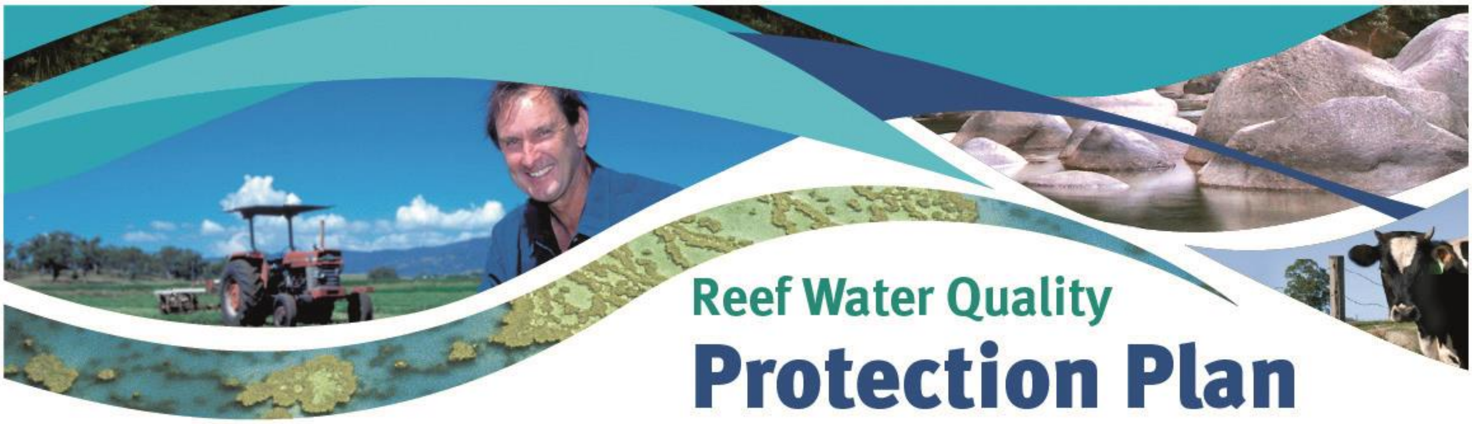

Total suspended solids, nutrient and pesticide loads (2011–2012) for rivers that discharge to the Great Barrier Reef

Great Barrier Reef Catchment
Loads Monitoring 2011–2012

Australian Government

Queensland
Government

Prepared by

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Executive summary

Diffuse pollutant loads discharged from rivers of the east coast of Queensland have caused a decline in water quality in the Great Barrier Reef lagoon. This decline in water quality is known to directly impact the health of the Great Barrier Reef and its ecosystems. The Reef Water Quality Protection Plan 2009 (Reef Plan 2009) and the revised Reef Water Quality Protection Plan 2013, aim to halt and reverse the decline in water quality and enhance the resilience of the Great Barrier Reef to other threatening processes (e.g. coral bleaching, ocean acidification, disease, climate change and overfishing) by improving land management practices. Only the Reef Plan 2009 is pertinent to the current report.

Reef Plan 2009 is underpinned by pollutant reduction targets measured against the baseline (anthropogenic) load reported in the Reef Water Quality Protection Plan First Report 2009 Baseline. These reduction targets include a 20 per cent reduction in anthropogenic load of total suspended solids by 2020; a 50 per cent reduction in anthropogenic load of nutrients (nitrogen and phosphorus) by 2013; and a 50 per cent reduction in photosystem II inhibitor herbicides[1] by 2013.

Progress towards Reef Plan 2009 targets is measured through the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program (Paddock to Reef Program) which is jointly funded by the Australian and Queensland governments. 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.

The monitoring data generated by this program provides a point of truth to validate loads predicted by catchment models. The loads predicted by the catchment models are used to report annually on progress towards the Reef Plan 2009 targets, as part of the annual Reef Report Card (i.e. Report Card 2012 and 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, Johnstone, Tully and Herbert catchments
- Burdekin region – Burdekin and Haughton catchments
- Mackay Whitsunday region – Plane and Pioneer catchments
- Fitzroy region – Fitzroy catchment
- Burnett Mary region – Burnett catchment

This report presents monitored annual loads and yields of pollutants based on monitoring data from the 2011–2012 monitoring year (i.e., 1 July 2011 to 30 June 2012). Following the strong La Niña conditions observed during 2010–2011, the 2011–2012 monitoring year saw a return to a more neutral weather pattern from March 2012, with total annual rainfall across the priority reef catchments generally near or

[1] Photosystem II herbicides are those herbicides that exert toxicity to plants by inhibiting the photosystem II component of photosynthesis. The priority herbicides for this program are ametryn, total atrazine, diuron, hexazinone and tebuthiuron.

slightly above average. A tropical low in mid to late March resulted in flooding in all priority reef catchments and resulted in the high annual recorded discharge at many end-of-system monitoring sites.

During the 2011–2012 monitoring year, discharge from the central Queensland rivers including the Burdekin, Pioneer, Plane and Fitzroy rivers all exceeded the long-term average discharge with exceedence probabilities between 18–28 per cent while in the Wet Tropics region discharge from all rivers were near the long-term annual average with exceedence probabilities ranging from 34–39 per cent. In the Normanby River in Cape York and the Burnett River in the south, annualised discharge was very low over the 2011–2012 monitoring year with exceedence probabilities of 86 per cent and 61 per cent respectively. The periods of highest discharge during 2011–2012 were:

- Early February – Herbert and Pioneer catchments and Cape, Belyando, Comet and Theresa Creek sub-catchments
- Late March – Barron, Herbert, Burdekin, Haughton, Pioneer, Plane and Fitzroy catchments

Ten end-of-system and fifteen sub-catchment sites were monitored for total suspended solids and nutrients during the 2011–2012 monitoring year. Photosystem II inhibitor pesticides were also monitored at eight end-of-system sites and three sub-catchment sites.

During 2011–2012, the monitored catchments generated approximately 5.6 million tonnes of total suspended solids, approximately 28,000 tonnes of nitrogen, and approximately 7800 tonnes of phosphorus. The Burdekin and Fitzroy catchments combined, representing 81 per cent of the monitored area, generated the highest loads of total suspended solids and nutrients including 83 per cent of the total suspended solids (4.6 million tonnes), 78 per cent of the total phosphorus (6100 tonnes) and 61 per cent of the total nitrogen (17,000 tonnes) loads.

The monitored annual load of the five photosystem II inhibitor herbicides (ametryn, total atrazine, diuron, hexazinone and tebuthiuron) was approximately 4.2 tonnes. The total monitored annual photosystem II inhibitor herbicide loads exported past the end-of-system monitoring sites were (from largest to smallest): 2100 kg of total atrazine, 1100 kg of tebuthiuron, 770 kg diuron, 200 kg of hexazinone and 48 kg of ametryn.

Total atrazine and diuron were detected at all monitored sites. The largest annual load of total atrazine was recorded in the Fitzroy River (1000 kilograms) which also had the largest annual load of tebuthiuron (890 kilograms). This is likely to be due to the large monitored catchment area, land use type and management practice. The largest loads of diuron (240 kg) and hexazinone (99 kg) occurred in the Tully catchment and the largest load of ametryn occurred in the Burdekin catchment (24 kg).

Yields (the load divided by the monitored surface area of the catchment) were calculated to compare the rate of pollutant delivery between catchments. The highest monitored annual yields of total suspended solids, total nitrogen and total phosphorus were derived from the North Johnstone and South Johnstone catchments. The Pioneer catchment also produced high monitored annual yields of the same three parameters. The Tully catchment produced high monitored annual yields of total nitrogen and Sandy Creek in the Plane catchment produced high monitored annual yields of total phosphorus. Conversely, the lowest monitored annual yields of total suspended solids, total nitrogen and total phosphorus occurred in the Burnett and Normanby catchments.

In 2011–2012, the largest monitored annual yield of ametryn was in Sandy Creek in the Plane catchment, total atrazine in Barratta Creek in the Haughton catchment, diuron in Sandy Creek in the Plane catchment and Tully catchment, hexazinone in the Tully catchment and tebuthiuron in the Fitzroy catchment.

This is the third technical report released by the Great Barrier Reef Catchment Loads Monitoring Program under Reef Plan 2009. The loads and yields data contained in this report complement the existing data collected over the previous five years to validate the catchment models which are used to monitor progress against the water quality improvement targets. The implementation of a quality management system including the delivery of specialist training to regional staff and installation of automated sampling equipment has further improved sample coverage during large flood events. The continuity of the data made available through the Great Barrier Reef Catchment Loads Monitoring Program will continue to provide a critical data resource for the effective management of Queensland natural resources.

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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; Rayment 2003). It is widely acknowledged that the Great Barrier Reef is at significant risk from degraded water quality caused by pollutants exported from catchments adjacent to the Great Barrier Reef (Wachenfeld et al. 1998; State of Queensland and Commonwealth of Australia 2003; Brodie et al. 2008; DPC 2008; 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). In order to improve water quality entering from these catchments, the Queensland and Australian Governments cooperatively initiated the Reef Water Quality Protection Plan 2009 (Reef Plan 2009) with the short-term goal to halt and reverse the decline in water quality entering the Great Barrier Reef lagoon by 2013 (DPC 2009a).

The Paddock to Reef Integrated Monitoring, Modelling and Reporting Program (Paddock to Reef program) measures progress towards Reef Plan goals and targets. The Paddock to Reef program is a joint collaboration involving the Australian and Queensland Governments, industry, regional natural resource management bodies and research organisations (DPC 2009b). 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.

To assist in evaluating progress towards the water quality targets of Reef Plan 2009, the Great Barrier Reef Catchment Loads Monitoring Program was implemented to monitor and report on loads of total suspended solids and nutrients in 11 priority catchments and loads of pesticides in eight priority catchments under the Paddock to Reef program.

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 over recent years (e.g. Nicholls 1988; Eyre 1998; Wachenfeld et al. 1998; Fabricius et al. 2005; Hunter and Walton 2008; Packett et al. 2009; Brodie et al. 2010; DPC 2011; Kroon et al. 2011; Smith et al. 2012; Turner et al. 2012; Kroon et al. 2013; Turner et al. 2013). Kroon et al. (2013) estimated that since European settlement the mean annual load of total suspended solids exported to the Great Barrier Reef lagoon has increased by 5.5 times, total nitrogen has increased by 5.7 times and total phosphorus has increased by 8.9 times. Photosystem II inhibitor herbicides were not present before European settlement. The majority of pollutant loads are generated during the wet season as runoff during flood 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).

Thirty-five catchments 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 over 1500 kilometres of the Queensland coastline (DPC 2011). Across the study area, there are substantial climatic differences within and between catchments, with highly variable rainfall, hydrology and geology.

These factors contribute to the high variability in estimated discharge volume and total suspended solids, nutrient and pesticide 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).

Of these 35 catchments, 11 catchments were monitored by the Great Barrier Reef Catchment Loads Monitoring Program in 2011–2012. The 11 catchments were selected based on inputs from the regional National Action Plan for Salinity and Water Quality Program officers, the Great Barrier Reef Marine Park Authority and the Australian Centre for Tropical Freshwater Research (DERM 2011a). The 11 priority monitored catchments and the natural resource management regions in which they occur are:

- Cape York region – Normanby catchment
- Wet Tropics region – Barron, Johnstone (including North Johnstone and South Johnstone rivers), Tully and Herbert catchments
- Burdekin region – Burdekin and Haughton catchments
- Mackay Whitsunday region – Plane and Pioneer catchments
- Fitzroy region – Fitzroy catchment
- Burnett Mary region – Burnett catchment

Grazing is the largest single land use within the Great Barrier Reef catchments (DPC 2011), 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 large amount of land set aside for conservation in State protected areas. In the Wet Tropics 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 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 is the fifth publication from the Great Barrier Reef Catchment Loads Monitoring Program, and third annual technical report in this series. The earlier technical reports being Turner et al. 2012 and Turner et al. 2013. The current report presents annual loads and yields (the load per square kilometre) from 11 priority reef catchments for total suspended solids, nutrients and pesticides in 2011–2012. These loads have been calculated using the same methods in each of the technical report series issued under the Paddock to Reef Program. Previous reports of the Great Barrier Reef Catchment Loads Monitoring Program have presented loads for 2006–2009 (Joo et al. 2012), 2009–2010 (Turner et al. 2012), 2010–2011 (Turner et al. 2013) and Smith et al. (2012) examined pesticide loads and assessed the toxicity and potential implications of mixtures of pesticides.

The scope of this report is confined to the estimation and reporting of loads exported from the monitored area of each catchment and as such these pollutant loads do not represent the total load discharged to the Great Barrier Reef lagoon[2]. This report does not link land uses or regions to loads or yields of total suspended solids or nutrients but does present land use yields of pesticides. The reported loads are estimated from monitoring data, which provides the 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 2013a; DPC 2013b; DPC 2014). The modelled loads are not presented in this report.

[2] Not all catchments that drain to the Great Barrier Reef lagoon were monitored. In addition, the end-of-system monitoring sites are not located at the mouth of the river or creek (refer to Section 2.1) and this unmonitored portion of the catchment or sub-catchment may contribute, remove or degrade total suspended solids, nutrients and pesticides.

