Total suspended solids, nutrient and pesticide loads (2013–2014) for rivers that discharge to the Great Barrier Reef

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Reef Water Quality Protection Plan

Total suspended solids, nutrient and pesticide loads (2013–2014) for rivers that discharge to the Great Barrier Reef

Great Barrier Reef Catchment Loads Monitoring Program

Australian Government

Queensland Government

Prepared by

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Executive summary

Poor water quality caused by diffuse pollutants being exported from catchments to the Great Barrier Reef lagoon is an important threat to the health and resilience of the Reef. Sediment, nutrient and pesticides leaving agricultural land have been identified as the most significant cause of poor water quality entering the Reef lagoon (Brodie et al. 2013a). The Reef Water Quality Protection Plan 2013 (Reef Plan 2013), which this report relates to, has the long term goal of ‘ensuring that by 2020 the quality of water entering the reef from broad scale land use has no detrimental effect on the health and resilience of the Great Barrier Reef’ (DPC 2013a).

Reef Plan 2013 established new land and catchment management targets and water quality targets that are measured against baseline conditions outlined in the preceding Reef Water Quality Protection Plan 2009. These reduction targets, to be achieved in 2018, are: at least a 20 per cent reduction in anthropogenic end-of-catchment loads of sediment and particulate nutrients; at least a 50 per cent reduction in anthropogenic end-of-catchment dissolved inorganic nitrogen loads; and at least a 60 per cent reduction in end-of-catchment pesticide loads.

Progress towards the Reef Plan 2013 water quality targets is measured based on modelled values (Waters et al. 2014) through the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program (Paddock to Reef Program). The Paddock to Reef Program includes catchment scale water quality monitoring of pollutant loads entering the Great Barrier Reef lagoon which is implemented through the Great Barrier Reef Catchment Loads Monitoring Program.

Under Reef Plan 2013, pollutant loads are calculated annually by the Great Barrier Reef Catchment Loads Monitoring Program in the following natural resource management regions and priority catchments:

- Cape York region – Normanby catchment
- Wet Tropics region – Barron, Mulgrave-Russell, Johnstone, Tully and Herbert catchments
- Burdekin region – Burdekin and Haughton catchments
- Mackay Whitsunday region – O’Connell, Pioneer and Plane catchments
- Fitzroy region – Fitzroy catchment
- Burnett Mary region – Burnett and Mary catchments.

This report presents annual loads calculated using monitoring data (monitored annual loads) and yields of pollutants based on monitoring data from the 2013–2014 monitoring year (i.e. 1 July 2013 to 30 June 2014). The data made available through the Great Barrier Reef Catchment Loads Monitoring Program provides a foundation to validate the catchment models used to monitor progress against Reef Plan 2013 water quality targets and thus assist in the effective management of Queensland and Australian natural resources.

During the 2013–2014 monitoring year, 12 end-of-system sites and 13 sub-catchment sites were monitored for total suspended solids and nutrients. Pesticides were monitored at 10 end-of-system sites and five sub-catchment sites. This is the first year that monitored annual loads have been reported for the Haughton, O’Connell and Mary rivers and Tinana Creek in the Mary catchment, and that event loads have been reported for the Mulgrave-Russell catchment. For the first time three tidally influenced sites on the Russell, Mulgrave and O'Connell rivers were monitored.

Total annual rainfall was generally above average in the monitored catchment in the Cape York region and average in all monitored catchments of the Wet Tropics region. In the Burdekin region, all monitored catchments received average to very much below average rainfall, and average rainfall was received across monitored catchments in the Mackay Whitsunday region. Rainfall across the monitored catchments of the Fitzroy region was generally below average to very much below average, and very much below average across most of the Burnett Mary region.

Reflecting the below average rainfall in the central and southern regions, annual discharge was below the long term mean in the majority of monitored rivers, and considerably below the long term mean discharge in the Burdekin, O'Connell, Fitzroy, Burnett and Mary rivers and Sandy Creek in the Plane catchment. Discharge in the Burdekin and Fitzroy rivers during the 2013–2014 monitoring year was the lowest monitored since commencement of the Great Barrier Reef Catchment Loads Monitoring Program in 2006. River discharge in the Mulgrave, Russell, North and South Johnstone, Tully and Herbert rivers was above their long term mean. Rainfall associated with severe Tropical Cyclone Ita resulted in moderate to major flooding in the Normanby, Barron, Mulgrave, Herbert and Haughton rivers and contributed a significant portion of the total annual discharge in the 2013–2014 monitoring year.

The monitored catchments generated approximately 1.4 million tonnes of total suspended solids, 12,000 tonnes of nitrogen and 1800 tonnes of phosphorus. Three catchments generated approximately 50 per cent of the combined load of total suspended solids and nutrients. The Herbert catchment generated the largest total suspended solids and nutrient loads, with the exception of dissolved organic nitrogen and dissolved inorganic phosphorus in which the Normanby and Fitzroy catchments generated the largest loads respectively, and the Johnstone (North and South Johnstone together) catchment which generated the largest loads of total phosphorus and particulate phosphorus. The Tully catchment made substantial contributions of most nitrogen fractions, the Burdekin catchment of total suspended solids and dissolved inorganic phosphorus, and the Fitzroy catchment of ammonium nitrogen and dissolved organic nitrogen.

The Burdekin and Fitzroy catchments typically contribute the largest annual loads of total suspended solids and nutrients, however in the 2013–2014 monitoring year the loads generated by these catchments was the lowest reported by this Program since 2006 and consistent with the record low discharge during this period.

A measure of the supply of pollutants from catchments is the yield (the load divided by the monitored surface area of the catchment). This metric allows a comparison of the rate of pollutant delivery between catchments standardised by area. The highest monitored yields of total suspended solids, total nitrogen, particulate nitrogen, total phosphorus and particulate phosphours occurred in the Johnstone (North and South Johnstone, together) catchment. The Tully catchment produced high yields of total suspended solids and all nutrient analytes, the O'Connell catchment produced high yields of ammonium nitrogen and Sandy Creek in the Plane catchment produced high yields of dissolved inorganic phosphorus. The lowest monitored yields of all total suspended solids and nutrient analytes generally occurred in the larger catchments of the Burnett, Burdekin and Fitzroy rivers.

The total monitored annual load of photosystem II inhibiting herbicides[1] exported past the monitoring sites were (from largest to smallest): 930 kg of total atrazine; 890 kg of total diuron; 230 kg of hexazinone; 160 kg of tebuthiuron; and 11 kg of ametryn. The combined toxicity-based load (toxic load[2]) of all monitored sites was 980 kg $TEq_{diuron,}$ with total diuron accounting for 890 kg TEq_{diuron}. Five catchments (the Tully, Pioneer and Herbert catchments, Sandy Creek in the Plane catchment and Barratta Creek in the Haughton catchment) accounted for 90 per cent of the combined annual toxic load.

The largest monitored land use yield (the load divided by the total surface area of land uses where the pesticide is registered for use) of ametryn was in Sandy Creek in the Plane catchment; total diuron, total atrazine and hexazinone in the Tully catchment, and tebuthiuron in the O'Connell catchment.

This is the fifth technical report to be released by the Great Barrier Reef Catchment Loads Monitoring Program and the first under Reef Plan 2013. The Paddock to Reef Integrated Monitoring, Modelling and Reporting Program was reviewed in 2013. This review resulted in decommissioning several sub-catchment sites and establishment of new end-of-system sites to provide data for previously unmonitored catchments and improve spatial alignment of the Great Barrier Reef Catchment Loads Monitoring Program and the Marine Monitoring Program. The underlying methods of the Great Barrier Catchment Loads Monitoring Program have not had major changes over the years to maintain consistency in the reported data. During the 2013–2014 monitoring year, a key improvement to the analysis of the water quality data was the introduction of the toxic load concept to report pesticide loads. The calculation of total diuron from its metabolites was also introduced.

[1] Photosystem II herbicides inhibit electron transport in the photosystem II reaction centre (located in the thylakoid membranes) which is required for converting light energy into chemical energy in plant photosynthesis.

[2] A toxic load is the combined load of a group of pesticides that have been converted to the mass of one particular pesticide, based on the pesticides' relative toxicities.

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1 Introduction

The Great Barrier Reef World Heritage Area is located off the north-east coast of Australia and is recognised as the largest coral reef ecosystem in the world (Furnas 2003). Its ecological, social and economic importance is widely acknowledged (DPC 2013a). In economic terms, industries associated with the Great Barrier Reef generate approximately $5.6 billion annually to the Queensland economy (QAO 2015). Poor water quality caused by pollutants exported from catchments adjacent to the Great Barrier Reef is considered one of the most significant threats to the Great Barrier Reef World Heritage Area (Wachenfeld et al. 1998; State of Queensland and Commonwealth of Australia 2003; Wooldridge et al. 2006; Brodie et al. 2008; DPC 2008, 2009a and 2013a; Hunter and Walton 2008; Brodie et al. 2009; Packett et al. 2009; Brodie et al. 2010; Brodie et al. 2013a; Brodie et al. 2013b; Schaffelke et al. 2013). Agricultural land has been identified as the major source of these pollutants (e.g. Brodie et al. 2013a; Brodie et al. 2013b; Schaffelke et al. 2013).

In order to improve water quality entering the Great Barrier Reef from these catchments, the Queensland and Australian governments cooperatively initiated the Reef Water Quality Protection Plan (Reef Plan) (DPC 2003), which has been updated in 2009 (DPC 2009a) and 2013 (DPC 2013a), as part of a commitment towards refining its approach and targets as new information emerges. Reef Plan 2009 held the short-term goal of halting and reversing the decline in water quality entering the Great Barrier Reef lagoon. Reef Plan 2013 builds on the earlier plan and includes refined land and catchment management targets and water quality targets, which are set to be achieved by 2018.

The Paddock to Reef Integrated Monitoring, Modelling and Reporting Program (Paddock to Reef program) measures and reports progress towards Reef Plan goal and targets through annual report cards. The Paddock to Reef program is a collaboration involving governments, industry bodies, regional natural resource management bodies, landholders and research organisations (DPC 2009b, 2013b). It is a world-leading approach to integrate data and information on management practices, catchment indicators, water quality and the health of the Great Barrier Reef.

The Great Barrier Reef Catchment Loads Monitoring Program was implemented in 2005 to monitor and report on loads of total suspended solids, nutrients and pesticides and assist in evaluating progress towards the water quality targets of Reef Plan. This is the fifth Great Barrier Reef Catchment Loads Monitoring Program report and the first under Reef Plan 2013 (DPC 2013a). Financial contributions by regional stakeholders allowed the Great Barrier Reef Catcher Reef Catchment Loads Monitoring Program to increase the number of catchments monitored during the 2013–2014 monitoring year to 25 sites in 14 priority catchments for total suspended solids and nutrients and 15 sites in 12 priority catchments for pesticides. Previously, the Great Barrier Reef Catchment Loads Monitoring Program monitored total suspended solids and nutrients at 25 sites in 11 priority catchments and pesticides at 11 sites in eight priority catchments (Turner et al. 2012, 2013; Wallace et al. 2014, 2015).

Evidence of elevated anthropogenic loads of total suspended solids, nutrients and pesticides exported to the Great Barrier Reef lagoon since European settlement has been reported extensively (e.g. Eyre 1998;

Wachenfeld et al. 1998; Fabricius et al. 2005; McKergow et al. 2005, Hunter and Walton 2008; Packett et al. 2009; Brodie et al. 2010; DPC 2011; Joo et al. 2011; Kroon et al. 2010 and 2012; Smith et al. 2012; Turner et al. 2012; Kroon et al. 2013; Turner et al. 2013; Wallace et al. 2014; Wallace et al. 2015; Waters et al. 2014). The anthropogenic load of total suspended solids exported to the Great Barrier Reef has increased by 2.9 times the predevelopment load (Waters et al. 2014). Similar increases above the predevelopment load were reported by Waters et al. (2014) for a variety of forms of nutrients including total nitrogen (1.8 times), total phosphorus (2.3 times) and dissolved inorganic nitrogen (2.0 times). Similar increases for pesticides could not be calculated as they were not present before European settlement. These estimates of the increase since pre-European times are considerably smaller than the earlier estimates of McKergow et al. (2005) and Kroon et al. (2010).

There are 35 catchments that flow into the Great Barrier Reef lagoon and cover an area of approximately 424,000 square kilometres. These catchments extend from the tropics to the subtropics and cover over 1,500 kilometres of the east coastline of Queensland (DPC 2011). Across the study area, there are substantial climatic, hydrological and geological differences within and between catchments. These factors contribute to a high variation in the discharge volume and pollutant loads between catchments and years (Furnas et al. 1997; Devlin and Brodie 2005; Joo et al. 2012; Smith et al. 2012; Turner et al. 2012; Turner et al. 2013; Wallace et al. 2014; Wallace et al. 2015). The majority of pollutant loads are generated during the wet season as runoff during high flow events from catchments adjacent to the Great Barrier Reef (Nicholls 1988; Eyre 1998; Smith et al. 2012; Turner et al. 2012; Kroon et al. 2013; Turner et al. 2013; Wallace et al. 2014; Wallace et al. 2015).

Of these 35 catchments, 14 priority catchments were monitored by the Great Barrier Reef Catchment Loads Monitoring Program in the 2013–2014 monitoring year. The 14 priority catchments were selected based on the Paddock to Reef Program Design 2013–2018 (DPC 2013b), which targets high priority areas. The 14 priority catchments and the natural resource management regions in which they occur are the:

- Normanby catchment – Cape York region
- Barron, Mulgrave-Russell, Johnstone, Tully and Herbert catchments – Wet Tropics region
- Burdekin and Haughton catchments – Burdekin region
- O'Connell, Pioneer and Plane catchments – Mackay Whitsunday region
- Fitzroy catchment – Fitzroy region
- Burnett and Mary catchments – Burnett Mary region.

Grazing is the single largest land use within the Great Barrier Reef catchments (DPC 2011), accounting for around 75 per cent of the total area (DSITIA 2012), with other significant land uses being conservation, forestry, sugarcane, horticulture and other cropping. In the Cape York region, the Normanby catchment is dominated by grazing and a large amount of land set aside for conservation in State protected areas. In the Wet Tropics region the main land uses are grazing in the west, sugarcane on the coastal flood plains and small areas of horticulture. Large areas of the Wet Tropics region are also set aside for conservation purposes in the Wet Tropics World Heritage Area. Land use in the Burdekin region is dominated by grazing with irrigated sugarcane, horticulture and cropping located in the lower Burdekin and Haughton catchments. Within the Mackay Whitsunday region the O'Connell, Pioneer and Plane catchments are dominated by grazing. This region also contains relatively large areas of sugarcane cultivation along the coastline and areas for nature conservation. Grazing, dry land cropping, irrigated cotton and mining are the dominant land uses within the Fitzroy region. Land use within the Burnett Mary region is a mixture of grazing, dairy, horticulture, sugarcane and other cropping (DPC 2011).

This report presents monitored annual loads and yields (the load divided by the monitored surface area of the catchment) for 14 priority catchments for sediments (measured as total suspended solids) and nutrients and monitored annual toxic loads for 12 priority catchments for pesticides in the 2013–2014 monitoring year. These loads for total suspended solids and nutrients were calculated using the same methods applied in each of the technical reports issued under the Paddock to Reef program (Turner et al. 2012; Turner et al. 2013; Wallace et al. 2014; Wallace et al. 2015) and the toxic loads were calculated following Smith et al. (in prep).

All data presented in this report are the loads and yields exported from the area upstream of the monitoring site(s) in each catchment and as such these pollutant loads do not represent the total load discharged to the Great Barrier Reef lagoon. Not all catchments that drain to the Great Barrier Reef lagoon were monitored. In addition, not all the end-of-system monitoring sites are located at the mouth of the river or creek (refer to Section 2.1) and in this unmonitored portion of the catchment or sub-catchment there may be contribution, removal, transformation or degradation of total suspended solids, nutrients and pesticides. This report does not link land uses, management practices or soil erosion processes (e.g. gullies, channel/bank or hill-slope erosion) to loads or yields of total suspended solids or nutrients but does present land use yields of pesticides. The reported loads are calculated from monitored water quality, which provides a point of truth to validate the modelled catchment loads. The loads predicted by the catchment models are used to report on progress towards water quality targets in the annual Reef Plan Report Card (DPC 2011; DPC 2013c; DPC 2013d; DPC 2014; DPC 2015).

Previous publications of the Great Barrier Reef Catchment Loads Monitoring Program have presented loads for the period 2006–2009 (Joo et al. 2012), 2009–2010 (Turner et al. 2012), 2010–2011 (Turner et al. 2013), 2011–2012 (Wallace et al. 2014) and 2012–2013 (Wallace et al. 2015). Other publications by the Great Barrier Reef Catchment Loads Monitoring Program include those by Smith et al. (2011; 2012; and 2014) and Vardy et al. (2015). Smith et al. (2011) determined the catchment specific dissipation half-lives of diuron and atrazine in three Great Barrier Reef catchments; Barratta Creek, Pioneer River and Sandy Creek. Smith et al. (2012) assessed the toxicity and potential implications of mixtures of pesticides detected in Great Barrier Reef catchments. Smith et al. (2014) reported the concentrations and loads of alternate pesticides (new pesticides being used instead of traditional pesticides such as diuron) in monitored Great Barrier Reef catchments and compared the relative toxicity of these chemicals to the priority photosystem II inhibiting herbicides[3], which were a focus of land use management change under Reef Plan 2009. Vardy et al. (2015) reported on the concentrations of nutrients and pesticides in groundwater in the lower Burdekin catchment,

[3] Photosystem II herbicides inhibit electron transport in the photosystem II reaction centre (located in the thylakoid membranes) which is required for converting light energy into chemical energy in plant photosynthesis.

the annual loads of these pollutants and the potential role of the riparian zone in modifying nutrient concentrations and loads.

2 Methods

2.1 Monitoring sites

Fourteen priority catchments were identified for monitoring under the Paddock to Reef program (DPC 2013b). The majority of monitoring sites (Figure 2.1 and Table 2.1) are located at existing Queensland Government stream gauging stations installed and maintained by the Department of Natural Resources and Mines. Sites are classified as either end-of-system or sub-catchment sites. End-of-system sites are defined as sites located at the lowest point in a river or creek where the volume of water passing that point can be accurately measured and typically not subject to tidal influence. As a result, the influence of runoff from areas lower in the catchment on water quality is unable to be assessed. Sub-catchment sites were selected to provide specific water quality data on various land uses or on a geographical region for enhanced validation of catchment models.

During the 2013–2014 monitoring year, three tidally influenced sites equipped with Acoustic Doppler Current Profilers were installed on the Russell and Mulgrave rivers in the Wet Tropics region and O’Connell river in the Mackay Whitsunday region. Acoustic Doppler Current Profilers can measure water velocity in tidally affected waterways and can therefore be situated as close as possible to the river mouth allowing for an increase in the monitored area of these priority catchments. Acoustic Doppler Current Profilers were installed but were not fully operational during 2013–2014.

Under Reef Plan 2013, 12 end-of-system sites and 13 sub-catchment sites located in 14 catchments were selected to monitor total suspended solids and nutrients (Table 2.2), while 10 end-of-system sites and five sub-catchment sites were selected to monitor pesticides (Table 2.2) (DPC 2013b). The changes made to monitoring sites for the 2013–2014 monitoring year involved the following (reasons for changes include obtaining greater spatial coverage, which allows validation of the modelling for additional catchments and enhancing nested monitoring between the Great Barrier Reef Catchment Loads Monitoring Program and the Marine Monitoring Programs. Further details can be found in DPC 2013b):

- decommissioning three sub-catchment sites in the Burdekin Region: Belyando River at Gregory Development Road, Cape River at Taemas and Suttor River at Bowen Development Road
- decommissioning one sub-catchment site in the Fitzroy Region: Isaac River at Yatton
- decommissioning two sub-catchment sites in the Burnett Mary Region: Burnett River at Jones Weir Tail Water and Burnett River at Eidsvold
- commissioning one end-of system site in the Burdekin Region: Haughton River at Powerline
- commissioning one end-of-system site in the Mackay Whitsunday Region: O’Connell River at Caravan Park
- commissioning two sub-catchment sites in the Wet tropics Region: Mulgrave River at Deeral and Russell River at East Russell, which together act as an end-of-system site
- commissioning two sub-catchment sites in the Burnett Mary Region: Mary River at Home Park and Tinana Creek at Barrage Head Water, which together act as an end-of-system site.

Consequently, between 1 July 2013 and 30 June 2014 monitoring was undertaken at 25 sites located in 14 priority catchments (Figure 2.1 and Table 2.1). All end-of-system sites and eight sub-catchment sites established before the 2013–2014 monitoring year were retained as monitoring sites of the Great Barrier Reef Catchment Loads Monitoring Program to allow collection of data over multiple years. Summary information on each monitoring site is included in Table 2.1.

2.2 Rainfall

Rainfall totals and rainfall decile data were obtained from the Commonwealth of Australia, Bureau of Meteorology National Climate Centre (BoM 2014a; BoM 2015a). These data were synthesised using ArcGIS to create maps of Queensland to display total annual rainfall and annual rainfall deciles for the 2013–2014 monitoring year.

2.3 Water quality sampling

Water samples were collected according to methods outlined in the Environmental Protection (Water) Policy Monitoring and Sampling Manual (DEHP 2013). Water quality samples were collected between 1 July 2013 and 30 June 2014. Two different sampling methods were used to collect water samples, depending on equipment availability and suitability for use at each site. The two methods used were manual grab sampling and automatic grab sampling using refrigerated pump samplers. The specific methods employed at each site are shown in Table 2.2.

Intensive sampling (daily or every few hours) occurred during high flow events and monthly sampling was undertaken during low or base flow (ambient) conditions. Where possible, total suspended solids, nutrients and pesticide samples were collected concurrently. Approximately 43 per cent of the total suspended solids and nutrient samples were collected by manual grab sampling and 57 per cent were collected using refrigerated automatic pump samplers. Pesticide samples were manually collected at six sites and collected using refrigerated automatic samplers fitted with glass bottles at nine sites.

All water samples were stored and transported in accordance with the Environmental Protection (Water) Policy Monitoring and Sampling Manual (DEHP 2013).

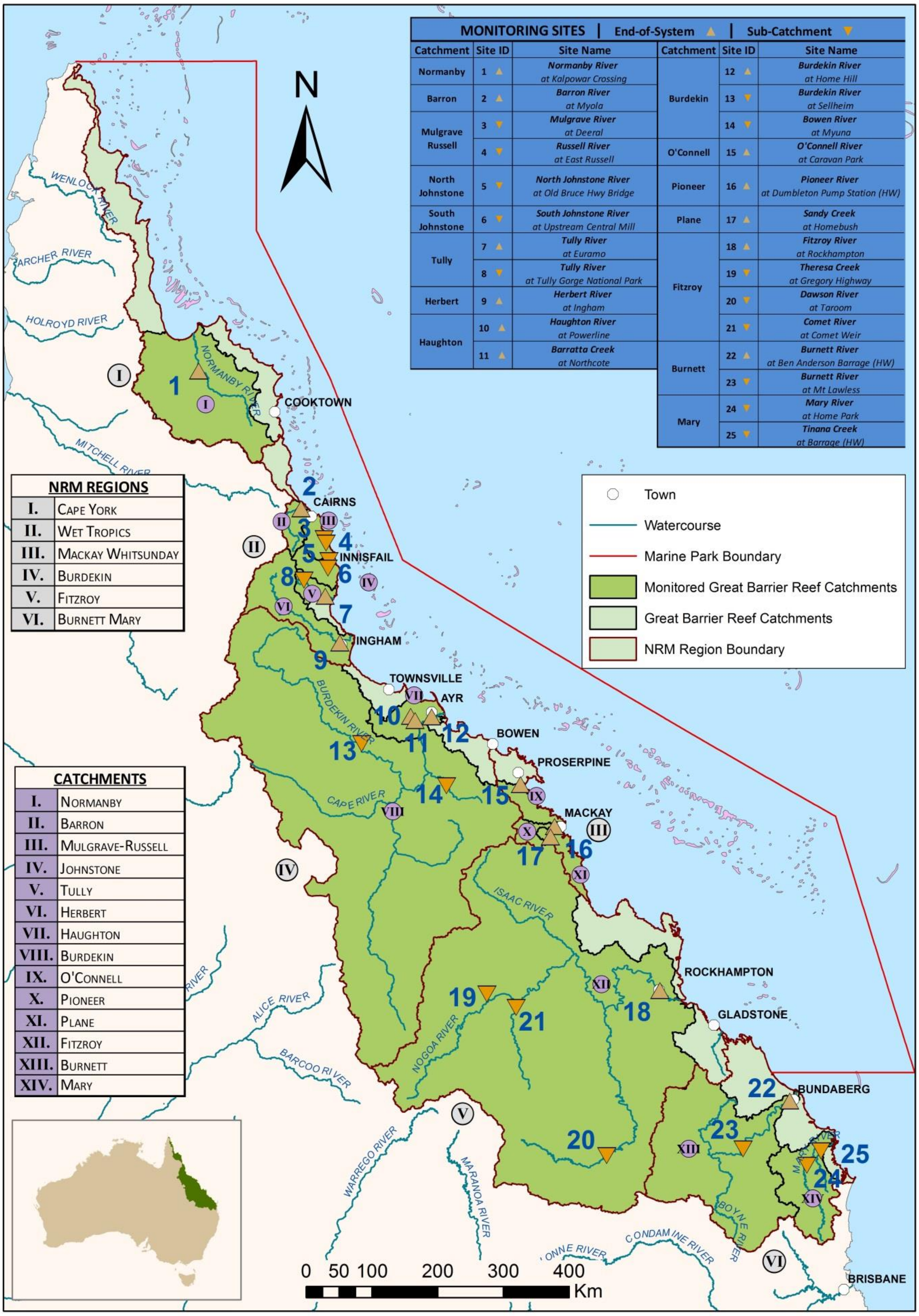


Figure 2.1 Map indicating the natural resource management regions, catchments and sites where the Great Barrier Reef Catchment Loads Monitoring Program monitored during the 2013–2014 monitoring year.

Table 2.1 Summary information on sites monitored during the 2013–2014 monitoring year by the Great Barrier Reef Catchment Loads Monitoring Program. Text in bold are end-of-system sites and the corresponding data, all others are sub-catchment sites.

NRM region	Catchment	Gauging station	River and site name	Type of site[#]	Site location		Total catchment surface area (km^2)*	Monitored surface area (km^2)	Per cent of catchment monitored
					Latitude	Longitude			
Cape York	Normanby	**105107A**	**Normanby River at Kalpowar Crossing**	**EoS**	**-14.91850**	**144.21000**	**24,399**	**12,934**	**53**
Wet Tropics	Barron	**110001D**	**Barron River at Myola**	**EoS**	**-16.79983**	**145.61211**	**2188**	**1945**	**89**
	Mulgrave-Russell	1110056	Mulgrave River at Deeral[$]	S-C	-17.20750	145.92639	1983	785	40
		1111019	Russell River at East Russell[$]	S-C	-17.26722	145.95444		524	26
	Johnstone	1120049	North Johnstone River at Old Bruce Highway Bridge (Goondi)[$]	S-C	-17.50594	145.99197	2325	959	41
		112101B	South Johnstone River at Upstream Central Mill[$]	S-C	-17.60889	145.97906		400	17
	Tully	**113006A**	**Tully River at Euramo**	**EoS**	**-17.99214**	**145.94247**	**1683**	**1450**	**86**
		113015A	Tully River at Tully Gorge National Park	S-C	-17.77260	145.65025		482	29
	Herbert	**116001F**	**Herbert River at Ingham**	**EoS**	**-18.63275**	**146.14267**	**9844**	**8581**	**87**
Burdekin	Haughton	**119003A**	**Haughton River at Powerline**	**EoS**	**-19.63314**	**147.11028**	**4051**	**1773**	**44**
		119101A	**Barratta Creek at Northcote**	**EoS**	**-19.69228**	**147.16879**		**753**	**19**
	Burdekin	**120001A**	**Burdekin River at Home Hill**	**EoS**	**-19.64361**	**147.39584**	**130,120**	**129,939**	**99**
		120002C	Burdekin River at Sellheim	S-C	-20.00778	146.43694		36,290	28
		120205A	Bowen River at Myuna	S-C	-20.58333	147.60000		7104	5
Mackay Whitsunday	O'Connell	**1240062**	**O'Connell River at Caravan Park**	**EoS**	**-20.56640**	**148.61170**	**850**	**825**	**96**
	Pioneer	**125013A**	**Pioneer River at Dumbleton Pump Station**	**EoS**	**-21.14407**	**149.07528**	**1572**	**1485**	**94**
	Plane	**126001A**	**Sandy Creek at Homebush**	**EoS**	**-21.28306**	**149.02278**	**2539**	**326**	**13**
Fitzroy	Fitzroy	**1300000**	**Fitzroy River at Rockhampton**	**EoS**	**-23.31754**	**150.48191**	**142,552**	**139,159**	**98**
		130206A	Theresa Creek at Gregory Highway	S-C	-23.42924	148.15138		8485	6
		130504B	Comet River at Comet Weir	S-C	-23.61247	148.55139		16,457	12
		130302A	Dawson River at Taroom	S-C	-25.63756	149.79014		15,846	11
Burnett Mary	Burnett	**136014A**	**Burnett River at Ben Anderson Barrage Head Water**	**EoS**	**-24.88963**	**152.29215**	**33,207**	**32,891**	**99**
		136002D	Burnett River at Mt Lawless	S-C	-25.54471	151.65494		29,355	88
	Mary	138014A	Mary River at Home Park[$]	S-C	-25.76833	152.52736	9466	6845	72
		138008A	Tinana Creek at Barrage Head Water[$]	S-C	-25.57196	152.71730		1284	14

EoS = end-of-system site, S-C = sub-catchment site, $ = the North Johnstone and South Johnstone rivers combined act as an end-of-system site, the Mulgrave and Russell rivers combined act as an end-of-system site, the Mary River and Tinana Creek combined act as an end-of-system site. *This includes the whole basin area, which contains catchments which might not drain directly to the river but are considered part of the same basin.

Table 2.2 Summary information on analytes measured and sample collection methods used by the Great Barrier Reef Catchment Loads Monitoring Program during the 2013–2014 monitoring year. Text in bold are end-of-system sites and the corresponding data, all others are sub-catchment sites.

NRM region	Catchment	Gauging station	River and site name	Analytes measured	Sample collection method
Cape York	Normanby	**105107A**	**Normanby River at Kalpowar Crossing**	**TSS & N**	**Manual**
Wet Tropics	Barron	**110001D**	**Barron River at Myola**	**TSS & N**	**Manual and automatic**
	Mulgrave-Russell	1110056	Mulgrave River at Deeral[$*]	TSS, N & PSII	Manual and automatic
		1111019	Russell River at East Russell[$*]	TSS, N & PSII	Manual and automatic
	Johnstone	1120049[+]	North Johnstone River at Old Bruce Highway Bridge (Goondi)[$]	TSS, N & PSII	Manual
		112101B	South Johnstone River at Upstream Central Mill[$]	TSS & N	Manual
	Tully	**113006A**	**Tully River at Euramo**	**TSS, N & PSII**	**Manual and automatic**
		113015A	Tully River at Tully Gorge National Park	TSS & N	Manual and automatic
	Herbert	**116001F**	**Herbert River at Ingham**	**TSS, N & PSII**	**Manual**
Burdekin	Haughton	**119003A**	**Haughton River at Powerline**	**TSS, N & PSII**	**Manual**
		119101A	**Barratta Creek at Northcote**	**TSS, N & PSII**	**Manual and automatic**
	Burdekin	**120001A[+]**	**Burdekin River at Home Hill**	**TSS, N & PSII**	**Manual**
		120002C	Burdekin River at Sellheim	TSS & N	Manual
		120205A	Bowen River at Myuna	TSS & N	Manual and automatic
Mackay Whitsunday	O'Connell	**1240062[+]**	**O'Connell River at Caravan Park***	**TSS, N & PSII**	**Manual and automatic**
	Pioneer	**125013A[+]**	**Pioneer River at Dumbleton Pump Station**	**TSS, N & PSII**	**Manual and automatic**
	Plane	**126001A**	**Sandy Creek at Homebush**	**TSS, N & PSII**	**Manual and automatic**
Fitzroy	Fitzroy	**1300000[+]**	**Fitzroy River at Rockhampton**	**TSS, N & PSII**	**Manual**
		130206A	Theresa Creek at Gregory Highway	TSS & N	Manual
		130302A	Dawson River at Taroom	TSS & N	Manual
		130504B	Comet River at Comet Weir	TSS & N	Manual
Burnett Mary	Burnett	**136014A[+]**	**Burnett River at Ben Anderson Barrage HW**	**TSS, N & PSII**	**Manual**
		136002D[+]	Burnett River at Mt Lawless	TSS & N	Manual and automatic
	Mary	138014A	Mary River at Home Park[$]	TSS, N & PSII	Manual and automatic
		138008A	Tinana Creek at Barrage HW[$]	TSS, N & PSII	Manual and automatic

TSS = total suspended solids, N = nutrients, PSII = photosystem II inhibiting herbicides, HW = headwater, + This site is not at a gauging station. Refer to Table 2.4, $ = the North Johnstone and South Johnstone rivers combined to act as an end-of-system site, the Mulgrave and Russell rivers combined act as an end-of-system site, the Mary River and Tinana Creek combined act as an end-of-system site, * = Acoustic Doppler Current Profiler installed.

2.4 Quality control

During the 2013–2014 monitoring year the Great Barrier Reef Catchment Loads Monitoring Program continued to implement its quality management system. This system has been used to govern all aspects of the program delivery since 2010 to ensure consistency and transparency in all areas of the program. Continual improvement in the program delivery has been achieved during the 2013–2014 monitoring year through implementation of the quality management system as demonstrated by:

- ongoing delivery of the Great Barrier Reef Catchment Loads Monitoring Quality Management training package to staff in partner organisations including Mulgrave Landcare and Catchment Group, Terrain Natural Resource Management, Reef Catchments and the Mary River Catchment Coordinating Committee
- installation of automated water quality monitoring equipment to improve sampling representivity during high flow events and to improve pollutant load estimates (i.e., at Mulgrave, Russell, O'Connell and Mary rivers and Tinana Creek in the Mary catchment)
- upgrade of software and hardware infrastructure at all automated water quality monitoring sites
- installation of automatic water quality samplers with glass bottles at six sites to allow for the automatic collection of water samples for analysis of pesticides (use of glass bottles is consistent with Australian and international standards).

2.5 Water quality sample analysis

Total suspended solids and nutrient analyses were undertaken by the Science Division Chemistry Centre (Dutton Park, Queensland) according to Standard Methods 2540 D, 4500-NO_3 I, 4500-NH_3 H, 4500-N_{org} D and 4500-P G (APHA-AWWA-WEF 2005). Total suspended solids samples were analysed using a gravimetric methodology and nutrient samples were analysed via segmented flow analysis (colourimetric techniques).

Queensland Health Forensic and Scientific Services Organics Laboratory (Coopers Plains, Queensland) analysed the water samples for pesticides. All pesticide samples were extracted via solid phase extraction and analysed using liquid chromatography-mass spectrometry (LC-MS) to quantify more than 40 pesticides (Appendix A) that included the five photosystem II inhibiting herbicides (ametryn, atrazine including its breakdown products desethyl atrazine and desisopropyl atrazine, diuron including its breakdown product 3,4-dichloroaniline, hexazinone and tebuthiuron). The solid-phase extraction coupled with the LC-MS analysis detects organic compounds with low octanol-water partition coefficient values (i.e., they tend to have high aqueous solubility). For the purpose of this report, atrazine together with its breakdown products is reported as 'total atrazine' and diuron and its breakdown product is reported as 'total diuron'. The total atrazine concentration for each sample was calculated according to Equation 1, which was then used to calculate a total atrazine load:

Equation 1

$$Total\ atrazine = C_e \times \frac{M_a}{M_e} + C_i \times \frac{M_a}{M_i} + C_a$$

where, *C* = concentration, *M* = molecular weight, *a* = atrazine, *e* = desethylatrazine and *i* = desisopropyl.

The total diuron concentration for each sample was calculated according to Equation 2, which was then used to calculate a total diuron load:

Equation 2

$$Total\ diuron = C_{dc} \times \frac{M_d}{M_{dc}} + C_d$$

where, *C* = concentration, *M* = molecular weight, *d* = diuron and *dc* = 3,4-dichloroaniline.

The Science Delivery Chemistry Centre (Dutton Park, Queensland) and Queensland Health Forensic and Scientific Services (Coopers Plains, Queensland) laboratories are both accredited by the National Association of Testing Authorities (NATA, Australia). Table 2.3 provides a summary of all analysed parameters, their practical quantitation limits and analytical uncertainty (measured as the 95 per cent confidence interval of the standard deviation).

Table 2.3 Summary information for each analyte measured and the corresponding practical quantitation limit and uncertainties.

Monitored pollutants	Abbreviation	Analytes measured	Practical quantitation limit	Uncertainty ±% (as reported by laboratory)
Sediments				
Total suspended solids	TSS	Total suspended solids	1 mg L^{-1}	12
Nutrients				
Total nitrogen	TN	Total nitrogen as N	0.03 mg L^{-1}	15
Particulate nitrogen	PN	Total nitrogen (suspended) as N	0.03 mg L^{-1}	15
Dissolved organic nitrogen	DON	Organic nitrogen (dissolved) as N	0.03 mg L^{-1}	15
Ammonium nitrogen as N	NH_4-N	Ammonium nitrogen as N	0.002 mg L^{-1}	8
Oxidised nitrogen as N	NO_x-N	Oxidised nitrogen as N	0.001 mg L^{-1}	8
Dissolved inorganic nitrogen	DIN	Ammonium nitrogen as N + Oxidised nitrogen as N	0.002 mg L^{-1}	8
Total phosphorus	TP	Total Kjeldahl phosphorus as P	0.02 mg L^{-1}	12
Particulate phosphorus	PP	Total phosphorus (suspended) as P	0.02 mg L^{-1}	15
Dissolved organic phosphorus	DOP	Organic phosphorus (dissolved) as P	0.02 mg L^{-1}	15
Dissolved inorganic phosphorus	DIP	Phosphate phosphorus as P	0.001 mg L^{-1}	8
Pesticides				
Ametryn	Pesticide (PSII inhibiting herbicide)	Ametryn	0.01 µg L^{-1}	52
Total atrazine		Atrazine, desethyl atrazine and desisopropyl atrazine	0.01 µg L^{-1}	24
Total diuron		Diuron and 3,4-Dichloroaniline	0.01 µg L^{-1}	21
Hexazinone		Hexazinone	0.01 µg L^{-1}	11
Tebuthiuron		Tebuthiuron	0.01 µg L^{-1}	8.6

2.6 River discharge

Where possible river discharge data (hourly-interpolated flow, $m^3 s^{-1}$) were extracted from the Department of Natural Resources and Mines, Surface Water Database using Hydstra pre-programmed scripts (DNRM 2012). The method used to calculate discharge by the Surface Water Database is presented in Appendix B. The preference was to use data with a quality code of 10 to 30, based on the Department of Natural Resources and Mines hydrographic methodology for quality rating flow data (DNRM 2014) (see Table 7.5, Appendix C, for an explanation of quality coding). If such data were not available due to a gauging station error, flows with a quality code of 59 or 60 were used (see Appendix C).

