176
3	10-2	Picnic Bay	39082	303	81
15	10-3	Nelly Bay	149753	1308	279
22	10-4	Arcadia	31813	380	75
58	10-5	Radical Bay	13806	387	48
57	10-6	Horseshoe Bay	194678	1921	361
56	10-7	Five Beach Bay	9825	468	47
55	10-8	Rollingstone Bay	3631	172	17
		Magnetic Island SB	485322	6527	1084
		Black Basin	21572359	335055	32115
		Ross Basin	39331033	344860	55216
		Black Ross WQIP area	61388714	686442	88416

Note: Updated using 9/6/09, 10/6/09 and 12/6/09 data

Pre settlement to 2045 TSS change (no STPs) Summary

	1850	**2005**	**2005-1850**	**% change**	**2021**	**2021-1850**	**% change**	**2045**	**2045-1850**	**% change**
	TSS kg/yr	**TSS kg/yr**	**TSS kg/yr**		**TSS kg/yr**	**TSS kg/yr**		**TSS kg/yr**	**TSS kg/yr**	
Crystal Creek	967,287	5,509,675	4,542,389	470	6,419,255	5,451,969	564	7,783,625	6,816,339	705
Rollingstone Creek	580,606	1,601,949	1,021,343	176	2,071,368	1,490,762	257	2,775,497	2,194,891	378
Bluewater Creek	582,066	2,805,025	2,222,960	382	2,802,835	2,220,770	382	2,799,550	2,217,485	381
Black River (no STP)	1,520,955	7,190,500	5,669,545	373	7,403,660	5,882,705	387	7,723,400	6,202,445	408
Black Basin	3,650,913	17,107,149	13,456,236	369	18,697,118	15,046,205	412	21,082,072	17,431,159	477
Bohle River (no STPs)	1,954,287	9,289,250	7,334,963	375	8,884,961	6,930,675	355	8,278,529	6,324,242	324
Lower Ross River	759,748	4,202,975	3,443,228	453	4,989,039	4,229,292	557	6,168,135	5,408,388	712
Upper Ross River	3,117,100	8,103,000	4,985,900	160	10,147,000	7,029,900	226	13,213,000	10,095,900	324
Stuart Creek (no STP)	609,550	1,649,800	1,040,250	171	2,427,980	1,818,430	298	3,595,250	2,985,700	490
Alligator Creek	1,901,285	2,103,495	202,210	11	3,789,503	1,888,218	99	6,318,515	4,417,230	232
Ross Basin	8,341,969	25,348,520	17,006,551	204	30,238,483	21,896,514	262	37,573,429	29,231,459	350
Magnetic Island	107,003	341,983	234,980	220	344,275	237,272	222	347,714	240,710	225
Black Ross Total	12,099,885	42,797,652	30,697,767	254	49,279,876	37,179,991	307	59,003,214	46,903,329	388

Pre settlement to 2045 TN change (no STPs) Summary

	1850	2005	2005-1850	% change	2021	2021-1850	% change	2045	2045-1850	% change
	TN kg/yr	TN kg/yr	TN kg/yr		TN kg/yr	TN kg/yr		TN kg/yr	TN kg/yr	
Crystal Creek	45,888	90,060	44,172	96	97,680	51,792	113	109,109	63,222	138
Rollingstone Creek	27,609	40,420	12,812	46	45,353	17,745	64	52,753	25,145	91
Bluewater Creek	27,685	92,637	64,952	235	95,134	67,448	244	98,879	71,193	257
Black River (no STP)	38,763	69,131	30,368	78	70,620	31,857	82	72,854	34,091	88
Black Basin	139,945	292,248	152,304	109	308,787	168,842	121	333,595	193,651	138
Bohle River (no STPs)	46,601	78,275	31,674	68	75,103	28,502	61	70,344	23,744	51
Lower Ross River	18,168	33,097	14,929	82	36,446	18,278	101	41,468	23,300	128
Upper Ross River	77,380	100,375	22,995	30	110,157	32,777	42	124,830	47,450	61
Stuart Creek (no STP)	14,783	18,944	4,161	28	23,543	8,760	59	30,441	15,659	106
Alligator Creek	42,749	42,687	-62	0	53,212	10,463	24	69,000	26,251	61
Ross Basin	199,680	273,377	73,697	37	298,460	98,780	49	336,083	136,403	68
Magnetic Island	5,084	6,282	1,198	24	6,214	1,130	22	6,112	1,028	20
Black Ross Total	344,709	571,908	227,198	66	613,461	268,752	78	675,791	331,082	96