2 Methods

2.1 Monitoring sites

Eleven priority catchments were identified for monitoring under the Paddock to Reef Program (DPC 2011; Carroll et al. 2012). Monitoring sites were established at existing Queensland Government stream gauging stations (Figure 2.1 and Table 2.1). 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, which does not have tidal influence and the volume of water passing that point can be accurately gauged. Sub-catchment sites are located on rivers that have different drainage basins to the major river for those catchments. Sub-catchment sites were selected to provide specific water quality data on various land uses or on a geographical region for enhanced catchment model validation.

Ten end-of-system sites and 15 sub-catchment sites were selected to monitor total suspended solids and nutrients (Table 2.2), while eight end-of-systems and three sub-catchment sites were selected to monitor photosystem II inhibitor pesticides (Table 2.2). All selected sites are fixed monitoring locations of the Great Barrier Reef Catchment Loads Monitoring Program to allow collection of data over multiple years. Summary information on each monitoring site including its gauging station identification, location, whether it is an end-of-system or sub-catchment site, the surface area of each catchment or sub-catchment and the area monitored is provided in Table 2.1.

Between 1 July 2011 and 30 June 2012 monitoring was undertaken at 25 sites located in the 11 priority catchments (Figure 2.1 and Table 2.1). These 25 sites have remained as fixed monitoring sites since commencement of the Great Barrier Reef Catchment Loads Monitoring Program in 2009–2010. Monitoring at three sites (Bowen River at Myuna, Dawson River at Taroom and Isaac River at Yatton) in 2011–2012 was not adequate for the calculation of total suspended solids and nutrient loads, therefore these sites have been omitted from this report.

2.2 Rainfall

Rainfall data were obtained from the Commonwealth of Australia, Bureau of Meteorology National Climate Centre data archive (BOM 2012a). These data were synthesised using ArcGIS to create maps of Queensland to display total annual rainfall and annual rainfall deciles during the 2011–2012 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 (DERM 2010). Water quality samples were collected between 1 July 2011 and 30 June 2012. 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 sampling using refrigerated pump samplers. The methods employed at each site are shown in Table 2.2.

Figure 2.1 Map indicating the natural resource management regions, catchments and sites where the Great Barrier Reef Catchment Loads Monitoring Program monitored in 2011–2012.

Table 2.1 Summary information on sites monitored as part of the Great Barrier Reef Catchment Loads Monitoring Program between 1 July 2011 and 30 June 2012. Sites in bold are end-of-system sites, 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
	Johnstone	112004A	North Johnstone River at Tung Oil	S-C[$]	-17.54564	145.93253	2325	925	40
		112101B	South Johnstone River at Upstream Central Mill	S-C[$]	-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**	**119101A**	**Barratta Creek at Northcote**	EoS	-19.69228	147.16879	4051	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
		120301B	Belyando River at Gregory Development Road	S-C	-21.53323	146.85961		35,411	27
		120302B	Cape River at Taemas	S-C	-20.99956	146.42712		16,074	12
		120310A	Suttor River at Bowen Development Road	S-C	-21.52075	147.04267		10,758	8
		120205A	Bowen River at Myuna	S-C	-20.58333	147.60000		7104	5
Mackay Whitsunday	**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	-23.38111	150.51691	142,552	139,159	98
		130401A	Isaac River at Yatton	S-C	-22.66583	149.11695		19,720	14
		130206A	Theresa Creek at Gregory Highway	S-C	-23.42924	148.15138		8485	6
		130302A	Dawson River at Taroom	S-C	-25.63756	149.79014		15,846	11
		130504B	Comet River at Comet Weir	S-C	-23.61247	148.55139		16,457	12
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
		136094A	Burnett River at Jones Weir Tail Water	S-C	-25.59483	151.29735		21,700	65
		136106A	Burnett River at Eidsvold	S-C	-25.40225	151.10327		7117	21

EoS = end-of-system site, S-C = sub-catchment site. + This site is not at a gauging station. Refer to Table 2.4. [$] = the North and South Johnstone rivers combined act as an end-of-system site.

Table 2.2 Summary information on analytes measured and sample collection methods as part of the Great Barrier Reef Catchment Loads Monitoring Program between 1 July 2011 and 30 June 2012. Sites in bold are end-of-system sites, 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
	Johnstone	112004A	$North Johnstone River at Tung Oil	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**	**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
		120301B	Belyando River at Gregory Development Road	TSS, N,	Manual and automatic
		120302B	Cape River at Taemas	TSS, N	Manual and automatic
		120310A	Suttor River at Bowen Development Road	TSS, N,	Manual and automatic
		120205A	Bowen River at Myuna	TSS, N	Manual and automatic
Mackay Whitsunday	**Pioneer**	**125013A**	**Pioneer River at Dumbleton Pump Station**	TSS, N, PSII	Manual and automatic
	Plane	**126001A**	**Sandy Creek at Homebush**	TSS, N, PSII	Manual
Fitzroy	**Fitzroy**	**1300000+**	**Fitzroy River at Rockhampton**	TSS, N, PSII	Manual
		130504B	Comet River at Comet Weir	TSS, N, PSII	Manual
		130401A	Isaac River at Yatton	TSS, N	Manual
		130302A	Dawson River at Taroom	TSS, N, PSII	Manual
		130206A	Theresa Creek at Gregory Highway	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
		136094A	Burnett River at Jones Weir Tail Water	TSS, N	Manual and automatic
		136106A	Burnett River at Eidsvold	TSS, N	Manual and automatic

TSS = total suspended solids, N = nutrients, PSII = photosystem II inhibitor herbicides, HW = headwater. + This site is not at a gauging station. Refer to Table 2.4. $ = the North and South Johnstone rivers combined act as an end-of-system site.

Intensive sampling (daily or every few hours) occurred during high flow events and reduced sampling (monthly) was undertaken during ambient (low or base-flow) conditions. Where possible, total suspended solids, nutrients and pesticide samples were collected concurrently. Approximately 50 per cent of the total suspended solids and nutrient samples were collected by manual grab sampling and 50 per cent were collected using refrigerated automatic pump samplers. All pesticide samples were manually collected except in the Pioneer catchment where an automatic sampler fitted with glass bottles was installed for the collection of pesticide samples.

Samples were stored and transported in accordance with the Environmental Protection (Water) Policy Monitoring and Sampling Manual (DERM 2010).

2.4 Quality control

During the 2011–2012 monitoring year the Great Barrier Reef Catchment Loads Monitoring Program continued to implement a formal 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 Great Barrier Reef Catchment Loads Monitoring Program. Continual improvement in the program delivery has been achieved through adoption of the quality management system and demonstrated through:

- ongoing delivery of Great Barrier Reef Catchment Loads Monitoring Quality Management training package to regional hydrographers and partner organisations including Terrain NRM
- continued development of new standard operating procedures to ensure all aspects of the program delivery are documented and undertaken in a manner consistent with state and national standards
- review of load calculation methods to evaluate the most appropriate load estimation models under a range of sampling strategies (see Thomson et al. 2012)

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 by a gravimetric methodology and nutrient samples were analysed via Flow Injection Analysis (colourimetric techniques).

Queensland Health Forensic and Scientific Services (Coopers Plains, Queensland) undertook the analysis of water samples for pesticides. All pesticide samples were extracted via solid phase extraction and analysed using liquid chromatography-mass spectrometry (LCMS) to quantify the five priority photosystem II inhibitor herbicides (ametryn, total atrazine (including atrazine and its breakdown products desethyl atrazine and desisopropyl atrazine), diuron, hexazinone and tebuthiuron). This is the first year that pesticides were extracted using solids phase extraction; liquid-liquid extraction methods were applied in the 2009–2010 and 2010–2011 monitoring years. A detailed comparison of the two extraction methods is provided in Appendix A. The loads and yields of other pesticides detected using liquid chromatography-mass spectrometry are presented in Appendix B.

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) for the analyses conducted. Table 2.3 provides a summary of all analysed parameters and their practical quantitation limits.

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

Monitored pollutants	Abbreviation	Analytes measured	Practical quantitation limit
Sediments			
Total suspended solids	TSS	Total suspended solids	1 mg L^{-1}
Nutrients			
Total nitrogen	TN	Total nitrogen as N	0.03 mg L^{-1}
Particulate nitrogen	PN	Total nitrogen (suspended) as N	0.03 mg L^{-1}
Dissolved organic nitrogen	DON	Organic nitrogen (dissolved) as N	0.03 mg L^{-1}
Dissolved inorganic nitrogen	DIN	Ammonium nitrogen as N	0.002 mg L^{-1}
		Oxidised nitrogen as N	0.001 mg L^{-1}
Total phosphorus	TP	Total Kjeldahl phosphorus as P	0.02 mg L^{-1}
Particulate phosphorus	PP	Total phosphorus (suspended) as P	0.02 mg L^{-1}
Dissolved organic phosphorus	DOP	Organic phosphorus (dissolved) as P	0.02 mg L^{-1}
Dissolved inorganic phosphorus	DIP	Phosphate phosphorus as P	0.001 mg L^{-1}
Pesticides			
Diuron	Pesticide (PSII)	Diuron	0.01 µg L^{-1}
Ametryn		Ametryn	0.01 µg L^{-1}
Total Atrazine		Atrazine, desethyl atrazine and desisopropyl atrazine	0.01 µg L^{-1}
Tebuthiuron		Tebuthiuron	0.01 µg L^{-1}
Hexazinone		Hexazinone	0.01 µg L^{-1}

2.6 River discharge

River discharge data (hourly-interpolated flow, $m^3 s^{-1}$) were extracted from the Department of Natural Resources and Mines, Surface Water Database using the Hydstra pre-programmed script (http://watermonitoring.derm.qld.gov.au/host.htm) (DNRM 2012). 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 (DERM 2011b). If such data were not available due to a gauging station error, flows with a quality code of 60 were used (see Appendix C).

If samples were collected at sites without an operating Department of Natural Resources and Mines gauging station (due to logistic or work health and safety reasons, or 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 at: Burdekin River at Home Hill, Fitzroy River at Rockhampton and Burnett River at Ben Anderson Barrage Head Water (Table 2.4). In general, the factors adjust the timing of the flow to account for the delay in time it takes water to flow from the gauging station to the monitoring site. The method used to calculate discharge by the Surface Water Database is presented in Appendix D.

The long-term mean annual discharge and historical maximum recorded flow for each monitoring site was calculated using data contained Surface Water Database. For three sites, 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.

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

Equation 1

$$P_e = 1 - \frac{R_i}{N + 1}$$

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.

Gauging station	River and site name	Timing and flow factors
120001A	Burdekin River at Home Hill	Estimated from discharge data for Clare GS 120006B where: $\text{Discharge}_{\text{Burdekin River at Home Hill}} = \text{Discharge}_{\text{Burdekin River at Clare}}$
125013A	Pioneer River at Dumbleton Pump Station	Historical discharge was estimated using data from Mirani Weir Tail Water GS 125007A where: $\text{Discharge}_{\text{Pioneer River Dumbleton Pump Station}} = \text{Discharge}_{\text{Mirani Weir Tail Water}}$
1300000	Fitzroy River at Rockhampton	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) is 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: $\text{Discharge}_{\text{Burnett River at Mt Lawless}} = \text{Discharge}_{\text{Yenda}}$

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 2011 and 30 June 2012 to calculate loads was assessed by determining the representivity of the data for each analyte using the method of Turner et al. (2012) which was based on elements of the Kroon et al. (2010) and Joo et al. (2012) methods. In previous years, the number of total suspended solids samples and their position on the hydrograph, was used as a proxy for the representivity rating for all analytes. In this report, we present the rating of sampling representivity for total suspended solids and all monitored nutrients individually. The rating of sampling representivity was assessed against two criteria:

1. the number of samples collected in the top five per cent of flow; and
2. the ratio between the highest flow rate sampled in 2011–2012 and the maximum flow rate recorded (both measured in $m^3 s^{-1}$).

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 at the monitoring sites 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 used 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 estimation

Load estimations were calculated using the Loads Tool component of the Water Quality Analyser 2.1.1.4 (eWater 2011). Annual and daily loads were estimated for total suspended solids and nutrients, including total nitrogen, particulate nitrogen, dissolved organic nitrogen, oxidised nitrogen, ammonium nitrogen, total phosphorus, particulate phosphorus, dissolved inorganic phosphorus and dissolved organic phosphorus. Annual and daily pesticide loads were also estimated for ametryn, total atrazine (atrazine and its metabolites), diuron, hexazinone and tebuthiuron. Whilst daily loads have been calculated for all analytes, only annual loads are presented in this report.

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}).

One of two models was used to calculate loads at each site: average load (linear interpolation of concentration)[3] or the Beale ratio. The average load (linear interpolation of concentration) and Beale ratio methods were applied using the following equations:

Average load (linear interpolation of concentration):

Equation 2

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

where c_j is the j^{th} sample concentration, and q_j is the inter-sample mean flow (eWater 2011).

Beale ratio:

Equation 3

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

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 2011; Joo et al. 2012).