When samples were collected at sites without an operational Department of Natural Resources and Mines gauging station (due to logistic or workplace health and safety reasons, or site decommissioning) a ‘timing and flow factor’ was calculated. Timing and flow factors were based on flow data from the nearest upstream gauging station(s). Timing and flow factors were applied to discharge data used in the calculation of loads during the 2013–2014 monitoring year at: North Johnstone River at Old Bruce Highway Bridge (Goondi), Burdekin River at Home Hill, O’Connell River at Caravan Park, Fitzroy River at Rockhampton, and Burnett River at Ben Anderson Barrage Head Water (Table 2.4). In general, the factors adjust the flow to account for the delay in the time it takes water to flow from the gauging station to the water quality sampling site and for the change in flow volume due to large changes in catchment area (greater than four per cent).

During the 2013–2014 monitoring year, Acoustic Doppler Current Profilers were not yet operational at the three installed sites (Mulgrave River at Deeral, Russell River at East Russell and O’Connell River at Caravan Park). Consequently, the timing and flow factor method was used to estimate flows for O’Connell River at Caravan Park (Table 2.4), and modelled daily flows were used for Mulgrave River at Deeral and Russel River at East Russell (Appendix D).

Due to insufficient flow gaugings for Tinana Creek at Barrage Head Water monitoring site daily discharge was simulated and calibrated by the Department of Natural Resources and Mines using the Source Catchments platform, Sacramento rainfall runoff model, coupled with the Parameter Estimation Software Tool (PEST) for the period 1 July 1970 to 30 June 2014, following the approach detailed in Zhang et al. (2013). Details for the calibration statistics can be found in Zhang (2015a).

Where possible, long term mean annual discharge and historical maximum recorded flow for each monitoring site was calculated using data contained in the Surface Water Database. For four sites, O’Connell River at Caravan Park, Pioneer River at Dumbleton Pump Station, Burnett River at Ben Anderson Barrage Head Water and Burnett River at Mt Lawless, historical discharge was estimated using discharge data from upstream gauging stations as described in Table 2.4. For Mulgrave River at Deeral, Russel River at East Russell and Tinana Creek at Barrage Head Water modelled historic daily flows were used.

The exceedance probability of monitored annual discharge for all sites was calculated using Equation 3. The exceedance probability is the probability that the observed annual discharge will be exceeded in any given year based on the historical flow records available for the monitoring site. See Table 3.1 for the period of flow records used in the calculation of the exceedance probabilities.

The exceedence probability (P_e) of the annual discharge was calculated for each monitored site by:

Equation 3

$$P_e = (1 - \frac{R_i}{N+1}) \times 100$$

where *R* is the rank of the i^{th} total annual (1 July to 30 June) discharge, and *N* is the number of annual discharge observations at the monitoring site.

Table 2.4 Timing and flow factors applied to calculate discharge at non-gauged monitoring sites and recently installed gauging stations[#] during the 2013–2014 monitoring year.

Gauging station	River and site name	Timing and flow factors
1120049	North Johnstone River at Old Bruce Highway Bridge (Goondi)	Estimated from discharge data for Tung Oil GS 112004A where: $\text{Discharge}_{\text{North Johnstone River at Old Bruce Highway Bridge (Goondi)}} = \text{Discharge}_{\text{North Johnstone River at Tung Oil}}$
120001A	Burdekin River at Home Hill	Estimated from discharge data for Clare GS 120006B where: $\text{Discharge}_{\text{Burdekin River at Home Hill}} = \text{Discharge}_{\text{Burdekin River at Clare}}$
1240062	O'Connell River at Caravan Park	Estimated using the HYCRSUM function in Hydstra using discharge data for Andromache River GS 124003A and O'Connell River GS 124001B
125013A	Pioneer River at Dumbleton Pump Station	Historical discharge was estimated using data from Mirani Weir Tail Water GS 125007A where: $\text{Discharge}_{\text{Pioneer River Dumbleton Pump Station}} = 1.226 \times \text{Discharge}_{\text{Mirani Weir Tail Water}}$
1300000	Fitzroy River at Rockhampton	Estimated from discharge data from The Gap GS 130005A where: $\text{Time}_{\text{Rockhampton}} = \text{Time}_{\text{The Gap}} + 14.5$ hours
136014A	Burnett River at Ben Anderson Barrage Head Water	Estimated from discharge data for Fig Tree GS 136007A, Degilbo GS 136011A and Perry GS 136019A where: $\text{Discharge}_{\text{Burnett River at Ben Anderson Barrage Head Water}} = \text{Discharge}_{\text{Fig Tree}} + \text{Discharge}_{\text{Degilbo}} + \text{Discharge}_{\text{Perry}}$ Historical discharge (pre-1988) was estimated from Walla GS 136001A and 136001B where: $\text{Discharge}_{\text{Burnett River at Ben Anderson Barrage Head Water}} = \text{Discharge}_{\text{Walla}}$
136002D	Burnett River at Mt Lawless	Historical discharge was estimated using data from Burnett River at Yenda GS 136002A where: $\text{Discharge}_{\text{Burnett River at Mt Lawless}} = \text{Discharge}_{\text{Yenda}}$

Sites where discharge was directly applied from another site or from the addition of multiple sites differed in catchment areas by less than four per cent. In all other cases a flow factor was included to account for the effect of catchment area difference on flow.

2.7 Data analysis

2.7.1 Rating of sampling representivity

The suitability of the total suspended solids and nutrients data at each site, between 1 July 2013 and 30 June 2014, to calculate loads, was assessed by determining the representivity of the data for total suspended solids and nutrients using the method of Turner et al. (2012), first used in 2009–2010, which was based on elements of the Kroon et al. (2010) and Joo et al. (2012) methods. The sampling representivity rating identifies the sample coverage achieved during the period of maximum discharge at each monitoring site. This method was applied under the assumption that the majority of the annual total suspended solids and nutrient loads are transported during the highest flow periods, which is generally the case

(Joo et al. 2012). In order to reliably calculate the annual pollutant load, the pollutant concentration data should be available for the periods of highest discharge. The rating of sampling representivity was assessed against two criteria:

1. the number of samples collected in the top five per cent of annual monitored flow
2. the ratio between the highest flow rate at which a water sample was collected in the 2013–2014 monitoring year and the maximum flow rate recorded.

The representivity was determined by assigning a score using the system presented in Table 2.5.

Table 2.5 Scores assigned to total suspended solids and nutrients data to determine their representivity.

Number of samples in top 5 per cent of flow	Score	Ratio of highest flow sampled to maximum flow recorded	Score
0 - 9	1	0.0 - 0.19	1
10 - 19	2	0.2 - 0.39	2
20 - 29	3	0.4 - 0.59	3
30 - 39	4	0.6 - 0.79	4
>40	5	>0.8	5

The rating of sample representivity for each analyte was the sum of the scores for the two criteria. Sample representivity for each analyte was rated as “excellent” when the total score was greater than or equal to eight, “good” when the total score was six or seven, “moderate” for total scores of four or five or “indicative” when the score was less than four. Furthermore, hydrographs were visually assessed to verify the representivity rating. The representivity of pesticide data was not assessed as the Turner et al. (2012) method is not appropriate due to maximum pesticide concentrations often not occurring at the same time as maximum flow.

2.7.2 Loads calculation

Loads were calculated using the Loads Tool component of the software Water Quality Analyser 2.1.1.4 (eWater 2012) and 2.1.1.6 (eWater 2015). The total suspended solids and nutrient loads were calculated using concentrations reported in milligrams per litre (mg L^{-1}) and loads for pesticides were calculated using concentration data in micrograms per litre (µg L^{-1}).

Annual and daily loads were calculated for total suspended solids and nutrients, including total nitrogen, particulate nitrogen, dissolved organic nitrogen, dissolved inorganic nitrogen (calculated by adding oxidised nitrogen and ammonium nitrogen), oxidised nitrogen, ammonium nitrogen, total phosphorus, particulate phosphorus, dissolved inorganic phosphorus and dissolved organic phosphorus. Annual and daily pesticide loads were also calculated for ametryn, total atrazine, total diuron, hexazinone and tebuthiuron. Whilst daily loads have been calculated for all analytes, only annual loads are presented in this report.

One of two methods was used to calculate loads at each site (a decision based on a Great Barrier Reef Catchment Loads Monitoring Program review that identified the need of a repeatable approach that can produce load estimates in a timely manner and that is not subjective (DERM 2011)): average load (linear interpolation of concentration)[4] or the Beale ratio. Average Load (linear interpolation of concentration) is the most accurate and reliable method, provided events are adequately sampled, or at least with reasonably representative sampling including the peak concentration (Joo et al. 2012). For poorly sampled and/or complex events the Beale ratio is one of the recommended methods (Joo et al. 2012). The average load (linear interpolation of concentration) and Beale ratio methods were applied using the following equations: Average load (linear interpolation of concentration):

Equation 4

$$Load = \sum_{j=1}^{n} \frac{c_j + c_{j+1}}{2} \times q_j$$

where c_j is the j^{th} sample concentration, and q_j is the inter-sample mean flow (eWater 2012).

Beale ratio:

Equation 5

$$Load = Q\left(\frac{\bar{l}}{\bar{q}}\right)\left\{\frac{1+\frac{1}{N}\frac{\rho\sigma L\sigma Q}{\bar{l}\bar{q}}}{1+\frac{1}{N}\frac{\sigma^2 Q}{\bar{q}^2}}\right\}$$

where Q is the total discharge for the period, $\bar{l}$ is the average load for a sample, L is the observed load, $\bar{q}$ is the average of *N* discharge measurements, σ is the standard error of L and ρ is the correlation coefficient for L and Q (eWater 2012).

2.7.2.1 Total suspended solids, nutrients and pesticides loads

The most appropriate method (average load (linear interpolation of concentration) or Beale ratio) to calculate annual pollutant loads was determined for each analyte at each site using the following criteria:

- if the majority of major events were well sampled on both the rise and fall, then the average load (linear interpolation of concentration) method was applied (e.g. Tully River at Euramo, Figure 7.8, Appendix E and Herbert River at Ingham, Figure 7.10, Appendix E)
- if the majority of the events were not adequately sampled but the representivity rating was "moderate", "good" or better, the Beale ratio was applied (e.g. Normanby River at Kalpowar Crossing, Figure 7.1, Appendix E and Burdekin River at Home Hill, Figure 7.15, Appendix E)

[4] This method was previously referred to as the 'Linear Interpolation' method in Water Quality Analyser 2.1.1.0 and Turner et al. (2012). The revised name 'average load (linear interpolation of concentration)' is consistent with the load calculation method of Letcher et al. (1999) as referred to in Water Quality Analyser 2.1.2.4.

- if the majority of the events were not adequately sampled and the representivitiy rating was “indicative”, then annual loads may be calculated using the Beale ratio method. No indicative loads due to low sampling representivity are reported for the 2013–2014 monitoring year; however, Tinana Creek in the Mary catchment was given an indicative rating as modelled daily flows were used to calculate loads and yields. This indicative rating was given as there were no measurements of flow (the dominant factor determining the magnitude of loads). The same is the case for event loads calculated for the Mulgrave and Russell rivers.

The most appropriate load calculation method varied between sites as the numbers of samples collected and the coverage over the hydrograph varied between sites (Appendix E). During the 2013–2014 monitoring year, for all sites the sampling for total suspended solids and nutrients and pesticides was similar. The same load calculation method was used for all analytes in each site with the exception of pesticides in the Pioneer River at Dumbleton. The use of the Beale ratio method to calculate pesticide loads for this site, as was used for all other analytes, would have greatly overestimated pesticide loads due to poor correlation of pesticide concentrations and flow during all monitored events in the 2013–2014 monitoring year. In this case, it was considered more accurate to use the average load (linear interpolation of concentration) method.

The load calculation method applied for total suspended solids, nutrients and pesticides at each monitoring site is provided in Table 3.2 to Table 3.6. Once the appropriate loads calculation method was determined, the loads were calculated using the following procedure:

- water quality concentration data with a date and time stamp were imported into Water Quality Analyser (eWater 2012, 2015) for each parameter
- discharge data were imported into Water Quality Analyser (eWater 2012, 2015) on an hourly or daily interpolated time stamp
- for total suspended solids and nutrients, if the water quality concentration values were below the practical quantitation limit specified by the Science Division Chemistry Centre (Table 2.3), the results were adjusted to a value of 50 per cent of the practical quantitation limit
- where pesticide concentrations were below the practical quantitation limit, but other samples in the same event detected the same pesticide, they were replaced by 50 per cent of the practical quantitation limit. In all other cases, where the sample concentration was reported as below the practical quantitation limit, results were adjusted to 0 $\mu g\ L^{-1}$ in order to not potentially overestimate the loads
- the water quality concentration data were then aligned to the hourly flow data (nearest time match)
- the hydrograph and water quality concentration data were checked for relevance and suitability (i.e. trends in relation to hysteresis, visual relationship of water quality concentrations to flow and representativeness)
- the data were then processed by the Loads Tool component of Water Quality Analyser (eWater 2012, 2015) using the appropriate loads calculation method (as outlined above) and annual loads for the 1 July 2013 to 30 June 2014 period were reported
- all calculated results were rounded to two significant figures.

At some sites, the average load (linear interpolation of concentration) method was determined to be the most appropriate calculation method, but inadequate ambient sampling points were available to calculate annual loads using Water Quality Analyser (eWater 2012; 2015). In these cases, a calculated data point that was 50 per cent of the lowest reported concentration was inserted into the dataset at 1 July 2013 and the lowest reported concentration was inserted into the dataset at 30 June 2014 to provide tie-down concentrations for calculations (eWater 2012).

The use of average load (linear interpolation of concentration) and Beale ratio loads calculation methods for total suspended solids, nutrients and pesticides is consistent with the previous monitoring years from 2006 to 2013 (Joo et al. 2011; Turner et al. 2012; Turner et al. 2013; Wallace et al. 2014; Wallace et al. 2015).

2.7.2.2 Toxicity-based loads (Toxic loads)

As part of our ongoing commitment to improving the Great Barrier Reef Catchment Loads Monitoring Program we have introduced the concept of a toxicity-based load (toxic load), which is a more toxicologically relevant measure for pesticides. A toxic load is the calculated load of a pesticide weighted by the pesticide's relative toxicity compared to the toxicity of diuron (Smith et al., *in prep*). The toxic load is therefore expressed as an equivalent mass of diuron, i.e. diuron equivalent kilograms, kg. The total toxic load is calculated by summing the toxic loads of five photosystem II inhibiting herbicides present in water samples from a catchment.

Toxic equivalency factors, adopted from Smith et al. (*in prep*), are the values used to weight the loads of each of the pesticides and are presented in Table 2.6. Photosystem II inhibiting herbicides all have the same toxic mode of action and therefore the total toxic load could be calculated. In this report we calculate the combined annual toxic load for ametryn, total atrazine, total diuron, hexazinone and tebuthiuron.

Table 2.6 Toxic equivalency factors for five photosystem II inhibiting herbicides relative to the toxicity of diuron used for the calculation of toxic loads (adopted from Smith et al., *in prep*).

	Ametryn	Atrazine	Diuron	Hexazinone	Tebuthiuron
Diuron equivalency factor	0.65	0.036	1	0.21	0.019

2.7.3 Yields

Yields are the load of pollutants (e.g. kilograms, kg, or tonnes, t) that originate from a monitored area of land (e.g. square kilometres, km^2) within a catchment (i.e. $t\ km^{-2}$ for total suspended solids and $kg\ km^{-2}$ for nutrients and pesticides). Yields provide a useful means of comparing the rate of pollutant delivery between different monitored areas (e.g. between catchments or between Natural Resource Management regions).

2.7.3.1 Total suspended solids and nutrient catchment yields

Catchment yields of total suspended solids and nutrients were calculated for all end-of-system and sub-catchment sites by dividing the monitored annual pollutant load of each analyte by the total monitored catchment area using Equation 6.

Equation 6

Catchment Yield = monitored annual load/monitored catchment area where catchment yield is expressed as t km^{-2} or kg km^{-2} and monitored catchment area is expressed as km^2 upstream of the monitoring site.

Total suspended solids and nutrients may originate from all land use types within the monitored area including areas set aside for conservation purposes. The yields of total suspended solids and nutrients are therefore presented as an average rate of pollutant delivery across the total monitored catchment area. Research conducted in the priority reef catchments has demonstrated high variability in the rate of pollutant delivery over varying temporal and spatial scales.

2.7.3.2 Pesticide land use yields

In this report, the methods used to calculate pesticide land use yields (the load divided by the total surface area of land uses where the pesticide is registered for use) are consistent with Wallace et al. (2015), which reported the monitored annual pesticide land use yields for all monitoring years between 2010 and 2013.

Agricultural chemicals, including photosystem II inhibiting herbicides, are registered for specific applications within the agricultural sector by the Australian Pesticides and Veterinary Medicines Authority. The registration of chemicals allows restrictions to be applied to control potential environmental impacts of these chemicals. These restrictions may include the crop type, timing and rate at which registered chemicals may be applied.

It is possible to use the registered chemical restriction information to determine which agricultural production purposes five photosystem II inhibiting herbicides were registered for during the 2013–2014 monitoring year. Together with land use data available through the Australian Collaborative Land Use Mapping Program, registered chemical information may be used to calculate the land use yield of photosystem II inhibiting herbicides, or ultimately for all detected pesticides.

In each monitored catchment, the land use data were obtained from the Queensland Land Use Monitoring Program, which is part of the Australian Collaborative Land Use Mapping Program sourced through the Queensland Government Information Service (DSITIA 2013). These land use data were aggregated into eleven categories, with only the aggregated land use area for cropping, forestry, grazing, horticulture and sugarcane used to determine the land use yields (i.e. monitored loads of pesticides were not attributed to the additional six land use categories of urban, mining, conservation, intensive animal production, water and other land uses). Aggregated land use categories used in the calculation of land use yields for the photosystem II inhibiting herbicides are presented in Table 2.8.

As these land use categories are an aggregation of land use data categories contained in the Queensland Land Use Monitoring Program dataset, it is acknowledged that these categories may include specific land uses to which the application of registered chemical is not permitted (e.g. ametryn may be applied to pineapples which are included in the horticulture land use category, but may not be applied to bananas which are also included in the horticulture land use category).

The binary codes (Table 2.7) indicate whether the pesticide is registered for application in an aggregated land use (indicated by a code of 1) or not (indicated by a code of 0) and whether validation criteria relating the allocation of pesticides to particular land uses have been met. The validation criteria applied to the binary coding were:

- the pesticide is registered for a land use contained in the aggregated land use category (e.g. pineapples in horticulture)
- the specific land use (e.g. pineapples) to which the pesticide is registered occurs upstream of the monitoring site.

The pesticide land use yields (LUY) in each catchment were calculated using Equation 7:

Equation 7

LUY = annual monitored pesticide load/LUA

where LUA is the total land use area (km^2) in each catchment based on the aggregated land use categories to which a pesticide may be applied.

The LUA was determined by:

Equation 8

LUA = ∑ (binary code x surface area of each aggregated land use category) (Table 2.7)

The resulting land use yields ($kg\ km^{-2}$) are the yields of pesticides from the monitored area for each aggregated land use category in each catchment.

These are likely underestimates of the actual yields as not all land to which use of a pesticide is permitted will have had that pesticide applied. Complicating this, is that pesticides are predominantly transported to waterways when pesticide applied land receives sufficient rain to cause surface run-off – agricultural land not receiving rain but registered for a pesticide will not significantly contribute to the load or yield, nonetheless this land has been included in the calculation.

The binary coding applied in the calculation of the land use yields in this report is the product of a consultative review undertaken with peak industry bodies (Wallace et al. 2015). Changes made to the binary code from previous reports (Turner et al. 2012 and Wallace et al. 2013) removed the implied linkage between a photosystem II inhibiting herbicide and aggregated land use categories through the application of the validation criteria outlined above. Key amendments to the binary coding arising from the review as detailed in Wallace et al. (2015) were:

- Binary code of ametryn in horticulture revised from 1 to 0
- Binary code of atrazine to horticulture revised from 1 to 0
- Binary code of atrazine in grazing revised from 1 to 0.

As an example of how these amendments have been applied, the binary coding for ametryn in horticulture was adjusted from 1 to a 0. This change was based on industry advice and analysis of spatial data. Whilst industry advised ametryn is widely used in the control of broad leaf weeds in the production of pineapples, the analysis of spatial data confirmed very limited or no pineapple production occurs upstream of most

monitoring sites in the priority catchments. The only catchment where pineapple production is known to occur in the upstream monitored area was Tinana Creek in the Mary catchment. However, ametryn was not detected above the analytical limit of reporting at this site during the 2013–2014 monitoring year.

The change to the binary code has meant that land use yields published prior to the 2012–2013 report are not directly comparable to those published subsequently. All the preceding land use yields were re-calculated using the new binary code and presented in Appendix E of Wallace et al. (2015).

Table 2.7 Binary codes indicating which photosystem II inhibiting herbicides are registered for the aggregated land use categories. A code of 1 indicates the pesticide is registered for application in that aggregated land use and the validation criteria.

Photosystem II inhibiting herbicides	Cropping	Forestry	Grazing	Horticulture	Sugarcane
Ametryn	0	0	0	0	1
Atrazine	1	1	0	0	1
Total Diuron	1	0	0	1	1
Hexazinone	0	1	1	0	1
Tebuthiuron	0	0	1	0	0

Table 2.8 Surface area of each aggregated land use category upstream of the monitoring sites (obtained from the Queensland Land Use Monitoring Program) for the 2013–2014 monitoring year. Text in bold are end-of-system sites and the corresponding data, all others are sub-catchment sites.

Catchment	Gauging station	River and site name	Monitored area (km^2)	Monitored area of catchment (%)	Cropping (km^2)	Forestry (km^2)	Grazing (km^2)	Horticulture (km^2)	Sugarcane (km^2)
Johnstone	1120049	North Johnstone River at Old Bruce Highway Bridge (Goondi)*	959	41	5.2	1.4	390	24	14
Tully	**113006A**	**Tully River at Euramo**	**1450**	**86**	**0.12**	**41**	**74**	**66**	**150**
Herbert	**116001F**	**Herbert River at Ingham**	**8581**	**87**	**32**	**400**	**5300**	**3.4**	**240**
Haughton	**119003A**	**Haughton River at Powerline**	**1773**	**44**	**4.6**	**33**	**1500**	**6.8**	**20**
	119101A	**Barratta Creek at Northcote**	**753**	**19**	**22**	**0.0**	**600**	**0.99**	**130**
Burdekin	**120001A**	**Burdekin River at Home Hill**	**129,939**	**99**	**1300**	**830**	**120,000**	**2.7**	**120**
O'Connell	**1240062**	**O'Connell River at Caravan Park**	**825**	**96**	**0.0**	**150**	**510**	**0.46**	**49**
Pioneer	**125013A**	**Pioneer River at Dumbleton Pump Station**	**1485**	**94**	**0.0**	**370**	**510**	**0.65**	**310**
Plane	**126001A**	**Sandy Creek at Homebush**	**326**	**13**	**0.0**	**34**	**100**	**1.1**	**160**
Fitzroy	**1300000**	**Fitzroy River at Rockhampton**	**139,159**	**98**	**9100**	**9000**	**110,000**	**42**	**3.3**
Burnett	**136014A**	**Burnett River at Ben Anderson Barrage Head Water**	**32,891**	**99**	**1200**	**4100**	**25,000**	**73**	**63**
Mary	138014A	Mary River at Home Park	6845	72	34	880	3900	41	14
	138008A	Tinana Creek at Barrage Head Water	1284	14	3.4	760	200	28	60

*Previously land use surface areas for this site were calculated based on the location of the North Johnstone River site at Tung Oil (monitored area of 925 km^2) where discharge was measured.

3 Results and discussion

Water quality monitoring at Theresa Creek at Gregory Highway, Comet River at Comet Weir and Burnett River at Mount Lawless was not sufficient to calculate annual loads for the 2013–2014 monitoring year (see Section 3.2 and Section 3.3). As a result, no annual loads for these sub-catchment sites are presented in this report.

Automatic samplers at the Mulgrave River at Deeral and Russell River at East Russell were only operational from February 2014. The first high flow event at both of these sites occurred prior to this time and subsequently inadequate sampling was achieved. As a result, it was only possible to calculate event loads for these two sites and no annual loads are reported. Event loads for total suspended solids, nutrients and pesticides are presented in Appendix D.

3.1 Rainfall and river discharge

Annual rainfall and rainfall deciles (with respect to long term mean rainfall) across the priority reef catchments and natural resource management regions during the 2013–2014 monitoring year are presented in Figure 3.1 and Figure 3.2.

During the 2013–2014 monitoring year, the Normanby catchment in the Cape York region received between 1000 and 1500 mm of rain, which is average to above average for that catchment. The monitored catchments of the Wet Tropics region received between 500 and 1000 mm in the west, increasing to 4500 mm in the upper Mulgrave and Russell catchments. Rainfall across the monitored catchments of the Wet Tropics region was generally average. In the Burdekin region, rainfall was average to very much below average (i.e. <500 to 1000 mm). The monitored catchments of the Mackay Whitsunday region received average rainfall (i.e. 1000 to 2000 mm) and much of the Fitzroy region received below average to very much below average rainfall (<500 to 1000mm). The monitored catchments of the Burnett Mary region received from less than 500 mm up to 1000mm of rain which was very much below average across most of the Burnett Mary region. A detailed monthly rainfall summary is presented in Appendix F.

Tropical Cyclone Ita, which made landfall on 11 April 2014 as a category 4 system near Cooktown in the Cape York region, was a notable weather event of the 2013–2014 monitoring year. The intensity of the weather system decreased rapidly as it tracked south over the Wet Tropics and Burdekin regions, eventually moving offshore near Proserpine on 13 April 2014. Tropical Cyclone Ita produced rainfall totals above 300 mm in areas of the Cape York, Wet Tropics and lower Burdekin regions (BoM, 2015b).

3.1.1 El Niño-Southern Oscillation and Southern Oscillation Index

The El Niño-Southern Oscillation remained neutral during the 2013–2014 monitoring year (BoM, 2014b). Most indicators of El Niño-Southern Oscillation remained at near-average levels, with some atmospheric indicators such as the Southern Oscillation Index fluctuating around neutral during the austral winter of 2013 and going neutral during the austral summer (BoM, 2014b). Fluctuations of the Southern Oscillation Index were typical of neutral El Niño-Southern Oscillation periods. The tropical Pacific Ocean warmed steadily towards the austral winter reaching surface temperature levels typically associated with a weak El Niño by late June 2014.

3.1.2 River discharge

River discharge during 2013–2014 monitoring year in the Burdekin, O'Connell, Fitzroy, Burnett and Mary rivers and in Sandy Creek in the Plane catchment was very much below the long term mean (Figure 3.3), with exceedence probabilities at end-of-system sites ranging from 59 per cent in the Burnett River to 85 per cent in the Burdekin River (Table 3.1). River discharge in the Normanby, Barron, Haughton and Pioneer rivers and in Barratta Creek in the Haughton catchment and Tinana Creek in the Mary catchment, was below the long term mean (Figure 3.3), with exceedence probabilities at these end-of-system sites ranging from 44 per cent in the Normanby River to 59 per cent in the Haughton River (Table 3.1). River discharge in the Mulgrave, Russell, North Johnstone, South Johnstone, Tully and Herbert rivers was above the long term mean (Figure 3.3) with exceedence probabilities at the end-of-system sites ranging from 24 per cent in the North Johnstone and Mulgrave rivers to 43 per cent in the South Johnstone River (Table 3.1).

Severe Tropical Cyclone Ita associated rainfall contributed a significant fraction of the 2013–2014 annual discharge in the Normanby, Barron, Mulgrave and Herbert rivers (Wallace et al. *in preparation*). The duration of Tropical Cyclone Ita associated high flow events in these rivers varied between 4 and 15 days (Wallace et al. *in preparation*).

Similar to the Burdekin River end-of-system site, discharge in the monitored Burdekin sub-catchments was very much below the long term mean annual discharge with exceedence probabilities of 62 and 75 per cent for the Bowen River and upper Burdekin River at Sellheim, respectively.

The monitored Fitzroy sub-catchments had among the lowest discharge relative to their long term mean annual discharge, with exceedence probabilities of 88 per cent for Theresa Creek and the Dawson River, and 91 per cent for the Comet River.

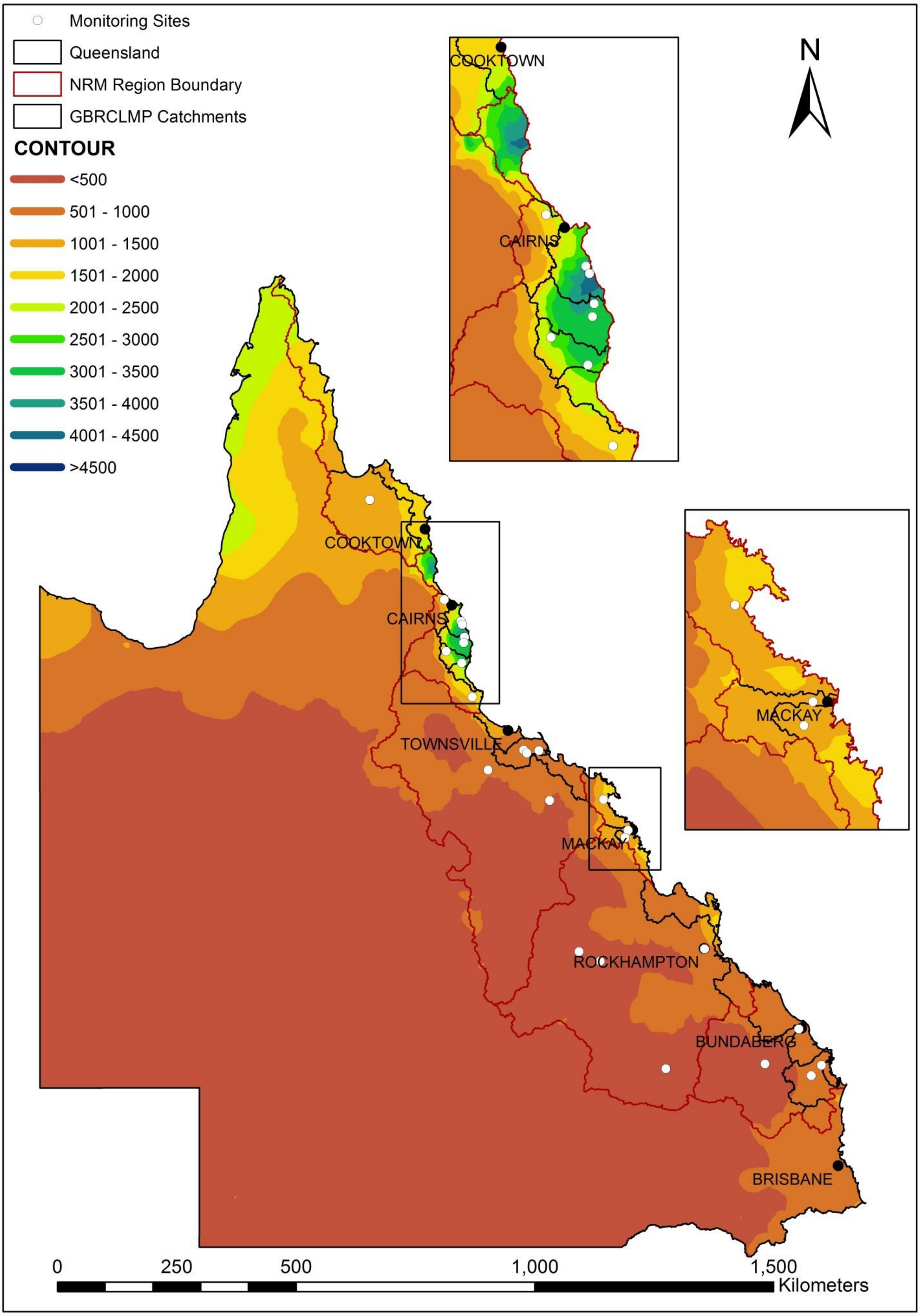


Figure 3.1 Queensland rainfall (millimetres) totals for 1 July 2013 to 30 June 2014 along with the monitored catchments and Great Barrier Reef Catchment Loads Monitoring Program sites.

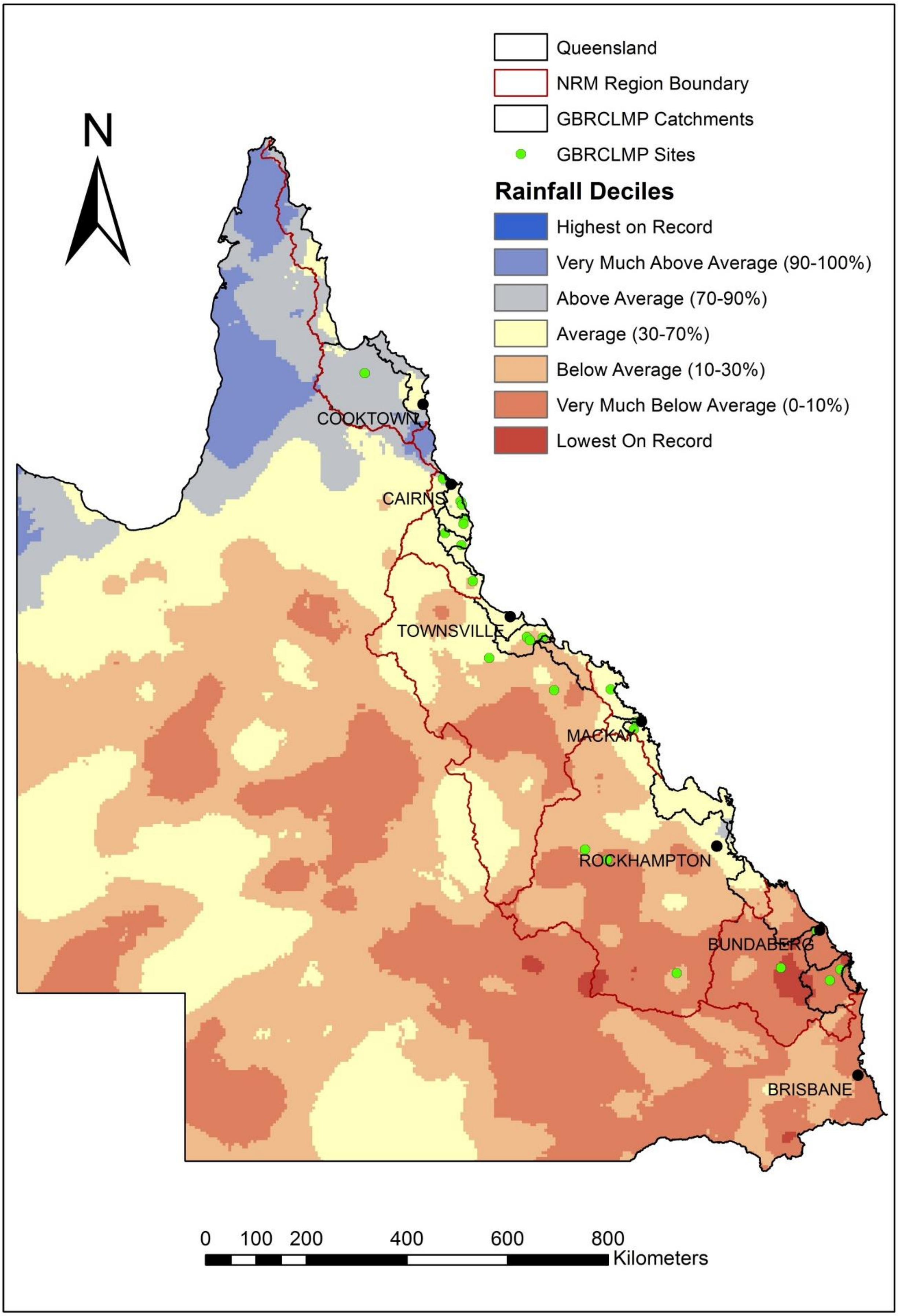


Figure 3.2 Queensland rainfall deciles with respect to long term mean rainfall for 1 July 2013 to 30 June 2014 along with the monitored catchments and Great Barrier Reef Catchment Loads Monitoring Program sites.