Pre settlement to 2045 TP change (no STPs) Summary

	1850	2005	2005-1850	% change	2021	2021-1850	% change	2045	2045-1850	% change
	TP kg/yr	TP kg/yr	TP kg/yr		TP kg/yr	TP kg/yr		TP kg/yr	TP kg/yr	
Crystal Creek	4,690	9,376	4,686	100	10,272	5,582	119	11,616	6,926	148
Rollingstone Creek	2,941	4,018	1,077	37	4,481	1,540	52	5,176	2,235	76
Bluewater Creek	3,100	4,637	1,537	50	4,510	1,410	45	4,320	1,219	39
Black River (no STP)	4,117	10,016	5,898	143	10,239	6,122	149	10,574	6,457	157
Black Basin	14,849	28,047	13,198	89	29,503	14,654	99	31,685	16,836	113
Bohle River (no STPs)	4,892	14,136	9,244	189	13,527	8,635	177	12,613	7,721	158
Lower Ross River	1,907	6,976	5,069	266	7,676	5,769	302	8,727	6,820	358
Upper Ross River	7,957	12,775	4,818	61	14,731	6,774	85	17,666	9,709	122
Stuart Creek (no STP)	1,537	2,957	1,420	92	3,774	2,237	146	5,001	3,464	225
Alligator Creek	4,618	4,807	190	4	6,581	1,964	43	9,242	4,624	100
Ross Basin	20,910	41,651	20,741	99	46,290	25,380	121	53,248	32,338	155
Magnetic Island	518	943	425	82	946	429	83	952	434	84
Black Ross Total	36,277	70,641	34,364	95	76,739	40,462	112	85,885	49,608	137

2045, 2021 and 2005 minus pre-settlement (1850) natural loads

	1850	**2005-1850**	**2021-1850**	**2045-1850**	**1850**	**2005-1850**	**2021-1850**	**2045-1850**	**1850**	**2005-1850**	**2021-1850**	**2045-1850**
	TSS kg/yr	**TSS kg/yr**	**TSS kg/yr**	**TSS kg/yr**	**TN kg/yr**	**TN kg/yr**	**TN kg/yr**	**TN kg/yr**	**TP kg/yr**	**TP kg/yr**	**TP kg/yr**	**TP kg/yr**
Crystal Creek	967,287	4,542,389	5,451,969	6,816,339	45,888	44,172	51,792	63,222	4,690	4,686	5,582	6,926
Rollingstone Creek	580,606	1,021,343	1,490,762	2,194,891	27,609	12,812	17,745	25,145	2,941	1,077	1,540	2,235
Bluewater Creek	582,066	2,222,960	2,220,770	2,217,485	27,685	64,952	67,448	71,193	3,100	1,537	1,410	1,219
Black River (no STP)	1,520,955	5,669,545	5,882,705	6,202,445	38,763	30,368	31,857	34,091	4,117	5,898	6,122	6,457
Black Basin	3,650,913	13,456,236	15,046,205	17,431,159	139,945	152,304	168,842	193,651	14,849	13,198	14,654	16,836
Bohle River (no STPs)	1,954,287	7,334,963	6,930,675	6,324,242	46,601	31,674	28,502	23,744	4,892	9,244	8,635	7,721
Lower Ross River	759,748	3,443,228	4,229,292	5,408,388	18,168	14,929	18,278	23,300	1,907	5,069	5,769	6,820
Upper Ross River	3,117,100	4,985,900	7,029,900	10,095,900	77,380	22,995	32,777	47,450	7,957	4,818	6,774	9,709
Stuart Creek (no STP)	609,550	1,040,250	1,818,430	2,985,700	14,783	4,161	8,760	15,659	1,537	1,420	2,237	3,464
Alligator Creek	1,901,285	202,210	1,888,218	4,417,230	42,749	-62	10,463	26,251	4,618	190	1,964	4,624
Ross Basin	8,341,969	17,006,551	21,896,514	29,231,459	199,680	73,697	98,780	136,403	20,910	20,741	25,380	32,338
Magnetic Island	107,003	234,980	237,272	240,710	5,084	1,198	1,130	1,028	518	425	429	434
Black Ross Total	12,099,885	30,697,767	37,179,991	46,903,329	344,709	227,198	268,752	331,082	36,277	34,364	40,462	49,608