2.7.2.1 Total suspended solids, nutrient and pesticides loads

The most appropriate method (average load (linear interpolation of concentration) or Beale ratio) to calculate annual loads of total suspended solids, total nutrients and dissolved nutrients was determined for each of the ten analytes at each site using the following criteria:

- if the majority of major events were sampled on both the rise and fall, then the average load (linear interpolation of concentration) method was applied (e.g. total suspended solids at Pioneer River at Dumbleton Pump Station, Figure 7.27, Appendix E)

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

- if the majority of the events were not adequately sampled but the representivity rating was "good" or better, the Beale ratio was applied (e.g. total suspended solids at Barron River at Myola, Figure 7.8, Appendix E)
- if the majority of the events were not adequately sampled and the representivitiy rating was "indicative", then annual loads were estimated using the Beale ratio method and reported as "indicative loads" (e.g. total suspended solids at Burnett River at Mt Lawless, Figure 7.33, Appendix E)

The most appropriate load calculation method varied between analytes within sites (e.g. total nitrogen load at Herbert River at Ingham was modelled by average load (linear interpolation of concentration) and dissolved inorganic nitrogen was modelled by Beale ratio), and analytes between sites (e.g. total suspended solids load at Tully River at Euramo was modelled by average load (linear interpolation of concentration) whilst total suspended solids load at Tully River at Tully Gorge National Park was modelled by Beale ratio). This occurred because not all water samples were analysed for the full suite of analytes every time samples were collected. This resulted in differences in the number of concentration data points at different stages of the hydrograph available for use in the calculation of loads (Appendix E).

The loads 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 2.1.1.4 (eWater 2011) for each parameter
- flow data ($m^3 s^{-1}$) were imported into Water Quality Analyser 2.1.1.4 (eWater 2011) on an hourly-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, the results were adjusted to a value of 50 per cent of the practical quantitation limit
- the flow data were then aligned to the water quality concentration data
- when 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 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 2.1.1.4 (eWater 2011) using the appropriate loads estimation method (as outlined above) and annual loads for the 1 July 2011 to 30 June 2012 period were reported.

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 2.1.1.4. In these cases, calculated data points that were 50 per cent of the lowest reported concentration were inserted into the dataset at 1 July 2011 and the lowest reported concentration was inserted into the dataset at 30 June 2012 to provide tie-down concentrations for calculations (eWater 2011).

The use of average load (linear interpolation of concentration) and Beale ratio loads calculation models for total suspended solids, nutrients and pesticides is consistent with the previous monitoring years from 2006 to 2011 (Joo et al. 2012; Turner et al. 2012; and Turner et al. 2013). This is the first year, however, that we have reported different model outputs based on the number of concentration points of each analyte, rather than using the number of concentration points of total suspended solids as a proxy for the number of concentration data points for all analytes.

2.7.3 Yields

Yields are the load of pollutants (e.g. tonnes, t) that originate from a monitored area of land (e.g. km^2) within a catchment (i.e. t km^{-2} for total suspended solids and nutrients or kg km^{-2} for pesticides). Yields provide a useful means of comparing the rate of pollutant delivery between monitored catchment areas. Yields were calculated for each pollutant at all sub-catchment and end-of-system sites by dividing each calculated annual pollutant load by the total monitored catchment area.

Yields also allow differences in the rate of pollutant loads derived from dominant land use types in each catchment or sub-catchment area (e.g. areas proportionally dominated by cane cropping vs. dry land grazing) to be identified (these are termed land use yields). Land use yields were only generated for pesticides as the use of registered chemicals such as pesticides is regulated to specific land uses (e.g. sugar cane). Appendix F provides a more detailed analysis of the priority photosystem II pesticide yields data by incorporating spatial data from the dominant land uses with each of the monitored priority catchments.

3 Results and discussion

Due to logistical reasons, monitoring at the Bowen River at Myuna, Dawson River at Taroom and Isaac River at Yatton sites during 2011–2012 was not sufficient to calculate annual loads (Section 3.2). As a result, no calculated data for these sub-catchment sites are presented in this report.

3.1 Rainfall and river discharge

Following the strong La Niña event observed during 2010–2011, the 2011–2012 monitoring year saw a return to a more neutral weather pattern with the southern oscillation index remaining positive between late-winter through to early summer, then moving into the negative range in late-summer and autumn.

The weather patterns observed during the 2011–2012 monitoring year were generally unremarkable compared to the extreme weather of the preceding year. Rainfall across the priority reef catchments for the 2011–2012 monitoring year (Figure 3.1) was generally average or slightly above average (Figure 3.2) with few flood events occurring in any of the priority reef catchments (Appendix E) (BOM 2011; BOM 2012b).

Rainfall during winter and early spring was generally near to slightly below average across the priority reef catchments. No significant flood events occurred in any of the monitored catchments during this period with the exception of minor flooding in the Tully and Johnstone catchments during the third week in October following moderate to heavy rainfall in the Wet Tropics region (BOM 2011).

Rainfall during the start of summer was below average to very much below average in the southern Burdekin Dry Tropics, Fitzroy and Burnett regions with some areas receiving the lowest rainfall on record. Rainfall in the Wet Tropics and Cape York natural resource management regions over this same period were near or above average. With the development of typical monsoonal weather pattern in early December, rainfall over the remainder of the summer and early autumn returned to average to above average conditions.

In mid to late March a tropical low moved from the north-west into Queensland, resulting in flooding in all priority reef catchments from the Normanby River in the north to the Burnett River in the south (BOM 2012b). Flooding associated with this low pressure system was the most significant event observed at the end-of-system monitoring sites in 2011–2012 monitoring year.

The priority reef catchments received slightly below average rainfall through much of April and May until an upper level trough produced widespread rain across the state in late May (BOM 2012b). Moderate to heavy falls were received in the Wet Tropics region resulting in small events in the Barron and Johnstone rivers and in the upper Fitzroy sub-catchments monitoring sites at Theresa Creek and Comet River (Appendix E).

During the 2011–2012 monitoring year, discharge in the rivers of the Wet Tropics region (Figure 3.3) were near the long-term annual average (100–119 per cent) with exceedence probabilities ranging from 34–52 per cent (Table 3.1 and Figure 3.3). In central Queensland, discharge in the Burdekin, Pioneer, Plane and Fitzroy rivers all exceeded the long-term average (Figure 3.3) with exceedence probabilities between 18–28 per cent (Table 3.1 and Figure 3.3). In the Normanby River in the north and Burnett River in the south, annualised discharge was very low over the 2011–2012 monitoring year reaching only 39 per cent and 45 per cent of the long-term annual average discharge and exceedence probabilities of 86 per cent and 61 per cent respectively (Table 3.1 and Figure 3.3).

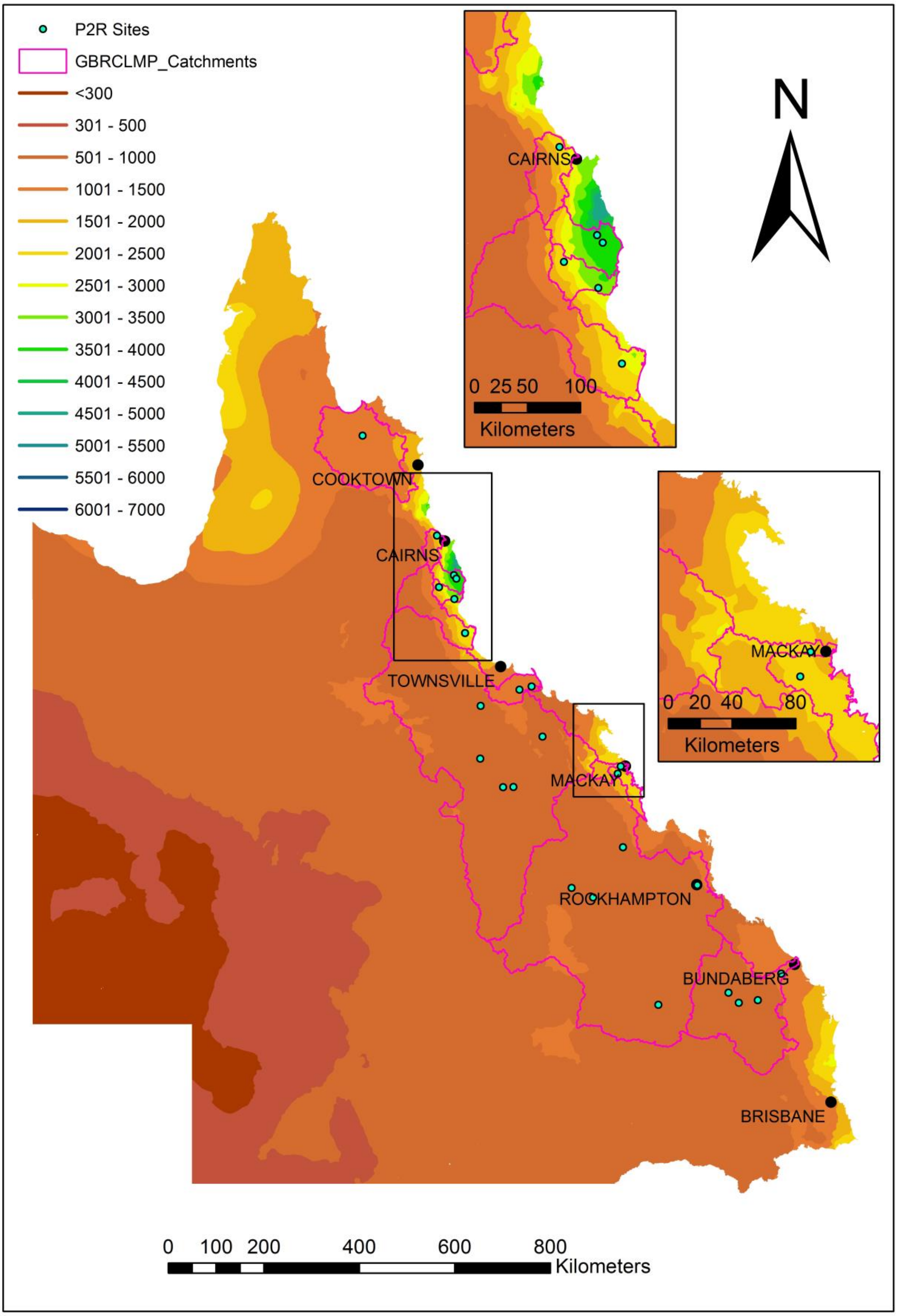


Figure 3.1 Queensland rainfall (millimetres) totals for 1 July 2011 to 30 June 2012 along with the monitored catchments and Great Barrier Reef Catchment Loads Monitoring Program sites.

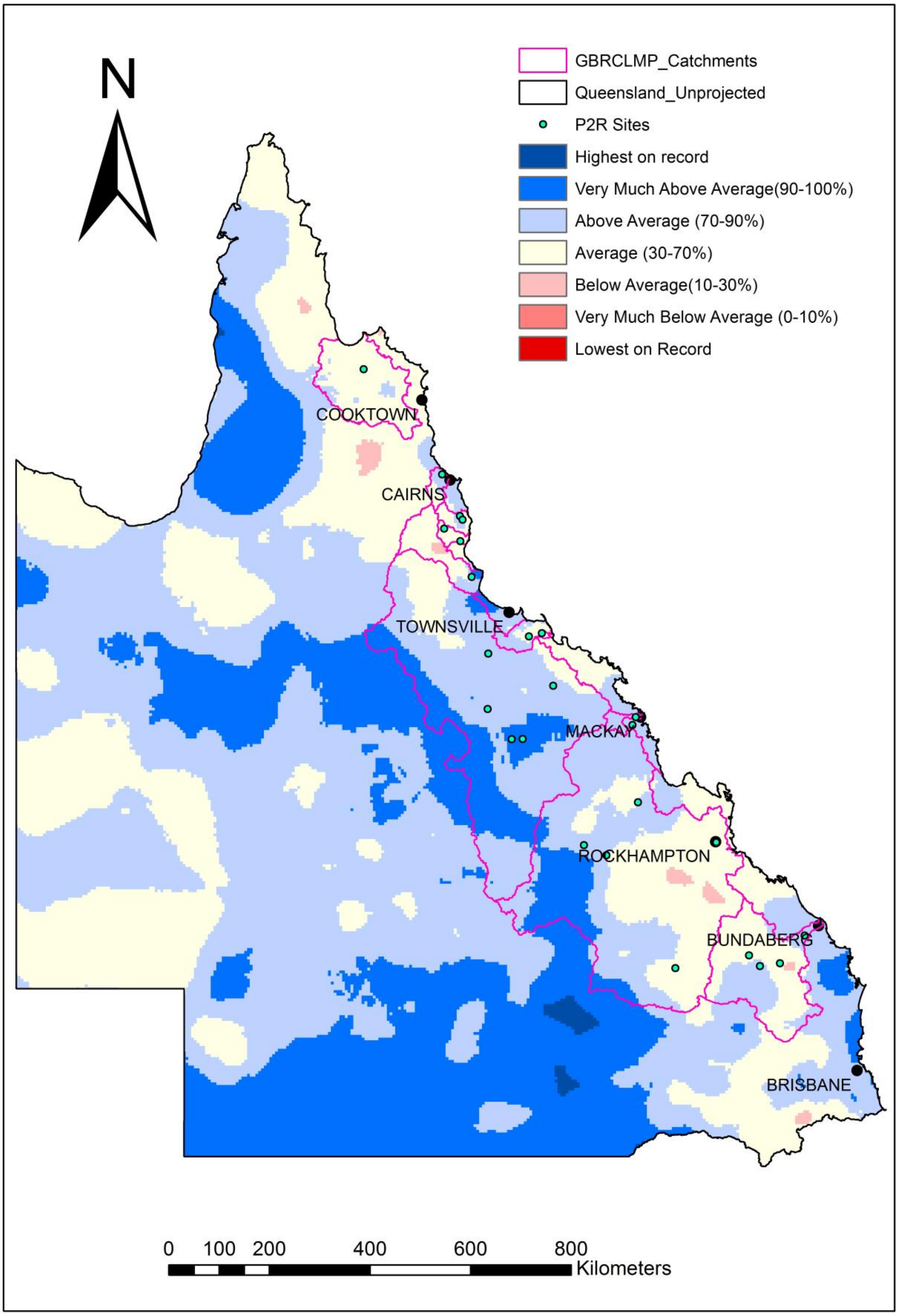


Figure 3.2 Queensland rainfall deciles for 1 July 2011 to 30 June 2012 along with the monitored catchments and Great Barrier Reef Catchment Loads Monitoring Program sites.