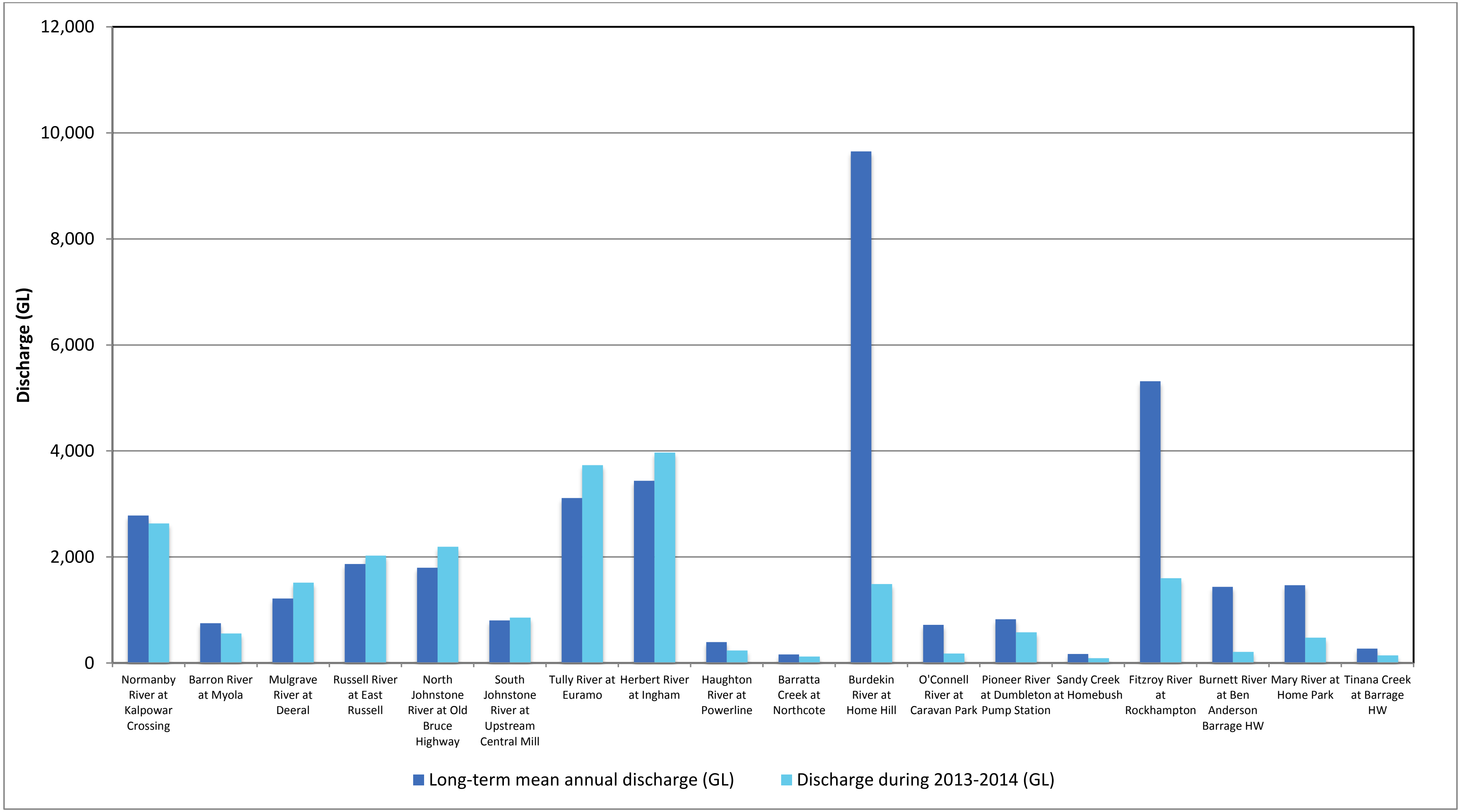


Figure 3.3 Annual discharge for the end-of-system sites (including the North Johnstone and South Johnstone sub-catchments, the Mulgrave River and Russell River sub-catchments and the Mary River and Tinana Creek sub-catchments) for the 2013–2014 monitoring year, compared to the long term mean annual discharge.

Table 3.1 The total and monitored area for each catchment and summary discharge and flow statistics for the 2013–2014 monitoring year. Text in bold are end-of-system sites and the corresponding data, all others are sub-catchment sites.

NRM region	Catchment	River and site name	Total catchment surface area (km^{-2})	Monitored surface area (km^{-2})	Monitored surface area of catchment (%)	Start year of flow records	Long term mean annual discharge (GL)	Discharge during 2013–2014 (GL)	Exceedence probability (%)	Discharge as a per cent of the long term mean annual discharge (%)	Historical maximum recorded flow ($m^3 s^{-1}$)	Maximum recorded flow 2013–2014 ($m^3 s^{-1}$)	Per cent of maximum recorded flow observed in 2013–2014 (%)
Cape York	Normanby	**Normanby River at Kalpowar Crossing**	**24,399**	**12,934**	**53**	**2005**	**2800**	**2600**	**44**	**95**	**2088**	**2056**	**98**
Wet Tropics	Barron	**Barron River at Myola**	**2188**	**1945**	**89**	**1957**	**760**	**560**	**53**	**74**	**3076**	**2271**	**74**
	Mulgrave-Russell[$]	Mulgrave River at Deeral	1983	785	40	1970	1200	1500	24	120	3069	1465	47
		Russell River at East Russell		524	26	1970	1870	2000	40	110	1152	446	39
	Johnstone[$]	North Johnstone River at Old Bruce Highway Bridge (Goondi)	2325	959	41	1966	1800	2200	24	120	3051	2262	74
		South Johnstone River at Upstream Central Mill		400	17	1974	800	860	43	110	1680	761	45
	Tully	**Tully River at Euramo**	**1683**	**1450**	**86**	**1972**	**3100**	**3700**	**31**	**120**	**1052**	**967**	**92**
		Tully River at Tully Gorge National Park		482	29	2009	1000	1100	40	110	1883	995	53
	Herbert	**Herbert River at Ingham**	**9844**	**8581**	**87**	**1915**	**3400**	**4000**	**39**	**110**	**11,267**	**10,416**	**92**
Burdekin	Haughton	**Haughton River at Powerline**	**4051**	**1773**	**44**	**1970**	**400**	**240**	**59**	**60**	**4454**	**955**	**21**
		Barratta Creek at Northcote		**753**	**19**	**1974**	**160**	**120**	**56**	**74**	**1695**	**377**	**22**
	Burdekin	**Burdekin River at Home Hill**	**130,120**	**129,939**	**99**	**1973**	**9700**	**1500**	**85**	**15**	**25,483**	**912**	**4**
		Burdekin River at Sellheim		36,290	28	1968	4700	1800	75	38	24,200	3034	13
		Bowen River at Myuna		7104	5	1960	960	430	62	45	10,480	804	8
Mackay Whitsunday	O'Connell	**O'Connell River at Caravan Park**	**850**	**825**	**96**	**1976**	**720**	**180**	**77**	**25**	**6541**	**1037**	**16**
	Pioneer	**Pioneer River at Dumbleton Pump Station**	**1572**	**1485**	**94**	**1977**	**830**	**580**	**48**	**70**	**4337**	**1023**	**24**
	Plane	**Sandy Creek at Homebush**	**2539**	**326**	**13**	**1966**	**170**	**94**	**60**	**54**	**1314**	**204**	**16**
Fitzroy	Fitzroy	**Fitzroy River at Rockhampton**	**142,552**	**139,159**	**98**	**1964**	**5300**	**1600**	**66**	**30**	**14,493**	**873**	**6**
		Theresa Creek at Gregory Highway		8485	6	1956	260	24	88	9	4234	90	2
		Comet River at Comet Weir		16,457	12	2002	980	3.0	91	0.30	3975	15	0.3
		Dawson River at Taroom		15,846	11	1911	400	46	88	12	5858	188	3
Burnett Mary	Burnett	**Burnett River at Ben Anderson Barrage Head Water**	**33,207**	**32,891**	**99**	**1910**	**1400**	**210**	**59**	**15**	**16,902**	**80**	**1**
		Burnett River at Mt Lawless		29,355	88	1909	1100	110	79	10	16,646	38	0.2
	Mary[$]	Mary River at Home Park	9466	6845	72	1982	1500	480	67	33	12,581	794	6
		Tinana Creek at Barrage Head Water		1284	14	1970	280	150	51	53	1124	244	22
Summary end-of-system catchment areas (including North Johnstone and South Johnstone rivers, Mulgrave and Russell rivers and Mary River and Tinana Creek)			366,779	342,858	93								

$ = the North and South Johnstone rivers combined act as an end-of-system site, the Mulgrave and Russell rivers combined act as an end-of-system site and the Mary River and Tinana Creek combined act as an end-of-system site.

3.2 Sampling representivity

The sampling representivity rating identifies the sample coverage achieved during the period of maximum flow at each monitoring site. The representivity metric was applied because the majority of the annual total suspended solids and nutrient loads are transported during the highest flow periods and in order to reliably calculate the annual pollutant load, it is important that the pollutant concentration data are available for the periods of highest flow. Table 3.2 provides a summary of the sampling representivity ratings – indicating those parameters and sites where the representivity is excellent or good, moderate and indicative. Table 7.12 and Table 7.13 in Appendix G provide the representivity rating and the number of samples used to calculate the loads and yields of total suspended solids and nutrients.

3.2.1 Total suspended solids, total nutrients and dissolved nutrients

Good or excellent sampling representivities were achieved at all end-of-system monitoring sites for all monitored analytes, with two exceptions (Table 3.2). These were the Haughton River at Powerline with moderate representivity for all analytes and O'Connell River at Caravan Park, which had a moderate representivity for total suspended solids (Table 3.2).

The Tully River at Tully Gorge National Park sub-catchment site had excellent representivity for all analytes (Table 3.2). The Bowen River at Myuna sub-catchment site had excellent representivity for total suspended solids and total nutrients and good sampling representivity for dissolved and particulate nutrients. The Burdekin River at Sellheim and Dawson River at Taroom sub-catchment sites had good sampling representivities for all analytes. In the manually sampled North Johnstone and South Johnstone river sub-catchment sites only moderate sampling representivities were achieved for all parameters. The Mary River at Home Park sub-catchment site had excellent representivity for all analytes. Whilst no indicative loads caused by low sampling representivity are reported this monitoring year (Table 3.2), calculated loads for Tinana Creek at Barrage Head Water were given an indicative rating as modelled daily flows were used to calculate loads.

During the 2013–2014 monitoring year, the Burnett River at Ben Anderson Barrage had markedly low flow which did not allow for the application of representivity metrics. The Average load (linear interpolation of concentration) method was selected as the best load calculation method for this site taking into consideration that coverage requirements for low flow monitoring are not as stringent as those for high flow (concentrations during low flow do not have such a high variability as those during high flow events).

Water quality monitoring at Theresa Creek at Gregory Highway, Comet River at Comet Weir and Burnett River at Mount Lawless was not sufficient to calculate annual loads for the 2013–2014 monitoring year, and sampling representivities were not calculated for these sites. As previously mentioned, the first high flow event of the year was not sampled at the Mulgrave River at Deeral and Russell River at East Russell sites. Consequently, only event loads were calculated for these two sites and sample representivity was not calculated.

3.3 Total suspended solids and nutrient loads and yields

The 2013–2014 monitored annual loads and yields of total suspended solids and nutrients were calculated using discharge and pollutant concentration data. The resulting loads are estimates of the mass of each analyte transported past the monitoring sites and do not necessarily represent the loads discharged to the Great Barrier Reef lagoon – as most of the end-of-system monitoring sites are not located at the mouth of the river or creek (refer to Section 2.1). In the unmonitored portion of the catchment or sub-catchment there may be contribution, removal, transformation or degradation of total suspended solids and nutrients. The annual loads discharged to the Great Barrier Reef for all 35 catchments are calculated using catchment models and are reported elsewhere in the Paddock to Reef program (DPC 2015).

The monitored annual loads and yields of total suspended solids and nutrients are presented in Table 3.2 to Table 3.4. The relative contribution of each monitored catchment to the total annual load for each parameter is presented in Figure 3.4 to Figure 3.14.

As previously mentioned, daily modelled flow was used to calculate loads for Tinana Creek at Barrage Head Water. Consequently, the calculated annual loads for this site, which are included in the results section, are considered indicative due to the intrinsic limitations of using modelled flow in place of measured flow.

3.3.1 Total suspended solids

3.3.1.1 Total suspended solid loads

The combined monitored annual load of total suspended solids for the priority catchments during the 2013–2014 monitoring year was 1.4 Mt (Table 3.2) of which, 58 per cent was derived from the Herbert (0.39 Mt; 28 per cent), Burdekin (0.22 Mt; 16 per cent) and Johnstone (North and South Johnstone together) (0.20 Mt; 14 per cent) catchments combined (Table 3.2 and Figure 3.4). The other monitored catchments contributed 42 per cent of the combined monitored load of which the Normanby catchment contributed the largest load (0.14 Mt; 10 per cent). The lowest monitored annual total suspended solids load during the 2013–2014 monitoring year was in the Burnett River (0.0013 Mt; 0.093 per cent). This is in contrast to 2012–2013 when the Burnett River produced the largest monitored annual load (3.7 Mt). The high flow event associated with severe Tropical Cyclone Ita contributed a significant fraction of the monitored annual total suspended solids load in the Normanby, Barron and Herbert Rivers (Wallace et al. *in preparation*).

In the previous monitored years between 2006 and 2013, the Burdekin and Fitzroy catchments contributed the majority of the monitored total suspended solids annual loads (between 52 per cent in 2012–2013 and 92 per cent in 2007–2008) (Joo et al. 2012; Turner et al. 2012; Turner et al. 2013; Wallace et al. 2014; Wallace et al. 2015). During the 2013–2014 monitoring year, the combined load from these two catchments accounted for just 20 per cent of the total annual monitored load (Table 3.2 and Figure 3.4), the lowest in all years (Joo et al. 2012; Turner et al. 2012; Turner et al. 2013; Wallace et al. 2014; Wallace et al. 2015). This is explained by the low discharge from the Burdekin and Fitzroy catchments during the 2013–2014 monitoring year (15 per cent and 30 per cent, respectively), which was also the lowest recorded since the Great Barrier Reef Catchment Loads Monitoring Program commenced in 2006.

In the Burdekin catchment, the highest monitored annual sub-catchment load occurred in the Burdekin River (monitored at Sellheim, 2.1 Mt), with a much lower monitored annual load of total suspended solids in the Bowen River (0.21 Mt) (Table 3.2). The monitored annual load of total suspended solids in the Burdekin River at Sellheim was approximately ten times more than the monitored annual Burdekin River end-of-system load. Marked differences in the monitored annual total suspended solids loads at these sites have been noted previously (Turner et al. 2012; Turner et al. 2013; Wallace et al. 2014; Wallace et al. 2015). The Burdekin Falls Dam, located in between these two sites, is known to cause a reduction in sediment load exported downstream mostly explained by the settling of coarse sediment, though the majority of the fine fraction is not retained by the dam (Bainbridge et al. 2014).

The Dawson River sub-catchment in the Fitzroy region produced a low monitored annual load of total suspended solids (0.026 Mt) during the 2013–2014 monitoring year, when compared to other catchments or years. The low relative load can be attributed to the very low discharge when compared to the long term mean discharge (see section 3.1.2) and to discharge in previous monitored years (Joo et al. 2012; Turner et al. 2012; Turner et al. 2013; Wallace et al. 2014; Wallace et al. 2015). Insufficient data were available to calculate an annual load of total suspended solids for the Theresa Creek and the Comet River sub-catchments.

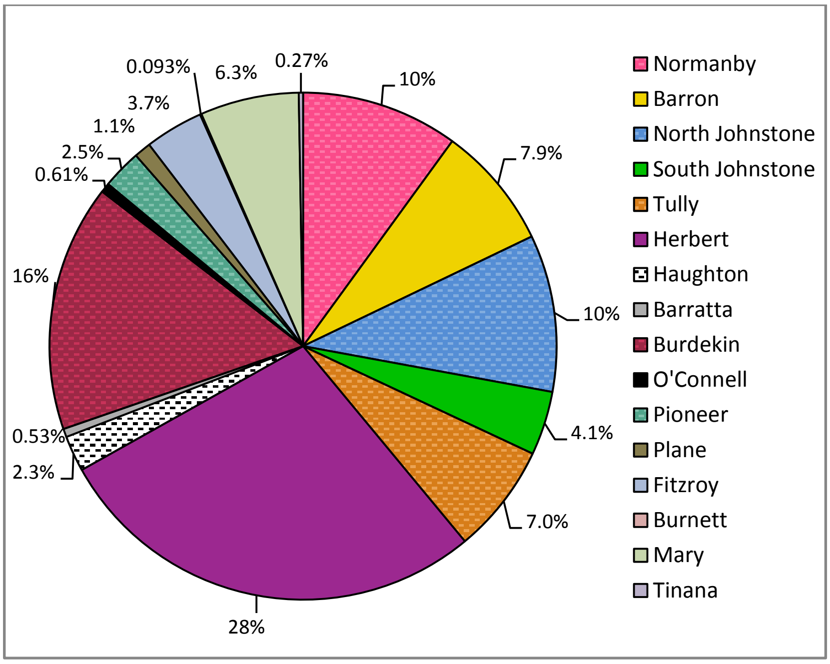


Figure 3.4 Per cent contribution from each catchment to the combined monitored annual total suspended solids load during the 2013–2014 monitoring year.

3.3.1.2 Total suspended solids yields

During the 2013–2014 monitoring year, the highest yield of total suspended solids was derived from the Johnstone catchment (145 t km^{-2}) (average of North and South Johnstone) (Table 3.3). A moderate yield of total suspended solids was monitored in the Tully (67 t km^{-2}) and Barron (56 t km^{-2}) catchments, Sandy Creek in the Plane catchment (46 t km^{-2}) and Herbert (45 t km^{-2}) catchment (Table 3.3). All of these catchments are located in the Wet Tropics and Mackay Whitsunday natural resource management regions and have

consistently produced the highest yields of total suspended solids during previous monitoring years (Turner et al. 2012 and 2013; Wallace et al. 2014; Wallace et al. 2015), except for 2012–2013 when the Burnett catchment produced the highest yield following major flooding associated with Tropical Cyclone Oswald.

The lowest monitored annual yields of total suspended solids during the 2013–2014 monitoring year occurred in the large inland catchments of the Burnett (0.040 t km^{-2}), Fitzroy (0.37 t km^{-2}) and Burdekin (1.7 t km^{-2}) rivers (Table 3.3). A major land use in these catchments is dry land grazing, which has been previously reported as contributing low yields of total suspended solids (Joo et al. 2012; Turner et al. 2012; Turner et al. 2013; Wallace et al. 2014, Wallace et al. 2015). The 2013–2014 monitoring year was particularly dry and total suspended solids yields from the Burdekin and Fitzroy catchments were the lowest observed since 2006. While the yield of total suspended solids is lower in these catchments during the 2013–2014 monitoring year, it has been estimated based on modelling that grazing lands typically contributes half of average annual baseline and anthropogenic loads exported to the Great Barrier Reef (Waters et al. 2014).

The yield of total suspended solids at the Burdekin sub-catchment monitoring sites was much higher than at the Burdekin River end-of-system monitoring site (Table 3.3). The monitored sub-catchment yield for the upper Burdekin River (monitored at Sellheim) was 57 t km^{-2} and the yield from the Bowen River sub-catchment was 29 t km^{-2}.

Within the Fitzroy, the monitored annual yield of total suspended solids at the Dawson River sub-catchment was 1.7 t km^{-2}. No data were available for Theresa Creek or Comet River sub-catchments during the 2013–2014 monitoring year.

3.3.2 Nitrogen

3.3.2.1 Nitrogen load

The combined monitored annual load of total nitrogen was 12 kt (Table 3.2) of which, 48 per cent was derived from the Herbert (2.6 kt; 22 per cent), Johnstone (North and South Johnstone together) (1.5 kt; 13 per cent) and Tully (1.5 kt; 13 per cent) catchments (Table 3.2 and Figure 3.5). The other monitored catchments contributed 52 per cent of the monitored annual load of which the Normanby (1.2 kt; 10 per cent) and Fitzroy (1.0 kt; 8.6 per cent) catchments contributed the largest loads (Table 3.2 and Figure 3.5). The lowest monitored annual total nitrogen load during the 2013–2014 monitoring year occurred in the Burnett River (0.1 kt; 0.86 per cent).

During the 2013–2014 monitoring year, the combined monitored annual load of dissolved inorganic nitrogen was 3.0 kt (Table 3.2). The largest monitored annual loads of dissolved inorganic nitrogen were derived from the Herbert (0.76 kt; 25 per cent) and Tully (0.64 kt; 21 per cent) catchments, which together accounted for 46 per cent of the combined monitored end-of-system load (Table 3.2 and Figure 3.6). Moderately sized loads were monitored in the Johnstone (North and South Johnstone together) (0.46 kt; 15 per cent), Mary (Mary River and Tinana Creek together) (0.32 kt; 11 per cent) and Pioneer catchments (0.26 kt; 8.6 per cent) (Table 3.2 and Figure 3.6). The remaining catchments each contributed less than 5 per cent of the combined monitored load (Figure 3.6), with the lowest end-of-system load monitored in the Burnett catchment (0.0063 kt; 0.21 per cent).

Oxidised nitrogen accounted for 90 per cent of the monitored dissolved inorganic nitrogen load during the 2013–2014 monitoring year (Table 3.2). The largest monitored annual loads of oxidised nitrogen were derived from the Herbert (0.71 kt; 26 per cent) and Tully (0.60 kt; 22 per cent) catchments, which together accounted for 48 per cent of the combined monitored end-of-system load. Moderately sized loads were also monitored in the Johnstone (North and South Johnstone together) (0.43 kt; 15 per cent), Mary (Mary River and Tinana Creek together) (0.30 kt; 11 per cent) and Pioneer catchments (0.23 kt; 8.4 per cent) (Table 3.2 and Figure 3.7). All remaining catchments each contributed less than 5 per cent of the monitored oxidised nitrogen load with the lowest monitored annual load occurring in the Burnett catchment (0.0053 kt; 0.19 per cent) (Table 3.2 and Figure 3.7).

The total monitored annual load of ammonium nitrogen during the 2013–2014 monitoring year was 310 t (Table 3.2). The largest monitored annual loads were derived from the Herbert (57 t; 18 per cent), Fitzroy (40 t; 13 per cent) and Tully (39 t; 13 per cent) catchments, which together accounted for 44 per cent of the combined monitored end-of-system load during the 2013–2014 monitoring year. Moderately sized loads were also monitored in the O'Connell (32 t; 10 per cent), Normanby (30 t; 9.6 per cent) and Pioneer (29 t; 9.3 per cent) catchments (Table 3.2 and Figure 3.8). All remaining catchments each contributed 7 per cent or less of the monitored ammonium nitrogen load, with the lowest monitored annual loads occurring in the Burnett catchment (1.0 t; 0.32 per cent).

The ratio of the monitored annual oxidised nitrogen load to the ammonium nitrogen load varied greatly amongst catchments. In the Johnstone (North and South Johnstone), Tully, Herbert, Haughton and Mary (Mary River and Tinana Creek together) catchments and Sandy Creek in the Plane catchment the relative proportion was high (12:1 to 21:1). In the Barron, Burdekin, Pioneer, Fitzroy and Burnett catchments the ratio was low but greater than 1 (2:1 to 8:1). In the Normanby and O'Connell catchments the ammonium nitrogen load was larger than the oxidised nitrogen load, resulting in the lowest relative proportion of oxidised nitrogen to ammonium nitrogen load with values of 0.7:1 and 0.4:1, respectively.

At the sub-catchment scale, the ratio of the monitored annual oxidised nitrogen load to the ammonium nitrogen load was similar between the North Johnstone and South Johnstone sub-catchment monitoring sites (21:1 and 20:1, respectively). In the Mary catchment however, the ratio was very different between the monitoring site Mary River at Home Park on the main channel (14:1) and the Tinana Creek sub-catchment (5.2:1). The ratio of oxidised nitrogen to ammonium load in the Upper Burdekin River sub-catchment (monitored at Sellheim) was twice the ratio monitored in the Bowen River sub-catchment (11:1 and 5.5:1, respectively).

During the 2013–2014 monitoring year, the combined monitored annual load of particulate nitrogen was 4.5 kt (Table 3.2). Similar to total suspended solids loads, the largest monitored annual loads of particulate nitrogen during the 2013–2014 monitoring year were derived from the Herbert (1.1 kt; 24 per cent), Johnstone (North and South Johnstone together) (0.79 kt; 17 per cent) and Tully (0.50 kt; 11 per cent) catchments, which together accounted for 52 per cent of the combined monitored end-of-system load. Moderately sized loads were also monitored in the Barron (0.42 kt; 9.2 per cent), Normanby (0.40 kt; 8.8 per cent) and Burdekin (0.40 kt; 8.8 per cent) catchments (Table 3.2 and Figure 3.9). The remaining catchments each contributed less than 6 per cent of the combined monitored load (Figure 3.9), with the lowest end-of-system load monitored in the Burnett catchment (0.025 kt; 0.55 per cent) (Table 3.2 and Figure 3.9).

The combined monitored annual load of dissolved organic nitrogen during the 2013–2014 monitoring year was 3.9 kt (Table 3.2). The largest monitored annual loads of dissolved organic nitrogen were derived from the Normanby (0.71 kt; 18 per cent), Herbert (0.69 kt; 18 per cent) and Fitzroy (0.63 kt; 16 per cent) catchments, which together accounted for 52 per cent of the combined monitored annual end-of-system load during the 2013–2014 monitoring year. Moderately sized loads were also monitored in the Tully (0.36 kt; 9.2 per cent) and Burdekin catchments (0.33 kt; 8.4 per cent) (Table 3.2 and Figure 3.10). The remaining catchments each contributed less than 7 per cent of the combined monitored load (Figure 3.10) with the lowest load from end-of-system sites occurring in Sandy Creek in the Plane catchment (0.056 kt; 1.4 per cent).

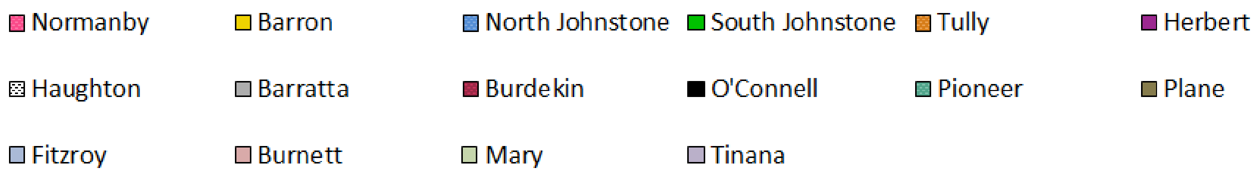
3.3.2.2 Nitrogen yields

The largest monitored annual yields of total nitrogen during the 2013–2014 monitoring year were derived from the Johnstone (North and South Johnstone) (1100 kg km^{-2}) and Tully (1100 kg km^{-2}) catchments (Table 3.3). Moderate yields of total nitrogen were derived from the Barron, Herbert, Haughton, O'Connell and Pioneer catchments, Sandy Creek in the Plane catchment and Mary catchment (between 100 and 480 kg km^{-2}). The highest yields of total nitrogen have consistently occurred in the Johnstone (North and South Johnstone), Tully and Pioneer catchments and Sandy Creek in the Plane catchment throughout the monitoring years (Joo et al. 2012; Turner et al. 2012; Turner et al. 2013; Wallace et al. 2014, Wallace et al. 2015), where a high proportion of cropping land use is present (DSITIA 2014). The lowest monitored annual yields of total nitrogen were derived from the larger inland catchments in which a dominant land use is dry land grazing, including the Burnett (3.1 kg km^{-2}), Burdekin (6.6 kg km^{-2}) and Fitzroy (7.2 kg km^{-2}) catchments, which is consistent with previous years (Joo et al. 2012; Turner et al. 2012; Turner et al. 2013; Wallace et al. 2014, Wallace et al. 2015).

The Tully catchment had the highest monitored annual yield of dissolved inorganic nitrogen (440 kg km^{-2}), which similar to previous years was driven by a high yield of oxidised nitrogen (410 kg km^{-2}) (Table 3.3). High to moderate yields of oxidised nitrogen were monitored across all catchments of the Wet Tropics and Mackay Whitsunday regions excluding the Barron catchment with a yield of 11 kg km^{-2} and the O'Connell catchment which had a low yield of 15 kg km^{-2} during the 2013–2014 monitoring year. The largest yields of ammonium nitrogen during the 2013–2014 monitoring year occurred in the O'Connell (39 kg km^{-2}), Tully (27 kg km^{-2}) and Pioneer (20 kg km^{-2}) catchments. The lowest yields of dissolved inorganic nitrogen, ammonium nitrogen and oxidised nitrogen occurred in the Burnett, Fitzroy and Burdekin catchments (Table 3.3).

The highest yield of particulate nitrogen during the 2013–2014 monitoring year occurred in the Johnstone catchment (North and South Johnstone) (580 kg km^{-2}), with high yields of particulate nitrogen also occurring in Tully (350 kg km^{-2}) catchment (Table 3.3). Moderate yields of particulate nitrogen were derived from the Barron, Herbert and Pioneer catchments and Sandy Creek in the Plane catchment (between 130 and 220 kg km^{-2}). The highest yields of particulate nitrogen have consistently occurred in the Johnstone (North and South Johnstone), Tully and Pioneer catchments and in Sandy Creek in the Plane catchment throughout the previous monitoring years (Joo et al. 2012; Turner et al. 2012; Turner et al. 2013; Wallace et al. 2014, Wallace et al. 2015). The lowest monitored annual yields of particulate nitrogen were derived from the Burnett (0.76 kg km^{-2}), Fitzroy (1.6 kg km^{-2}) and Burdekin (3.1 kg km^{-2}) catchments.

The monitored annual yield of dissolved organic nitrogen during the 2013–2014 monitoring year was similar amongst the small coastal catchments in the Wet Tropics and Mackay Whitsunday regions (Table 3.3) with the highest yields derived from the Tully (250 kg km^{-2}) and Johnstone (North and South Johnstone) (190 kg km^{-2}) catchments and Sandy Creek in the Plane catchment (170 kg km^{-2}). The lowest yields of dissolved organic nitrogen during the 2013–2014 monitoring year were derived from the Burnett (2.1 kg km^{-2}), Burdekin (2.6 kg km^{-2}) and Fitzroy (4.5 kg km^{-2}) catchments.



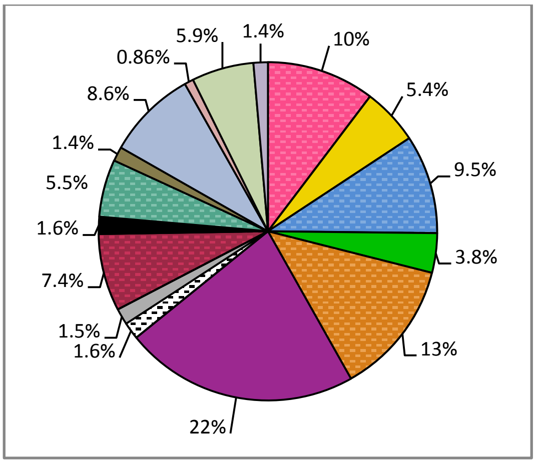


Figure 3.5 Per cent contribution from each catchment to the combined monitored annual total nitrogen load during the 2013–2014 monitoring year.

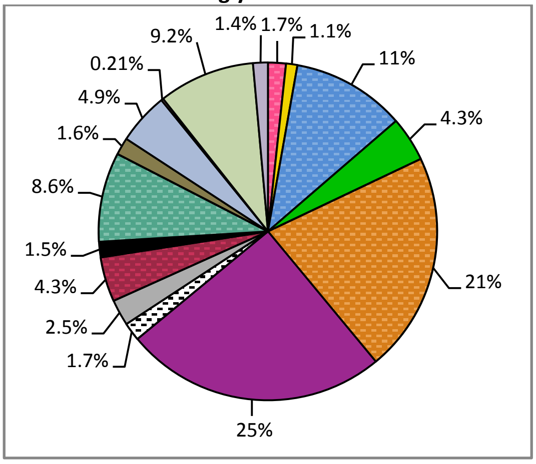


Figure 3.6 Per cent contribution from each catchment to the combined monitored annual dissolved inorganic nitrogen load during the 2013–2014 monitoring year.

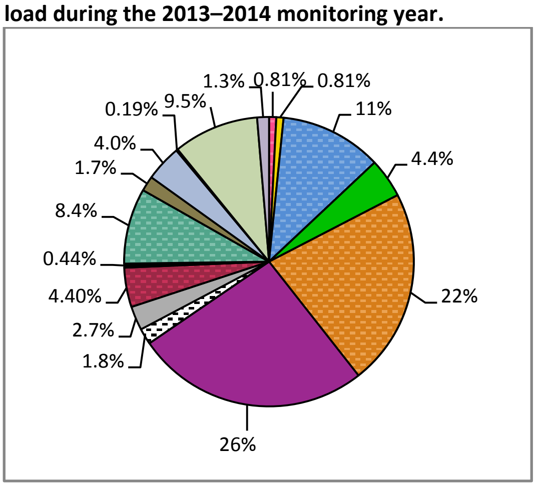


Figure 3.7 Per cent contribution from each catchment to the combined monitored annual oxidised nitrogen load during the 2013–2014 monitoring year.

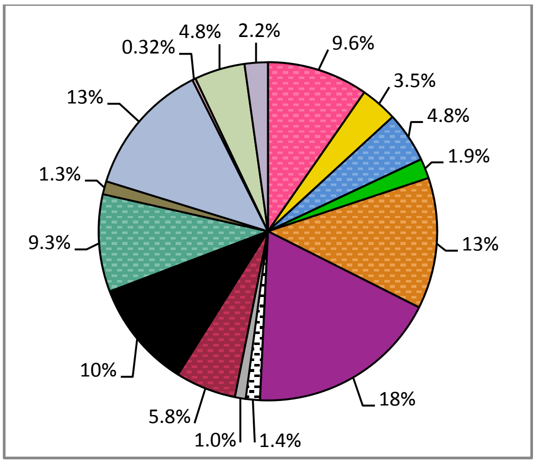


Figure 3.8 Per cent contribution from each catchment to the combined monitored annual ammonium nitrogen load during the 2013–2014 monitoring year.

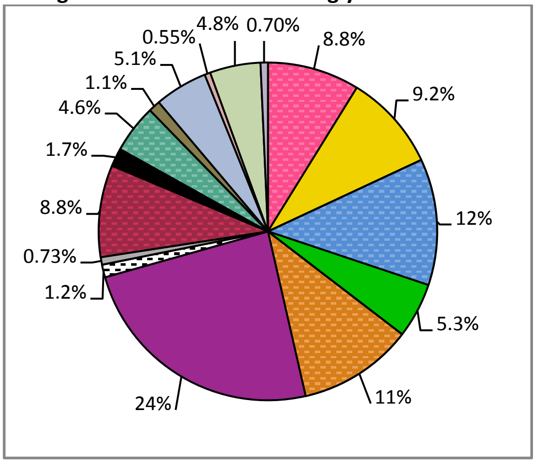


Figure 3.9 Per cent contribution from each catchment to the combined monitored annual particulate nitrogen load during the 2013–2014 monitoring year.

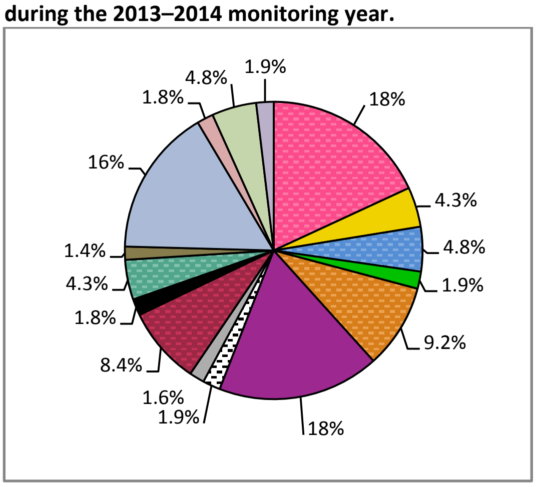


Figure 3.10 Per cent contribution from each catchment to the combined monitored annual dissolved organic nitrogen load during the 2013–2014 monitoring year.

3.3.3 Phosphorus

3.3.3.1 Phosphorus load

The combined monitored annual load of total phosphorus during the 2013–2014 monitoring year was 1.8 kt (Table 3.2) of which, 43 per cent was derived from the Johnstone (North and South Johnstone together) (0.39 kt; 22 per cent) and Herbert (0.37 kt; 21 per cent) catchments (Table 3.2 and Figure 3.11). The Normanby (0.17 kt; 9.6 per cent), Burdekin (0.16 kt; 9.1 per cent), Fitzroy (0.16 kt; 9.1 per cent) and Tully (150 kt; 8.5 per cent) catchments, although individually smaller contributors, contributed 36 per cent of the combined monitored end-of-system total phosphorus load. The lowest monitored total phosphorus load occurred in the Burnett River (6.4 t; 0.36 per cent), which can be attributed to an annual discharge of 15 per cent of the long term mean in 2013–2014 monitoring year (see section 3.1.2).

During the 2013–2014 monitoring year, the combined monitored annual load of dissolved inorganic phosphorus was 250 t (Table 3.2). The largest monitored annual loads of dissolved inorganic phosphorus were derived from the Fitzroy (65 t; 26 per cent) and Burdekin (35 t; 14 per cent) catchments, which combined accounted for 40 per cent of the total end-of-system load during the 2013–2014 monitoring year (Table 3.2 and Figure 3.12). Moderately sized loads were also monitored in the Johnstone (North and South Johnstone together) (26 t; 11 per cent), Herbert (25 t; 10 per cent) and Pioneer (25 t; 10 per cent) catchments (Table 3.2 and Figure 3.12). The remaining catchments each contributed 6 per cent or less of the combined monitored annual load (Figure 3.12) with the lowest load occurring in the Burnett catchment (0.34 t; 0.14 per cent).

During the 2013–2014 monitoring year, the combined monitored annual load of particulate phosphorus was 1.4 kt (Table 3.2), which accounted for 78 per cent of the total phosphorus monitored annual load (1.8 kt). Similar to total suspended solids, the largest monitored annual loads of particulate phosphorus were derived from the Johnstone (North and South Johnstone together) (0.35 kt; 25 per cent) and the Herbert catchments (0.33 kt; 24 per cent), which accounted for 49 per cent of the combined monitored end-of-system load during the 2013–2014 monitoring year (Table 3.2 and Figure 3.13). Moderately sized loads were also monitored in the Normanby (0.14 kt; 10 per cent), Burdekin (0.13 kt; 9.3 per cent), Tully (0.11 kt; 7.8 per cent) and Fitzroy (0.094 kt; 6.7 per cent) catchments (Table 3.2 and Figure 3.13). The lowest load during the 2013–2014 monitoring year occurred in the Burnett catchment (3.8 t; 0.27 per cent).

The combined monitored annual load of dissolved organic phosphorus during the 2013–2014 monitoring year was 220 t (Table 3.2). The largest monitored annual loads of dissolved organic phosphorus were derived from the Herbert (40 t; 18 per cent), Tully (38 t; 17 per cent), Johnstone (North and South Johnstone together) (31 t; 14 per cent) and the Normanby (29 t; 13 per cent) catchments, which together accounted for 62 per cent of the combined monitored end-of-system load during the 2013–2014 monitoring year (Table 3.2 and Figure 3.14). The remaining catchments each contributed less than 9 per cent of the combined monitored load (Figure 3.14) with the lowest load from end-of-system sites occurring in Barratta Creek in the Haughton catchment (1.8 t; 0.82 per cent).