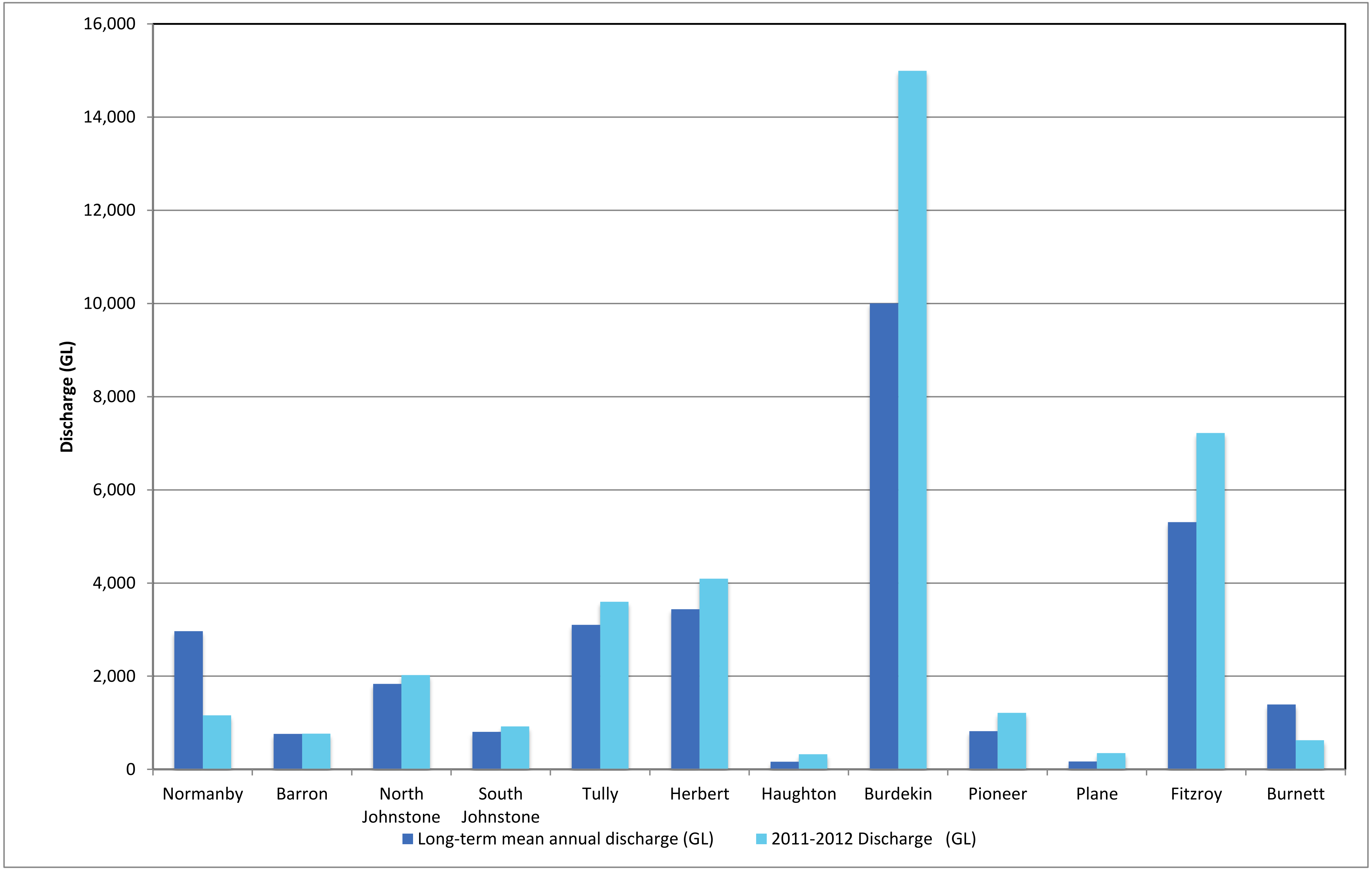


Figure 3.3 Annual discharge for the end-of-system sites (including the North Johnstone and South Johnstone sub-catchments) between 1 July 2011 and 30 June 2012, compared to the long-term mean annual discharge.

Table 3.1 The total and monitored area for each catchment and summary discharge and flow statistics for the 2011–2012 monitoring year. Sites in bold are end-of-system sites, 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 2011–2012 (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 2011–2012 ($m^3 s^{-1}$)	Per cent of maximum recorded flow observed in 2011–2012 (%)
Cape York	Normanby	**Normanby River at Kalpowar Crossing**	24,399	12,934	53	2005	2969	1162	86	39	2088	517	25
Wet Tropics	Barron	**Barron River at Myola**	2188	1945	89	1957	766	767	38	100	3076	1869	61
	Johnstone	North Johnstone River at Tung Oil[$]	2325	925	40	1966	1836	2024	52	110	3051	1730	57
		South Johnstone River at Upstream Central Mill[$]		400	17	1974	808	923	40	114	1680	902	54
	Tully	**Tully River at Euramo**	1683	1450	86	1972	3104	3601	34	116	1052	773	73
		Tully River at Tully Gorge National Park		482	29	12/2009	1060	797	67	75	637	280	33
	Herbert	**Herbert River at Ingham**	9844	8581	87	1915	3441	4096	39	119	11,267	3183	28
Burdekin	Haughton	**Barratta Creek at Northcote**	4051	753	19	1974	167	326	20	195	1107	977	88
	Burdekin	**Burdekin River at Home Hill**	130,120	129,939	99	1973	10,004	14,992	18	150	25,483	17,103	67
		Burdekin River at Sellheim		36,290	28	1968	4855	6589	32	136	24,200	13,841	57
		Belyando River at Gregory Development Road		35,411	27	1976	697	1861	16	267	4269	1126	26
		Cape River at Taemas		16,074	12	1968	695	1515	25	218	2995	2608	87
		Suttor River at Bowen Development Road		10,758	8	2006	821	804	50	98	2379	1258	53
Mackay Whitsunday	Pioneer	**Pioneer River at Dumbleton Pump Station**	1572	1485	94	1977	822	1217	26	148	4337	2601	60
	Plane	**Sandy Creek at Homebush**	2539	326	13	1966	173	351	18	203	1314	1066	81
Fitzroy	Fitzroy	**Fitzroy River at Rockhampton**	142,552	139,159	98	1964	5308	7222	28	136	14,493	4919	34
		Theresa Creek at Gregory Highway		8485	6	1956	270	498	17	184	4234	587	14
		Dawson River at Taroom		15,846	11	1911	406	387	36	95	5858	739	13
		Comet River at Comet Weir		16,457	12	2002	1187	1108	44	93	3975	1325	33
Burnett Mary	Burnett	**Burnett River at Ben Anderson Barrage Head Water**	33,207	32,891	99	1910	1394	629	61	45	14,357	481	3
		Burnett River at Mt Lawless		29,355	88	1909	1018	457	44	45	14,983	361	2
		Burnett River at Jones Weir Tail Water		21,700	65	1981	464	342	31	74	8932	465	5
		Burnett River at Eidsvold		7117	21	1960	177	186	16	105	3561	433	12
Summary end-of-system loads			354,480	330,788			30,792	37,310		83			

[$] = the North and South Johnstone rivers 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 discharge 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 model the annual pollutant discharge, it is important that the pollutant concentration data are available for the periods of highest discharge. Table 3.2 provides a summary of the sampling representivity ratings – indicating those parameters and sites where the representivity is good and excellent; moderate; and indicative. Table 7.7 and Table 7.8 in Appendix G provide the representivity rating for all parameters and sites.

3.2.1 Total suspended solids, total nutrients and dissolved nutrients

For the 2011–2012 monitoring year, good or excellent sampling representivities were achieved at all end-of-system monitoring sites for all analytes except at the Herbert River at Ingham where moderate sample representivity was attained for dissolved and particulate nutrients (Table 3.2). In the Johnstone River, good sampling representivity was achieved at the North Johnstone River for all analytes however only moderate sampling representivity was achieved at the South Johnstone River (Table 3.2).

A high level of sampling representivity was achieved in many of the sub-catchment monitoring sites. In the Burdekin sub-catchments good or excellent sampling representivity was achieved at Belyando, Cape and Suttor rivers (Table 3.2). These representivities are a marked improvement on the results for previous years (Turner et al. 2012; Turner et al. 2013) and is attributed to the employment of a staff member specifically to collect samples in this region and maintain the automatic sampling equipment. The logistical challenge of achieving a good or excellent representivity rating at manually sampled sites is demonstrated by only achieving moderate sampling representivity rating at the upper Burdekin River at Sellheim site. The Burdekin River at Sellheim, unlike the other sub-catchment monitoring sites in the Burdekin, does not have an automatic sampler installed. The indicative representivity at this site (Table 3.2 to Table 3.4) was due to no samples being manually collected during the two major flow events of this year as the site was not accessible due to flooding.

In the Fitzroy River sub-catchments, sampling representivity at the manually sampled Theresa Creek and Comet River sites was moderate for all analytes (Table 3.2 to Table 3.4).

In the upper Burnett River good or excellent sampling representivity was achieved at Eidsvold and Jones Weir sites for all analytes with monthly samples collected throughout the year and the single large flow event in late March was well sampled at Eidsvold (Figure 7.35, Appendix E). Whilst monthly samples were collected from the Burnett River at Mt Lawless monitoring site, sampling during the largest flow events was limited and subsequently impacted on the representivity rating for all analytes, with only indicative loads calculable for the Burnett River at Mt Lawless.

3.3 Total suspended solids and nutrient loads and yields

The 2011–2012 annual loads and yields of total suspended solids and nutrients for the 11 monitored catchments were determined using discharge and contaminant 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 the end-of-system monitoring sites are not located at the mouth of the river or creek (refer to Section 2.1) and this unmonitored portion of the catchment or sub-catchment may contribute, remove or degrade total suspended solids, nutrients and pesticides. The annual loads discharged to the Great Barrier Reef for all 35 catchments are estimated using catchment modelling and are reported elsewhere in the Paddock to Reef Program (DPC 2011).

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.

3.3.1 Total suspended solids

3.3.1.1 Total suspended solid loads

The combined annual load of total suspended solids for the 11 priority catchments was 5.6 Mt (Table 3.2) of which over 80 per cent was derived from the Burdekin (3.3 Mt; 59 per cent) and Fitzroy (1.3 Mt; 24 per cent) catchments (Table 3.2 and Figure 3.4). The annual loads of total suspended solids in all other catchments were low, with each catchment contributing less than five per cent of the monitored total suspended solids load during 2011–2012, with the lowest monitored total suspended solids load occurring in Barratta Creek in the Haughton catchment (11 kt; 0.19 per cent).

In the Burdekin catchment, the highest sub-catchment load was the indicative monitored annual load calculated for the upper Burdekin river (measured at Sellheim, 2.4 Mt), with lower monitored annual loads of total suspended solids in the Cape (0.22 Mt), Belyando (0.16 Mt) and Suttor (0.056 Mt) rivers (Table 3.2).

The end-of-system monitored annual load of total suspended solids in the Burnett River during the 2011–2012 monitoring year was 15 kt (Table 3.2). The Burnett catchment end-of-system load was approximately 54 per cent of the indicative load calculated for Mt Lawless located upstream of Paradise Dam and 32 per cent of the indicated total suspended solid load monitored at Jones Weir. It has previously been suggested that the reduced load of total suspended solids monitored at the end-of-system site may be due solids settling out of suspension as water velocity reduces as it enters Paradise Dam (Turner et al. 2012 and Turner et al. 2013).

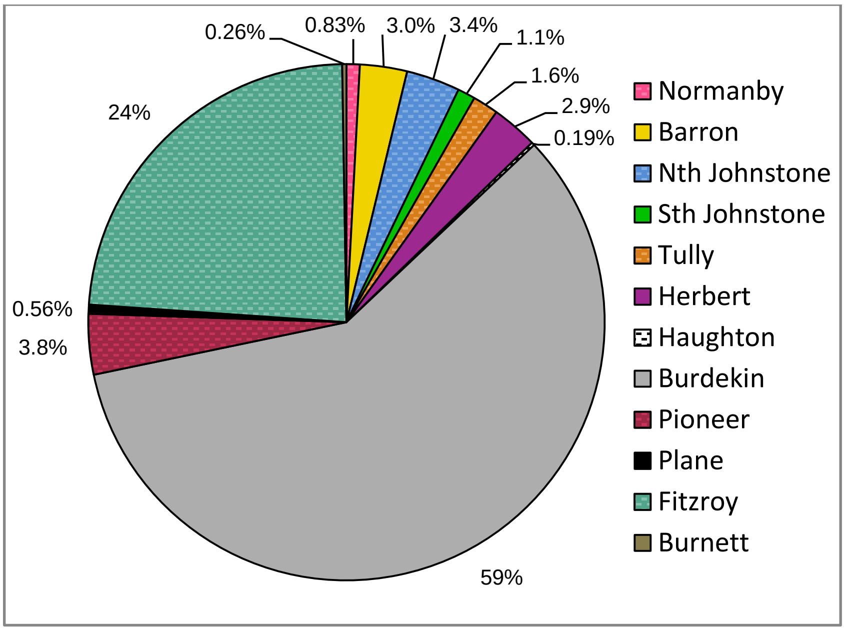


Figure 3.4 Per cent contribution from each catchment to the combined monitored total suspended solids annual load.

3.3.1.2 Total suspended solids yields

During the 2011–2012 monitoring year, the highest yields of total suspended solids were derived from the North Johnstone (200 t km^{-2}), South Johnstone (150 t km^{-2}) and Pioneer (140 t km^{-2}) catchments. Moderate yields also occurred in Sandy Creek in the Plane catchment (96 t km^{-2}) and the Barron (84 t km^{-2}) and Tully (62 t km^{-2}) catchments (Table 3.3). These catchments are located in the Wet Tropics and Mackay Whitsunday natural resource management regions where intensive agricultural land uses, including sugarcane and horticultural production, represent a high proportion of the land use (DPC 2011).

The lowest monitored annual yields of total suspended solids at end-of-system sites occurred in Barratta Creek in the Haughton catchment (14 t km^{-2}) and the Fitzroy (9.5 t km^{-2}), Normanby (3.6 t km^{-2}) and Burnett (0.45 t km^{-2}) catchments (Table 3.3). Land use in these larger catchments is predominately dry land grazing which have been reported previously as contributing lower yields of total suspended solids (Turner et al. 2012; Turner et al. 2013).

The yield of total suspended solids varied greatly amongst the sub-catchments of the Burdekin region (Table 3.3). The upper Burdekin sub-catchment monitored at Sellheim (67 t km^{-2}) had the highest monitored annual yield of total suspended solids; 5–17 times greater than the monitored annual yield of total suspended solids from the Cape (14 t km^{-2}), Suttor (5.2 t km^{-2}) and Belyando (4.5 t km^{-2}) catchments (Table 3.3). This result supports the findings of Prosser et al. (2002) which demonstrated the upper Burdekin River sub-catchment has a high rate of erosion and low rate of sediment deposition in the floodplain compared to the monitored sub-catchments of the Belyando and Suttor rivers which contain extensive lowland floodplains and lower rates of sediment supply.

In the Burnett catchment, the monitored annual yields of total suspended solids (including the indicative values for Mt Lawless) were fairly consistent amongst the three sub-catchment monitoring sites, Burnett River at Eidsvold (2.0 t km^{-2}), Burnett River at Jones Weir Tail Water (2.1 t km^{-2}) and Burnett River at Mt Lawless (0.96 t km^{-2}) (Table 3.3). These yields are considerably larger than the Burnett end-of-system monitored annual yield of 0.45 t km^{-2}.

Within the Fitzroy River sub-catchments the monitored annual yields of total suspended solids varied approximately four-fold between the Comet River (42 t km^{-2}) and Theresa Creek (11 t km^{-2}) (Table 3.3); discharge in the Comet River was 2.2 times larger than Theresa Creek over the same period. No data were available for the Dawson or Isaac rivers during the 2011–2012 monitoring year.

3.3.2 Nitrogen

3.3.2.1 Nitrogen load

The combined monitored annual total nitrogen load of the 11 priority reef catchments during the 2011–2012 monitoring year was 28 kt (Table 3.2). The Burdekin (11 kt; 38 per cent), Fitzroy (6.4 kt; 23 per cent) and Herbert (3.1 kt; 11 per cent) rivers produced the largest loads of total nitrogen with the Tully (1.8 kt; 6.5 per cent) and North Johnstone (1.5 kt; 5.3 per cent) rivers also contributing substantial loads. All remaining catchments each contributed less than five per cent of the monitored annual total nitrogen load with Sandy Creek in the Plane catchment contributing the lowest total nitrogen load by an end-of-system site (0.26 kt; 0.92 per cent).

During the 2011–2012 monitoring year the combined monitored annual load of dissolved inorganic nitrogen was 5.4 kt (Table 3.2). The largest monitored annual loads of dissolved inorganic nitrogen were derived from the Herbert (1.3 kt; 23 per cent), Burdekin (1.2 kt; 22 per cent), Tully (1.0 kt; 19 per cent), Fitzroy (0.95 kt; 18 per cent) and North Johnstone (0.36 kt; 6.6 per cent) catchments (Table 3.2 and Figure 3.6). The remaining catchments each contributed less than five per cent of the combined monitored load (Figure 3.6) with the lowest loads from end-of-system sites occurring in Sandy Creek in the Plane catchment (0.024 kt; 0.44 per cent) and Normanby (0.022 t; 0.41 per cent) catchments.

Oxidised nitrogen accounted for 94 per cent of the monitored dissolved inorganic nitrogen load during the 2011–2012 monitoring year. The Herbert (1.2 kt; 24 per cent), Burdekin (1.1 kt; 22 per cent), Tully (0.99 kt; 19 per cent) and Fitzroy (0.87 kt; 17 per cent) rivers together accounted for over 80 per cent of the monitored oxidised nitrogen load. The North Johnstone River (0.34 kt; 6.7 per cent) also contributed substantially to the total oxidised nitrogen load. All remaining sites each contributed less than five per cent of the monitored oxidised nitrogen load.

The relative proportion of the ammonium nitrogen load to the oxidised nitrogen load varied greatly amongst catchments during the 2011–2012 monitoring year. In the Normanby and Burnett catchments the relative proportions were low (1:1.4 and 1:2, respectively) whilst in the Tully (1:34) and Herbert (1:31) the relative proportions were very high.

During the 2011–2012 monitoring year, an annual monitored load of approximately 340 t of ammonium nitrogen was derived from all priority reef catchments (Table 3.2). The largest monitored annual loads were derived from the Burdekin (94 t; 28 per cent), Fitzroy (81 t; 24 per cent) and Herbert (39 t; 11 per cent) catchments. Moderate monitored annual loads were also derived from the Pioneer (31 t; 9.1 per cent), Tully (29 t; 8.4 per cent) and North Johnstone (18 t; 5.4 per cent) catchments with all remaining catchments each contributing less than five per cent of the total monitored annual ammonium nitrogen load. The lowest loads were derived from Barratta Creek in the Haughton catchment (4.9 t; 1.5 per cent) and Sandy Creek in the Plane catchment (3.5 t; 1.0 per cent).

The total monitored annual particulate nitrogen load across all monitored catchments in 2011–2012 was 13 kt (Table 3.2). The majority of the particulate nitrogen load was derived from the large inland catchments of the Burdekin (5.8 kt; 44 per cent) and Fitzroy (3.0 kt; 23 per cent) catchments (Table 3.2 and Figure 3.9). The North Johnstone (0.88 kt; 6.7 per cent), Herbert (0.84 kt; 6.3 per cent) and Pioneer (0.82 kt; 6.2 per cent) catchments also contributed moderate loads of particulate nitrogen with the remaining catchments each contributing less than five per cent of the monitored load. The lowest monitored annual load of particulate nitrogen was derived from the Burnett catchment and Barratta Creek in the Haughton catchment with 0.11 kt (0.82 per cent) and 0.094 kt (0.71 per cent), respectively.

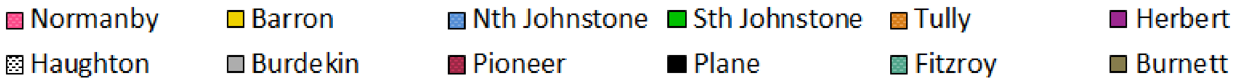
The monitored annual load of dissolved organic nitrogen, 8.9 kt, followed a similar trend to the particulate nitrogen load with the majority coming from the large dry inland catchments of the Burdekin (3.6 kt; 41 per cent), Fitzroy 2.4 kt; 27 per cent) and Herbert (0.89 kt; 10 per cent) catchments (Table 3.2 and Figure 3.10). All remaining sites each contributed less than five per cent of the dissolved organic nitrogen load with the lowest monitored annual loads derived from Sandy Creek in the Plane catchment (0.081 kt; 0.91 per cent) and South Johnstone (0.080 kt; 0.90 per cent) catchment.

3.3.2.2 Nitrogen yields

The largest monitored annual yields of total nitrogen and particulate nitrogen were derived from the North Johnstone (1600 kg km^{-2}; 950 kg km^{-2}, respectively) and South Johnstone (1500 kg km^{-2}; 780 kg km^{-2}, respectively) catchments (Table 3.3). High yields of total nitrogen also occurred in the Tully (1200 kg km^{-2}) and Pioneer (870 kg km^{-2}) catchments and Sandy Creek in the Plane catchment (780 kg km^{-2}). These catchments contain high proportions of intensive agricultural land uses including irrigated cropping (DPC 2011) which is in contrast to the large inland catchments which are dominated by grazing and had comparatively low yields of total nitrogen and particulate nitrogen. The lowest monitored annual yields of total nitrogen were derived from the Burnett (12 kg km^{-2}) and Normanby (38 kg km^{-2}) catchments, followed by the Fitzroy (46 kg km^{-2}) and Burdekin (81 kg km^{-2}) catchments (Table 3.3).

The monitored annual yield of dissolved organic nitrogen 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 North Johnstone (260 kg km^{-2}) catchment, Sandy Creek in the Plane catchment (250 kg km^{-2}), and the Tully (240 kg km^{-2}) catchments. The lowest yields of dissolved organic nitrogen were derived from the Burnett (7.4 kg km^{-2}) and Fitzroy (17 kg km^{-2}) catchments.

The Tully and South Johnstone catchments had the highest monitored annual yields of dissolved inorganic nitrogen with 700 kg km^{-2} and 510 kg km^{-2}, respectively which was driven by high loads of oxidised nitrogen in both of these catchments (Table 3.3). The high yield of ammonium nitrogen was similar for the Pioneer (21 kg km^{-2}), North Johnstone and South Johnstone catchments (each with 20 kg km^{-2}) and the Tully (17 kg km^{-2}) catchment. The lowest yields of dissolved inorganic nitrogen during the 2011–2012 monitoring year occurred in the Burnett (1.3 kg km^{-2}) and Normanby (1.7 kg km^{-2}) catchments (Table 3.3).



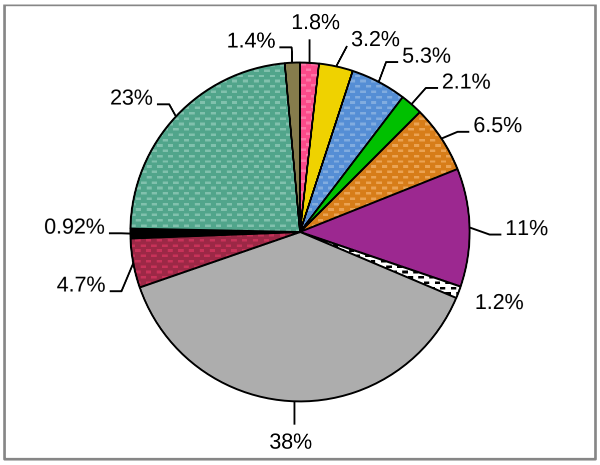


Figure 3.5 Per cent contribution from each catchment to the combined monitored total nitrogen annual load.

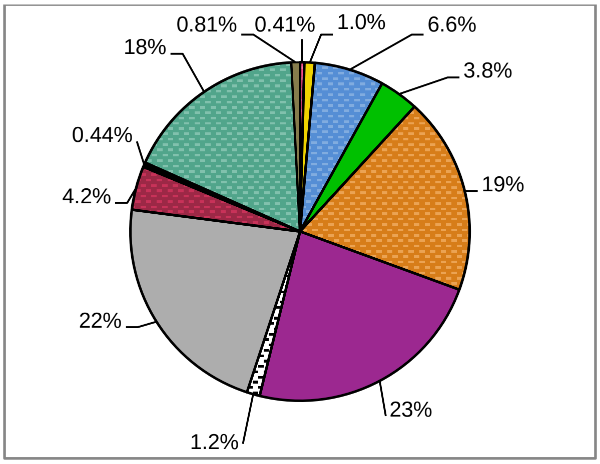


Figure 3.6 Per cent contribution from each catchment to the combined monitored dissolved inorganic nitrogen annual load.