3.3.3.2 Phosphorus yields

The largest monitored annual yield of total phosphorus during the 2013–2014 monitoring year was derived from the Johnstone catchment (280 kg km^{-2}) (Table 3.4). Moderate yields of total phosphorus were derived from the Tully, Herbert, Pioneer and O'Connell catchments and Sandy Creek in the Plane catchment (between 43 and 100 kg km^{-2}). The lowest monitored annual yields of total phosphorus were derived from the larger catchments in which a dominant land use is dry land grazing, including the Burnett (0.20 kg km^{-2}), Fitzroy (1.2 kg km^{-2}), and Burdekin (1.3 kg km^{-2}) catchments, which is consistent with previous years (Turner et al. 2012; Turner et al. 2013; Wallace et al. 2014; Wallace et al. 2015).

The monitored annual yield of dissolved inorganic phosphorus at Sandy Creek in the Plane catchment (35 kg km^{-2}) was markedly higher compared to all other monitored catchments during the 2013–2014 monitoring year. It was approximately twice the monitored yield in the Johnstone (North and South Johnstone) (20 kg km^{-2}) and Pioneer (17 kg km^{-2}) catchments. The lowest monitored annual yields of dissolved inorganic phosphorus were derived from the Burnett (0.010 kg km^{-2}), Burdekin (0.27 kg km^{-2}) and Fitzroy (0.47 kg km^{-2}) catchments (Table 3.4).

Similar to total phosphorus, the highest yield of particulate phosphorus during the 2013–2014 monitoring year occurred in the Johnstone catchment (North and South Johnstone) (260 kg km^{-2}). High yields of particulate phosphorus also occurred in the Tully catchment (79 kg km^{-2}) (Table 3.4). Moderate yields of particulate phosphorus were derived from the Herbert, O'Connell, Pioneer and Tully catchments and from Sandy Creek in the Plane catchment (between 39 and 80 kg km^{-2}). The lowest monitored annual yields of particulate phosphorus during the 2013–2014 monitoring year were derived from the Burnett (0.12 kg km^{-2}), Fitzroy (0.67 kg km^{-2}) and Burdekin (1.0 kg km^{-2}) catchments (Table 3.4).

The highest yields of dissolved organic phosphorus during the 2013–2014 monitoring year were derived from the Tully (26 kg km^{-2}) and Johnstone (North and South Johnstone) (22 kg km^{-2}) catchments. Consistent with all other monitored phosphorus fractions, the lowest yields of dissolved organic phosphorus were derived from the Burnett (0.07 kg km^{-2}), Burdekin (0.11 kg km^{-2}) and Fitzroy (0.13 kg km^{-2}) catchments (Table 3.4).

Normanby | Barron | North Johnstone | South Johnstone | Tully | Herbert
Haughton | Barratta | Burdekin | O'Connell | Pioneer | Plane
Fitzroy | Burnett | Mary | Tinana

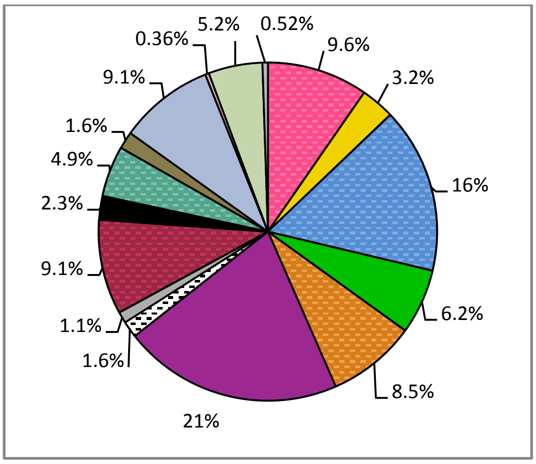


Figure 3.11 Per cent contribution from each catchment to the combined monitored annual total phosphorus load during the 2013–2014 monitoring year.

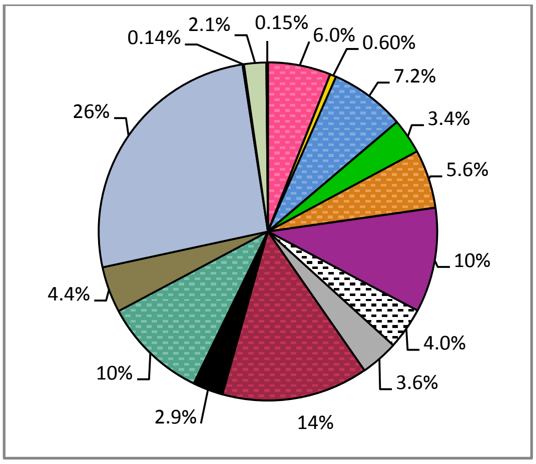


Figure 3.12 Per cent contribution from each catchment to the combined monitored annual dissolved inorganic phosphorus load during the 2013–2014 monitoring year.

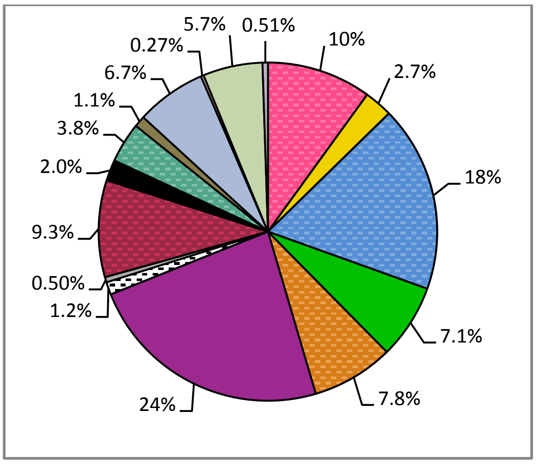


Figure 3.13 Per cent contribution from each catchment to the combined monitored annual particulate phosphorus load during the 2013–2014 monitoring year.

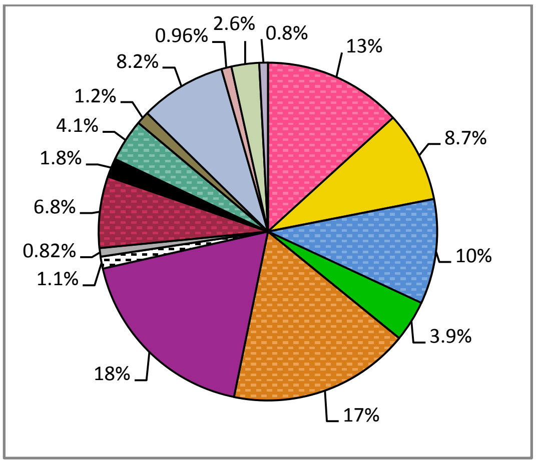


Figure 3.14 Per cent contribution from each catchment to the combined monitored annual dissolved organic phosphorus load during the 2013–2014 monitoring year.

Table 3.2 Monitored annual total suspended solids and nutrient loads for the 2013–2014 monitoring year. Text in bold are end-of-system sites and the corresponding data, all others are sub-catchment sites. Green shading = excellent or good representivity rating; orange shading = moderate representivity; red shading = indicative representivity and grey shading = no representivity calculated.

NRM region	Catchment	Gauging station	River and site name	TSS (t)	TN (t)	PN (t)	NO_x-N (t)	NH_4-N (t)	DIN (t)	DON (t)	TP (t)	DIP (t)	PP (t)	DOP (t)
Cape York	Normanby	**105107A[B]**	**Normanby River at Kalpowar Crossing**	**140,000**	**1,200**	**400**	**22**	**30**	**52**	**710**	**170**	**15**	**140**	**29**
Wet Tropics	Barron	**110001D[B]**	**Barron River at Myola**	**110,000**	**630**	**420**	**22**	**11**	**33**	**170**	**57**	**1.5**	**38**	**19**
	Johnstone	1120049[B]	North Johnstone River at Old Bruce Highway Bridge (Goondi)[$]	140,000	1,100	550	310	15	330	190	280	18	250	22
		112101B[B]	South Johnstone River at Upstream Central	57,000	440	240	120	5.9	130	73	110	8.4	100	8.6
	Tully	**113006A[L]**	**Tully River at Euramo**	**98,000**	**1,500**	**500**	**600**	**39**	**640**	**360**	**150**	**14**	**110**	**38**
		113015A[L]	Tully River at Tully Gorge National Park	27,000	390	180	70	7.5	78	86	45	1.0	35	11
	Herbert	**116001F[L]**	**Herbert River at Ingham**	**390,000**	**2,600**	**1,100**	**710**	**57**	**760**	**690**	**370**	**25**	**330**	**40**
Burdekin	Haughton	**119003A[B]**	**Haughton River at Powerline**	**32,000**	**190**	**55**	**49**	**4.2**	**53**	**75**	**28**	**10**	**17**	**2.5**
		119101A[L]	**Barratta Creek at Northcote**	**7,400**	**180**	**33**	**73**	**3.2**	**76**	**64**	**19**	**9.0**	**7.0**	**1.8**
	Burdekin	**120001A[B]**	**Burdekin River at Home Hill**	**220,000**	**860**	**400**	**120**	**18**	**130**	**330**	**160**	**35**	**130**	**15**
		120002C[B]	Burdekin River at Sellheim	2,100,000	2,600	1,100	190	18	200	440	990	42	450	18
		120205A[B]	Bowen River at Myuna	210,000	620	400	49	8.9	58	150	160	14	140	5.7
Mackay Whitsunday	O'Connell	**1240062[B]**	**O'Connell River at Caravan Park**	**8,500**	**190**	**79**	**12**	**32**	**45**	**70**	**40**	**7.2**	**28**	**3.9**
	Pioneer	**125013A[B]**	**Pioneer River at Dumbleton Pump Station**	**35,000**	**640**	**210**	**230**	**29**	**260**	**170**	**86**	**25**	**54**	**8.9**
	Plane	**126001A[B]**	**Sandy Creek at Homebush**	**15,000**	**160**	**51**	**46**	**3.9**	**50**	**56**	**29**	**11**	**15**	**2.7**
Fitzroy	Fitzroy	**1300000[B]**	**Fitzroy River at Rockhampton**	**52,000**	**1,000**	**230**	**110**	**40**	**150**	**630**	**160**	**65**	**94**	**18**
		130302A[L]	Dawson River at Taroom	26,000	86	39	11	1.0	12	24	32	10	21	0.5
Burnett Mary	Burnett	**136014A[L]**	**Burnett River at Ben Anderson Barrage**	**1,300**	**100**	**25**	**5.3**	**1.0**	**6.3**	**70**	**6.4**	**0.34**	**3.8**	**2.1**
	Mary	138014A[L]	Mary River at Home Park[$]	88,000	690	220	260	15	280	190	91	5.3	80	5.8
		138008A[L]	Tinana Creek at Barrage Head Water[$]*	3,800	160	32	36	6.9	43	74	9.2	0.38	7.2	1.8
Total load (end-of-system sites plus North Johnstone, South Johnstone, Mary River and Tinana Creek)				1,400,000	12,000	4,500	2,700	310	3,000	3,900	1,800	250	1,400	220

The number of concentration data points used in the calculation of loads for all analytes is presented in Appendix G. TSS = total suspended solids; TN = total nitrogen; PN = particulate nitrogen; NOx-N = oxidised nitrogen as N; NH4-N = ammonium nitrogen as N; DIN = dissolved inorganic nitrogen (DIN = (NOx-N) + (NH4-N)); DON = dissolved organic nitrogen; TP = total phosphorus; DIP = dissolved inorganic phosphorus; PP = particulate phosphorus; DOP = dissolved organic phosphorus; B = Beale ratio method used to calculate loads; L = average load (linear interpolation of concentration) method used to calculate loads; $ = the North and South Johnstone rivers combined act as an end-of-system site, and the Mary River and Tinana Creek combined act as an end-of-system site; *Loads for Tinana Creek at Barrage are indicative considering modelled daily flow was used for load calculations.

Table 3.3 Total suspended solids and nitrogen yields calculated for the 2013–2014 monitoring year along with the per cent of catchment monitored. Text in bold are end-of-system sites and the corresponding data, all others are sub-catchment sites. Green shading = excellent or good representivity rating; orange shading = moderate representivity; red shading = indicative representivity and grey shading = no representivity calculated.

NRM region	Catchment	Gauging station	River and site name	Monitored area of catchment (%)	TSS (t km^{-2})	TN (kg km^{-2})	PN (kg km^{-2})	NO_x-N (kg km^{-2})	NH_4-N (kg km^{-2})	DIN (kg km^{-2})	DON (kg km^{-2})
Cape York	Normanby	**105107A[B]**	**Normanby River at Kalpowar Crossing**	**53**	**11**	**90**	**31**	**1.7**	**2.3**	**4.0**	**55**
Wet Tropics	Barron	**110001D[B]**	**Barron River at Myola**	**89**	**56**	**320**	**220**	**11**	**5.6**	**17**	**87**
	Johnstone	1120049[B]	North Johnstone River at Old Bruce Highway Bridge (Goondi)[$]	40	150	1,100	580	330	16	340	200
		112101B[B]	South Johnstone River at Upstream Central Mill[$]	17	140	1,100	590	310	15	330	180
	Tully	**113006A[L]**	**Tully River at Euramo**	**86**	**67**	**1,100**	**350**	**410**	**27**	**440**	**250**
		113015A[L]	Tully River at Tully Gorge National Park	29	57	800	370	150	15	160	180
	Herbert	**116001F[L]**	**Herbert River at Ingham**	**87**	**45**	**300**	**130**	**82**	**6.7**	**89**	**80**
Burdekin	Haughton	**119003A[B]**	**Haughton River at Powerline**	**44**	**18**	**100**	**31**	**28**	**2.4**	**30**	**40**
		119101A[L]	**Barratta Creek at Northcote**	**19**	**10**	**240**	**43**	**97**	**4.2**	**100**	**90**
	Burdekin	**120001A[B]**	**Burdekin River at Home Hill**	**99**	**1.7**	**6.6**	**3.1**	**0.89**	**0.14**	**1.0**	**2.6**
		120002C[B]	Burdekin River at Sellheim	28	57	72	31	5.1	0.49	5.6	12
		120205A[B]	Bowen River at Myuna	5	29	87	56	6.9	1.3	8.2	21
Mackay Whitsunday	O'Connell	**1240062[B]**	**O'Connell River at Caravan Park**	**96**	**10**	**240**	**96**	**15**	**39**	**54**	**85**
	Pioneer	**125013A[B]**	**Pioneer River at Dumbleton Pump Station**	**94**	**24**	**430**	**140**	**150**	**20**	**170**	**120**
	Plane	**126001A[B]**	**Sandy Creek at Homebush**	**13**	**46**	**480**	**160**	**140**	**12**	**150**	**170**
Fitzroy	Fitzroy	**1300000[B]**	**Fitzroy River at Rockhampton**	**98**	**0.37**	**7.2**	**1.6**	**0.78**	**0.29**	**1.1**	**4.5**
		130302A[L]	Dawson River at Taroom	11	1.7	5.4	2.5	0.70	0.06	0.76	1.5
Burnett Mary	Burnett	**136014A[L]**	**Burnett River at Ben Anderson Barrage HW Water**	**99**	**0.040**	**3.1**	**0.76**	**0.16**	**0.030**	**0.19**	**2.1**
	Mary	138014A[L]	Mary River at Home Park[$]	72	13	100	33	38	2	40	27
		138008A[L]	Tinana Creek at Barrage HW[$]	14	3.0	130	25	28	5.4	34	58

The number of concentration data points used in the calculation of loads for all analytes is presented in Appendix G. TSS = total suspended solids; TN = total nitrogen; PN = particulate nitrogen; NOx-N = oxidised nitrogen as N; NH4-N = ammonium nitrogen as N; DIN = dissolved inorganic nitrogen (DIN = (NOx-N) + (NH4-N)); DON = dissolved organic nitrogen;B = Beale ratio method used to calculate loads; L = average load (linear interpolation of concentration) method used to calculate loads; and $ = the North and South Johnstone rivers combined act as an end-of-system site, and the Mary River and Tinana Creek combined act as an end-of-system site; *Yields for Tinana Creek at Barrage are indicative considering modelled daily flow was used for load calculations.

Table 3.4 Phosphorus yields calculated for the 2013–2014 monitoring year along with the per cent of catchment monitored. Text in bold are end-of-system sites and the corresponding data, all others are sub-catchment sites. Green shading = excellent or good representivity rating; orange shading = moderate representivity; red shading = indicative representivity and grey shading = no representivity calculated.

NRM region	Catchment	Gauging station	River and site name	Monitored area of catchment (%)	TP ($kg\ km^{-2}$)	DIP ($kg\ km^{-2}$)	PP ($kg\ km^{-2}$)	DOP ($kg\ km^{-2}$)
Cape York	Normanby	**105107A[B]**	**Normanby River at Kalpowar Crossing**	**53**	**13**	**1.2**	**11**	**2.2**
Wet Tropics	Barron	**110001D[B]**	**Barron River at Myola**	**89**	**29**	**0.79**	**20**	**10**
	Johnstone	1120049[B]	North Johnstone River at Old Bruce Highway Bridge (Goondi)[$]	40	290	18	260	23
		112101B[B]	South Johnstone River at Upstream Central Mill[$]	17	280	21	250	21
	Tully	**113006A[L]**	**Tully River at Euramo**	**86**	**100**	**10**	**79**	**26**
		113015A[L]	Tully River at Tully Gorge National Park	29	94	2.1	73	24
	Herbert	**116001F[L]**	**Herbert River at Ingham**	**87**	**43**	**2.9**	**39**	**4.6**
Burdekin	Haughton	**119003A[B]**	**Haughton River at Powerline**	**44**	**16**	**5.6**	**9.4**	**1.4**
		119101A[L]	**Barratta Creek at Northcote**	**19**	**25**	**12**	**9.3**	**2.3**
	Burdekin	**120001A[B]**	**Burdekin River at Home Hill**	**99**	**1.3**	**0.27**	**1.0**	**0.11**
		120002C[B]	Burdekin River at Sellheim	28	27	1.2	12	0.49
		120205A[B]	Bowen River at Myuna	5	23	2.0	19	0.81
Mackay Whitsunday	O'Connell	**1240062[B]**	**O'Connell River at Caravan Park**	**96**	**48**	**8.8**	**34**	**4.7**
	Pioneer	**125013A[B]**	**Pioneer River at Dumbleton Pump Station**	**94**	**58**	**17**	**36**	**6.0**
	Plane	**126001A[B]**	**Sandy Creek at Homebush**	**13**	**88**	**35**	**45**	**8.2**
Fitzroy	Fitzroy	**1300000[B]**	**Fitzroy River at Rockhampton**	**98**	**1.2**	**0.47**	**0.67**	**0.13**
		130302A[L]	Dawson River at Taroom	11	2.0	0.61	1.3	0.032
Burnett Mary	Burnett	**136014A[L]**	**Burnett River at Ben Anderson Barrage HW**	**99**	**0.20**	**0.010**	**0.12**	**0.07**
	Mary	138014A[L]	Mary River at Home Park[$]	72	13	0.77	12	0.85
		138008A	Tinana Creek at Barrage HW[$]	14	7.2	0.29	5.6	1.4

The number of concentration data points used in the calculation of loads for all analytes is presented in Appendix G. TSS = total suspended solids; TN = total nitrogen; PN = particulate nitrogen; NOx-N = oxidised nitrogen as N; NH4-N = ammonium nitrogen as N; DIN = dissolved inorganic nitrogen (DIN = (NOx-N) + (NH4-N)); DON = dissolved organic nitrogen; B = Beale ratio method used to calculate loads; L = average load (linear interpolation of concentration) method used to calculate loads; and $ = the North and South Johnstone rivers combined act as an end-of-system site, and the Mary River and Tinana Creek combined act as an end-of-system site; *Yields for Tinana Creek at Barrage are indicative considering modelled daily flow was used for load calculations.

3.4 Pesticide loads, toxicity-based loads (toxic loads) and yields

In this section, the monitored mass loads and yields of five photosystem II inhibiting herbicides are presented. In addition, their toxicity-based load (toxic load) (refer to Section 2.7.2.2) at the 15 monitoring sites (Table 3.5) are presented for the first time. The toxic load is the sum of the monitored annual loads of the five photosystem II inhibiting herbicides following conversion to diuron equivalent loads using diuron equivalency factors (Table 2.6)

3.4.1.1 Pesticide loads

The monitored annual loads of photosystem II inhibiting herbicides ametryn, total atrazine, total diuron, hexazinone and tebuthiuron were calculated for ten monitored end-of-system sites and five sub-catchment monitoring sites. Only event loads are reported for the Mulgrave and Russell rivers (Appendix D) due to insufficient monitoring during a large flow event at the start of the wet season (see Section 3). The loads of the other pesticides detected are presented in Appendix A. In presenting monitored annual loads for the Mary River and Tinana Creek sub-catchments it is highlighted that monitoring at these sites commenced midway through the monitoring year. The contribution of the unmonitored portion of the year has been estimated using tie down concentrations derived from the monitored water quality data at each site, respectively. Whilst the unmonitored portion of the total annual discharge at the Mary River and Tinana Creek sites was only 19 per cent and 3.9 per cent, respectively, the concentration of photosystem II inhibiting herbicides during the unmonitored period is not known.

This is the first year that photosystem II inhibiting herbicide loads are reported for the Mulgrave-Russell, Haughton and O'Connell catchments, and Mary and Tinana sub-catchments. The inclusion of these sites has increased both the number of monitored catchments from 10 to 14 and the catchment area monitored for photosystem II inhibiting herbicides to 326,236 km^2 (an increase of 3.5 per cent) compared to that monitored under Reef Plan 2009 (see Turner et al. 2012; Turner et al. 2013; Wallace et al. 2013 and Wallace et al. 2015). This should be considered when comparing the results from this year to previous years.

The total monitored annual load of the five photosystem II inhibiting herbicides exported past the monitoring sites were (from largest to smallest): 930 kg of total atrazine; 890 kg of total diuron; 230 kg of hexazinone; 160 kg of tebuthiuron; and 11 kg of ametryn (Table 3.5). The per cent contribution of each monitored catchment to the total monitored annual loads of the five photosystem II inhibiting herbicides is presented in Figure 3.15 to Figure 3.19.

During the 2013–2014 monitoring year total diuron was the only photosystem II inhibiting herbicide detected[5] at all monitored sites (Table 3.5). Total atrazine was detected at all sites except in the Mary River at Home Park. Hexazinone was detected in all catchments except the Haughton, Fitzroy, and Burnett catchments (Table 3.5). Ametryn was only detected at five sites in the Haughton, O'Connell, Pioneer and Plane catchments, and tebuthiuron was only detected at five sites in the Haughton, Burdekin, O'Connell and Fitzroy catchments (Table 3.5).

[5] Detected means that the chemical referred to was measured at a concentration greater than the limit of reporting.

The largest monitored annual loads of ametryn were in the Pioneer catchment (5.7 kg; 53 per cent) and Sandy Creek in the Plane catchment (3.9 kg; 36 per cent) which together accounted for approximately 90 per cent of the total monitored annual ametryn load (11 kg) (Table 3.5, Figure 3.15). Small loads of ametryn were also monitored in Barratta Creek in the Haughton catchment (0.92 kg; 8.6 per cent) and in the Haughton (0.2 kg; 1.9 per cent) and O'Connell catchments (0.033 kg; 0.31 per cent) (Table 3.5, Figure 3.15).

The Tully and Pioneer rivers contributed more than half of the total monitored total atrazine load (930 kg) with 250 kg (27 per cent) and 230 kg (25 per cent), respectively (Table 3.5, Figure 3.16). A moderate load of total atrazine was also monitored in Barratta Creek in the Haughton catchment (160 kg; 17 per cent), with smaller contributions from Sandy Creek in the Plane catchment (79 kg; 8.5 per cent) and the Herbert (73 kg; 7.9 per cent) and Burdekin (62 kg; 6.7 per cent) catchments (Table 3.5, Figure 3.16). The remaining catchments each contributed less than 5 per cent to the total monitored annual load of total atrazine with the lowest reported load coming from Tinana Creek in the Mary catchment (1.8 kg; 0.19 per cent).

The Pioneer and Tully rivers combined contributed more than half of the total monitored annual total diuron load (890 kg) with 260 kg and 240 kg, respectively (Table 3.5). Moderate contributions to the monitored annual load of total diuron were also derived from Sandy Creek in the Plane catchment (120 kg; 14 per cent), the Herbert catchment (110 kg; 12 per cent) and Barratta Creek in the Haughton catchment (72 kg; 8.1 per cent) (Table 3.5, Figure 3.17). All other catchments contributed less than four per cent of the monitored annual total diuron load with the lowest reportable load monitored in the Burnett River (0.14 kg; 0.016 per cent) (Table 3.5, Figure 3.17).

Hexazinone was detected at nine of the 13 monitored sites with the largest loads of hexazinone derived from the Tully (88 kg; 38 per cent), Pioneer (43 kg; 19 per cent) and Herbert (40 kg; 17 per cent) catchments and Sandy Creek in the Plane catchment (36 kg; 16 per cent) (Table 3.5, Figure 3.18). The monitored load of hexazinone in all other catchments was comparatively low with the smallest detected load occurring in the Burdekin catchment (0.45 kg; 0.19 per cent) (Table 3.5, Figure 3.18).

The largest monitored annual load of tebuthiuron was derived from the Fitzroy catchment (140 kg) which accounted for 88 per cent of the total monitored tebuthiuron load (Table 3.5, Figure 3.19). The load of tebuthiuron at the other four sites, where tebuthiuron was detected, ranged from 0.24 kg in the Haughton River (0.15 per cent) to 11 kg in the O'Connell River (6.9 per cent) to (Table 3.5, Figure 3.19).

3.4.1.2 Toxic load

During the 2013–2014 monitoring year, the combined toxic load of all monitored sites, excluding the Mulgrave and Russell Rivers, was 980 kg TEq_{diuron} (Table 3.5). The pesticide that contributed most to the total annual toxic load was total diuron, accounting for 890 of the 980 kg TEq_{diuron}. Reflecting the importance of diuron to the toxic loads it was the waterways with the highest annual loads of total diuron that were the main contributors to the total annual toxic load (i.e. Pioneer River (280 kg TEq_{diuron}; 29 per cent); Tully River (270 kg TEq_{diuron}; 27 per cent); Sandy Creek in the Plane catchment (130 kg TEq_{diuron}; 14 per cent); Herbert River (120 kg TEq_{diuron}; 12 per cent) and Barratta Creek in the Haughton catchment (79 kg TEq_{diuron}; 8.0 per cent)) (Table 3.5). The calculated annual toxic load at all remaining sites was less than five per cent of the total calculated annual toxic load with the lowest toxic load occurring in the Burnett River catchment (0.29 kg TEq_{diuron}; 0.030 per cent) (Table 3.5).

3.4.1.3 Pesticide land use yields

Pesticide land use yields of five photosystem II inhibiting herbicides have been calculated for 13 sites monitored during 2013–2014. Land use yields are not reported for the Mulgrave and Russell rivers as only event loads were calculated during the current reporting period. The land use yields for each monitored catchment are presented in Table 3.6. Based on the catchments where land use yields could be calculated, total atrazine and total diuron had the highest yields with means of 0.37 and 0.39 kg km^{-2}. The other three photosystem II inhibiting herbicides had markedly lower average yields of between 0.06 to 0.05 kg km^{-2}.

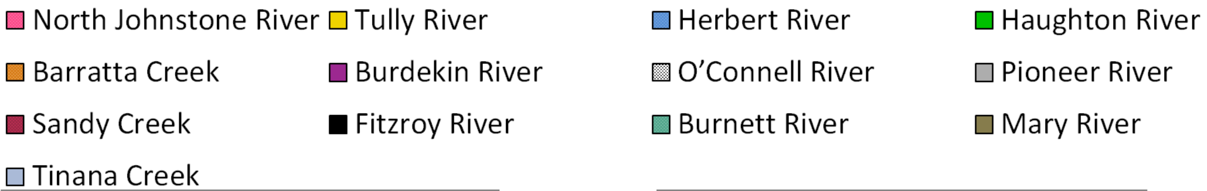
The highest land use yields of ametryn occurred in Sandy Creek in the Plane catchment (0.025 kg km^{-2}) and Pioneer catchment (0.018 kg km^{-2}) (Table 3.6). The land use yields in these catchments were approximately twice the ametryn land use yield calculated for the Haughton catchment (0.0098 kg km^{-2}) and approximately three times greater than Barratta Creek in the Haughton catchment (0.0069 kg km^{-2}) (Table 3.6). The lowest calculable land use yield occurred in the O'Connell catchment (0.00067 kg km^{-2}).

Although total atrazine was detected in all catchments other than the Mary, the land use yields varied substantially across the monitored area with similar high land use yields in the Tully catchment (1.3 kg km^{2}) and North Johnstone sub-catchment (1.0 kg km^{-2}), and Barratta Creek in the Haughton catchment (1.0 kg km^{-2}) (Table 3.6). Comparatively moderate land use yields of total atrazine also occurred in Sandy Creek in the Plane catchment (0.42 kg km^{-2}) and Pioneer catchment (0.34 kg km^{-2}) during 2013–2014. The land use yield in all other catchments where total atrazine was detected were low, with the lowest monitored land use yield of total atrazine occurring in the Burnett catchment (0.00081 kg km^{-2}) (Table 3.6).

The highest monitored land use yields of total diuron occurred in the Tully catchment (1.1 kg km^{-2}) and North Johnstone sub-catchment (0.79 kg km^{-2}) with moderate yields also calculated for the Pioneer catchment (0.84 kg km^{-2}) and Sandy Creek in the Plane catchment (0.77 kg km^{-2}) (Table 3.6). The lowest calculable land use yields of total diuron were in the Burdekin (0.0070 kg km^{-2}), Fitzroy (0.0015 kg km^{-2}) and Burnett (0.00010 kg km^{-2}) catchments.

The land use yield of hexazinone in the Tully catchment (0.33 kg km^{-2}) was approximately three times greater than the land use yield in Sandy Creek in the Plane catchment (0.12 kg km^{-2}) that had the second highest land use yield of hexazinone in the 2013–2014 monitoring year. The land use yield of hexazinone in all other catchments was comparatively low with the lowest calculable land use yield occurring in the Burdekin catchment (0.0000037 kg km^{-2}) (Table 3.6).

The highest calculable land use yields of tebuthiuron during the 2013–2014 monitoring year were in the O'Connell (0.022 kg km^{-2}) and Fitzroy (0.0013 kg km^{-2}) catchments. The land use yield in the Burdekin catchment (0.000069 kg km^{-2}) was the lowest calculable land use yield during the 2013–2014 monitoring year (Table 3.6).



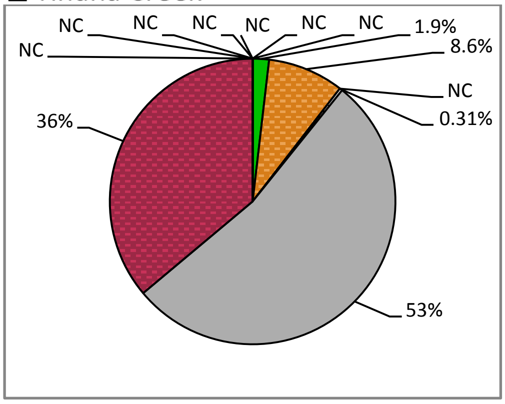


Figure 3.15 Per cent contribution from all sites monitored for pesticides to the combined monitored annual ametryn load during the 2013–2014 monitoring year (NC = load not calculable).

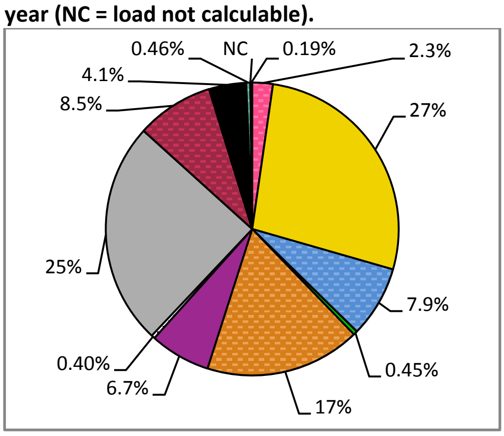


Figure 3.16 Per cent contribution from all sites monitored for pesticides to the combined monitored annual total atrazine load during the 2013–2014 monitoring year (NC = load not calculable).

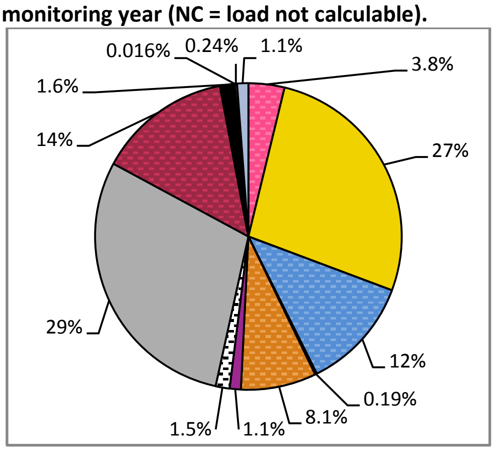


Figure 3.17 Per cent contribution from all sites monitored for pesticides to the combined monitored annual total diuron load during the 2013–2014 monitoring year.

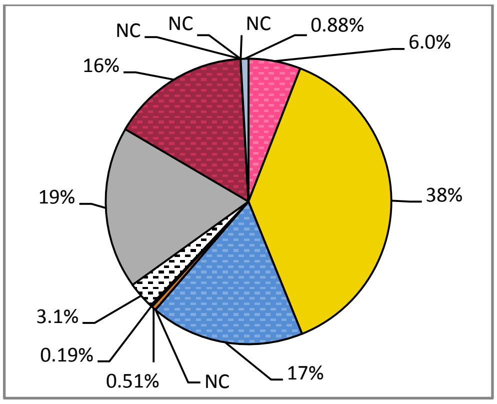


Figure 3.18 Per cent contribution from all sites monitored for pesticides to the combined monitored annual hexazinone load during the 2013–2014 monitoring year (NC = load not calculable).

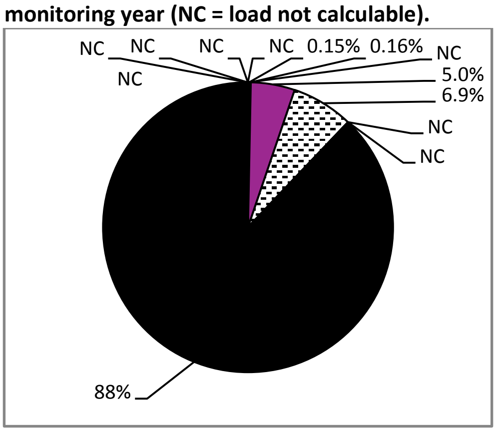


Figure 3.19 Per cent contribution from all sites monitored for pesticides to the combined monitored annual tebuthiuron load during the 2013–2014 monitoring year (NC = load not calculable).

Table 3.5 Monitored annual loads and total toxic loads for the 2013-20114 monitoring year calculated for five photosystem II inhibiting herbicides: ametryn, total atrazine, total diuron, hexazinone and tebuthiuron. Text in bold are end-of-system sites and the corresponding data, all other are sub-catchment sites.

NRM region	Catchment	Gauging station	River and site name	Monitored area (km^{-2})	Monitored area of catchment (%)	n	Ametryn mass load (kg)	Total Atrazine mass load (kg)	Total Diuron mass load (kg)	Hexazinone mass load (kg)	Tebuthiuron mass load (kg)	Total Toxic Load (diuron-equivalent kg)
Wet Tropics	Johnstone	1120049[B]	North Johnstone River at Old Bruce Highway Bridge (Goondi)[$]	959	41	41	NC	21	34	14	NC	38
	Tully	**113006A[L]**	**Tully River at Euramo**	**1450**	**86**	**93**	**NC**	**250**	**240**	**88**	**NC**	**270**
	Herbert	**116001F[L]**	**Herbert River at Ingham**	**8581**	**87**	**83**	**NC**	**73**	**110**	**40**	**NC**	**120**
Burdekin	Haughton	**119003A[B]**	**Haughton River at Powerline**	**1773**	**44**	**20**	**0.20**	**4.2**	**1.7**	**NC**	**0.24**	**2.0**
		119101A[L]	**Barratta Creek at Northcote**	**753**	**19**	**44**	**0.92**	**160**	**72**	**1.2**	**0.26**	**79**
	Burdekin	**120001A[B]**	**Burdekin River at Home Hill**	**129,939**	**99**	**22**	**NC**	**62**	**10**	**0.45**	**8**	**12**
Mackay Whitsunday	O'Connell	**1240062[B]**	**O'Connell River at Caravan Park**	**825**	**96**	**40**	**0.033**	**3.7**	**13**	**7.1**	**11**	**15**
	Pioneer	**125013A[L]**	**Pioneer River at Dumbleton Pump Station**	**1485**	**94**	**59**	**5.7**	**230**	**260**	**43**	**NC**	**280**
	Plane	**126001A[B]**	**Sandy Creek at Homebush**	**326**	**13**	**48**	**3.9**	**79**	**120**	**36**	**NC**	**130**
Fitzroy	Fitzroy	**1300000[B]**	**Fitzroy River at Rockhampton**	**139,159**	**98**	**24**	**NC**	**38**	**14**	**NC**	**140**	**18**
Burnett Mary	Burnett	**136014A[L]**	**Burnett River at Ben Anderson Barrage Head Water**	**32,891**	**99**	**27**	**NC**	**4.3**	**0.14**	**NC**	**NC**	**0.29**
	Mary	138014A[L]	Mary River at Home Park[$]	6845	72	63	NC	NC	2.1	NC	NC	2.1
		138008A[L]	Tinana Creek at Barrage Head Water[$*]	1284	14	23	NC	1.8	10	2.0	NC	10
Total monitored annual load (excluding Mulgrave and Russell rivers)				326,236		587	11	930	890	230	160	980

n = the number of grab samples used to calculate loads; NC = a load was not calculated as all the concentrations for all samples collected were below the practical quantitation limit or there were insufficient samples collected over the year to calculate a load; B = Beale ratio method used to calculate loads; L = average load (linear interpolation of concentration) method used to calculate loads; $ = the Mary River and Tinana Creek combined act as an end-of-system site; *Loads for Tinana Creek at Barrage are indicative considering modelled daily flow was used for load calculations

Table 3.6 The monitored annual yields calculated for five photosystem II inhibiting herbicides: ametryn, total atrazine, total diuron, hexazinone and tebuthiuron for the 2013–2014 monitoring year.