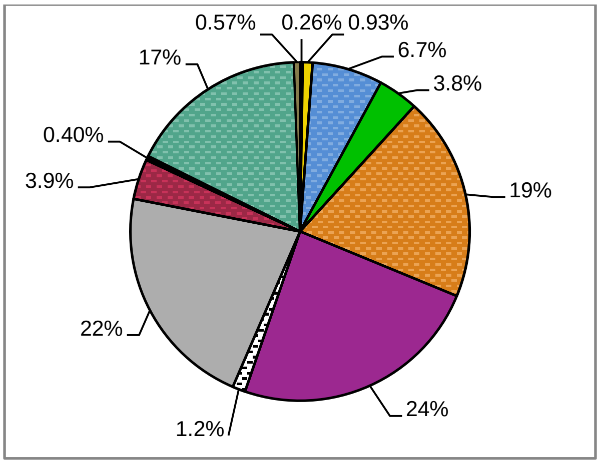


Figure 3.7 Per cent contribution from each catchment to the combined monitored oxidised nitrogen annual load.

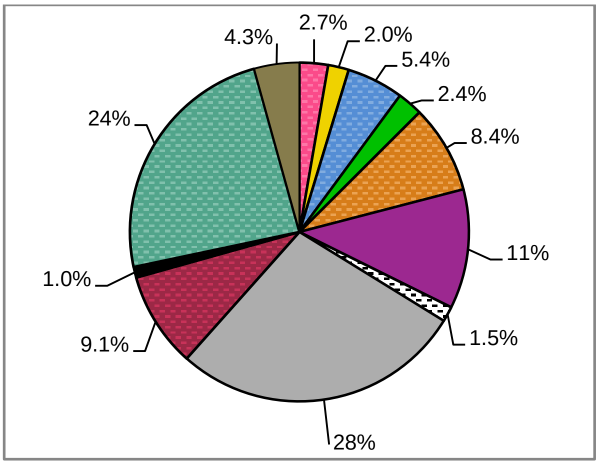


Figure 3.8 Per cent contribution from each catchment to the combined monitored ammonium nitrogen annual load.

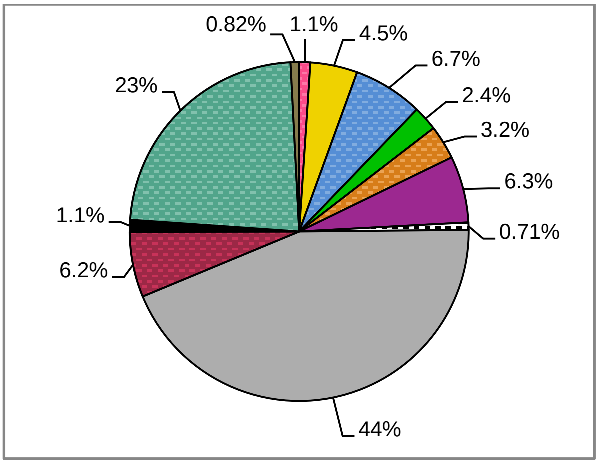


Figure 3.9 Per cent contribution from each catchment to the combined monitored particulate nitrogen annual load.

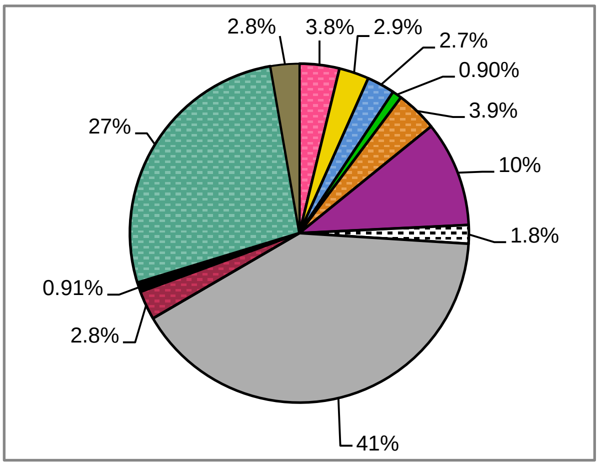


Figure 3.10 Per cent contribution from each catchment to the combined monitored dissolved organic nitrogen annual load.

3.3.3 Phosphorus

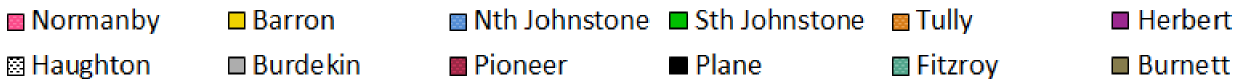
3.3.3.1 Phosphorus load

During the 2011–2012 monitoring year, approximately 7.8 kt of total phosphorus was exported from the 11 priority reef catchments (Table 3.2). The majority of the total phosphorus load was produced by the Burdekin (3.4 kt; 44 per cent) and Fitzroy (2.7 kt; 34 per cent) catchments. With the exception of the North Johnstone (0.4 kt; 5.2 per cent), the remaining catchments each contributed less than five per cent of the annual monitored total phosphorus load (Table 3.2 and Figure 3.11), with the lowest total phosphorus loads occurring in the Burnett (0.047 kt; 0.61 per cent) catchment and Barratta Creek in the Haughton catchment (0.060 kt; 0.77 per cent).

The combined dissolved organic phosphorus monitored annual load from all monitored catchments was 880 t (Table 3.2). The Burdekin (340 t; 39 per cent), Fitzroy (210 t; 24 per cent), Herbert (86 kt; 9.8 per cent) and Tully (79 t; 9.0 per cent) catchments accounted for approximately 82 per cent of the monitored annual dissolved organic phosphorus load, with all remaining catchments each contributing less than five per cent of the cumulative monitored annual load during the 2011–2012 monitoring year (Figure 3.12). The smallest loads of dissolved organic phosphorus were monitored in Barratta Creek in the Haughton catchment (11 t; 1.2 per cent) and Sandy Creek in the Plane catchment (9.1 t; 1.0 per cent) (Figure 3.12).

The combined monitored annual dissolved inorganic phosphorus load from all monitored catchments during 2011–2012 was 1.6 kt (Table 3.2). Fifty-seven per cent of the dissolved inorganic phosphorus load was derived from the Fitzroy (890 kt) catchment which was approximately twice the load exported from the Burdekin (480 t; 31 per cent) catchment which had the second largest dissolved inorganic phosphorus load during the 2011–2012 monitoring year (Figure 3.13). The proportionally high contribution from the Fitzroy catchment is consistent with the observed trend over 2009–2011 monitoring years (Turner et al. 2012 and Turner et al. 2013), however these results differ from the period 2006–2009 when the dissolved inorganic phosphorus load from both of these catchments were similar (Joo et al. 2012). All remaining catchments produced three per cent or less of the monitored annual load (Figure 3.13).

The monitored annual particulate phosphorus load accounted for approximately three quarters of the total phosphorus monitored annual load exported from the monitored reef catchments (Table 3.2) which is consistent with previous monitoring years (Turner et al. 2012; Turner et al. 2013). The majority of the monitored annual particulate phosphorus load was derived from the Burdekin (2.7 kt; 48 per cent) and Fitzroy (1.6 kt; 28 per cent) catchments (Figure 3.14). The North Johnstone catchment produced 0.37 kt (6.5 per cent) of particulate phosphorus with all other catchments producing less than five per cent of the monitored annual load with the lowest loads occurring in the Burnett catchment (0.032 kt; 0.57 per cent) and Barratta Creek in the Haughton (0.026 kt; 0.46 per cent) catchment.



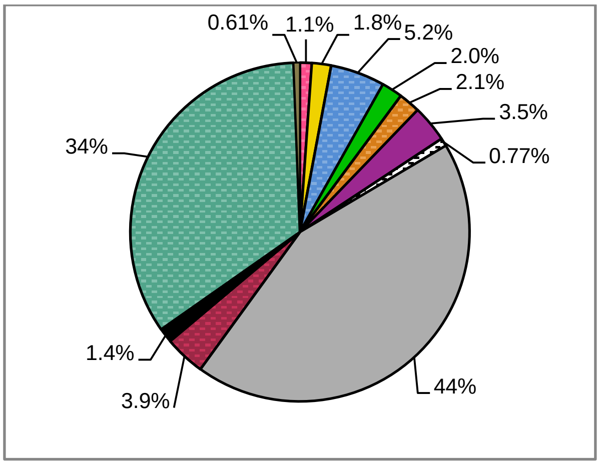


Figure 3.11 Per cent contribution from each catchment to the combined monitored total phosphorus annual load.

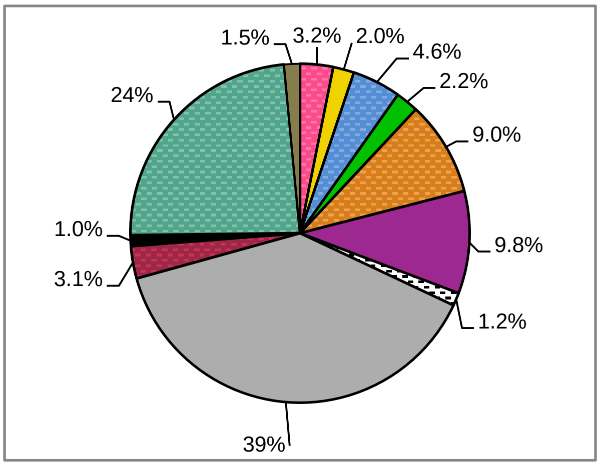


Figure 3.12 Per cent contribution from each catchment to the combined monitored dissolved organic phosphorus annual load.

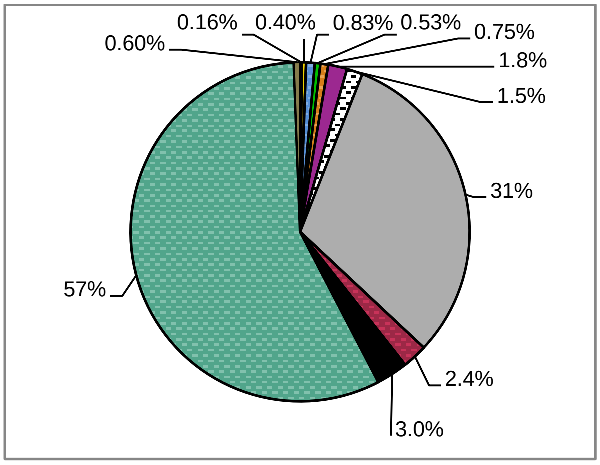


Figure 3.13 Per cent contribution from each catchment to the combined monitored dissolved inorganic phosphorus annual load.

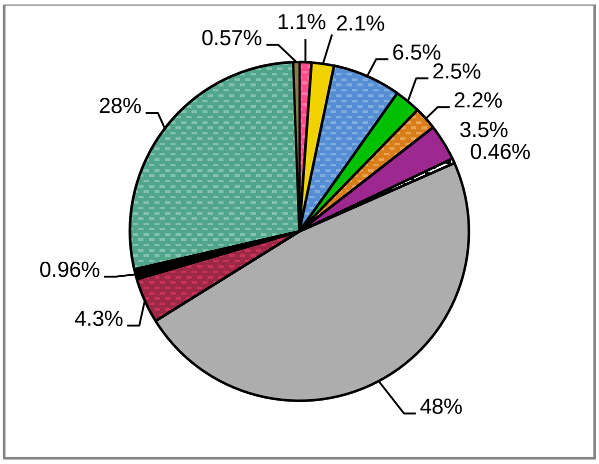


Figure 3.14 Per cent contribution from each catchment to the combined monitored particulate phosphorus annual load.

3.3.3.2 Phosphorus yields

The North Johnstone and South Johnstone catchments and Sandy Creek in the Plane catchment produced the highest monitored annual yields of total phosphorus (440 kg km^{-2}, 390 kg km^{-2} and 330 kg km^{-2}, respectively) (Table 3.4). High total phosphorus monitored annual yields were also derived from the Pioneer catchment (200 kg km^{-2}). The remainder of the catchments all had markedly lower monitored annual yields, with only the Tully River having a value greater than 100 kg km^{-2}. The four highest monitored annual yields of particulate phosphorus were in descending order the North and South Johnstone catchments, Sandy Creek in the Plane catchment and the Pioneer catchment (400 kg km^{-2}, 350 kg km^{-2}, 170 kg km^{-2} and 170 kg km^{-2}, respectively) with all the remaining sites having much lower monitored annual yields (Table 3.4). The Tully and the North and South Johnstone catchments had the highest monitored annual yields of dissolved organic phosphorus (55 kg km^{-2}, 44 kg km^{-2} and 48 kg km^{-2}, respectively). Notably, the monitored annual yield of dissolved inorganic phosphorus in Sandy Creek in the Plane catchment (140 kg km^{-2}) was approximately five-times greater than the next highest yielding catchments – Barratta Creek in the Haughton catchment (31 kg km^{-2}) and the Pioneer (25 kg km^{-2}) catchment. The Burnett and Normanby catchments had the lowest monitored annual yields of all forms of phosphorus, except dissolved organic phosphorus where the lowest monitored annual yields where in the Fitzroy (1.5 kg km^{-2}) and Burnett (0.40 kg km^{-2}) catchments (Table 3.4).

Table 3.2 Estimated total suspended solids and nutrient loads for 2011–2012. Sites in bold are end-of-system sites, all others are sub-catchment sites. Green shading = excellent or good representivity rating; Orange shading = moderate representivity; Red shading = indicative representivity.