PSII herbicide	Registered land use types	River and site name	Land use yield (kg km^{-2})
Ametryn	Sugarcane	North Johnstone River at Old Bruce Highway Bridge[B]	NC
		Tully River at Euramo[L]	NC
		Herbert River at Ingham[L]	NC
		Haughton River at Powerline[B]	0.0098
		Barratta Creek at Northcote[L]	0.0069
		Burdekin River at Home Hill[B]	NC
		O'Connell River at Caravan Park[B]	0.00067
		Pioneer River at Dumbleton Pump Station[L]	0.018
		Sandy Creek at Homebush[B]	0.025
		Fitzroy River at Rockhampton[B]	NC
		Burnett River at Ben Anderson Barrage Head Water[L]	NC
		Mary River at Home Park[L]	NC
		Tinana Creek at Tinana Barrage Head Water[L]	NC
Total atrazine	Cropping, forestry, and sugarcane	North Johnstone River at Old Bruce Highway Bridge[B]	1.0
		Tully River at Euramo[L]	1.3
		Herbert River at Ingham[L]	0.11
		Haughton River at Powerline[B]	0.072
		Barratta Creek at Northcote[L]	1.0
		Burdekin River at Home Hill[B]	0.027
		O'Connell River at Caravan Park[B]	0.019
		Pioneer River at Dumbleton Pump Station[L]	0.34
		Sandy Creek at Homebush[B]	0.42
		Fitzroy River at Rockhampton[B]	0.0021
		Burnett River at Ben Anderson Barrage Head Water[L]	0.00081
		Mary River at Home Park[L]	NC
		Tinana Creek at Tinana Barrage Head Water[L]	0.0022
Total diuron	Cropping, horticulture and sugarcane	North Johnstone River at Old Bruce Highway Bridge[B]	0.78
		Tully River at Euramo[L]	1.1
		Herbert River at Ingham[L]	0.40
		Haughton River at Powerline[B]	0.053
		Barratta Creek at Northcote[L]	0.46
		Burdekin River at Home HillB	0.0070
		O'Connell River at Caravan Park[B]	0.26
		Pioneer River at Dumbleton Pump Station[L]	0.84
		Sandy Creek at Homebush[B]	0.77
		Fitzroy River at Rockhampton[B]	0.0015
		Burnett River at Ben Anderson Barrage Head Water[L]	0.00010
		Mary River at Home Park[L]	0.024
		Tinana Creek at Tinana Barrage Head Water[L]	0.11
Hexazinone	Forestry, grazing and sugarcane	North Johnstone River at Old Bruce Highway Bridge[B]	0.035
		Tully River at Euramo[L]	0.33
		Herbert River at Ingham[L]	0.0067
		Haughton River at Powerline[B]	NC
		Barratta Creek at Northcote[L]	0.0016
		Burdekin River at Home Hill[B]	0.0000037
		O'Connell River at Caravan Park[B]	0.010
		Pioneer River at Dumbleton Pump Station[L]	0.036
		Sandy Creek at Homebush[B]	0.12
		Fitzroy River at Rockhampton[B]	NC
		Burnett River at Ben Anderson Barrage Head Water[L]	NC
		Mary River at Home Park[L]	NC
		Tinana Creek at Tinana Barrage Head Water[L]	0.0020
Tebuthiuron	Grazing	North Johnstone River at Old Bruce Highway Bridge[B]	NC
		Tully River at Euramo[L]	NC
		Herbert River at Ingham[L]	NC
		Haughton River at Powerline[B]	0.00016
		Barratta Creek at Northcote[L]	0.00044
		Burdekin River at Home Hill[B]	0.000069
		O'Connell River at Caravan Park[B]	0.022
		Pioneer River at Dumbleton Pump Station[L]	NC
		Sandy Creek at Homebush[B]	NC
		Fitzroy River at Rockhampton[B]	0.0013
		Burnett River at Ben Anderson Barrage Head Water[L]	NC
		Mary River at Home Park[L]	NC
		Tinana Creek at Tinana Barrage Head Water[L]	NC

NC = not calculable.

4 Conclusions

The Great Barrier Reef Catchment Loads Monitoring Program calculated the monitored annual loads and yields of total suspended solids and ten forms of nitrogen and phosphorus for 12 end-of-system sites and 13 sub-catchment sites covering 14 priority catchments during the 2013–2014 monitoring year. The monitored annual loads and yields of five photosystem II inhibiting herbicides were also calculated for 10 end-of-system sites and five sub-catchment monitoring sites covering 12 priority catchments. During the 2013–2014 monitoring year:

- Priority reef catchments received average to above average rainfall in the Cape York and in the Wet Tropics regions, average to very much below average rainfall in the Burdekin region, average rainfall in the Mackay Whitsunday region, below average to very much below average in much of the Fitzroy region, and very much below average across most of the Burnett Mary region
- Severe Tropical Cyclone Ita made landfall on 11 of April 2014 as a category 4 system near Cooktown in the Cape York region. Widespread 24-hour rainfalls of over 300 mm were recorded in the Cape York and Wet Tropics region and lower Burdekin region resulting moderate to major flooding in some monitored priority reef catchments in these regions
- River discharge was below the long term mean in the majority of monitored rivers and considerably below the long term mean discharge in the Burdekin, O'Connell, Fitzroy, Burnett and Mary rivers and Sandy Creek in the Plane catchment, and below the long term mean in the Normanby, Barron Haughton and Pioneer rivers and Barratta Creek in the Haughton catchment and Tinana creek in the Mary catchment. River discharge in the Mulgrave, Russell, North Johnstone, South Johnstone, Tully and Herbert rivers was above the long term mean
- Good to excellent sampling representivity was achieved at most end-of-system monitoring sites for all monitored analytes. The exceptions were the Haughton River at Powerline which had moderate representivity for all analytes and the O'Connell River at Caravan Park which had moderate representivity for total suspended solids
- This is the first year in which loads are reported for the Mulgrave, Russell and O'Connell tidally influenced sites, for the Haughton River end-of-system site and for two sites in the Mary catchment, Mary River at Home Park and Tinana Creek at Barrage Head Water – this was achieved through collaborations with regional natural resource management organisations
- The monitored catchments generated approximately 1.4 million tonnes of total suspended solids, 12,000 tonnes of nitrogen and 1800 tonnes of phosphorus
- Three catchments generated approximately 50 per cent of the combined load of total suspended solids and nutrients. The Herbert catchment generated the largest total suspended solids and nutrient loads, with the exception of dissolved organic nitrogen and dissolved inorganic phosphorus in which the Normanby and Fitzroy catchments generated the largest loads respectively, and the Johnstone (North and South Johnstone together) catchment which generated the largest loads of total phosphorus and particulate phosphorus
- The monitored annual loads of total suspended solids and nutrients for the Burdekin and Fitzroy catchments were the lowest since monitoring began in 2006–2007. Normally, these two catchments

are the largest contributors. The small loads of these catchments are explained by their very low end-of-system discharge, which was the lowest recorded between the 2006–2014 monitoring years.

- The Johnstone (North and South Johnstone together), Tully, Burdekin and Fitzroy catchments accounted for a large proportion of combined monitored annual loads of total suspended solids and nutrient fractions. The Johnstone (North and South Johnstone together) catchment made substantial contributions of particulate nitrogen and particulate phosphorus. The Tully catchment made substantial contributions of most nitrogen fractions, the Burdekin catchment of dissolved inorganic phosphorus and the Fitzroy catchment of ammonium nitrogen and dissolved organic nitrogen
- The Burnett catchment generally produced the lowest loads of total suspended solids and all nutrients analytes, except dissolved organic phosphorus loads, which were lowest in Barratta Creek in the Haughton catchment. Notably, the annual discharge in the Burnett River during the 2013–2014 monitoring year was only 10 per cent of the long term mean with an exceedance probability of 79 per cent
- The highest yields of total suspended solids and all forms of nitrogen and phosphorus occurred in the Johnstone (North and South Johnstone together) catchment, followed by the Tully catchment. The Pioneer catchment produced high yields of ammonium nitrogen and Sandy Creek in the Plane catchment high yields of dissolved inorganic phosphorus
- The lowest monitored yields of total suspended solids and nutrients generally occurred in the larger catchments of the Burnett, Burdekin and Fitzroy rivers, where a dominant land use is dry land grazing and the discharge in each of these rivers was very much below the long term mean during the 2013–2014 monitoring year
- The total monitored annual photosystem II inhibiting herbicide loads (excluding Russell and Mulgrave rivers) were, in descending order: 930 kg of total atrazine; 890 kg of total diuron; 230 kg of hexazinone; 160 kg of tebuthiuron; and 11 kg of ametryn
- Total diuron was the only photosystem II inhibiting herbicide detected at all monitored sites; total atrazine was detected at all sites except in the Mary River; hexazinone was detected at all sites except in the Haughton, Fitzroy, Burnett and Mary rivers; ametryn was only detected in the Haughton, O'Connell and Pioneer rivers and Sandy Creek in the Plane catchment; and tebuthiuron was detected in the Haughton, Burdekin, O'Connell and Fitzroy rivers
- The largest monitored annual loads of ametryn were in the Pioneer catchment and Sandy Creek in the Plane catchment. The Pioneer and Tully catchments produced the largest monitored annual loads of total diuron, total atrazine and hexazinone. The largest monitored annual load of tebuthiuron was in the Fitzroy catchment
- The combined calculated toxic load of all monitored sites was 980 kg TEQ_{diuron}. The main contributors of the annual toxic loads were the Pioneer and Tully catchments. Total diuron was the photosystem II inhibiting herbicide that contributed the most to the annual toxic load being responsible for 890 kg of the 980 kg of total diuron equivalents
- The largest monitored annual land use yield of ametryn was in Sandy Creek in the Plane catchment; total diuron, total atrazine and hexazinone in the Tully catchment, and tebuthiuron in the O'Connell catchment.

Monitored data in 2013–2014 and data from previous monitored years (2006–2013) indicate the importance of discharge in explaining the variability of loads between catchments and years. Increasing the understanding of how discharge in combination with other catchment variables (e.g. land use, vegetation cover) explains catchment exported loads would allow for the detection of potential trends in time towards reduction targets.

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6 References

APHA-AWWA-WEF (American Public Health Association, American Water Works Association and Water Environment Federation) (2005). Standard methods for the examination of water and wastewater, 21st edition. Clesceri L.S., Greenberg A.E., Trussell R.R. (eds). American Public Health Association, American Water Works Association and Water Environment Federation, Washington, USA.

Bainbridge, Z.T., Lewis, S.E., Smithers, S.G., Kuhnert, P.M., Henderson, B.L. and Brodie, J.E. (2014). Fine-suspended sediment and water budgets for a large, seasonally dry tropical catchment: Burdekin River catchment, Queensland, Australia. *Water Resources Research*, DOI: 10.1002/2013WR014386.

BoM (Bureau of Meteorology) (2013a). Monthly Weather Review – Queensland, August 2013. Available from: <http://www.bom.gov.au>. Downloaded: 6 May 2015.

BoM (Bureau of Meteorology) (2013b). Monthly Weather Review – Queensland, September 2013. Available from: <http://www.bom.gov.au>. Downloaded: 6 May 2015.

BoM (Bureau of Meteorology) (2013c). Monthly Weather Review – Queensland, October 2013. Available from: <http://www.bom.gov.au>. Downloaded: 6 May 2015.

BoM (Bureau of Meteorology) (2013d). Monthly Weather Review – Queensland, November 2013. Available from: <http://www.bom.gov.au>. Downloaded: 6 May 2015.

BoM (Bureau of Meteorology) (2013e). Monthly Weather Review – Queensland, December 2013. Available from: <http://www.bom.gov.au>. Downloaded: 7 May 2015.

BoM (Bureau of Meteorology) (2014a). Archive – Twelve month rainfall totals for Queensland. Available from: <http://www.bom.gov.au>. Downloaded: 10 July 2014.

BoM (Bureau of Meteorology) (2014b). ENSO Wrap-Up Archive, 02 July 2013 to 01 July 2014. Available from: <http://www.bom.gov.au>. Downloaded: 22 May 2015.

BoM (Bureau of Meteorology) (2014c). Monthly Weather Review – Queensland, January 2014. Available from: <http://www.bom.gov.au>. Downloaded: 7 May 2015.

BoM (Bureau of Meteorology) (2014d). Monthly Weather Review – Queensland, February 2014. Available from: <http://www.bom.gov.au>. Downloaded: 7 May 2015.

BoM (Bureau of Meteorology) (2014e). Monthly Weather Review – Queensland, March 2014. Available from: <http://www.bom.gov.au>. Downloaded: 7 May 2015.

BoM (Bureau of Meteorology) (2014f). Monthly Weather Review – Queensland, April 2014. Available from: <http://www.bom.gov.au>. Downloaded: 7 May 2015.

BoM (Bureau of Meteorology) (2014g). Monthly Weather Review – Queensland, May 2014. Available from: <http://www.bom.gov.au>. Downloaded: 7 May 2015.

BoM (Bureau of Meteorology) (2014h). Monthly Weather Review – Queensland, June 2014. Available from: <http://www.bom.gov.au>. Downloaded: 7 May 2015.

BoM (Bureau of Meteorology) (2014i). Monthly Weather Review – Queensland, July 2014. Available from: <http://www.bom.gov.au>. Downloaded: 7 May 2015.

BoM (Bureau of Meteorology) (2015a). National Climate Centre – Twelve month rainfall decile data for Queensland.

BoM (Bureau of Meteorology) (2015b). Annual climate statement 2014. Issued on 06/01/2015. Available from: < http://www.bom.gov.au/climate/current/annual/aus/>. Downloaded: 6 May 2015.

Brodie, J.E., Binney J., Fabricius K., Gordon I., Hoegh-Gouldberg O., Hunter H., Peter O'Reagain P., Pearson R., Quick M., Thorburn P., Waterhouse J., Webster I. and Wilkinson S. (2008). *Synthesis of evidence to support the Scientific Consensus Statement on Water Quality in the Great Barrier Reef.* The State of Queensland, Department of the Premier and Cabinet, Brisbane, Australia. Available from: <http://reefplan.qld.gov.au/resources/assets/reef-consensus.pdf>. Downloaded: 20 May 2015.

Brodie, J.E., Waterhouse, J., Lewis, S., Bainbridge, Z. and Johnson, J. (2009). Current Loads of Priority Pollutants Discharged from Great Barrier Reef Catchments to the Great Barrier Reef. ACTFR Technical Report 09/02. Australian Centre for Tropical Freshwater Research, Townsville, Australia.

Brodie, J., Devlin, M., Haynes, D. and Waterhouse, J. (2010). Assessment of the eutrophication status of the Great Barrier Reef Lagoon (Australia). *Biogeochemistry*, 106(2):281.

Brodie, J., Waterhouse, J., Schaffelke, B., Kroon, F., Thorburn, P., Rolfe, J., Johnson, J., Fabricus, K., Lewis, S., Devlin, M., Warne, M.St.J. and McKenzie, L. (2013a). *Scientific Consensus Statement – Land use impacts on Great Barrier Reef water quality and ecosystem condition*. Reef Water Quality Protection Plan Secretariat, Brisbane, Queensland. 9p. Available from: <http://www.reefplan.qld.gov.au/resourccecs/assets/reef-consensus-statement-2013.pdf>. Downloaded: 20 May 2015.

Brodie, J., Waterhouse, J., Schaffelke, B., Furnas, M., Maynard, J., Collier, C., Lewis, S., Warne, M.St.J., Fabricus, K., Devlin, M., McKenzie, L., Yorkston, H., Randall, L., Bennett, J. and Brando, V. (2013b). *2013 Scientific Consensus Statement. Chapter 3 – Relative risks to the Great Barrier Reef from degraded water quality.* Reef Water Quality Protection Plan Secretariat, Brisbane, Queensland. 58p. Available from: http://www.reefplan.qld.gov.au/about/scientific-consensus-statement/water-quality-risks.aspx>. Downloaded: 20 May 2015.

DEHP (Department of Environment and Heritage Protection) (2013). Monitoring and Sampling Manual 2009, Version 2, July 2013, format edits. Brisbane, Australia. Available from: <https://www.ehp.qld.gov.au/water/monitoring/monitoring_and_sampling_manual.html>. Downloaded: 22 May 2015.

DERM (Department of Environment and Resource Management) (2011). Reef Plan I5 Event Monitoring Program Internal Review, October 2011, Brisbane, Australia.

Devlin, M. and Brodie, J. (2005). Terrestrial discharge into the Great Barrier Reef Lagoon: Nutrient behaviour in coastal waters. *Marine Pollution Bulletin*, 51(1–4): 9–22.

DNRM (Department of Natural Resources and Mines) (2012). River discharge dataset (hourly-interpolated flow, $m^3 s^{-1}$), Surface Water Database, Queensland Government, Available from: <http://watermonitoring.derm.qld.gov.au/host.htm>. Downloaded: 8 November 2014.

DNRM (Department of Natural Resources and Mines) (2014). Quality coding water monitoring data (WM58), version 3.0, Brisbane Qld: State of Queensland, DNRM, Service Delivery.

DPC (Department of Premier and Cabinet) (2003). Reef Water Quality Protection Plan 2003. Reef Water Quality Protection Plan Secretariat, Brisbane, Australia.

DPC (Department of Premier and Cabinet) (2008). Scientific consensus statement on water quality in the Great Barrier Reef. Reef Water Quality Protection Plan Secretariat, Brisbane, Australia. Available from: <http://www.reefplan.qld.gov.au/about/assets/scientific-consensus-statement-on-water-quality-in-the-gbr>. Downloaded: 20 May 2015.

DPC (Department of Premier and Cabinet) (2009a). Reef Water Quality Protection Plan 2009. Reef Water Quality Protection Plan Secretariat, Brisbane, Australia.

DPC (Department of Premier and Cabinet) (2009b). Paddock to Reef Program – Integrated monitoring, modelling and reporting. Reef Water Quality Protection Plan Secretariat, Brisbane, Australia. Available from: <http://www.reefplan.qld.gov.au/measuring-success/assets/paddock-to-reef.pdf>. Downloaded: 22 May 2015.

DPC (Department of Premier and Cabinet) (2011). Reef Water Quality Protection Plan – First Report Card (2009 Baseline). Reef Water Quality Protection Plan Secretariat, Brisbane, Australia. Available from: <http://www.reefplan.qld.gov.au/abobut/assets/gbr.pdf>. Downloaded: 20 May 2015.

DPC (Department of the Premier and Cabinet) (2013a). Reef Water Quality Protection Plan 2013, Securing the health and resilience of the Great Barrier Reef World Heritage Area and adjacent catchments, Reef Water Quality Protection Plan Secretariat, Brisbane. Available from: <http://www.reefplan.qld.gov.au>. Downloaded: 20 May 2015.

DPC (Department of Premier and Cabinet) (2013b). Paddock to Reef Program – Integrated monitoring, modelling and reporting. Program Design 2013-2018. Reef Water Quality Protection Plan Secretariat, Brisbane, Australia.

DPC (Department of Premier and Cabinet) (2013c). Reef Water Quality Protection Plan – Second Report Card. Reef Water Quality Protection Plan Secretariat, Brisbane, Australia. Available from: <http://reefplan.qld.gov.au/about/assets/gbr-second-report.pdf>. Downloaded: 20 May 2015.

DPC (Department of Premier and Cabinet) (2013d). Reef Water Quality Protection Plan – Report Card 2011. Reef Water Quality Protection Plan Secretariat, Brisbane, Australia. Available from:

<http://reefplan.qld.gov.au/measuring-success/report-cards/assets/report-card-2011.pdf>. Downloaded: 20 May 2015.

DPC (Department of Premier and Cabinet) (2014). Reef Water Quality Protection Plan – Report Card 2012 and 2013. Reef Water Quality Protection Plan Secretariat, Brisbane, Australia. Available from: <http://www.reefplan.qld.gov.au/measuring-success/report-cards/assets/report-card-2012-2013.pdf> Downloaded: 13 May 2015.

DPC (Department of Premier and Cabinet) (2015). Reef Water Quality Protection Plan – Report Card 2014. Reef Water Quality Protection Plan Secretariat, Brisbane, Australia. Available from: <http://www.reefplan.qld.gov.au/measuring-success/report-cards/assets>. Downloaded: September 2015.

DSITIA (Department of Science, Information Technology, Innovation and the Arts) (2012). Land use summary 1999–2009: Great Barrier Reef catchments. Queensland Department of Science, Information Technology, Innovation and the Arts, Brisbane.

DSITIA (Department of Science, Information Technology, Innovation and the Arts) (2013). Queensland Land Use Mapping Program (QLUMP). Available from: http://qldspatial.information.qld.gov.au/catalogue/custom/index.page. Downloaded: 5 June 2013

eWater Cooperative Research Centre (2012). Water Quality Analyser v2.1.1.4. eWater Cooperative Research Centre, Canberra, Australia.

eWater Cooperative Research Centre (2015). Water Quality Analyser v2.1.1.6. eWater Cooperative Research Centre, Canberra, Australia.

Eyre, B. (1998). Transport, retention and transformation of material in Australian estuaries. *Estuaries*, 21(4A): 540–551.

Fabricius, K. E., De'ath, G., McCook, L., Turak, E. and Williams, D. Mc.B. (2005). Changes in algal, coral and fish assemblages along water quality gradients on the inshore Great Barrier Reef. *Marine Pollution Bulletin*, 51(1–4): 384–398.

Furnas, M., Mitchell A. and Skuza M. (1997). River inputs of nutrient and sediments to the Great Barrier Reef. In: Wachenfeld, D., Oliver, J., Davis, K., (eds). Proceedings of the State of the Great Barrier Reef World Heritage Area Workshop GBRMPA, Workshop Series No. 23, 27–29 November, 1995, Townsville, Australia.

Furnas, M. (2003). Catchments and Corals: Terrestrial Runoff to the Great Barrier Reef. Australian Institute of Marine Science, Townsville, Australia. Available from: <http://epubs.aims.gov.au/handle/11068/6477>. Downloaded: 20 May 2015.

Grayson, R., Argent, R., Nathan, R., McMahon, T. and Mein, R. (1996). Hydrological Recipes. Cooperative Research Centre for Catchment Hydrology, Melbourne, Victoria.

Hunter, H., Walton R. (2008). Land-use effects on fluxes of suspended sediment, nitrogen and phosphorus from a river catchment of the Great Barrier Reef, Australia. *Journal of Hydrology*, 356(1–2): 131–146.

Joo, M., Raymond, M., Huggins, R. and Turner, R. (2011). Sediment and nutrient loads. Ten priority Great Barrier Reef Catchments 2006-2009. Department of Environment and Resource Management, Brisbane.

Joo, M., Raymond, M., McNeil, V., Huggins, R., Turner, R. and Choy S. (2012). Estimates of sediment and nutrient loads in 10 major catchments draining to the Great Barrier Reef during 2006–2009. *Marine Pollution Bulletin*, 65(4–9): 150–166.

Kroon, F., Kuhnert, P., Henderson, B., Henderson, A., Turner, R., Huggins, R., Wilkinson, S., Abbot, B., Brodie, J. and Joo, M. (2010). Baseline pollutant loads to the Great Barrier Reef. CSIRO: Water for a Healthy Country Flagship Report Series, Australia. ISSN: 1835-095X. 41 pp.

Kroon, F., Kuhnert, P., Henderson, B., Wilkinson, S., Kinsey-Henderson, A., Abbott, B., Brodie, J. and Turner, R. (2012). River loads of suspended solids, nitrogen, phosphorus and herbicides delivered to the Great Barrier Reef Lagoon. *Marine Pollution Bulletin*, 65(4–9): 167–181.

Kroon, F., Turner, R., Smith, R., Warne, M.St.J., Hunter, H., Bartley, R., Wilkinson, S., Lewis, S., Waters, D. and Carroll, C. (2013). *Scientific Consensus Statement. Chapter 3 – Sources of sediment, nutrients, pesticides and other pollutants in the Great Barrier Reef catchment.* Reef Water Quality Protection Plan Secretariat, Brisbane, Queensland. 42p. Available from: <http://reefplan.qld.gov.au/about/scientific-consensus/sources-of-pollutants.aspx>. Downloaded: 20 May 2015.

Letcher, R., Jakeman, T., Merrit, W., McKee, L., Eyre, B. and Baginska, B. (1999). Review of techniques to estimate catchment exports – Technical report. New South Wales Environment Protection Authority, Sydney, Australia.

McKergow, L.A., Prosser, I.P., Hughes, A.O. and Brodie, J. (2005). Sources of sediment to the Great Barrier Reef World Heritage Area. *Marine Pollution Bulletin*, 51 (1–4): 200–211.

Nicholls, N. (1988). El Niño and rainfall variability. *Journal of Climate*, 1: 418–442.

Packett, R., Dougall, C., Rohde, K. and Noble, R. (2009). Agricultural lands are hot-spots for annual runoff polluting the southern Great Barrier Reef Lagoon. *Marine Pollution Bulletin*, 58: 976–986.

QAO (Queensland Audit Office). (2015). Managing water quality in Great Barrier Reef Catchments. Report 20: 2014-15. Brisbane, Queensland. 95p.

Schaffelke, B., Anthony, K., Blake, J., Brodie, J., Collier, C., Devlin, M., Fabricus, K., Martin, K., McKenzie, L., Negri, A., Ronan, M., Thompson, A. and Warne, M.St.J. (2013). *2013 Scientific Consensus Statement. Chapter 1 – Marine and coastal ecosystem impacts.* Reef Water Quality Protection Plan Secretariat, Brisbane, Queensland. 47p. Available from: <http://reefplan.qld.gov.au/about/scientific-consensus-statement/ecosystem-impacts>. Downloaded: 20 May 2015.

Smith, R., Turner, R., Vardy, S. and Warne, M.St.J. (2011). Using a convolution integral model for assessing pesticide dissipation time at the end of catchments. In Proceedings of the Modelling and Simulation Society of Australian and New Zealand, 2011 Conference, Perth.

Smith, R., Middlebrook, R., Turner, R., Huggins, R., Vardy, S. and Warne, M.St.J. (2012). Large-scale pesticide monitoring across Great Barrier Reef catchments – Paddock to Reef Integrated Monitoring, Modelling and Reporting Program. *Marine Pollution Bulletin*, 65(4–9): 117–127.

Smith, R., Turner, R., Vardy, S., Huggins, R., Wallace, R. and Warne, M.St.J. (2014). An evaluation of the prevalence of alternate pesticides of environmental concern in Great Barrier Reef catchments. Water Quality and Investigations, Environmental Monitoring and Assessment Science, Department of Science, Information Technology and the Arts, Brisbane. Available from: <http://www.qld.gov.au/environment/agriculture/sustainable-farming/reef>. Downloaded: 8 November 2014.

Smith, R.A., Warne, M.St.J., Mengersen, K. and Turner, R.D.R. Toxicity-based pollutant loads: A multispecies toxic equivalency approach. *In prep*.

State of Queensland and Commonwealth of Australia (2003). Reef Water Quality Protection Plan: For catchments adjacent to the Great Barrier Reef World Heritage Area. Queensland Department of Premier and Cabinet, Brisbane, Australia. Available from: <http://reefplan.qld.gov.au/about/assets/reefplan-2003.pdf>. Downloaded: 20 May 2015.

Turner, R.D.R., Huggins, R., Wallace, R., Smith, R.A., Vardy, S. and Warne, M.St.J. (2012). Sediment, nutrient, and pesticide loads: Great Barrier Reef Catchment Loads Monitoring Program 2009–2010. Department of Science, Information Technology, Innovation and the Arts, Brisbane. Available from: <http://reefplan.qld.gov.au/measuring-success/paddock-to-reef/assets/2009-2010-gbr-catchment-loads-report.pdf>. Downloaded: 22 May 2014.

Turner, R.D.R., Huggins, R., Wallace, R., Smith, R.A., Vardy, S. and Warne, M.St.J. (2013). Total suspended solids, nutrient and pesticide loads (2010–2011) for rivers that discharge to the Great Barrier Reef: Great Barrier Reef Catchment Loads Monitoring Program 2010–2011. Department of Science, Information Technology, Innovation and the Arts, Brisbane. Available from:<http://www.reefplan.qld.gov.au/measuring-success/paddock-to-reef/assets/2010-2011-gbr-catchment-loads-report.pdf>. Downloaded: 22 May 2015.

Vardy, S., Turner, R.D.R., Lindeman, S., Orr, D., Smith, R.A., Huggins, R., Gardiner, R. and Warne, M.St.J. (2015). Pesticides and nutrients in groundwater and their transport to rivers from sugar cane cropping in the lower Burdekin. Department of Science, Information Technology, Innovation and the Arts. Brisbane. 81 pp. Available from: <https://publications.qld.gov.au/dataset/96b694a5-69f0-428b-95a3-b9aba58f2a3e/resource/66691d9b-8b04-48e5-8f71-97cb91f9b01f/download/pesticidesandnutrientsgroundwaterburdekin53cfinalmetadata.pdf>. Downloaded: June 2015.

Wachenfeld, D.R., Oliver, J.K. and Morrissey, J.I. (1998). State of the Great Barrier Reef World Heritage Area. Great Barrier Reef Marine Park Authority, Townsville, Australia.

Wallace, R., Huggins, R., Smith, R.A., Turner, R.D.R., Vardy, S. and Warne, M.St.J. (2014). Total suspended solids, nutrient and pesticide loads (2011–2012) for rivers that discharge to the Great Barrier Reef – Great

Barrier Reef Catchment Loads Monitoring Program 2011–2012. Department of Science, Information Technology, Innovation and the Arts. Brisbane. Available from: <http://www.reefplan.qld.gov.au/measuring-success/paddock-to-reef/assets/2011-2012-gbr-catchcment-loads-report.pdf>. Downloaded: 22 May 2015.

Wallace, R., Huggins, R., Smith, R.A., Turner, R.D.R., Garzon-Garcia, A. and Warne, M.St.J. (2015). Total suspended solids, nutrient and pesticide loads (2012–2013) for rivers that discharge to the Great Barrier Reef – Great Barrier Reef Catchment Loads Monitoring Program 2012–2013. Department of Science, Information Technology and Innovation. Brisbane. <http://www.reefplan.qld.gov.au/measuring-success/paddock-to-reef/assets/2012-2013-gbr-catchcment-loads-report.pdf>. Downloaded: 22 May 2015.

Wallace, R., Huggins, R., Turner, R.D.R. and Warne, M.St.J. Total suspended solids and nutrient loads discharged to the Great Barrier Reef following Tropical Cyclone Ita. Department of Science, Information Technology and Innovation.Brisbane. *In prep*.

Waters, D.K., Carroll, C., Ellis, R., Hateley, L., McCloskey, G.L., Packett, R., Dougall, C. and Fentie, (2014). Modelling reductions of pollutant loads due to improved management practices in the Great Barrier Reef catchments – Whole of GBR, Technical Report, Volume 1, Queensland Department of Natural Resources and Mines, Toowoomba, Queensland (ISBN: 978-1- 7423-0999). Available from: http://www.reefplan.qld.gov.au/measuring-success/paddock-to-reef/assets/great-barrier-reef-catchment-modelling-report.pdf. Downloaded: 10 September, 2015.

Wooldridge, S., Brodie, J. and Furnas, M. (2006). Exposure of inner-shelf reefs to nutrient enriched runoff entering the Great Barrier Reef Lagoon: Post-European changes and the design of water quality targets. *Marine Pollution Bulletin,* 52: 1467-1479.

Zhang, X., Waters, D. and Ellis, R. (2013). Evaluation of Simhyd, Sacramento and GR4J rainfall runoff models in two contrasting Great Barrier Reef catchments. 20th International Congress on Modelling and Simulation, Adelaide, Australia.

Zhang, X. (2015a). Calibration of Source Models for Burnett-Mary catchments: Summary of Calibration of Hydrology for Source Model of Burnett-Mary Catchments, Department of Science, Information Technology and Innovation, Queensland Government.

Zhang, X. (2015b). Calibration of Source Models for Wet Tropics Catchments: Summary of Calibration of Hydrology for Source Model of Wet Tropics Catchments, Department of Science, Information Technology and Innovation, Queensland Government.

7 Appendices

Appendix A Loads of other pesticides detected by the Great Barrier Reef Catchment Loads Monitoring Program

All water samples collected for the analysis of pesticides were analysed via LC-MS as described in Section 2.5. The LC-MS analytical suite is capable of detecting more than 40 pesticides and their breakdown products (i.e. additional to the five photosystem II inhibiting herbicides presented in the body of the report) (See Table 7.1). The monitored annual loads of the detected additional pesticides were calculated using the methods previously described in Section 2.7.2.1. The results presented in this section of the report are the monitored annual loads of these detected additional pesticides, 2,4-D, bromacil, fluometuron, fluroxypyr, haloxyfop, imidacloprid, imidacloprid metabolites, isoxaflutole, MCPA, metolachlor, metribuzin, metsulfuron-methyl, prometryn, propazine-2-hydroxy (a metabolite of the herbicide propazine), simazine, terbuthylazine, triclopyr, clothianidin, total imazapic, imazethapyr, acifluorfen, and 3,4-dichloroaniline (a metabolite of the herbicide diuron).

The monitored annual loads of atrazine and its metabolites, desethyl atrazine and desisopropyl atrazine, are also presented although they will not be discussed further as the total atrazine load is already considered in Section 3.4. Similarly, the monitored annual loads of diuron and its metabolite 3,4-dichloroaniline will not be discussed as the loads of total diuron have been presented in Section 3.4.

The total monitored annual loads of other pesticides detected by the LC-MS analysis suite ranged from 0.055 kg of imidacloprid metabolites and 0.15 kg of imazethapyr, which was only detected in Sandy Creek in the Plane catchment, to 530 kg of imidacloprid which was detected broadly across the Wet Tropics, Burdekin Dry Tropics and Mackay Whitsunday regions. These loads are comparable to those of the five photosystem II inhibiting herbicides, indicating it is essential to continue monitoring and calculating the loads of these pesticides.

Of the additional chemicals 2,4-D and metolachlor were detected in the most catchments – each occurring in all but one catchment. The largest loads of 2,4-D occurred in the Tully (120 kg; 28 per cent), Herbert (100 kg; 24 per cent) and Pioneer (72 kg; 17 per cent) catchments, together accounting for 70 per cent of the monitored annual load. Metolachlor was detected in all catchments other than the O'Connell. The total monitored annual load of metolachlor (140 kg) was predominantly derived from the Tully (54 kg; 38 per cent) and Fitzroy (43 kg; 31 per cent) catchments.

Sandy Creek in the Plane catchment had the highest number of additional pesticides detected with 17 chemicals including imazethapyr (0.15 kg) and aciflurofen (0.29 kg) which were only detected at this site. Barratta Creek in the Haughton catchment had the second highest number of additional chemicals detected with 13 chemicals.

Bromacil was only detected in three catchments with more than 99 per cent of the monitored annual load (42 kg) derived from the Fitzroy catchment (32 kg; 76 per cent) and Tinana sub-catchment (10 kg; 24 per cent) and only a small load monitored in the Pioneer catchment (0.18 kg; 0.43 per cent).

Fluometuron was only detected in the Tully catchment with a total monitored annual load of 12 kg and Terbuthylazine was only detected in the Fitzroy catchment (12 kg; 100 per cent).

The largest monitored annual load of fluroxypyr (110 kg) occurred in the Herbert catchment (66 kg; 61 per cent) with the O'Connell (11 kg; 10 per cent) being the only other catchment with a load greater than 10 kg. The smallest monitored load occurred in the Tinana sub-catchment (0.36 kg; 0.34 per cent).

Haloxyfop was detected in all regions (total monitored annual load of 5.0 kg) except the Fitzroy with the total annual monitored load in the Tully catchment accounting for 62 per cent of the total monitored load (5.0 kg). Smaller loads of haloxyfop were also monitored in Tinana Creek in the Mary catchment (1.2 kg; 24 per cent), Sandy Creek in the Plane catchment (0.54 kg; 11 per cent) and Barratta Creek in the Haughton catchment (0.15 kg; 3.0 per cent).

Imidacloprid (total monitored annual load of 530 kg) was detected in all monitored sites in the Wet Tropics and Burdekin Dry Tropics regions and two of three sites in the Mackay Whitsunday region. The largest monitored annual loads of imidacloprid were in the Tully catchment (240 kg; 46 per cent) and North Johnstone sub-catchment (180 kg; 34 per cent) with moderate monitored annual loads of imidacloprid also derived from the Herbert (48 kg; 9.1 per cent) and Pioneer (33 kg; 6.3 per cent) catchments. The monitored annual loads of imidacloprid in other catchments where this herbicide was detected were low and accounted for less than 4 per cent of the total monitored annual imidacloprid load during the 2013–2014 monitoring year.

Isoxaflutole (total monitored annual load of 22 kg) was detected in all three monitored sites of the Mackay Whitsunday region and one site in each of the Wet Tropics (the Tully River) and Burdekin (Barratta Creek in the Haughton catchment) regions. The largest monitored annual loads were derived from Barratta Creek in the Haughton catchment (8.4 kg; 39 per cent), Tully (5.6 kg; 26 per cent) and Pioneer (3.7 kg; 17 per cent) catchments. The smallest calculable monitored annual load of isoxaflutole was in the O'Connell catchment (1.1 kg; 5.1 per cent).

MCPA was detected in all sites in the Burdekin and Mackay Whitsunday regions and one site in the Burnett Mary region. The total annual monitored load of MCPA was 36 kg. The largest monitored loads of MCPA occurred in the Burdekin (11 kg; 31 per cent), Haughton (9.3 kg; 26 per cent) and Pioneer (5.7 kg; 16 per cent) catchments. The lowest monitored annual load of MCPA occurred in the O'Connell catchment (0.54 kg; 1.5 per cent).

Metribuzin (total monitored annual load of 70 kg) was detected at six sites in the Wet Tropics, Burdekin and Mackay Whitsunday regions. The largest monitored annual load occurred in the Tully catchment (25 kg; 36 per cent). The monitored annual load of metribuzin was similar in the Pioneer River (16 kg; 23 per cent) and Sandy Creek in the Plane catchment (14 kg; 20 per cent), smaller loads were monitored in Barratta Creek in the Haughton catchment (9.1 kg; 13 per cent) and in the O'Connell catchment (6.1 kg; 8.7 per cent). The smallest calculable monitored annual load of metribuzin occurred in the Haughton River (0.014 kg; 0.02 per cent).

The total monitored annual load of metsulfuron-methyl was 4.7 kg with the majority of this load occurring in the Tully catchment (3.6 kg; 77 per cent). The smallest calculable monitored annual load of metsulfuron-methyl occurred in the Haughton catchment (0.093 kg; 2.0 per cent).

Propazin-2-hydroxy was only detected in two catchments with 0.53 kg monitored in Barratta Creek in the Haughton catchment and 0.095 kg at Sandy Creek in the Plane catchment. The total annual monitored load was 0.63 kg.

The total monitored annual load of simazine was only 2.2 kg, with the largest load occurring in the Mary River (1.5 kg; 67 per cent). Small loads of simazine were also monitored in the North Johnstone sub-catchment (0.43 kg; 19 per cent) and Barratta Creek in the Haughton catchment (0.25 kg; 11 per cent). The smallest calculable load of simazine was in Sandy Creek in the Plane catchment (0.048 kg; 2.2 per cent).

Terbuthylazine was only detected in the Fitzroy River and the total annual monitored load was 12 kg.

Triclopyr was detected in all regions except the Fitzroy with a total monitored annual load of 27 kg. The largest monitored annual loads occurred in the Tully River (9.5 kg; 35 per cent), Tinana Creek in the Mary catchment (9.1 kg; 33 per cent) and Mary River (4.2 kg; 15 per cent). The load of triclopyr was similar in the two monitored catchments in the Haughton catchment with 2.0 kg (7.3 per cent) and 1.7 kg (6.2 per cent) occurring in the Haughton River and Barratta Creek in the Haughton catchment, respectively. The smallest calculable annual monitored load was in Sandy Creek in the Plane catchment (0.063 kg; 0.23 per cent).

Clothianidin was detected at only three sites (North Johnstone, Tully and Sandy Creek in the Plane catchment) and had a total annual monitored load of 26 kg. Eighty-six per cent of the monitored load came from the North Johnstone (22 kg) sub-catchment with small contributions from the Tully catchment (3.2 kg; 13 per cent) and Sandy Creek in the Plane catchment (0.35 kg; 1.4 per cent).

Total imazapic was only detected in Barratta Creek in the Haughton catchment (1.7 kg; 11 per cent) and in Sandy Creek in the Plane catchment (14 kg; 89 per cent) and had a total annual monitored load of 16 kg.

Table 7.1 Pesticides analysed for by the Great Barrier Catchment Loads Monitoring Program

Pesticide	Reporting Limit (µg L^{-1})	Pesticide	Reporting Limit (µg L^{-1})
2,4-D	0.01	MCPB	0.01
2,4-DB	0.01	Mecoprop	0.01
3,4-Dichloroaniline	0.04	Mesosulfuron methyl	0.01
Acifluorfen	0.01	Metolachlor	0.01
Ametryn	0.01	Metribuzin	0.01
Atrazine	0.01	Metsulfuron methyl	0.01
Bromacil	0.01	Napropamide	0.01
Clomazone	0.01	Prometryn	0.01
Clothianidin	0.01	Propachlor	0.01
Cyanazine	0.01	Propazin-2-hydroxy	0.02
Desethyl Atrazine	0.01	Sethoxydim (including Clethodim)	0.02
Desisopropyl Atrazine	0.01	Simazine	0.01
Diuron	0.01	Sulfosulfuron	0.01
Ethametsulfuron methyl	0.01	Tebuthiuron	0.01
Fluometuron	0.01	Terbuthylazine	0.01
Fluroxypyr	0.03	Terbuthylazine desethyl	0.01
Flusilazole	0.01	Terbutryn	0.01
Haloxyfop (acid)	0.01	Thiamethoxam	0.02
Hexazinone	0.01	Total Diuron	0.08
Imazethapyr	0.01	Total Imazapic	0.07
Imidacloprid	0.01	Total Imidacloprid	0.03
Imidacloprid metabolites	0.01	Triclopyr	0.02
Isoxaflutole	0.01	Trifloxysulfuron	0.01
MCPA	0.01		

Table 7.2 The monitored annual loads calculated for the additional pesticides: 2,4-D, acifluorfen, bromacil, clothiandin, fluometuron, fluroxypyr, haloxyfop and imazethapyr. Text in bold are end-of-system sites and the corresponding data, all others are sub-catchment sites.

NRM region	Catchment	Gauging station	River and site name	n	2,4-D (kg)	Acifluorfen (kg)	Bromacil (kg)	Clothiandin (kg)	Fluometuron (kg)	Fluroxypyr (kg)	Haloxyfop (kg)	Imazethapyr (kg)
Wet Tropics	Johnstone	1120049	North Johnstone River at Old Bruce Highway Bridge (Goondi)[B]	41	14	NC	NC	22	NC	NC	NC	NC
	Tully	**113006A**	**Tully River at Euramo**[L]	93	120	NC	NC	3.2	12	NC	3.1	NC
	Herbert	**116001F**	**Herbert River at Ingham**[L]	83	100	NC	NC	NC	NC	66	NC	NC
Burdekin	Haughton	**119003A**	**Haughton River at Powerline**[B]	20	3.7	NC	NC	NC	NC	4.9	NC	NC
		119101A	**Barratta Creek at Northcote**[L]	44	17	NC	NC	NC	NC	7.3	0.15	NC
	Burdekin	**120001A**	**Burdekin River at Home Hill**[B]	22	24	NC	NC	NC	NC	NC	NC	NC
Mackay Whitsunday	O'Connell	**1240062**	**O'Connell River at Caravan Park**[B]	40	16	NC	NC	NC	NC	11	NC	NC
	Pioneer	**125013A**	**Pioneer River at Dumbleton Pump Station**[L]	59	72	NC	0.18	NC	NC	9.3	NC	NC
	Plane	**126001A**	**Sandy Creek at Homebush**[B]	48	46	0.29	NC	0.35	NC	6.5	0.54	0.15
Fitzroy	Fitzroy	**1300000**	**Fitzroy River at Rockhampton**[B]	24	NC	NC	32	NC	NC	NC	NC	NC
Burnett Mary	Burnett	**136014A**	**Burnett River at Ben Anderson Barrage Head Water**[L]	27	0.082	NC	NC	NC	NC	NC	NC	NC
	Mary	138014A	Mary River at Home Park[L]	63	6.2	NC	NC	NC	NC	2.0	NC	NC
		138008A	Tinana Creek at Barrage Head Water[L]	23	2.8	NC	10	NC	NC	0.36	1.2	NC
Total (monitored end-of-system sites)				587	420	0.29	42	26	12	110	5.0	0.15

n = the number of grab samples used to calculate loads; NC = a load was not calculated as all the concentrations were below the practical quantitation limit or there were insufficient samples collected over the year to calculate a load; L = average load (linear interpolation of concentration) method used to calculate loads; B = Beale ratio method used to calculate loads.

Table 7.3 The monitored annual loads calculated for the additional pesticides: imidacloprid, imidacloprid metabolites, isoxaflutole, MCPA, metolachlor, metribuzin, metsulfuron-methyl and propazin-2-hydroxy. Text in bold are end-of-system sites and the corresponding data, all others are sub-catchment sites.

NRM region	Catchment	Gauging station	River and site name	n	Imidacloprid (kg)	Imidacloprid metabolites (kg)	Isoxaflutole (kg)	MCPA (kg)	Metolachlor (kg)	Metribuzin (kg)	Metsulfuron-methyl (kg)	Propazin-2-hydroxy (kg)
Wet Tropics	Johnstone	1120049	North Johnstone River at Old Bruce Highway Bridge (Goondi)[B]	41	180	NC	NC	NC	0.14	NC	NC	NC
	Tully	**113006A**	**Tully River at Euramo**[L]	93	240	NC	5.6	NC	54	25	3.6	NC
	Herbert	**116001F**	**Herbert River at Ingham**[L]	83	48	NC	NC	NC	9.2	NC	NC	NC
Burdekin	Haughton	**119003A**	**Haughton River at Powerline**[B]	20	0.067	NC	NC	9.3	0.12	0.014	0.093	NC
		119101A	**Barratta Creek at Northcote**[L]	44	2.2	NC	8.4	4.0	7.6	9.1	0.47	0.53
	Burdekin	**120001A**	**Burdekin River at Home Hill**[B]	22	5.4	NC	NC	11	4.4	NC	NC	NC
Mackay Whitsunday	O'Connell	**1240062**	**O'Connell River at Caravan Park**[B]	40	NC	NC	1.1	0.54	NC	6.1	NC	NC
	Pioneer	**125013A**	**Pioneer River at Dumbleton Pump Station**[L]	59	33	NC	3.7	5.7	2.7	16	NC	NC
	Plane	**126001A**	**Sandy Creek at Homebush**[B]	48	17	0.055	3.0	4.2	15	14	0.5	0.095
Fitzroy	Fitzroy	**1300000**	**Fitzroy River at Rockhampton**[B]	24	NC	NC	NC	NC	43	NC	NC	NC
Burnett Mary	Burnett	**136014A**	**Burnett River at Ben Anderson Barrage Head Water**[L]	27	NC	NC	NC	NC	1.3	NC	NC	NC
	Mary	138014A	Mary River at Home Park[L]	63	NC	NC	NC	NC	1.4	NC	NC	NC
		138008A	Tinana Creek at Barrage Head Water[L]	23	NC	NC	NC	1.2	1.8	NC	NC	NC
Total monitored load including sub-catchment sites				587	530	0.055	22	36	140	70	4.7	0.63

n = the number of grab samples used to calculate loads; NC = a load was not calculated as all the concentrations were below the practical quantitation limit or there were insufficient samples collected over the year to calculate a load; L = average load (linear interpolation of concentration) method used to calculate loads; B = Beale ratio method used to calculate loads.

Table 7.4 The monitored annual loads calculated for the additional pesticides: simazine, terbuthylazine, triclopyr, total imazapic, total atrazine and its metabolites atrazine, desethylatrazin and desisopropylatrazine, and total diuron including its metabolites diuron and 3,4-dichloroaniline. Text in bold are end-of-system sites and the corresponding data, all others are sub-catchment sites.

NRM region	Catchment	Gauging station	River and site name	n	Simazine (kg)	Terbuthy-lazine (kg)	Triclopyr (kg)	Total Imazapic (kg)	Total atrazine (kg)			Total diuron (kg)	
									Atrazine (kg)	Desethyl-atrazine (kg)	Desisop-ropylatra-zine (kg)	Diuron (kg)	3,4 dichl-oroaniline (kg)
Wet Tropics	Johnstone	1120049	North Johnstone River at Old Bruce Highway Bridge (Goondi)[B]	41	0.43	NC	NC	NC	12	3.5	NC	34	NC
	Tully	**113006A**	**Tully River at Euramo**[L]	93	NC	NC	9.5	NC	200	32	6.7	240	NC
	Herbert	**116001F**	**Herbert River at Ingham**[L]	83	NC	NC	NC	NC	45	22	NC	110	NC
Burdekin	Haughton	**119003A**	**Haughton River at Powerline**[B]	20	NC	NC	2.0	NC	2.9	1.2	0.17	1.2	0.076
		119101A	**Barratta Creek at Northcote**[L]	44	0.25	NC	1.7	1.7	110	33	12	70	1.5
	Burdekin	**120001A**	**Burdekin River at Home Hill**[B]	22	NC	NC	NC	NC	50	6.2	3.9	7.5	0.62
Mackay Whitsunday	O'Connell	**1240062**	**O'Connell River at Caravan Park**[B]	40	NC	NC	0.41	NC	2.5	0.36	0.16	13	NC
	Pioneer	**125013A**	**Pioneer River at Dumbleton Pump Station**[L]	59	NC	NC	NC	NC	190	22	9	250	4.0
	Plane	**126001A**	**Sandy Creek at Homebush**[B]	48	0.048	NC	0.063	14	64	8.8	3.7	120	2.4
Fitzroy	Fitzroy	**1300000**	**Fitzroy River at Rockhampton**[B]	24	NC	12	NC	NC	38	NC	NC	14	NC
Burnett Mary	Burnett	**136014A**	**Burnett River at Ben Anderson Barrage Head Water**[L]	27	NC	NC	0.36	NC	4.3	NC	NC	0.14	NC
	Mary	138014A	Mary River at Home Park[L]	63	1.5	NC	4.2	NC	NC	NC	NC	2.1	NC
		138008A	Tinana Creek at Barrage Head Water[L]	23	NC	NC	9.1	NC	1.8	NC	NC	10	NC
Total (monitored end-of-system sites)				587	2.2	12	27	16	720	130	36	870	8.6

Data shaded blue (atrazine, desethyl atrazine,desisopropyl atrazine and diuron and 3,4-dichloroaniline) have already been incorporated in the calculation of total atrazine and total diuron and have been presented in the main body of this report. n = the number of grab samples used to calculate loads; NC = a load was not calculated as all the concentrations were below the practical quantitation limit or there were insufficient samples collected over the year to calculate a load; L = average load (linear interpolation of concentration) method used to calculate loads; B = Beale ratio method used to calculate loads.

Appendix B Calculation of discharge

Discharge as contained in the Queensland Government surface water database is calculated following the equation:

Equation 9

$$q = va$$

where, q is the discharge ($m^3 s^{-1}$), v = average velocity of the flow in the cross-sectional area (ms^{-1}) and a = the cross-sectional area of the river (m^2).

Discharge is calculated for sub-sectional areas of the river channel and summed to determine the discharge across the whole cross-sectional area. Sub-sectional areas were calculated from a known width multiplied by the river gauge height at time *t*. Flow velocity was determined for each cross-sectional area at time *t* using a current meter.

During the 2013–2014 monitoring year, river gauge height was recorded by gauging stations using a float or a pressure sensor at intervals of approximately 15 minutes. Flow records were extracted for each site from the Queensland Government electronic data management system (Hydstra).

Appendix C Discharge data quality

The total period (hours) during the 2013–2014 monitoring year where discharge was calculated from interpolated height data is provided in Table 7.5. Discharge which was calculated from interpolated height data were assigned a quality code of 59 or 60 (refer to Table 7.5).

Table 7.5 Per cent of annual discharge period calculated using interpolated discharge. Text in bold are end-of-system sites and gauging stations and the corresponding data, all others are sub-catchment sites.

Catchment	Gauging station	River and site name	Time period (hours)	Quality code[1]	Per cent of annual discharge calculated using interpolated discharge
Normanby	**105107A**	**Normanby River at Kalpowar Crossing**	**73**	**60**	**1**
Barron	**110001D**	**Barron River at Myola**	**0**		**0**
Johnstone	1120049	North Johnstone River at Old Bruce Highway Bridge (Goondi)	0		0
	112101B	South Johnstone River at Upstream Central Mill	0		0
Tully	**113006A**	**Tully River at Euramo**	**0**		**0**
	113015A	Tully River at Tully Gorge National Park	33	60	<1
Herbert	**116001F**	**Herbert River at Ingham**	**4**	**60**	**<1**
Haughton	**119003A**	**Haughton River at Powerline**	**0**		**0**
	119101A	**Barratta Creek at Northcote**	**358**	**60**	**4**
Burdekin	**120001A**	**Burdekin River at Home Hill**	**0**		**0**
	120002C	Burdekin River at Sellheim	0		0
	120205A	Bowen River at Myuna	0		0
O'Connell	**1240062**	**O'Connell River at Caravan Park**	**847**	**60**	**10**
Pioneer	**125013A**	**Pioneer River at Dumbleton Pump Station**	**103**	**60**	**1**
Plane	**126001A**	**Sandy Creek at Homebush**	**0**		**0**
Fitzroy	**1300000**	**Fitzroy River at Rockhampton**	**0**		**0**
	130206A	Theresa Creek at Gregory Highway			
	130302A	Dawson River at Taroom	0		0
	130504B	Comet River at Comet Weir			
Burnett	**136014A**	**Burnett River at Ben Anderson Barrage Head Water**	**0**		**0**
	136002D	Burnett River at Mt Lawless			
Mary	138014A	Mary River at Home Park	0		0
	138008A	Tinana Creek at Barrage Head Water#	NA	NA	NA

[1] Quality codes are explained in Table 7.6; # modelled discharge was used in the calculation of loads for this site.

Table 7.6 Description of discharge data quality codes (DNRM 2014).

Discharge data quality code	Description
10	Good
15	No flow
20	Fair
30	Poor
59	CITEC – Derived height
60	Estimate
160	Suspect

Appendix D Event-based loads in Mulgrave River at Deeral and Russell River at East Russell

New monitoring sites were installed in the Mulgrave River and Russell River by the Great Barrier Reef Catchment Loads Monitoring Program in early 2014. Installation of these sites was made possible through partnership funding provided by Terrain Natural Resource Management

Intensive collection of water samples did not commence at this site until February 2014 following the provision of formal training to regional partners. Due to the absence of water quality concentration data for the first six months of the monitoring year prior to January, including a period of major flooding in the Russell River, only mass loads for event periods that were well sampled are presented in this report. Further, the installation of Acoustic Doppler Current Profilers at these sites was not complete at the commencement of the monitoring year, therefore discharge data for these sites was derived through modelling approaches based on measured discharge at upstream gauging stations (see River discharge section, below).

Monitoring locations

The Mulgrave River and Russell River monitoring sites are located in the mid-estuaries of these catchments. The upstream influence of tidal exchange in both of these catchments is relatively limited owing to the topography and freshwater inflows from these catchments, which on average receive the highest annual rainfall totals within Australia. The topography of these catchments is steep, with small floodplains confined between the foothills of the Bellenden Ker Range to the west and the coastal ranges of the Russell River National Park and Grey Peaks National Park.

The setting of the Mulgrave River and Russell River sites in the mid-estuary of these catchments has substantially increased the total monitored areas above that which would have been attained if the sites were co-located with existing Department of Natural Resources and Mines hydrographic monitoring stations in the mid-catchment. The increase in monitored catchment area also substantially increases the monitored area of agricultural land uses which are predominantly located on the floodplains of these catchments.

Water quality sampling

Water quality sampling at the Mulgrave River and Russell River commenced in mid-February 2014. As no samples were collected during the first six months of the monitoring year and no samples during the first major event of the year at the Russell River, mass loads are only reported for high flow event periods which are known to contribute much of the pollutant load to the Great Barrier Reef.

Water samples were collected and analysed according to methods outlined in Section 2.3. Summary information on analytes measured and sample collection methods are provided in Table 2.2.

River discharge

Daily discharge for the Mulgrave River and Russell River were simulated and calibrated by the Department of Natural Resources and Mines using the Source Catchments platform Sacramento rainfall runoff model coupled with the Parameter Estimation Software Tool (PEST) for the period 1 July 1970 to 30 June 2014, following the approach detailed in Zhang et al. (2013). Zhang et al. (2013) demonstrated that the Sacramento model provides better performance in reproducing long term daily discharge and high flow event scenarios than the Source Catchments platform alternate models Simhyd and GR4J.

The hydrology statistics used to calibrate the Mulgrave and Russell catchments (based on three upstream gauging stations) are provided in Table 7.7. (Zhang et al. 2015b). The calibration site at the Mulgrave River at Peets Bridge is the lowest gauged site within the catchment. And similarly within the Russell catchment, Russell River at Bucklands and Babinda Creek at Babinda are the two lowest gauges on the primary tributaries in the Russell catchment.

Table 7.7 Summary hydrology statistics used to calibrate the Sacramento rainfall runoff model in the Mulgrave and Russell basin for the period 1 July 1970 to 30 June 2014.

Gauging station	River and site name	R^2	NSE*	Bias of total flow	Bias of high flow
111007A	Mulgrave River at Peets Bridge	0.91	0.83	0.0%	-0.2%
111101D	Russell River at Bucklands	0.94	0.89	-2.5%	-3.3%
111102B	Babinda Creek at Babinda	0.90	0.81	-6.2%	-4.5%

*Nash-Sutcliffe coefficient of efficiency for daily simulated flow versus observed on a 1:1 line.

Event definitions

The high flow event periods for the Mulgrave River and Russell River were determined using the Lyne and Hollick filter (see Grayson et al. 1996). The Lyne and Hollick filter were applied to historic daily discharge for the period 1 July 1970 to 30 June 2014 calculated using the Sacramento rainfall runoff model (see River discharge section, above). The Lyne and Hollick filter was applied in three passes to smooth the data. The temporal extent of daily discharge data that was used to run the Lyne and Hollick filter for each site and filtering parameter are provided in Table 7.8.

The high flow event periods defined for the Mulgrave River and Russell River are provided in Table 7.9 with the calculated mass loads.

Table 7.8 Modelled historic discharge and Lyne and Hollick filtering parameters applied in the separation of base flow at the Mulgrave and Russell River.

Catchment	Monitored river and site name	Historic daily flow period	Annual discharge time step (2013–2014)	Alpha	Historical base flow index
Mulgrave-Russell	Mulgrave River at Deeral	01/07/1970 – present	Daily	0.925	0.51
	Russell River at East Russell	07/07/1970 – present	Daily	0.975	0.42

Total suspended solids and nutrient event loads

Russell Catchment

The largest monitored loads of total suspended solids in the Russell catchment occurred during the second and third events (2800 t and 2900 t, respectively) during which equal discharge was received from both events (160,000 ML). The loads of total suspended solids during the first and fourth events were similar (1900 t – 1500 t, respectively) however this discharge during the first event (190,000 ML) was more than twice the discharge during the final monitored event of the year (91,000 ML) (Table 7.9).

In the Russell catchment, the monitored load of total nitrogen decreased progressively with each event from a peak of 45 t during Event 1 down to 30 t during Event 4. The monitored load of dissolved organic nitrogen was equal during the first two events (17 t) then decreased to only 4.1 t during Event 3, returning to 11 t during the last event of the year. The load of particulate nitrogen was similar between the first and third events (10 t cf. 11 t) and the second and fourth events (2.2 t cf. 4.8 t). A similar trend also occurred in the monitored load of dissolved inorganic nitrogen, with equal loads during the first and third events (both 19 t) and second and fourth events (9.9 t cf. 12 t). The high load of dissolved inorganic nitrogen during the first and third events was driven by substantially higher loads of oxidised nitrogen during these two events. The ratio of oxidised nitrogen to ammonium nitrogen also varied substantially between events from a maximum of 19 in Event 3 to a low of 2.7 in Event 4.

The monitored load of total phosphorus was equal in the first two events (both 4.7 t) and similar amongst the last two events (2.9 t cf. 2.8 t). Event 1 produced the largest monitored load of particulate phosphorus (4.3 t) with similar loads in the remaining three events (Table 7.9). The load of dissolved organic phosphorus ranged from a 1.9 t in Event 1 to 0.91 t in Event 4. Similarly, the monitored load of dissolved inorganic phosphorus ranged from 0.90 t in Event 1 down to 0.11 t in Event 4.

Mulgrave Catchment

In the Mulgrave catchment, the high discharge associated with Event 2 resulted in the largest monitored loads of total suspended solids and all monitored nutrients. The load of total suspended solids during Event 2 (17,000 t) was substantially greater than the monitored total suspended solids loads in all three other events which ranged from 3600 t in Event 1 down to 600 t in Event 4 (Table 7.9).

The monitored load of total nitrogen during Event 2 (120 t) was three times greater than the monitored load in Event 1 (40 t) and nine times greater than Event 3 (13 t). Dissolved organic nitrogen followed a similar trend, with the maximum load occurring during Event 2 (36 t) and the lowest load occurring during Event 3 (2.1 t). The load of particulate nitrogen during Event 2 (64 t) was very high compared to all other monitored events. The load of dissolve inorganic nitrogen ranged from 14 t during Event 2 to 5.7 t in Event 3. The ratio of oxidised nitrogen to ammonium nitrogen ranged from a low of 3.7 during Event 2 to 14 in Event 4.

The largest monitored load of total phosphorus occurred during the Event 2 (14 t) with a moderate load also associated with Event 1 (5.4 t). The load of total phosphorus was similarly low during the last two events (0.98 t cf. 0.95 t). This comparative trend in the monitored mass loads between events was similar for all other measured phosphorus parameters – highest loads occurring during Event 2 and Event 1 followed by small loads in Events 3 and 4 (Table 7.9).

Pesticide event loads

Russell catchment

At the Russell River, total diuron and hexazinone were detected above the analytical limit of reporting during all monitored events. The largest loads of total diuron (13 kg) and hexazinone (5.6 kg) were monitored during Event 1 (Table 7.10) with much lower loads monitored during the subsequent three events. Total atrazine was only detected during the first two events with the largest load monitored during Event 1 (4.7 kg). Ametryn and tebuthiuron were not detected above the analytical limit of reporting at the Russell River during 2013–2014 monitoring year.

The total toxic loads decreased with each subsequent event from 14 kg TEq_{diuron} in Event 1 down to 0.79 kg TEq_{diuron} in Event 4 (Table 7.10). Total diuron contributed substantially to the calculated total toxic loads during all events; ranging from 85 to 91 per cent.

Six additional pesticides were also detected at the Russell River (excluding atrazine and diuron), with only 2,4-D and imidacloprid detected in all four events (Table 7.11). The largest load of 2,4-D (4.0 kg) was monitored during Event 1 and the largest load of imidacloprid (6.4 kg) monitored during Event 3. The remaining four pesticides detected at the Russell River were only detected during Event 1. The monitored load of fluroxypyr was 3.8 kg, with equal loads of MCPA (1.1 kg) and metribuzin (1.1 kg). The load of metsulfuron-methyl (0.94 kg) was similarly low and not detected during the subsequent events of the 2013–2014 monitoring year.

Mulgrave catchment

At the Mulgrave River, pesticides were only detected during the first two monitored events; the concentration of pesticides in all samples collected during the third and fourth events were below the analytical limit of reporting. A total of nine pesticides were detected during the first two events, with all nine detected during Event 1 and six pesticides during Event 2 (excluding atrazine and diuron) (Table 7.10 and Table 7.11).

The monitored load of total atrazine during Event 1 (2.6 kg) was approximately twice the monitored load during Event 2 (1.4 kg) (Table 7.10). In contrast, the mass load of total diuron and hexazinone was larger during Event 2 with 2.0 kg cf. 3.0 kg and 0.67 kg cf. 1.3 kg, respectively. Ametryn and tebuthiuron were not detected above the analytical limit of reporting during the four monitored events.

The total toxic load was low in both Event 1 (2.2 kg TEq_{diuron}) and Event 2 (3.3 kg TEq_{diuron}) (Table 7.10). Total diuron contributed 91 per cent of the calculated total toxic load during both events.

Six additional pesticides (excluding total atrazine and total diuron) were detected at the Mulgrave River during Event 1, with only three of these pesticides detected during Event 2 (Table 7.11). The largest load of

2,4-D was monitored during Event 1 (4.6 kg), which was approximately three times greater than the load of 2,4-D (1.7 kg) during Event 2. The loads of MCPA (1.4 kg and 1.3 kg, respectively) and imidacloprid (1.3 kg and 1.4 kg, respectively) were similar across both events. Metribuzin, fluroxypyr and triclopyr were only detected in Event 1 with monitored loads of 0.78 kg, 2.8 kg and 1.6 kg, respectively (Table 7.11).

Table 7.9 Defined high flow event periods, sample coverage and monitored total suspended solids and nutrient event loads for the Mulgrave River and Russell River.

River and site name	Event number	Event start date and time	Event finish data and time	Event duration (days)	n	Discharge (ML)	TSS (t)	TN (t)	DON (t)	PN (t)	DIN (t)	NH4 (t)	NOx (t)	TP (t)	PP (t)	DOP (t)	DIP (t)
Mulgrave River at Deeral	1 [L]	19/3/2014 00:00	29/03/2014 00:00	10	32	120,000	3600	40	13	11	8.2	1.1	7.1	5.4	4.1	1.3	0.61
	2 [L]	10/04/2014 00:00	18/04/2014 00:00	8	23	250,000	17,000	120	36	64	14	3.0	11	14	12	2.5	1.7
	3 [B]	13/05/204 00:00	24/05/2014 00:00	12	10	65,000	1300	13	2.1	4.1	5.7	0.49	5.2	0.98	0.77	0.61	0.25
	4 [B]	07/06/2014 00:00	19/06/2014 00:00	12	4	83,000	600	19	7.2	2.1	9.5	0.63	8.9	0.95	0.83	0.83	0.33
Russell River at East Russell	1 [B]	19/03/2014 00:00	31/03/2014 00:00	12	21	190,000	1900	45	17	10	19	1.5	17	4.7	4.3	1.9	0.90
	2 [L]	10/04/2014 00:00	21/04/2014 00:00	11	21	160,000	2800	39	17	2.2	9.9	1.2	8.7	4.7	1.5	1.5	0.29
	3 [B]	14/05/2014 00:00	28/05/2014 00:00	14	13	160,000	2900	35	4.1	11	19	0.97	18	2.9	1.6	1.6	0.39
	4 [B]	09/06/2014 00:00	21/06/2014 00:00	12	3	91,000	1500	30	11	4.8	12	3.1	8.5	2.8	1.9	0.91	0.11

[L] = average load (linear interpolation of concentration) method used to calculate loads; [B] = Beale ratio method used to calculate loads

Table 7.10 Defined high flow event periods, sample coverage and monitored event loads and total toxic-equivalent load calculated for the five photosystem II inhibiting herbicides: ametryn, total atrazine, total diuron, hexazinone and tebuthiuron for the Mulgrave River and Russell River.

River and site name	Event number	Event start date and time	Event finish data and time	Event duration (days)	n	Discharge (ML)	Ametryn mass load (kg)	Total Atrazine mass load (kg)	Total Diuron mass load (kg)	Hexazinone mass load (kg)	Tebuthiuron mass load (kg)	Total Toxic Load (diuron – equivalent kg)
Mulgrave River at Deeral	1 [L]	19/3/2014 00:00	29/03/2014 00:00	10	28	120,000	NC	2.6	2.0	0.67	NC	2.2
	2 [L]	10/04/2014 00:00	18/04/2014 00:00	8	21	250,000	NC	1.4	3.0	1.3	NC	3.3
	3 [B]	13/05/204 00:00	24/05/2014 00:00	11	10	65,000	NC	NC	NC	NC	NC	NC
	4 [B]	07/06/2014 00:00	19/06/2014 00:00	12	4	83,000	NC	NC	NC	NC	NC	NC
Russell River at East Russell	1 [B]	19/03/2014 00:00	02/04/2014 00:00	14	20	190,000	NC	4.7	13	5.6	NC	14
	2 [L]	10/04/2014 00:00	22/04/2014 00:00	12	19	160,000	NC	0.80	3.6	1.6	NC	4.0
	3 [B]	11/05/2014 00:00	29/05/2014 00:00	18	13	160,000	NC	NC	1.9	1.5	NC	2.2
	4 [B]	07/06/2014 00:00	20/06/2014 00:00	13	4	91,000	NC	NC	0.67	0.57	NC	0.79

[L] = average load (linear interpolation of concentration) method used to calculate loads; [B] = Beale ratio method used to calculate loads

Table 7.11 Defined high flow event periods, sample coverage and monitored event loads calculated for the additional pesticides: 2,4-D, MCPA, metribuzin, fluroxypyr, tricopyr, imidacloprid and metsulfuron-methyl for the Mulgrave River and Russell River.

River and site name	Event number	Event start date	Event finish date	Event duration (days)	n	Discharge (ML)	2,4-D (kg)	MCPA (kg)	Metribuzin (kg)	Fluroxypyr (kg)	Triclopyr (kg)	Imidacloprid (kg)	Metsulfuron -methyl (kg)	Atrazine (kg)	Diuron (kg)
Mulgrave River at Deeral	1 [L]	19/3/2014 00:00	29/03/2014 00:00	10	28	120,000	4.6	1.4	0.78	2.8	1.6	1.3	NC	2.6	2
	2 [L]	10/04/2014 00:00	18/04/2014 00:00	8	21	250,000	1.7	1.3	NC	NC	NC	1.4	NC	1.4	3
	3 [B]	13/05/204 00:00	24/05/2014 00:00	11	10	65,000	NC	NC	NC	NC	NC	0.38	NC	NC	NC
	4 [B]	07/06/2014 00:00	19/06/2014 00:00	12	4	83,000	NC	NC	NC	NC	NC	NC	NC	NC	NC
Russell River at East Russell	1 [B]	19/03/2014 00:00	02/04/2014 00:00	14	20	190,000	4.0	1.1	1.1	3.8	NC	3.6	0.94	4.7	13
	2 [L]	10/04/2014 00:00	22/04/2014 00:00	12	19	160,000	0.90	NC	NC	NC	NC	3.5	NC	0.8	3.6
	3 [B]	11/05/2014 00:00	29/05/2014 00:00	18	13	160,000	0.84	NC	NC	NC	NC	6.4	NC	NC	1.9
	4 [B]	07/06/2014 00:00	20/06/2014 00:00	13	4	91,000	0.46	NC	NC	NC	NC	1.8	NC	NC	0.67

[L] = average load (linear interpolation of concentration) method used to calculate loads; [B] = Beale ratio method used to calculate loads

Appendix E Hydrograph plots of discharge and sample collection points

Figures in Appendix E are presented in the order of the location of the catchment from north to south.

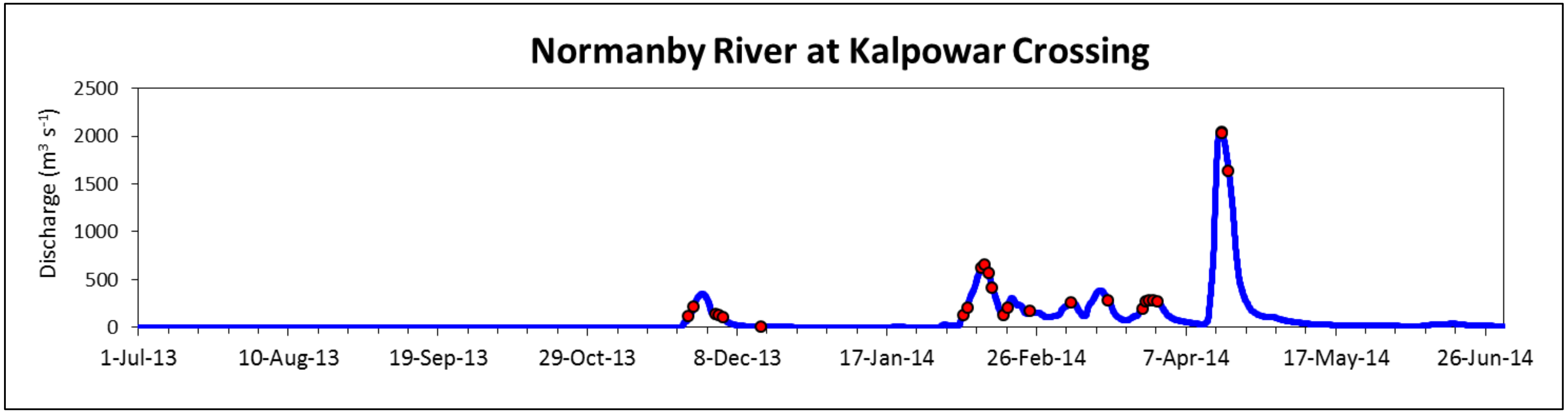

Figure 7.1 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Normanby River at Kalpowar Crossing between 1 July 2013 and 30 June 2014. Representivity rating was good for all analytes.

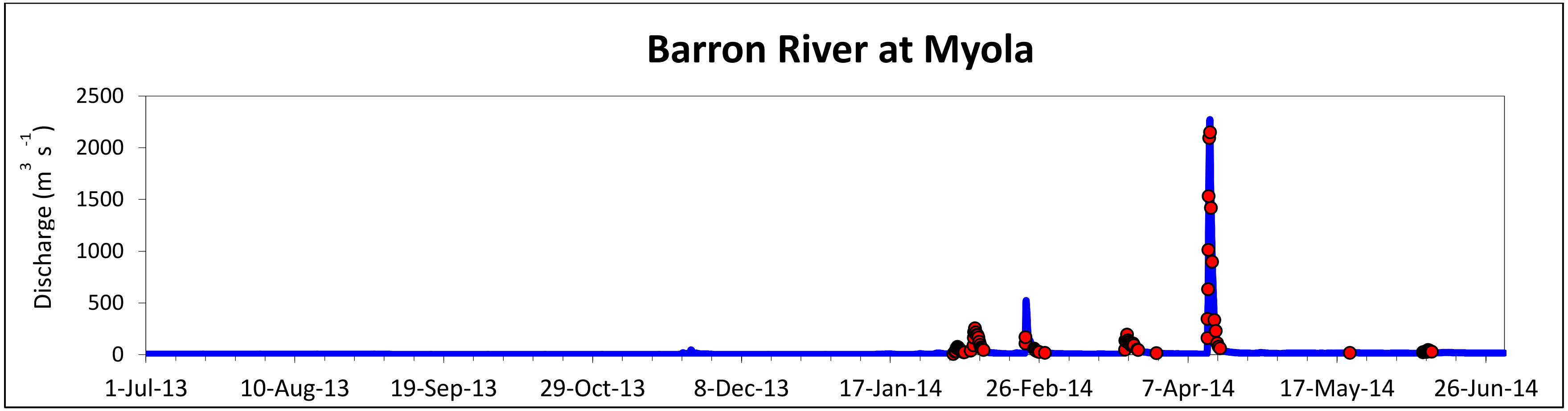

Figure 7.2 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Barron River at Myola between 1 July 2013 and 30 June 2014. Representivity rating was excellent for all analytes.

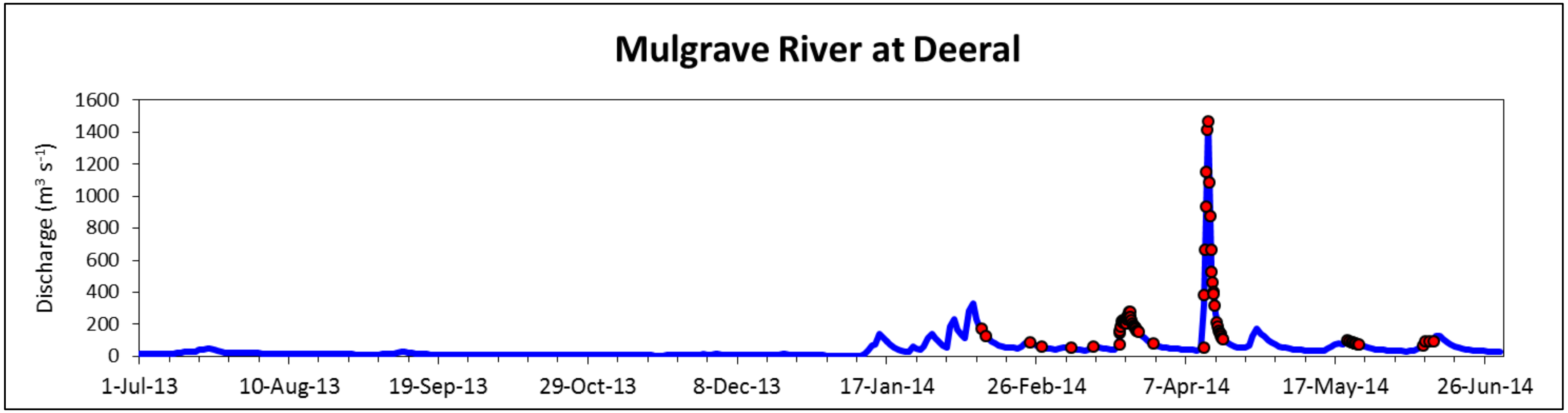

Figure 7.3 Hydrograph showing modelled discharge (blue line) (Appendix D) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients and five photosystem II inhibiting herbicides (red circles) in the Mulgrave River at Deeral between 1 July 2013 and 30 June 2014. Representivity rating was not evaluated for this site considering sampling only started in February 2014.