Catchment	Gauging station	River and site name	n	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)
Normanby	**105107A[L]**	**Normanby River at Kalpowar Crossing**	39	46,000	490	140	13	9.2	22	340	87	2.5	65	28
Barron	**110001D[B]**	**Barron River at Myola**	48	160,000	890	590	47	6.7	54	250	143	6.2	120	18
Johnstone	112004A[B]	North Johnstone River at Tung Oil[$]	45	190,000	1,500	880	340	18	360	240	400	13	370	41
	112101B[B]	South Johnstone River at Upstream Central Mill[$]	21	61,000	590	310	190	8.2	200	80	160	8.2	140	19
Tully	**113006A[L]**	**Tully River at Euramo**	311	90,000	1,800	430	990	29	1,000	350	160	12	130	79
	113015A[B]	Tully River at Tully Gorge National Park	38	7000	380	71	220	8.1	220	94	22	2.2	19	17
Herbert	**116001F[L/B]**	**Herbert River at Ingham**	79	160,000	3,100	840	1,200	39	1,300	890	270	28	200	86
Haughton	**119101A[L]**	**Barratta Creek at Northcote**	116	11,000	320	94	62	4.9	67	160	60	24	26	11
Burdekin	**120001A[L]**	**Burdekin River at Home Hill**	56	3,300,000	11,000	5,800	1,100	94	1,200	3,600	3,400	480	2,700	340
	120002C[B]	Burdekin River at Sellheim	31	2,400,000	510	3,200	410	44	450	1,500	2,000	200	1,700	150
	120301B[L]	Belyando River at Gregory Development Road	102	160,000	1,300	430	24	21	45	870	390	150	200	53
	120302B[L/B]	Cape River at Taemas	91	220,000	1,200	640	20	9.8	30	530	250	16	220	32
	120310A[B]	Suttor River at Bowen Development Road	32	55,600	690	210	6.1	8.4	15	470	150	40	93	21
Pioneer	**125013A[L]**	**Pioneer River at Dumbleton Pump Station**	100	210,000	1,300	820	200	31	230	250	300	37	250	27
Plane	**126001A[B]**	**Sandy Creek at Homebush**	27	31,000	260	150	20	3.5	24	81	110	47	54	9.1
Fitzroy	**1300000[L]**	**Fitzroy River at Rockhampton**	28	1,300,000	6,400	3,000	870	81	950	2,400	2,700	890	1,600	210
	130206A[B]	Theresa Creek at Gregory Highway	12	89,000	400	180	29	4.6	33	180	170	59	96	14
	130504B[B]	Comet River at Comet Weir	20	700,000	1,400	900	160	14	170	340	810	180	600	34
Burnett	**136014A[L]**	**Burnett River at Ben Anderson Barrage Head Water**	50	15,000	400	110	29	15	44	240	47	9.3	32	13
	136002D[B]	Burnett River at Mt Lawless	11	28,000	410	120	55	14	70	210	75	21	44	11
	136094A[B]	Burnett River at Jones Weir Tail Water	11	46,000	320	120	30	23	53	150	65	8.1	49	7.5
	136106A[L]	Burnett River at Eidsvold	23	14,000	180	80	14	6.1	20	78	32	6.0	21	5.2
Total load (EoS sites plus North Johnstone and South Johnstone rivers)			925	5,600,000	28,000	13,000	5,100	340	5,400	8,900	7,800	1,600	5,700	880

n = number of concentration data points used in the calculation of total suspended solids loads – the number of concentration data points used for the load calculation of loads for all other analytes is presented in Appendix G TSS = total suspended solids; TN = total nitrogen; PN = particulate nitrogen; NO_x-N = oxidised nitrogen as N; NH_4-N = ammonium nitrogen as N; DIN = dissolved inorganic nitrogen (DIN = (NO_x-N) + (NH_4-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 EoS = end-of-system.

Table 3.3 Total suspended solids and nitrogen yields calculated for 2011–2012 along with monitored area and per cent of catchment monitored. Sites in bold are end-of-system sites, all others are sub-catchment sites. Green shading = excellent or good representivity rating; Orange shading = moderate representivity; Red shading = indicative representivity.

Catchment	Gauging station	River and site name	Monitored area (km^2)	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 ($kg\ km^{-2}$)
Normanby	**105107A[L]**	**Normanby River at Kalpowar Crossing**	12,934	53	3.6	38	11	1.0	0.71	1.7	26
Barron	**110001D[B]**	**Barron River at Myola**	1945	89	84	460	310	24	3.4	28	130
Johnstone	112004A[B]	North Johnstone River at Tung Oil[$]	925	40	200	1,600	950	370	20	390	260
	112101B[B]	South Johnstone River at Upstream Central Mill[$]	400	17	150	1,500	780	490	20	510	200
Tully	**113006A[L]**	**Tully River at Euramo**	1450	86	62	1,200	290	680	20	700	240
	113015A[B]	Tully River at Tully Gorge National Park	482	29	14	790	150	450	17	460	200
Herbert	**116001F[L/B]**	**Herbert River at Ingham**	8581	87	19	360	100	140	4.5	150	100
Haughton	**119101A[L]**	**Barratta Creek at Northcote**	753	19	14	420	120	83	6.6	89	210
Burdekin	**120001A[L]**	**Burdekin River at Home Hill**	129,939	99	25	81	45	8.4	0.72	9.2	28
	120002C[B]	Burdekin River at Sellheim	36,290	28	67	140	87	11	1.2	12	40
	120301B[L]	Belyando River at Gregory Development Road	35,411	27	4.5	37	12	0.69	0.60	1.3	25
	120302B[L/B]	Cape River at Taemas	16,074	12	14	74	40	1.3	0.61	1.9	33
	120310A[B]	Suttor River at Bowen Development Road	10,758	8	5.2	64	19	0.57	0.78	1.4	44
Pioneer	**125013A[L]**	**Pioneer River at Dumbleton Pump Station**	1485	94	140	870	550	130	21	150	170
Plane	**126001A[B]**	**Sandy Creek at Homebush**	326	13	96	780	460	62	11	73	250
Fitzroy	**1300000[L]**	**Fitzroy River at Rockhampton**	139,159	98	9.5	46	22	6.2	0.58	6.8	17
	130206A[B]	Theresa Creek at Gregory Highway	8485	6	11	47	22	3.4	0.55	3.9	21
	130504B[B]	Comet River at Comet Weir	16,457	12	42	85	54	10	0.83	10	20
Burnett	**136014A[L]**	**Burnett River at Ben Anderson Barrage Head Water**	32,891	99	0.45	12	3.3	0.88	0.44	1.3	7.4
	136002D[B]	Burnett River at Mt Lawless	29,355	88	0.96	14	4.2	1.9	0.49	2.4	7.2
	136094A[B]	Burnett River at Jones Weir Tail Water	21,700	65	2.1	15	5.5	1.4	1.1	2.5	7.0
	136106A[L]	Burnett River at Eidsvold	7117	21	2.0	25	11	1.9	0.85	2.8	11

TSS = total suspended solids; TN = total nitrogen; PN = particulate nitrogen; NO_x-N = oxidised nitrogen as N; NH_4-N = ammonium nitrogen as N; DIN = dissolved inorganic nitrogen (DIN = (NO_x-N) + (NH_4-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.

Table 3.4 Phosphorus yields calculated for 2011–2012 along with monitored area and per cent of catchment monitored. Sites in bold are end-of-system sites, all others are sub-catchment sites. Green shading = excellent or good representivity rating; Orange shading = moderate representivity; Red shading = indicative representivity.

Catchment	Gauging station	River and site name	Monitored area (km^2)	Monitored area of catchment (%)	TP ($kg\ km^{-2}$)	DIP ($kg\ km^{-2}$)	PP ($kg\ km^{-2}$)	DOP ($kg\ km^{-2}$)
Normanby	**105107A[L]**	**Normanby River at Kalpowar Crossing**	12,934	53	6.7	0.20	5.0	2.1
Barron	**110001D[B]**	**Barron River at Myola**	1,945	89	73	3.2	62	9.0
Johnstone	112004A[B]	North Johnstone River at Tung Oil[$]	925	40	440	14	400	44
	112101B[B]	South Johnstone River at Upstream Central Mill[$]	400	17	390	20	350	48
Tully	**113006A[L]**	**Tully River at Euramo**	1,450	86	110	8.0	86	55
	113015A[B]	Tully River at Tully Gorge National Park	482	29	45	4.5	40	36
Herbert	**116001F[L/B]**	**Herbert River at Ingham**	8581	87	32	3.3	23	10
Haughton	**119101A[L]**	**Barratta Creek at Northcote**	753	19	79	31	35	14
Burdekin	**120001A[L]**	**Burdekin River at Home Hill**	129,939	99	26	3.7	21	2.6
	120002C[B]	Burdekin River at Sellheim	36,290	28	54	5.4	46	4.0
	120301B[L]	Belyando River at Gregory Development Road	35,411	27	11	4.2	5.5	1.5
	120302B[L/B]	Cape River at Taemas	16,074	12	15	1.0	13	2.0
	120310A[B]	Suttor River at Bowen Development Road	10,758	8	14	3.8	8.7	2.0
Pioneer	**125013A[L]**	**Pioneer River at Dumbleton Pump Station**	1,485	94	200	25	170	18
Plane	**126001A[B]**	**Sandy Creek at Homebush**	326	13	330	140	170	28
Fitzroy	**1300000[L]**	**Fitzroy River at Rockhampton**	139,159	98	19	6.4	11	1.5
	130206A[B]	Theresa Creek at Gregory Highway	8485	6	20	7.0	11	1.6
	130504B[B]	Comet River at Comet Weir	16,457	12	49	11	36	2.0
Burnett	**136014A[L]**	**Burnett River at Ben Anderson Barrage Head Water**	32,891	99	1.4	0.28	0.99	0.40
	136002D[B]	Burnett River at Mt Lawless	29,355	88	2.6	0.72	1.5	0.38
	136094A[B]	Burnett River at Jones Weir Tail Water	21,700	65	3.0	0.37	2.6	0.35
	136106A[L]	Burnett River at Eidsvold	7,117	21	4.5	0.84	3.0	0.73

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; and [$] = the North and South Johnstone rivers combined act as an end-of-system site.

3.4 Pesticide loads and yields

3.4.1.1 Annual load

The monitored annual loads of the five priority photosystem II herbicides, ametryn, total atrazine (atrazine and its breakdown products desethyl atrazine and desisopropyl atrazine), diuron, hexazinone and tebuthiuron, were calculated for each monitored site (Table 3.5). The contribution of each catchment to the total monitored annual load at the end-of-system sites (including the North Johnstone River) for each pesticide are presented in Figure 3.15 to Figure 3.19. The loads of other herbicides detected by the LCMS analysis are presented in Appendix B; metolachlor, in particular contributes substantially to the total annual monitored herbicide load during the 2011–2012 monitoring year.

When all catchments are considered together, the total monitored annual load of the five priority photosystem II herbicides exported past the end-of-system monitoring sites were (from largest to smallest): 2100 kg of total atrazine; 1100 kg of tebuthiuron; 770 kg diuron; 200 kg of hexazinone; and 48 kg of ametryn (Table 3.5).

Of the five priority photosystem II herbicides, only total atrazine and diuron were detected at all end-of-system and sub-catchment monitoring sites (Table 3.5). The largest monitored annual load of total atrazine occurred in the Fitzroy (1000 kg; 49 per cent) with smaller but considerable contributions from the Burdekin and Pioneer catchments and Barratta Creek in the Haughton catchment (360 kg, 220 kg and 220 kg, respectively or 17 per cent, 10 per cent and 11 per cent, respectively, Table 3.5 and Figure 3.16). The largest load of diuron occurred in the Tully catchment (240 kg; 32 per cent) with the Herbert (150 kg; 19 per cent) and Pioneer (140 kg; 18 per cent) catchments also making significant contributions. In contrast, the Burnett catchment produced the lowest calculable monitored annual load of total atrazine (10 kg; 0.49 per cent) and diuron (12 kg; 1.6 per cent) of all monitored end-of-system sites (Table 3.5, Figure 3.16 and Figure 3.17, respectively).

Ametryn was detected at six of the eight end-of-system sites with the largest monitored annual load (24 kg) derived from the Burdekin catchment, accounting for 50 per cent of the total ametryn load during the 2011–2012 monitoring year (Table 3.5 and Figure 3.15). The lowest calculable load of ametryn was from Barratta Creek (2.2 kg; 4.6 per cent) in the Haughton catchment. Ametryn was not detected in the Fitzroy and Burnett catchment or any sub-catchment monitoring sites including the North Johnstone River (Table 3.5).

Hexazinone was detected at all end-of-system monitoring sites except the Burdekin and Fitzroy catchments and at only one sub-catchment monitoring site, Comet River at Comet Weir (6.7 kg). The largest monitored annual load of hexazinone was derived from the Tully river (99 kg), accounting for 49 per cent of the combined monitored end-of-system load of 200 kg (Table 3.5).