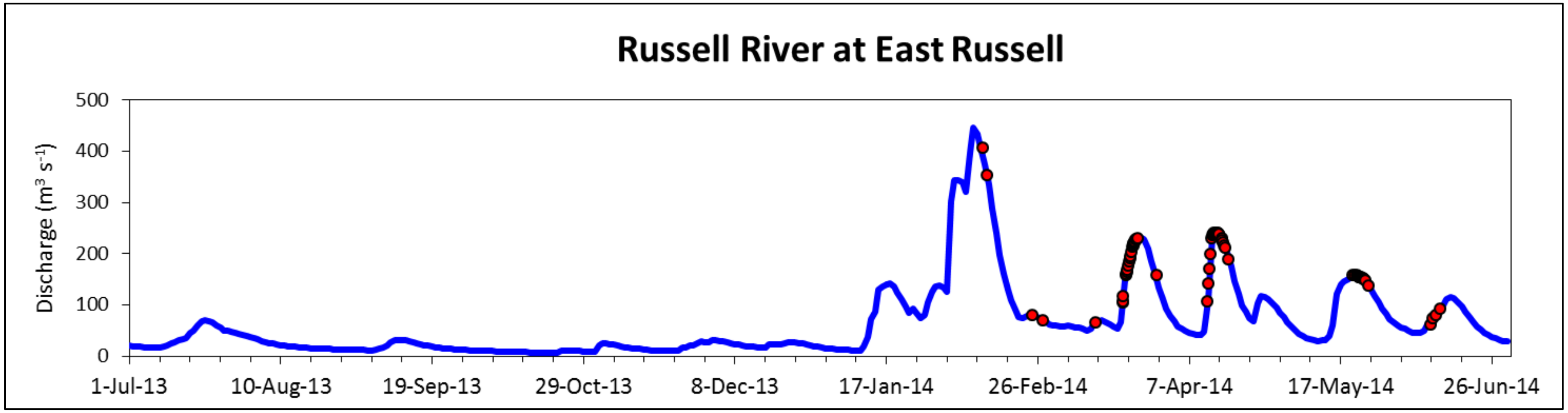

Figure 7.4 Hydrograph showing modelled discharge (blue line) (Appendix D) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Russell River at East Russell between 1 July 2013 and 30 June 2014. Representivity rating was not evaluated for this site considering sampling only started in February 2014.

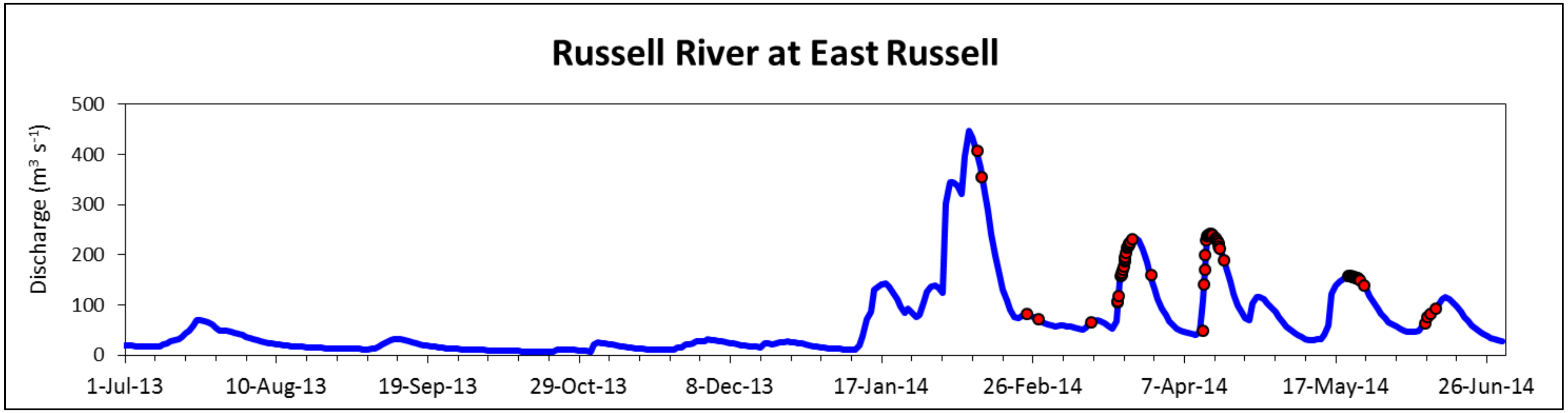

Figure 7.5 Hydrograph showing modelled discharge (blue line) (Appendix D) and sample coverage for five photosystem II inhibiting herbicides (red circles) in the Russell River at East Russell between 1 July 2013 and 30 June 2014. Sample representivity was not assessed for pesticides.

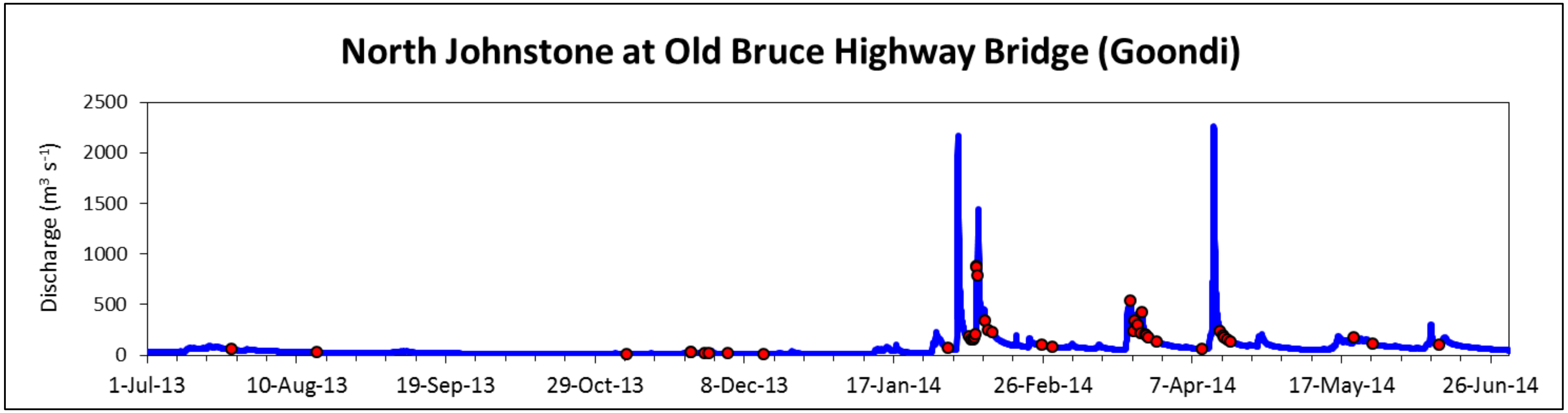

Figure 7.6 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients and five photosystem II inhibiting herbicides (red circles) in the North Johnstone River at Old Bruce Highway Bridge (Goondi) between 1 July 2013 and 30 June 2014. Representivity rating was moderate for all analytes. Sample representivity was not assessed for pesticides.

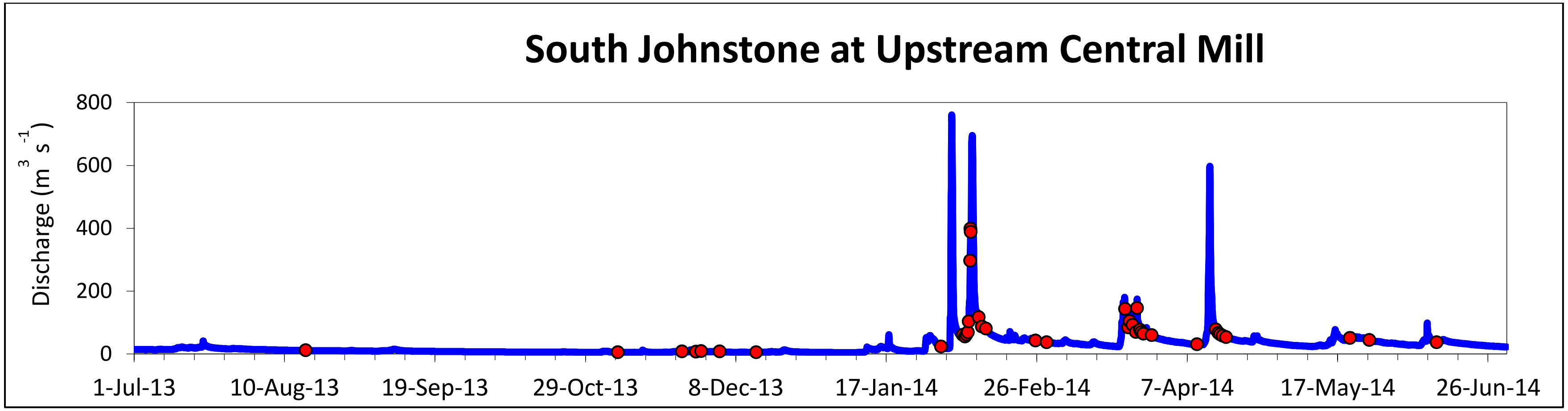

Figure 7.7 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the South Johnstone River at Upstream Central Mill between 1 July 2013 and 30 June 2014. Representivity rating was moderate for all analytes.

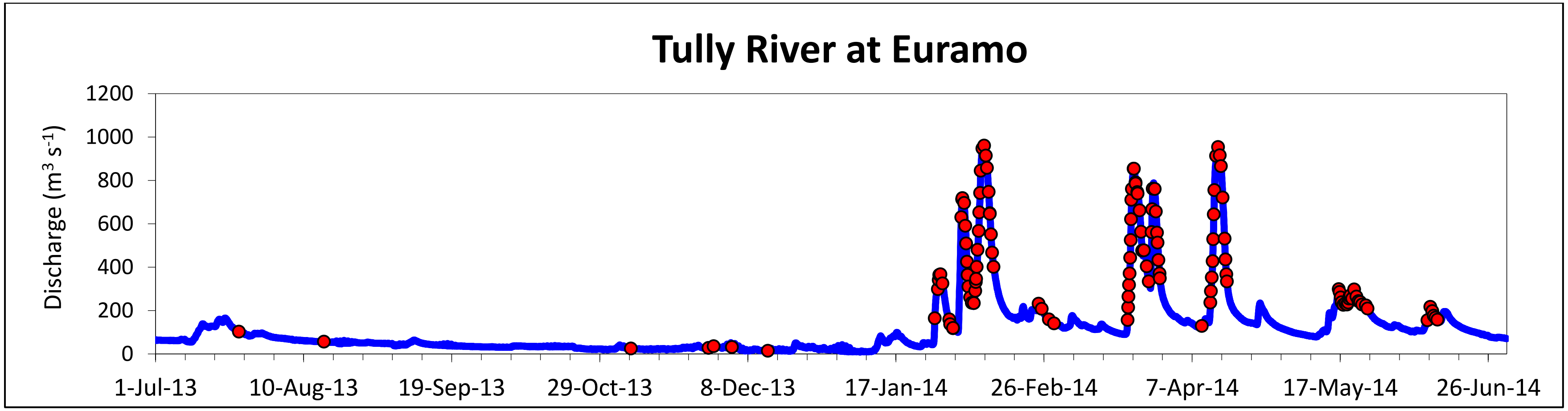

Figure 7.8 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Tully River at Euramo between 1 July 2013 and 30 June 2014. Representivity rating was excellent for all analytes.

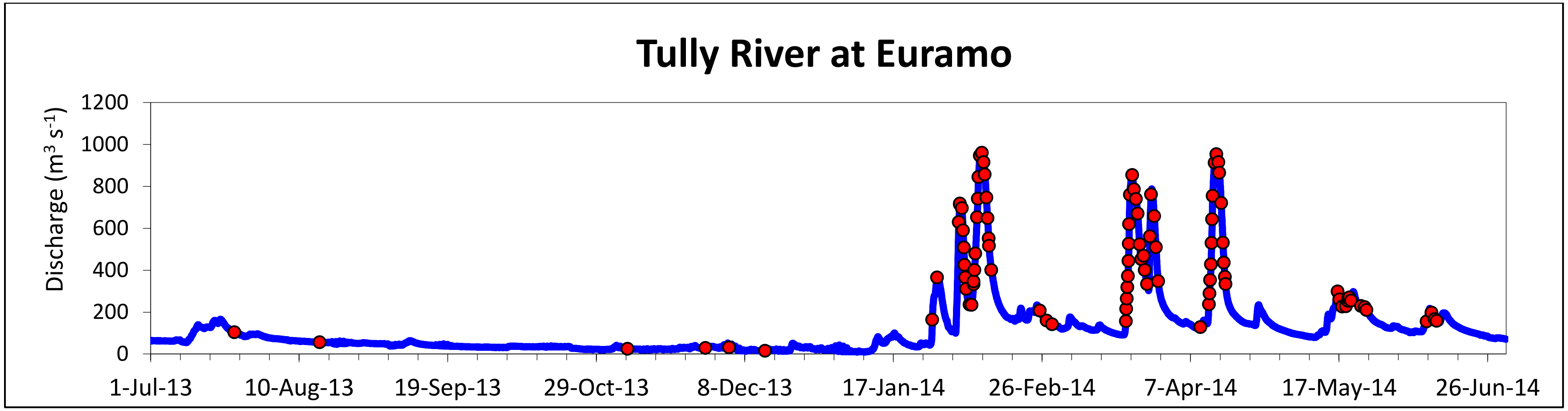

Figure 7.9 Hydrograph showing discharge (blue line) and sample coverage for five photosysterm II inhibiting herbicides (red circles) in the Tully River at Euramo between 1 July 2013 and 30 June 2014. Sample representivity was not assessed for pesticides.

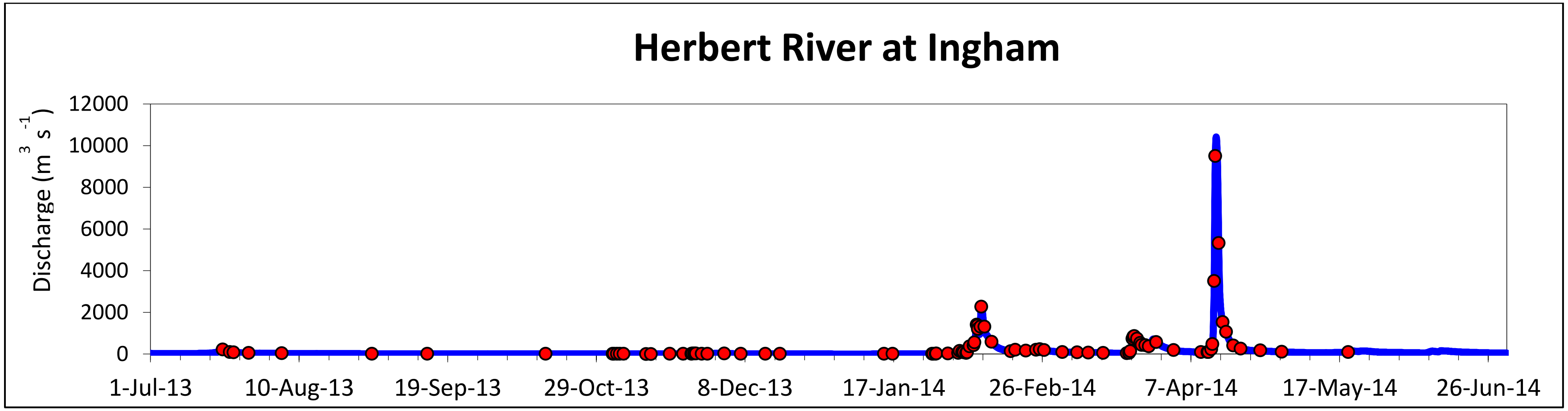

Figure 7.10 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients and five photosystem II inhibiting herbicides (red circles) in the Herbert River at Ingham between 1 July 2013 and 30 June 2014. Representivity rating was excellent for all analytes. Sample representivity was not assessed for pesticides.

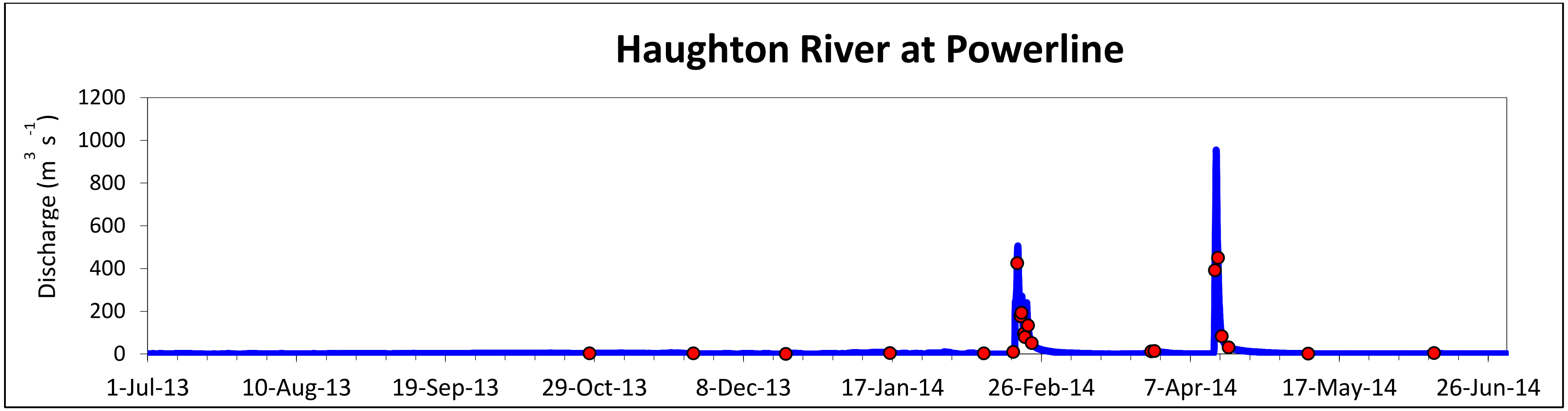

Figure 7.11 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Haughton River at Powerline between 1 July 2013 and 30 June 2014. Representivity rating was moderate for all analytes.

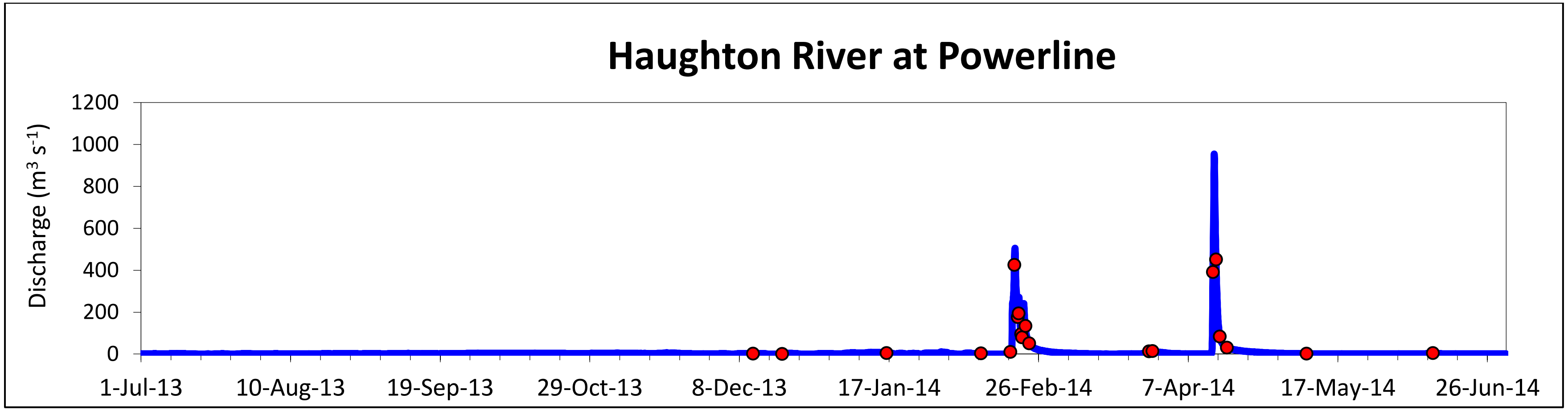

Figure 7.12 Hydrograph showing discharge (blue line) and sample coverage for five photosystem II inhibiting herbicides (red circles) in the Haughton River at Powerline between 1 July 2013 and 30 June 2014. Sample representivity was not assessed for pesticides.

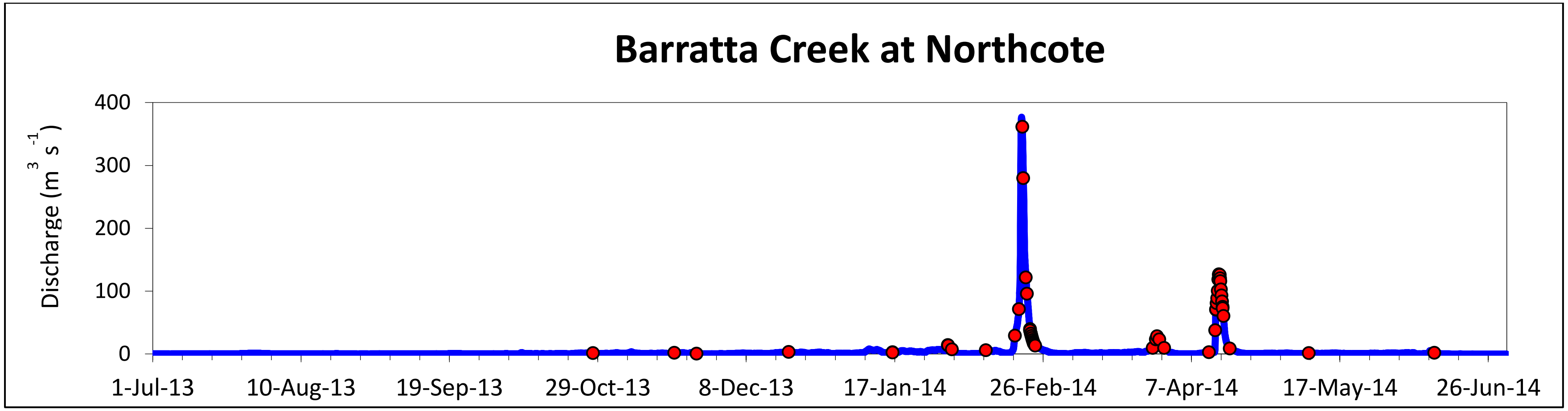

Figure 7.13 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients sample coverage (red circles) in Barratta Creek at Northcote between 1 July 2013 and 30 June 2014. Representivity rating was excellent for all analytes.

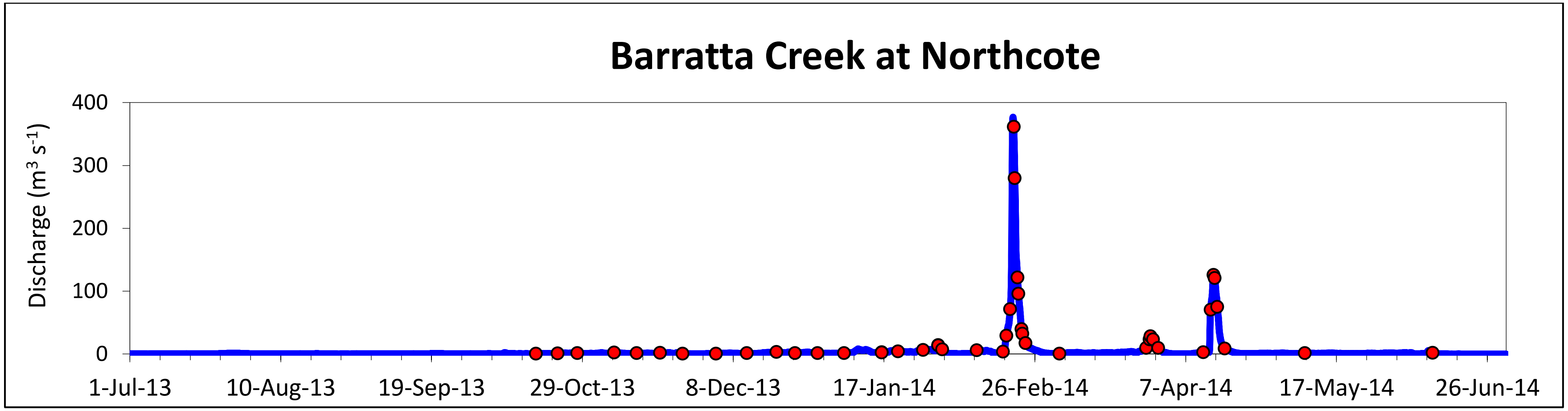

Figure 7.14 Hydrograph showing discharge (blue line) and sample coverage for five photosystem II inhibiting herbicides (red circles) in Barratta Creek at Northcote between 1 July 2013 and 30 June 2014. Sample representivity was not assessed for pesticides.

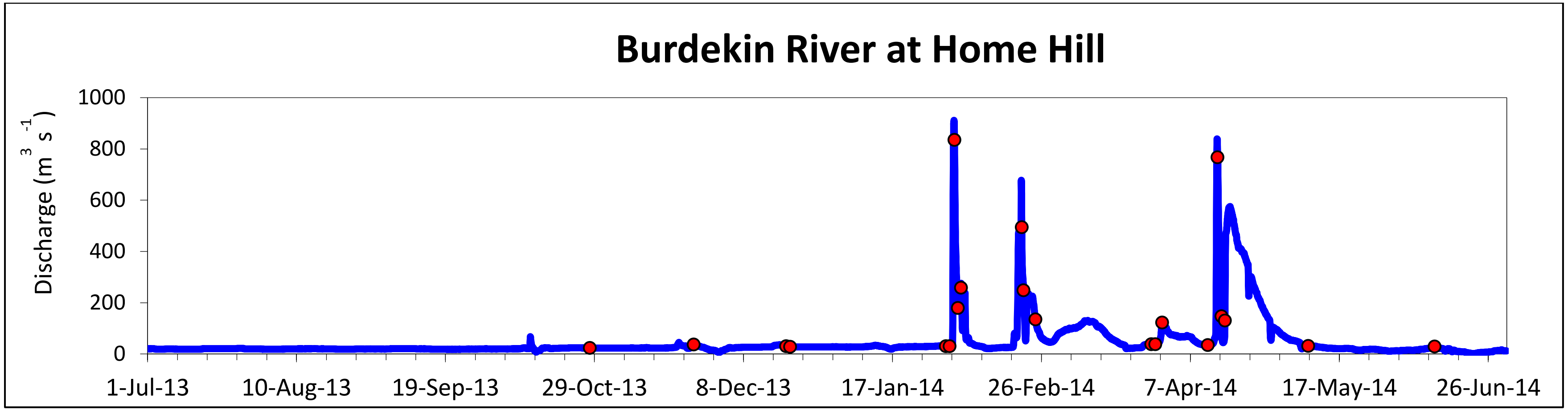

Figure 7.15 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Burdekin River at Home Hill between 1 July 2013 and 30 June 2014. Representivity rating was good for all analytes.

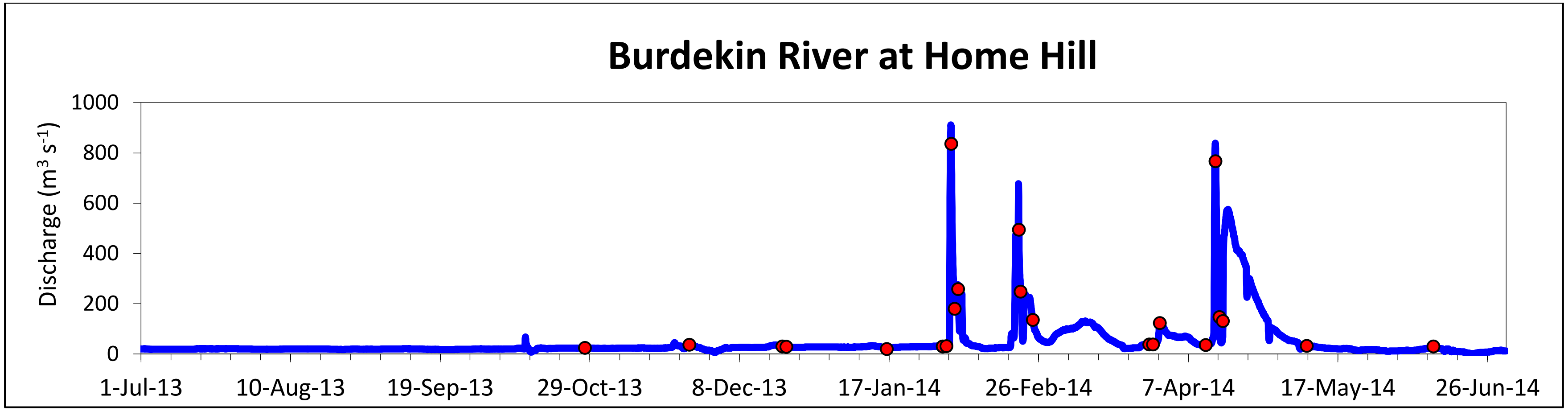

Figure 7.16 Hydrograph showing discharge (blue line) and photosystem II inhibiting herbicide sample coverage (red circles) in the Burdekin River at Home Hill between 1 July 2013 and 30 June 2014. Sample representivity was not assessed for pesticides.

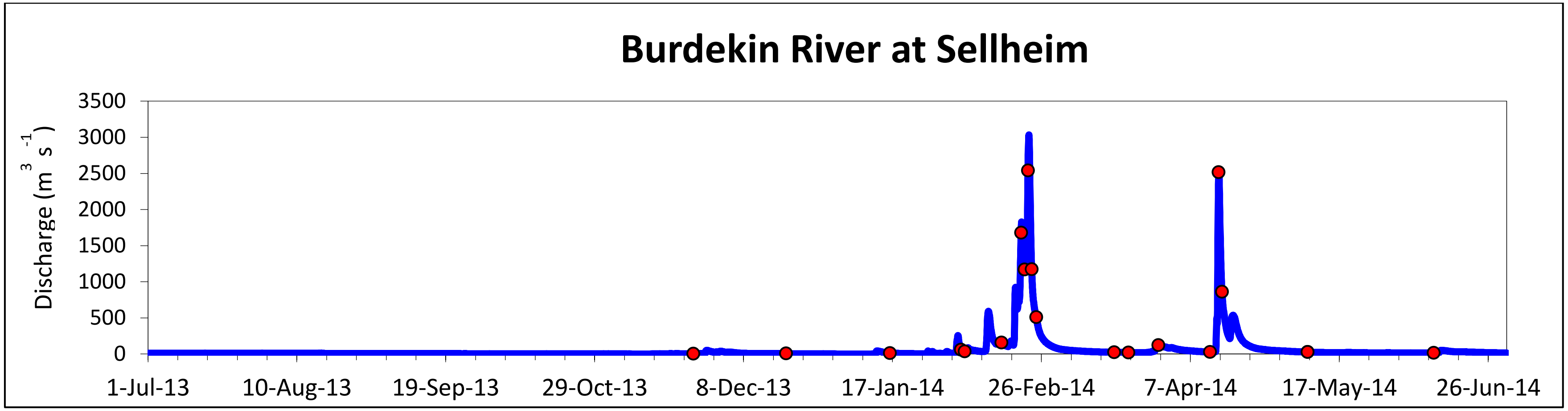

Figure 7.17 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Burdekin River at Sellheim between 1 July 2013 and 30 June 2014. Representivity rating was good for all analytes.

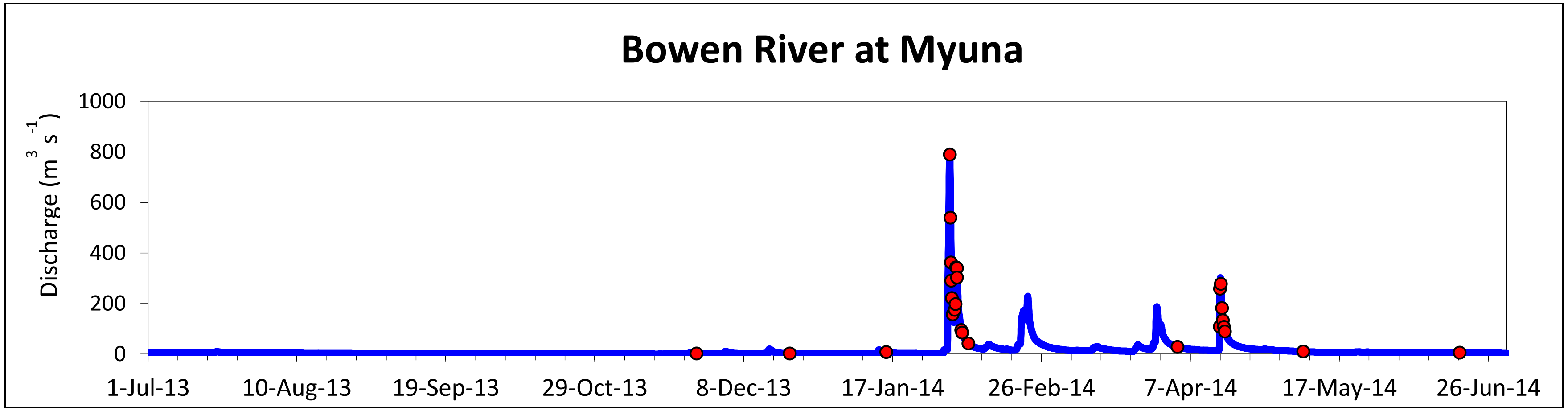

Figure 7.18 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Bowen River at Myuna between 1 July 2013 and 30 June 2014. Representivity rating was good or excellent for all analytes.

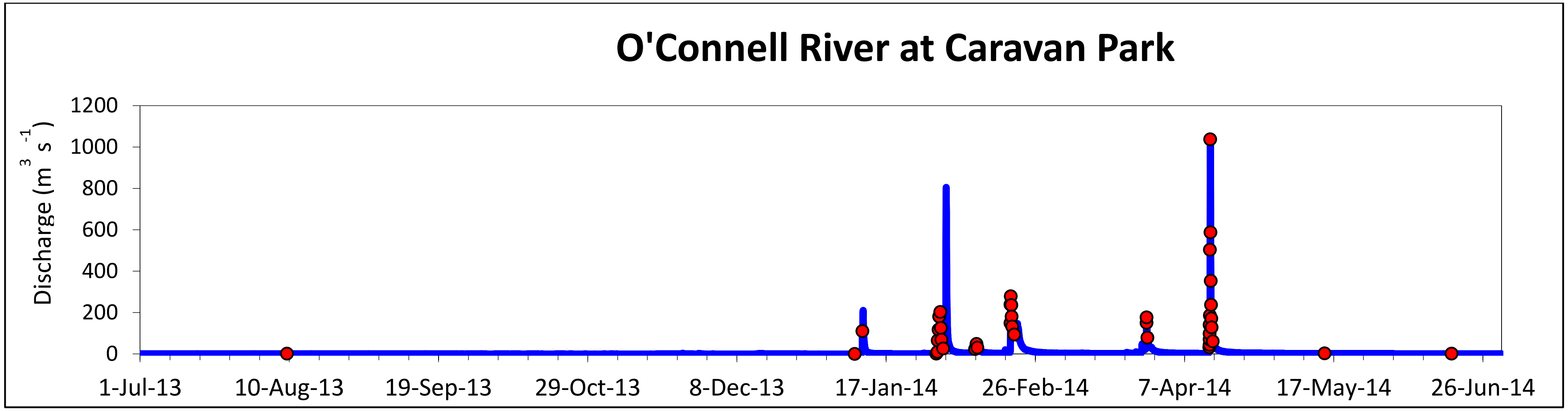

Figure 7.19 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients and and photosystem II inhibiting herbicide sample coverage (red circles) in the O'Connell River at Caravan Park between 1 July 2013 and 30 June 2014. Representivity rating was moderate for total suspended solids and good for the other analytes. Sample representivity was not assessed for pesticides.

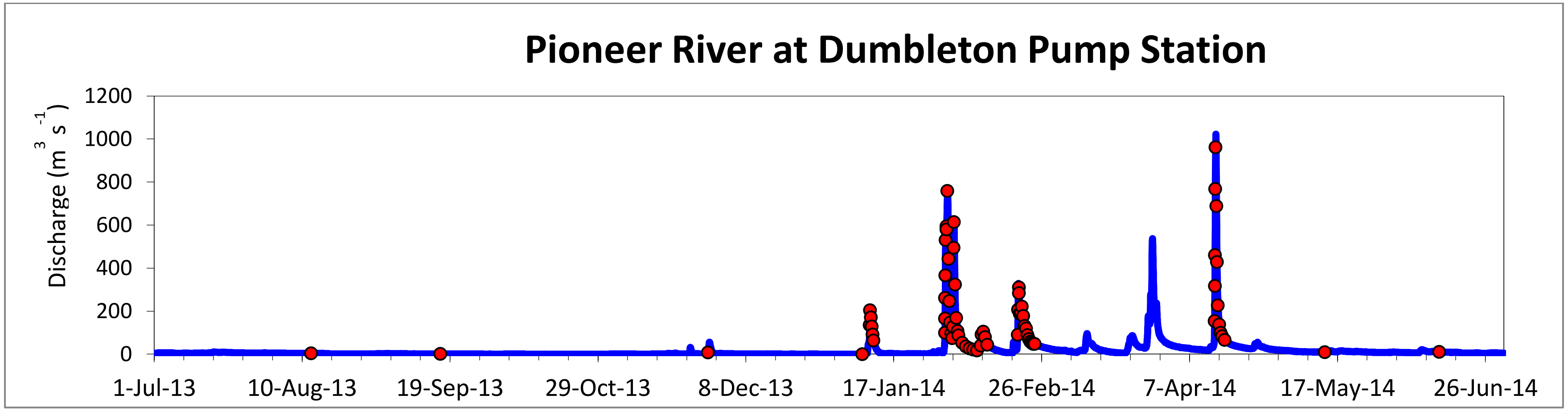

Figure 7.20 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Pioneer River at Dumbleton Pump Station between 1 July 2013 and 30 June 2014. Representivity rating was excellent for all analytes.

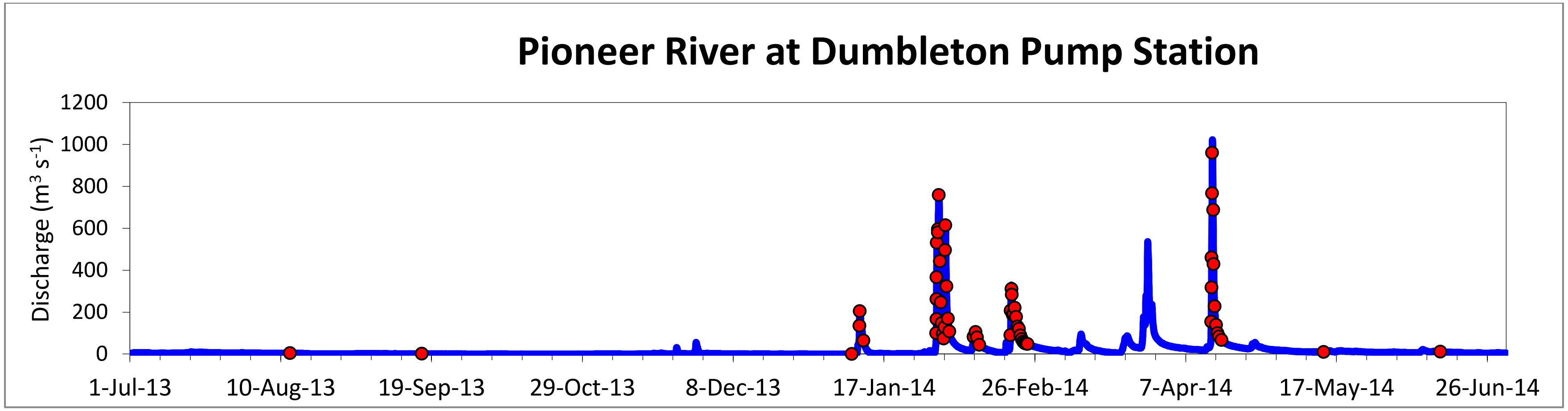

Figure 7.21 Hydrograph showing discharge (blue line) and photosystem II inhibiting herbicide sample coverage (red circles) in the Pioneer River at Dumbleton Pump Station between 1 July 2013 and 30 June 2014. Sample representivity was not assessed for pesticides.

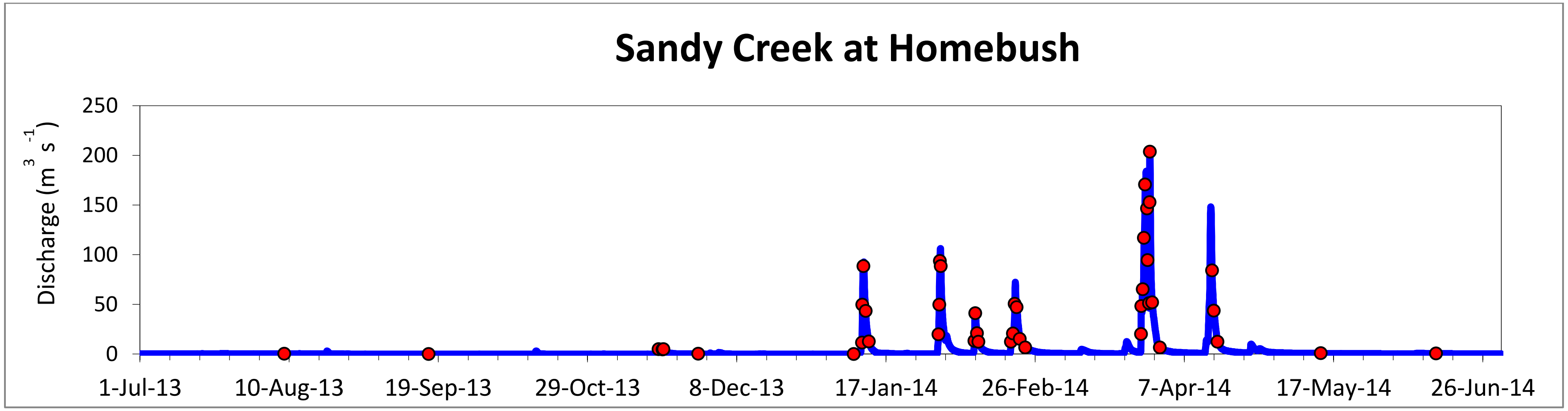

Figure 7.22 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in Sandy Creek at Homebush between 1 July 2013 and 30 June 2014. Representivity rating was excellent for all analytes.

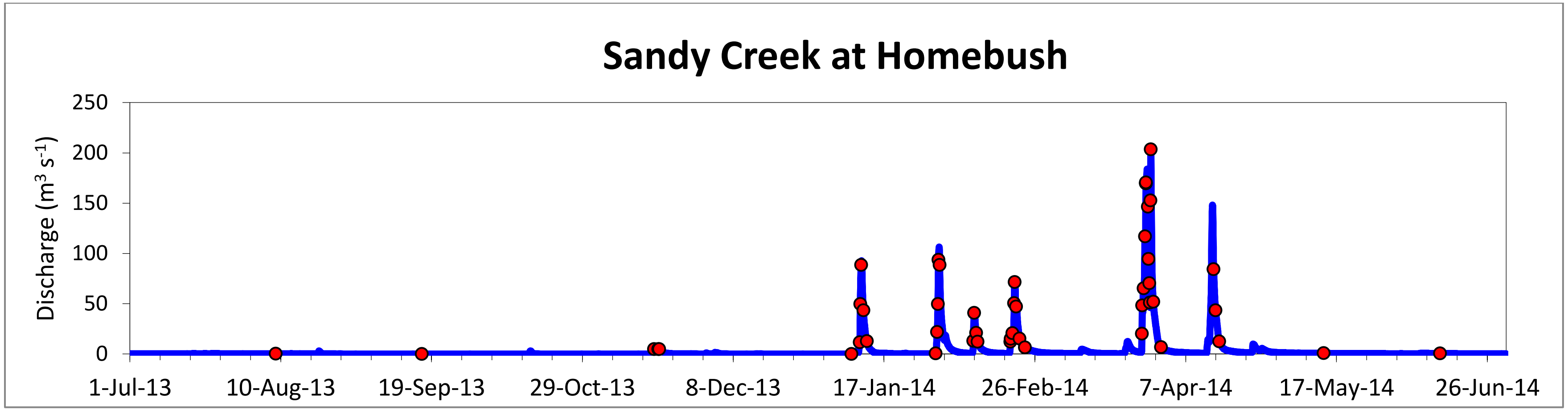

Figure 7.23 Hydrograph showing discharge (blue line) and photosystem II inhibiting herbicide sample coverage (red circles) in Sandy Creek at Homebush between 1 July 2013 and 30 June 2014. Sample representivity was not assessed for pesticides.

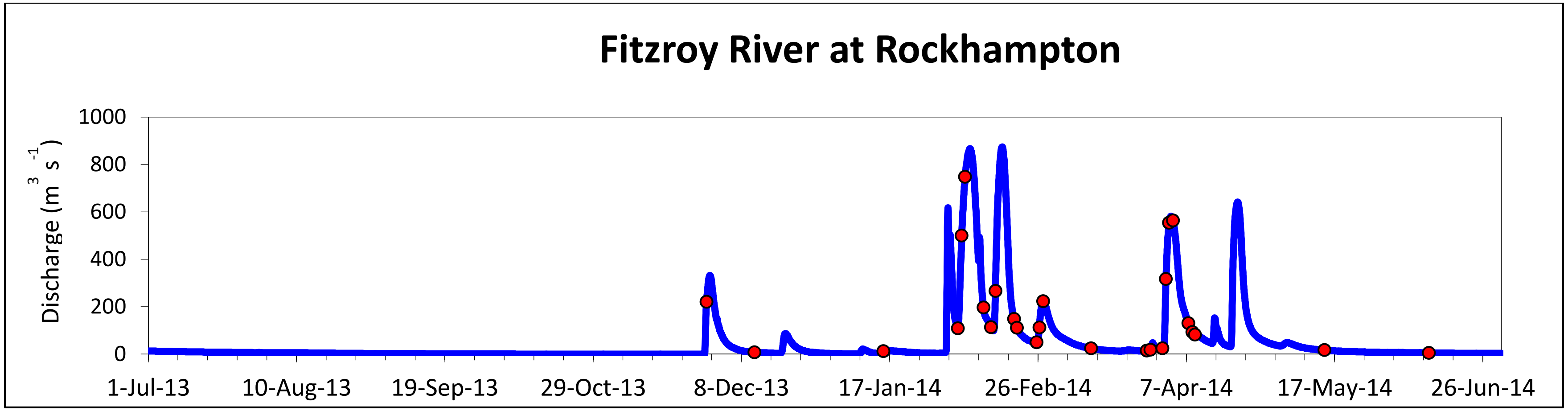

Figure 7.24 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Fitzroy River at Rockhampton between 1 July 2013 and 30 June 2014. Representivity rating was good for all analytes.

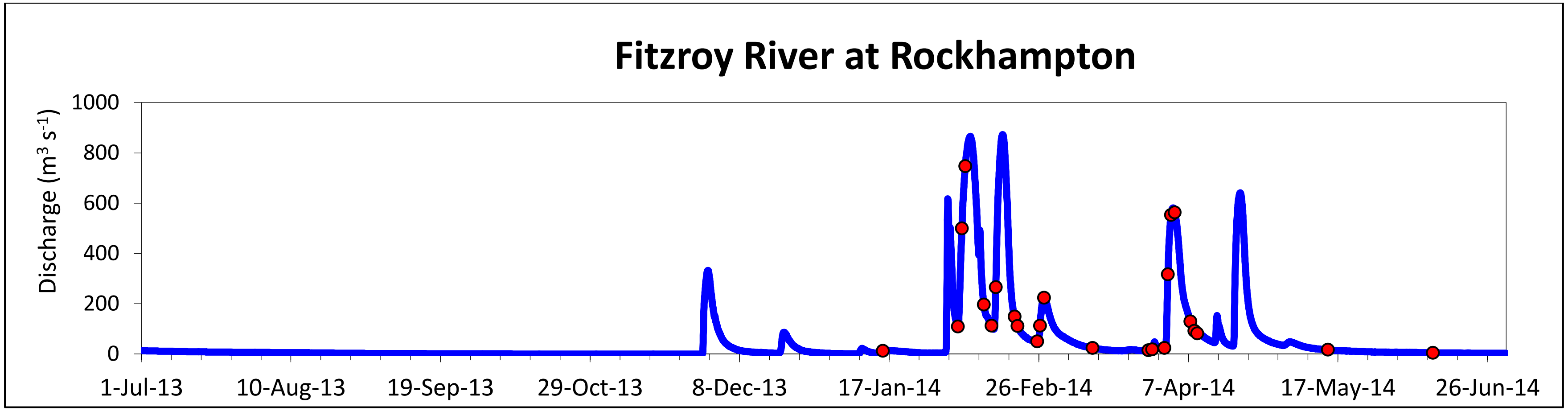

Figure 7.25 Hydrograph showing discharge (blue line) and photosystem II inhibiting herbicide sample coverage (red circles) in the Fitzroy River at Rockhampton between 1 July 2013 and 30 June 2014. Sample representivity was not assessed for pesticides.

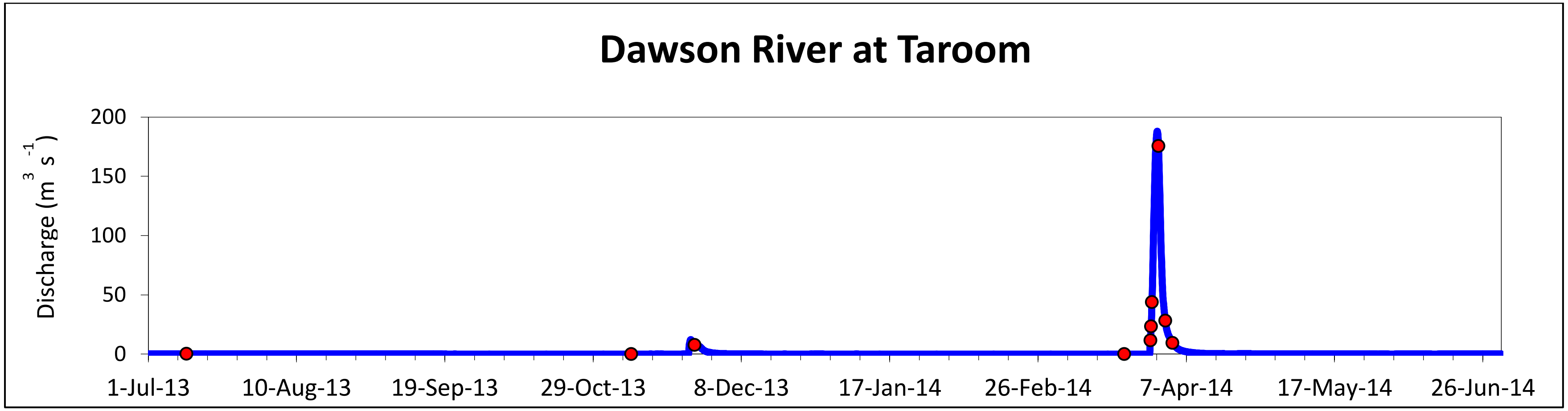

Figure 7.26 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Dawson River at Taroom between 1 July 2013 and 30 June 2014. Representivity rating was good for all analytes.

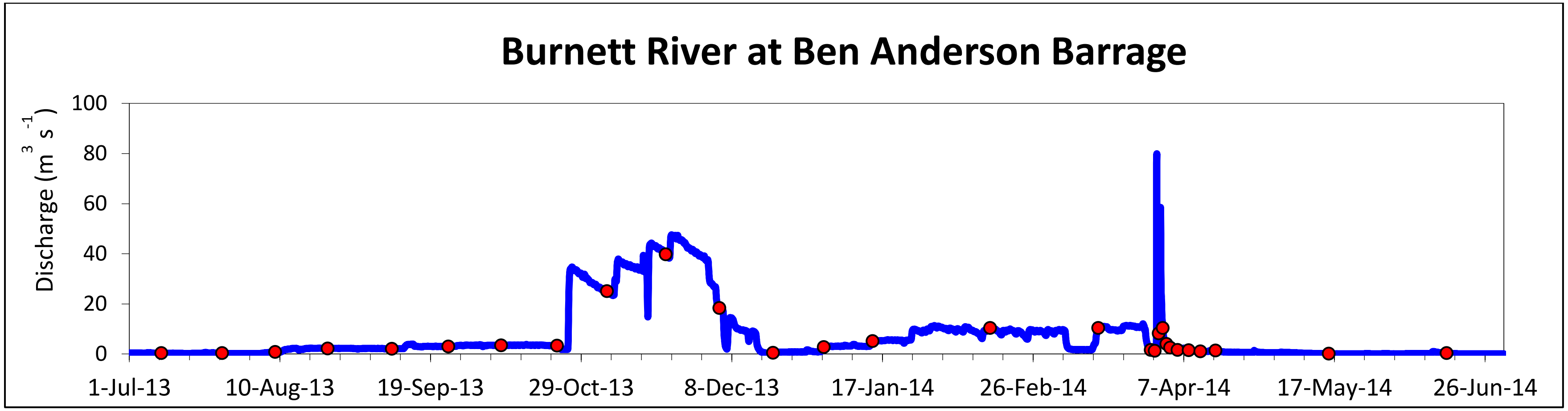

Figure 7.27 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Burnett River at Ben Anderson Barrage Head Water between 1 July 2013 and 30 June 2014. Representivity rating was not estimated for this site because of the low discharge present.

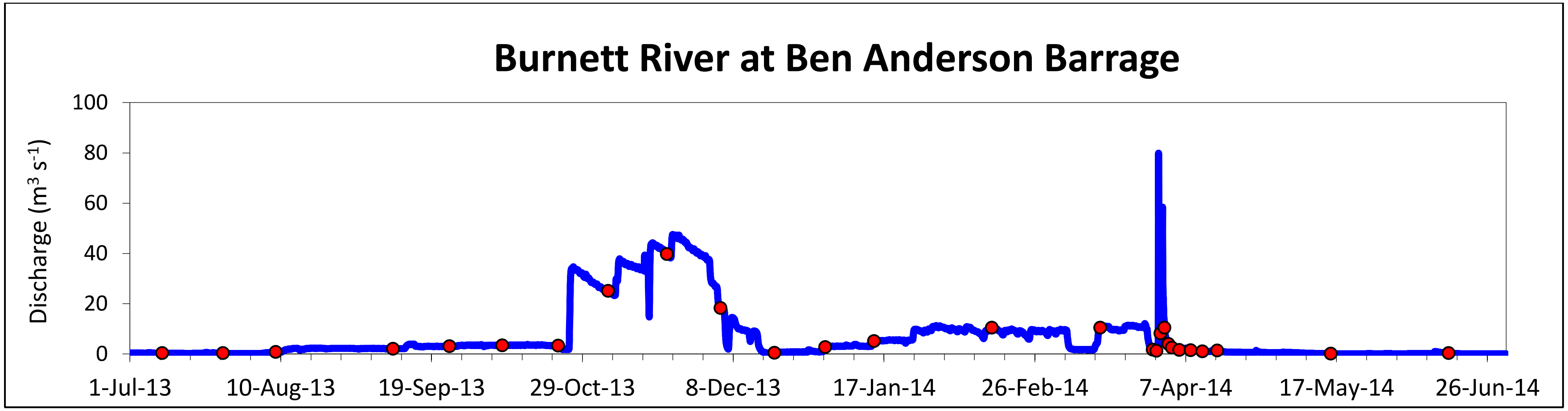

Figure 7.28 Hydrograph showing discharge (blue line) and photosystem II inhibiting herbicide sample coverage (red circles) in the Burnett River at Ben Anderson Barrage Head Water between 1 July 2013 and 30 June 2014. Sample representivity was not assessed for pesticides.

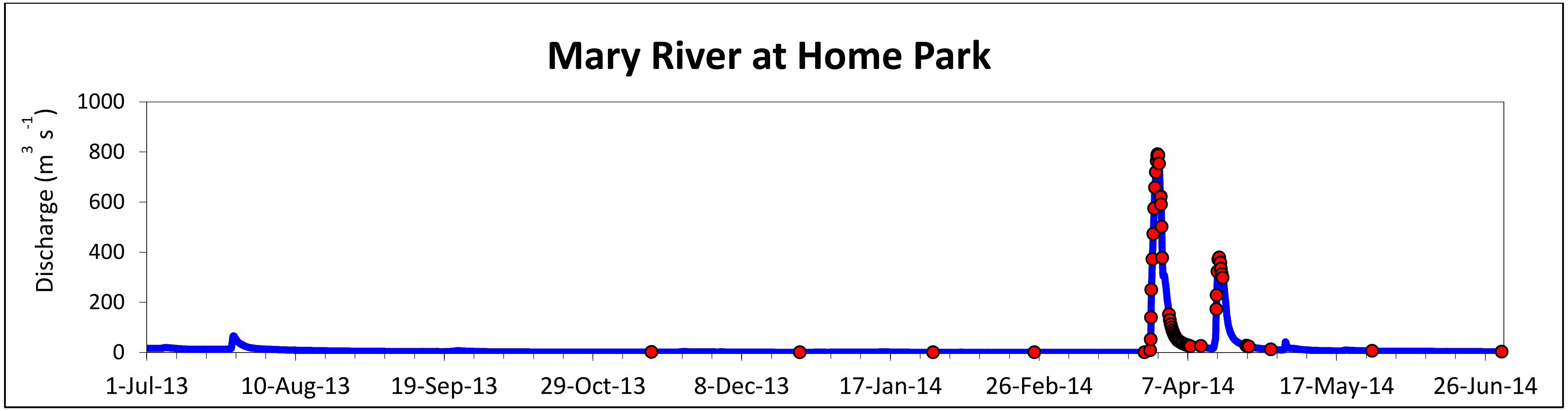

Figure 7.29 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Mary River at Home Park between 1 July 2013 and 30 June 2014. Representivity rating was excellent for all analytes.

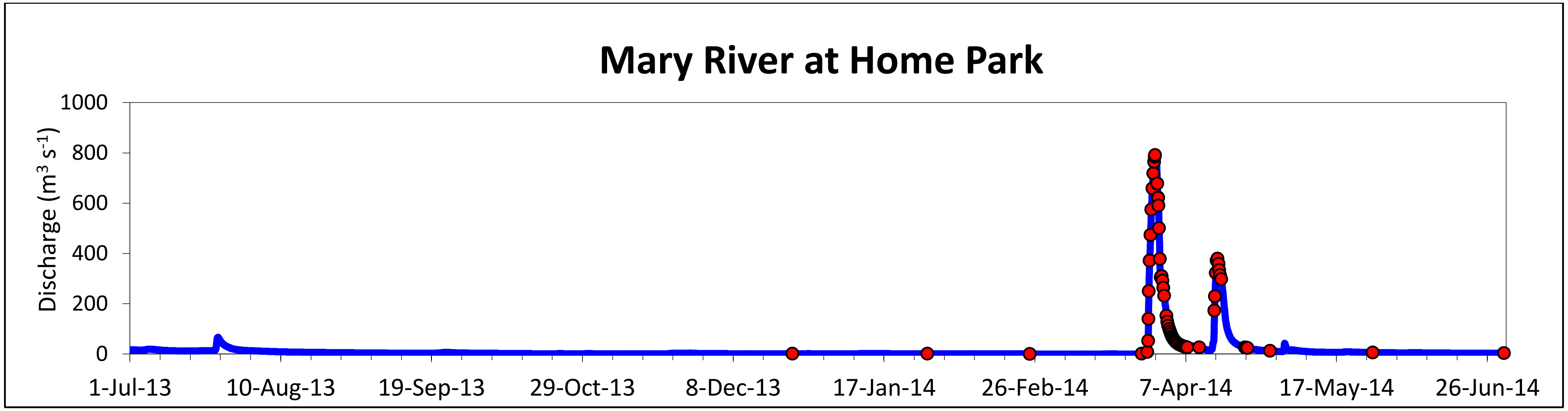

Figure 7.30 Hydrograph showing discharge (blue line) and photosystem II inhibiting herbicide sample coverage (red circles) in the Mary River at Home Park between 1 July 2013 and 30 June 2014. Sample representivity was not assessed for pesticides.

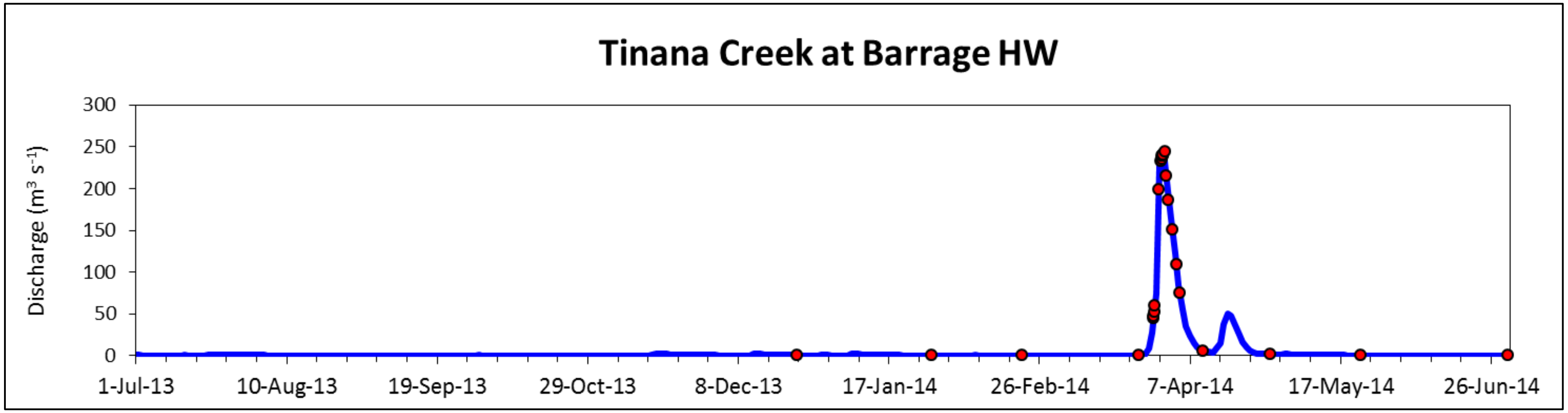

Figure 7.31 Hydrograph showing modelled discharge (blue line) (Section 2.6) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients and photosystem II inhibiting herbicide sample coverage (red circles) in Tinana Creek at Barrage Head Water between 1 July 2013 and 30 June 2014. Sample representivity was not assessed for this site.

Appendix F Monthly rainfall summary during 2013–2014

Rainfall in the Wet Tropics region was above average in July 2013 (BoM 2013a). Districts to the south of Townsville received mostly patchy, below average rainfall during July 2013 (BoM 2013a).

There was almost no rain during August 2013 in Queensland, which is usual for the tropical north but less usual for the southern part of the state. The latter received below average to very much below average rainfall in August (BoM 2013b).

During September 2013 small parts of the Cape York region received above average rainfall (BoM 2013c). The rest of the priority reef catchments received below average to very much below average rainfall during this month (BoM 2013c).

The trend for below average to very much below average rainfall continued during October 2013 for most of the priority reef catchments (BoM 2013d), except for the Normanby catchment, where coastal showers towards the end of the month caused average to above average rainfall in this area (BoM 2013d).

During November 2013 the majority of the priority reef catchments received from average to above average rainfall. The Normanby catchment and some areas of the Fitzroy catchment received very much above average rainfall and some areas in the latter registered the highest November rainfall on record (BoM 2013e). The first flush of the wet season occurred during November in the Normanby and Fitzroy river catchments.

During December 2013 rainfall was from below average to very much below average for most of the priority reef catchments (BoM 2014c). In fact, Queensland received the third-lowest December total on record since 1900 (BoM 2014c).

During January 2014 Tropical Cyclone Dylan made landfall to the east of Bowen (January 31). Tropical Cyclone Dylan weakened to a tropical low and continued to move inland bringing between 100 to 200 mm of rain across the Pioneer catchment where the first high flow events of the season occurred, and the northern sub-catchments of the Fitzroy River (BoM 2014d). Despite some locally heavy rainfalls, January total rainfall in the priority reef catchments was from average to very much below average, with the lowest relative rainfall occurring in the Herbert, Fitzroy, Burnett and Mary river catchments (BoM 2014d).

During the beginning of February 2014 Ex-Tropical Cyclone Dylan and the monsoon through caused isolated moderate to heavy rainfall in the coastal areas of the Mackay Whitsunday region and in the O'Connell catchment (BoM 2014e). Most of the priority reef catchments received average rainfall with some areas of the Cape York and Wet Tropics regions having above average rainfall (BoM 2014e). The Burnett Mary region received below average to very much below average rainfall during February 2014 (BoM 2014e).

In March 2014 most of the priority reef catchment areas received average rainfall with only some areas of the Mackay Whitsunday region and the Cape York and Fitzroy River catchments receiving above average rainfall (BoM 2014f). The Burnett Mary region received from above average to very much above average rainfall during March (BoM 2014f). The first high flow event of the year occurred during March in the Mary River.

During April 2014 deviation from average monthly rainfall only occurred in the Wet Tropic region and the upper Burdekin River, which had below average to very much below average rainfall, and in some areas of the Fitzroy catchment, which had above average rainfall (BoM 2014g). Rainfall associated with Tropical Cyclone Ita, which made landfall on 11 April 2014 as a category 4 system near Cooktown in the Cape York region, caused 24 hour rainfall in excess of 300 mm in many areas of the Cape York and Wet Tropics natural resource management regions. This resulted in the largest event during the 2013–2014 monitoring year in the Normanby, Barron, Mulgrave, North Johnstone, Herbert, Haughton, O'Connell and Pioneer rivers and major flooding in the Normanby, Barron and Herbert rivers.

In May 2014 a persistent high-pressure system brought onshore easterly winds over coastal Queensland, causing wet conditions in some areas of the central and northern Queensland coast (BoM 2014f). Despite these conditions, most of the priority reef catchments had average to below average rainfall, except for catchments in the Wet Tropics region, which had above average rainfall (BoM 2014h).

During June 2014 the Normanby River catchment had very much above average rainfall, catchments in the Wet Tropics region had from average to above average rainfall, the Burdekin River catchment and most of the Fitzroy River catchment had average rainfall, and some areas of the Fitzroy River catchment and the Burnett and Mary river catchments had below average rainfall (BoM 2014i).

Appendix G Representivity rating of all monitored annual total suspended solids and nutrient loads

Table 7.12 The number of samples collected and the representivity rating for monitored sites in 2013–2014. Text in bold are end-of-system sites and the corresponding data, all others are sub-catchment sites. Green shading = excellent or good representivity rating; orange shading = moderate representivity; red shading = indicative representivity; grey shading = no representivity calculated; and black shading = no loads calculated.

NRM region	Catchment	Gauging station	River and site name	TSS		TN		PN		NO_x-N		NH_4-N		DIN	
				n	Rating	n	Rating	n	Rating	n	Rating	n	Rating	n	Rating
Cape York	Normanby	**105107A[B]**	**Normanby River at Kalpowar Crossing**	**27**	**good**	**26**	**good**	**26**	**good**	**26**	**good**	**26**	**good**	**26**	**good**
Wet Tropics	Barron	**110001D[B]**	**Barron River at Myola**	**79**	**excellent**	**82**	**excellent**	**67**	**excellent**	**67**	**excellent**	**67**	**excellent**	**67**	**excellent**
	Johnstone	1120049[B]	North Johnstone River at Old Bruce Highway Bridge (Goondi)[$]	43	moderate	43	moderate	43	moderate	43	moderate	43	moderate	43	moderate
		112101B[B]	South Johnstone River at Upstream Central	42	moderate	42	moderate	42	moderate	42	moderate	42	moderate	42	moderate
	Tully	**113006A[L]**	**Tully River at Euramo**	**122**	**excellent**	**127**	**excellent**	**119**	**excellent**	**124**	**excellent**	**124**	**excellent**	**124**	**excellent**
		113015A[L]	Tully River at Tully Gorge National Park	80	excellent	80	excellent	67	excellent	67	excellent	67	excellent	67	excellent
	Herbert	**116001F[L]**	**Herbert River at Ingham**	**89**	**excellent**	**88**	**excellent**	**88**	**excellent**	**88**	**excellent**	**88**	**excellent**	**88**	**excellent**
Burdekin	Haughton	**119003A[B]**	**Haughton River at Powerline**	**22**	**moderate**	**22**	**moderate**	**22**	**moderate**	**22**	**moderate**	**22**	**moderate**	**22**	**moderate**
		119101A[L]	**Barratta Creek at Northcote**	**56**	**excellent**	**56**	**excellent**	**52**	**excellent**	**52**	**excellent**	**52**	**excellent**	**52**	**excellent**
	Burdekin	**120001A[B]**	**Burdekin River at Home Hill**	**23**	**good**	**23**	**good**	**23**	**good**	**23**	**good**	**23**	**good**	**23**	**good**
		120002C[B]	Burdekin River at Sellheim	22	good	22	good	20	good	20	good	20	good	20	good
		120205A[B]	Bowen River at Myuna	30	excellent	30	excellent	29	good	29	good	29	good	29	good
Mackay Whitsunday	O'Connell	**1240062[B]**	**O'Connell River at Caravan Park**	**35**	**moderate**	**42**	**good**	**42**	**good**	**42**	**good**	**42**	**good**	**42**	**good**
	Pioneer	**125013A[B]**	**Pioneer River at Dumbleton Pump Station**	**68**	**excellent**	**71**	**excellent**	**63**	**excellent**	**66**	**excellent**	**66**	**excellent**	**66**	**excellent**
	Plane	**126001A[B]**	**Sandy Creek at Homebush**	**42**	**excellent**	**44**	**excellent**	**44**	**excellent**	**44**	**excellent**	**44**	**excellent**	**44**	**excellent**
Fitzroy	Fitzroy	**1300000[B]**	**Fitzroy River at Rockhampton**	**27**	**good**	**27**	**good**	**27**	**good**	**27**	**good**	**27**	**good**	**27**	**good**
		130206A	Theresa Creek at Gregory Highway												
		130302A[L]	Dawson River at Taroom	11	good	11	good	8	good	8	good	8	good	8	good
		130504B	Comet River at Comet Weir												
Burnett Mary	Burnett	**136014A[L]**	**Burnett River at Ben Anderson Barrage Head Water**	**28**		**28**		**28**		**28**		**28**		**28**	
		136002D	Burnett River at Mt Lawless												
	Mary	138014A[L]	Mary River at Home Park[$]	64	excellent	64	excellent	58	excellent	58	excellent	58	excellent	58	excellent
		138008A[L]	Tinana Creek at Barrage Head Water[$]												

n = number of concentration data points used in the calculation of loads; TSS = total suspended solids; TN = total nitrogen; PN = particulate nitrogen; NOx-N = oxidised nitrogen as N; NH4-N = ammonium nitrogen as N; DIN = dissolved inorganic nitrogen (DIN = (NOx-N) + (NH4-N)); DON = dissolved organic nitrogen; TP = total phosphorus; DIP = dissolved inorganic phosphorus; PP = particulate phosphorus; DOP = dissolved organic phosphorus; and \$ = the North and South Johnstone rivers combined act as an end-of-system site, and the Mary River and Tinana Creek combined act as an end-of-system site.

Table 7.13 The number of samples collected and the representivity rating for monitored sites in 2013–2014. Text in bold are end-of-system sites and the corresponding data, all others are sub-catchment sites. Green shading = excellent or good representivity rating; orange shading = moderate representivity; red shading = indicative representivity; grey shading = no representivity calculated; black shading = no loads calculated.

NRM region	Catchment	Gauging station	River and site name	DON		TP		DIP		PP		DOP	
				n	Rating	n	Rating	n	Rating	n	Rating	n	Rating
Cape York	Normanby	**105107A[B]**	**Normanby River at Kalpowar Crossing**	**26**	**good**	**26**	**good**	**26**	**good**	**26**	**good**	**26**	**good**
Wet Tropics	Barron	**110001D[B]**	**Barron River at Myola**	**67**	**excellent**	**82**	**excellent**	**67**	**excellent**	**67**	**excellent**	**67**	**excellent**
	Johnstone	1120049[B]	North Johnstone River at Old Bruce Highway Bridge (Goondi)[$]	43	moderate	43	moderate	43	moderate	43	moderate	43	moderate
		112101B[B]	South Johnstone River at Upstream	42	moderate	42	moderate	42	moderate	42	moderate	42	moderate
	Tully	**113006A[L]**	**Tully River at Euramo**	**119**	**excellent**	**127**	**excellent**	**124**	**excellent**	**119**	**excellent**	**119**	**excellent**
		113015A[L]	Tully River at Tully Gorge National Park	67	excellent	80	excellent	67	excellent	67	excellent	67	excellent
	Herbert	**116001F[L]**	**Herbert River at Ingham**	**88**	**excellent**	**89**	**excellent**	**89**	**excellent**	**89**	**excellent**	**89**	**excellent**
Burdekin	Haughton	**119003A[B]**	**Haughton River at Powerline**	**22**	**moderate**	**22**	**moderate**	**22**	**moderate**	**22**	**moderate**	**22**	**moderate**
		119101A[L]	**Barratta Creek at Northcote**	**52**	**excellent**	**56**	**excellent**	**52**	**excellent**	**52**	**excellent**	**52**	**excellent**
	Burdekin	**120001A[B]**	**Burdekin River at Home Hill**	**23**	**good**	**23**	**good**	**23**	**good**	**23**	**good**	**23**	**good**
		120002C[B]	Burdekin River at Sellheim	20	good	22	good	20	good	20	good	20	good
		120205A[B]	Bowen River at Myuna	29	good	30	excellent	29	good	29	good	29	good
Mackay Whitsunday	O'Connell	**1240062[B]**	**O'Connell River at Caravan Park**	**42**	**good**	**42**	**good**	**42**	**good**	**42**	**good**	**42**	**good**
	Pioneer	**125013A[B]**	**Pioneer River at Dumbleton Pump**	**63**	**excellent**	**71**	**excellent**	**66**	**excellent**	**63**	**excellent**	**63**	**excellent**
	Plane	**126001A[B]**	**Sandy Creek at Homebush**	**44**	**excellent**	**44**	**excellent**	**44**	**excellent**	**44**	**excellent**	**44**	**excellent**
Fitzroy	Fitzroy	**1300000[B]**	**Fitzroy River at Rockhampton**	**27**	**good**	**27**	**good**	**27**	**good**	**27**	**good**	**27**	**good**
		130206A	Theresa Creek at Gregory Highway										
		130302A[L]	Dawson River at Taroom	8	good	11	good	8	good	8	good	8	good
		130504B	Comet River at Comet Weir										
Burnett Mary	Burnett	**136014A[L]**	**Burnett River at Ben Anderson Barrage Head Water**	**28**		**28**		**28**		**28**		**28**	
		136002D	Burnett River at Mt Lawless										
	Mary	138014A[L]	Mary River at Home Park[$]	58	excellent	64	excellent	58	excellent	58	excellent	58	excellent
		138008A[L]	Tinana Creek at Barrage Head Water[$]										

n = the number of concentration data points used for the load calculation; TSS = total suspended solids; TN = total nitrogen; PN = particulate nitrogen; NOx-N = oxidised nitrogen as N; NH4-N = ammonium nitrogen as N; DIN = dissolved inorganic nitrogen (DIN = (NOx-N) + (NH4-N)); DON = dissolved organic nitrogen; TP = total phosphorus; DIP = dissolved inorganic phosphorus; PP = particulate phosphorus; DOP = dissolved organic phosphorus; and $ = the North and South Johnstone rivers combined act as an end-of-system site and the Mary River and Tinana Creek combined act as an end-of-system site.