The combined monitored annual load of tebuthiuron during the 2011–2012 monitoring year was 1100 kg with the Fitzroy (890 kg; 79 per cent) and Burdekin (230 kg; 20 per cent) catchments contributing at least 99 per cent of this load (Table 3.5 and Figure 3.19). Small loads of tebuthiuron were monitored at the Tully catchment, Barratta Creek in the Haughton catchment and the Pioneer and Burnett catchments (Table 3.5).

Tebuthiuron was detected in all sub-catchment monitoring sites with a substantial load derived from the Comet River (110 kg) in the Fitzroy catchment.

3.4.1.2 Annual yield

The Tully catchment produced the highest monitored annual yield of hexazinone (0.068 kg km^{-2}) and the highest monitored annual yield of diuron along with Sandy Creek in the Plane catchment (both 0.17 kg km^{-2}) (Table 3.6). Of all end-of-system monitoring sites, Sandy Creek in the Plane catchment (0.0089 kg km^{-2}) produced the highest monitored annual yield of ametryn (Table 3.6), Barratta Creek in the Haughton catchment produced the highest yield of total atrazine (0.29 kg km^{-2}) and the Fitzroy catchment produced the highest yield of tebuthiuron at 0.0064 kg km^{-2} (Table 3.6). The Comet River sub-catchment in the Fitzroy produced the highest monitored annual yield of tebuthiuron of all monitored areas (0.0065 kg km^{-2}).

The lowest calculable monitored annual yield of total atrazine (0.00032 kg km^{-2}), hexazinone (0.00017kg km^{-2}) and tebuthiuron (0.000052 kg km^{-2}) occurred in the Burnett catchment which received low rainfall during the monitoring year. The Burdekin catchment, which in contrast received above average rainfall over the same period, reported the lowest calculable loads of ametryn (0.00018 kg km^{-2}) and diuron (0.00022 kg km^{-2}).

The annual yields of pesticides presented in this section were calculated using the total monitored catchment area. The application of pesticides however, is regulated to specific land uses (e.g. sugarcane production) which in many cases will be much less than the total monitored catchment area. The calculation of the pesticide yield based on the area of land to which the regulated chemical is permitted for use, allows a more detailed analysis of the annual yields within the study area. This more detailed analysis of the land use yield of pesticides including the assumptions required for these analysis are presented in Appendix F.

Table 3.5 The annual loads calculated for the five priority photosystem II herbicides: ametryn, total atrazine, diuron, hexazinone and tebuthiuron. Sites in bold are end-of-system sites, all others are sub-catchment sites.

Catchment	Gauging station	River and site name	Monitored area (km^2)	Monitored area of catchment (%)	n	Ametryn (kg)	Total Atrazine (kg)	Diuron (kg)	Hexazinone (kg)	Tebuthiuron (kg)
Johnstone	112004A[B]	North Johnstone River at Tung Oil	925	40	32	NC	14	16	NC	0.3
Tully	**113006A[B]**	**Tully River at Euramo**	1450	86	73	6.2	150	240	99	4.4
Herbert	**116001F[L]**	**Herbert River at Ingham**	8581	87	77	3.7	47	150	49	NC
Haughton	**119101A[L]**	**Barratta Creek at Northcote**	753	19	93	2.2	220	60	2.9	1.3
Burdekin	**120001A[L]**	**Burdekin River at Home Hill**	129,939	99	52	24	360	28	NC	230
Pioneer	**125013A[L]**	**Pioneer River at Dumbleton Pump Station**	1485	94	149	8.7	220	140	27	0.9
Plane	**126001A[B]**	**Sandy Creek at Homebush**	326	13	26	2.9	58	55	16	NC
Fitzroy	**1300000[L]**	**Fitzroy River at Rockhampton**	139,159	98	28	NC	1000	66	NC	890
	130206A[B]	Theresa Creek at Gregory Highway	8,845	6	13	NC	250	17	NC	11
	130504B[B]	Comet River at Comet Weir	16,457	12	18	NC	580	7	6.7	110
Burnett	**136014A[L]**	**Burnett River at Ben Anderson Barrage Head Water**	32,891	99	48	NC	10	12	5.6	1.7
Total (end-of-system sites plus the North Johnstone River)			320,000		580	48	2100	770	200	1100

n = the number of grab samples used to estimate loads; NC = a load was not calculated as all the concentrations for all samples collected were below the practical quantitation limit;
[L] = average load (linear interpolation of concentration) method used to calculate loads; [B] = Beale ratio method used to calculate loads

Table 3.6 The annual yields calculated for the five priority photosystem II herbicides: ametryn, atrazine, diuron, hexazinone and tebuthiuron. Sites in bold are end-of-system sites, all others are sub-catchment sites.

Catchment	Gauging station	River and site name	Monitored area (km^2)	Monitored area of catchment (%)	Ametryn ($kg\ km^{-2}$)	Total Atrazine ($kg\ km^{-2}$)	Diuron ($kg\ km^{-2}$)	Hexazinone ($kg\ km^{-2}$)	Tebuthiuron ($kg\ km^{-2}$)
Johnstone	112004A[B]	North Johnstone River at Tung Oil	925	40	NC	0.016	0.017	NC	0.00032
Tully	**113006A[B]**	**Tully River at Euramo**	1450	86	0.0043	0.11	0.17	0.068	0.0030
Herbert	**116001F[L]**	**Herbert River at Ingham**	8581	87	0.00043	0.0054	0.017	0.0057	NC
Haughton	**119101A[L]**	**Barratta Creek at Northcote**	753	19	0.0029	0.29	0.080	0.0039	0.0017
Burdekin	**120001A[L]**	**Burdekin River at Home Hill**	129,939	99	0.00018	0.0028	0.00022	NC	0.0018
Pioneer	**125013A[L]**	**Pioneer River at Dumbleton Pump Station**	1485	94	0.0059	0.15	0.091	0.018	0.00061
Plane	**126001A[B]**	**Sandy Creek at Homebush**	326	13	0.0089	0.18	0.17	0.050	NC
Fitzroy	**1300000[L]**	**Fitzroy River at Rockhampton**	139,159	98	NC	0.0074	0.00047	NC	0.0064
	130206A[B]	Theresa Creek at Gregory Highway	8,845	6	NC	0.030	0.0020	NC	0.0012
	130504B[B]	Comet River at Comet Weir	16,457	12	NC	0.035	0.00042	0.00041	0.0065
Burnett	**136014A[L]**	**Burnett River at Ben Anderson Barrage Head Water**	32,891	99	NC	0.00032	0.00037	0.00017	0.000052

NC = not calculated. [L] = average load (linear interpolation of concentration) method used to calculate loads; [B] = Beale ratio method used to calculate loads

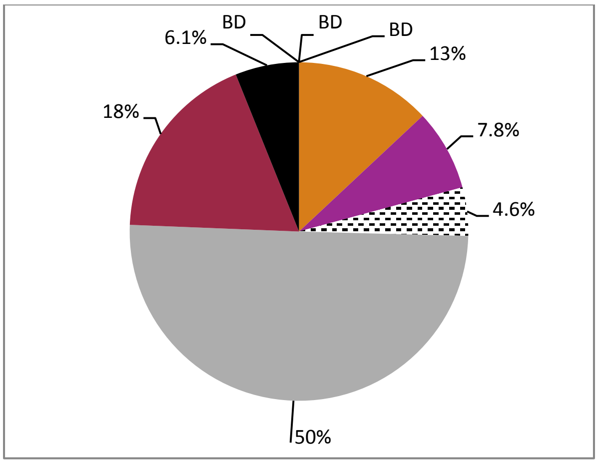


Figure 3.15 Per cent contribution from each end-of-system site (including North Johnstone) to the combined monitored ametryn load.

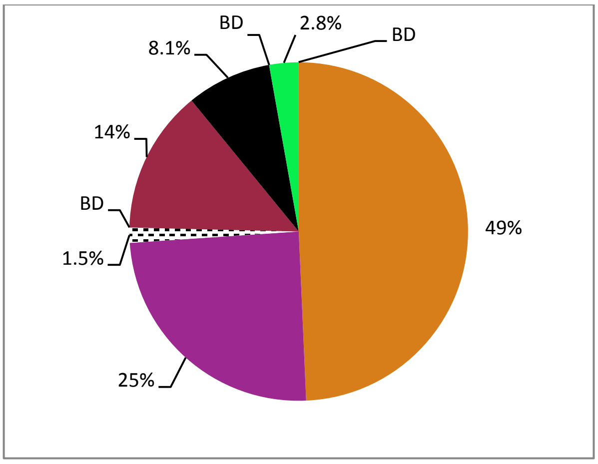


Figure 3.18 Per cent contribution from each end-of-system site (including North Johnstone) to the combined monitored hexazinone load.

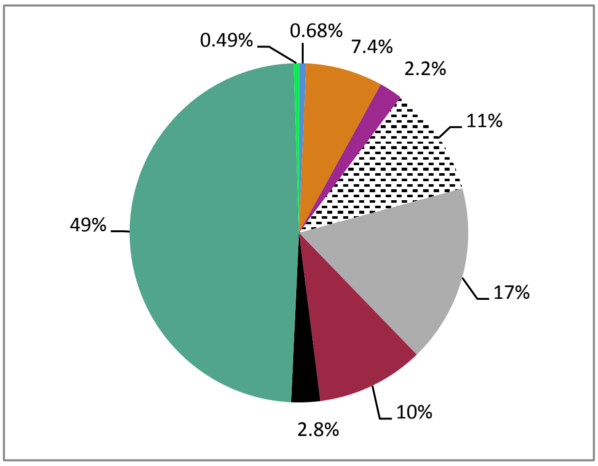


Figure 3.16 Per cent contribution from each end-of-system site (including North Johnstone) to the combined monitored total atrazine load.

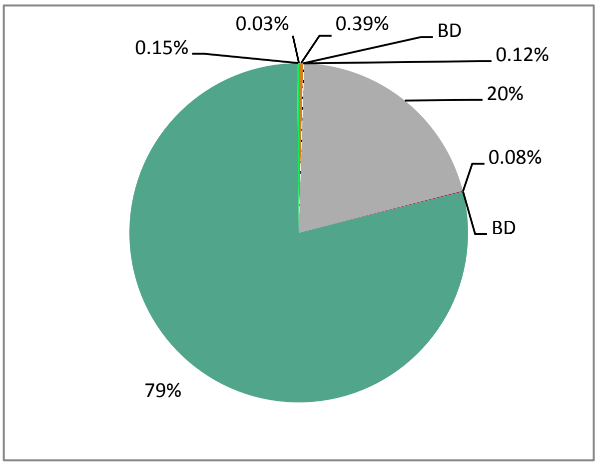


Figure 3.19 Per cent contribution from each end-of-system site (including North Johnstone) to the combined monitored tebuthiuron load.

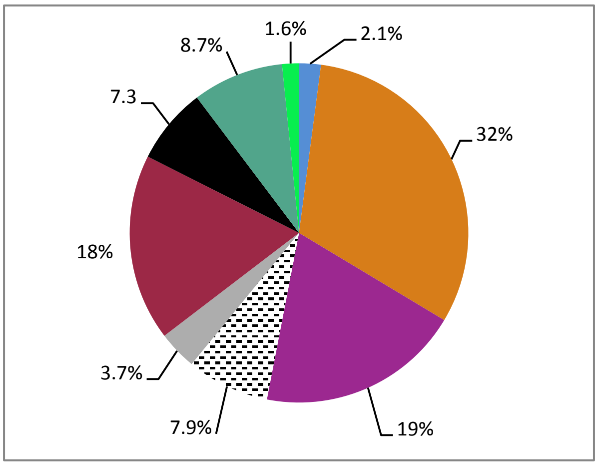


Figure 3.17 Per cent contribution from each end-of-system site (including North Johnstone) to the combined monitored diuron load.

4 Conclusions

The Great Barrier Reef Catchment Loads Monitoring Program determined the monitored annual loads and yields of total suspended solids and ten forms of phosphorus and nitrogen, for ten end-of-system sites and 15 sub-catchment sites, covering 11 catchments, during the 2011–2012 monitoring year. The monitored annual loads and yields of five photosystem II inhibitor herbicides were also determined for eight end-of-system sites and three sub-catchment sites covering nine catchments. During 2011–2012:

- All priority reef catchments received average or slightly above average annual rainfall over the monitoring year.
- The long-term mean annual discharge was exceeded in nine of the eleven monitored catchments.
- Discharge in the Burnett and Normanby catchments was considerably below average.
- Good to excellent sampling representivity was achieved for the majority of end-of-system and sub-catchment monitoring sites providing robust loads data for the validation of catchment models. This was achieved through delivery of specialist water quality training to regional staff and installation of automated sampling equipment at additional priority catchment monitoring sites.
- The monitored catchments generated approximately 5.6 million tonnes of total suspended solids, 28,000 tonnes of nitrogen and 7800 tonnes of phosphorus.
- The Burdekin and Fitzroy catchments generated the highest loads of all non-herbicide pollutants except for dissolved inorganic nitrogen loads, which were particularly high in the Herbert and Tully catchments due to high oxidised nitrogen. The Burdekin and Fitzroy catchments accounted for approximately 83 per cent of the total suspended solids, 61 per cent of the total nitrogen and 78 per cent of the total phosphorus loads.
- Sandy Creek in the Plane catchment, Barratta Creek in the Haughton catchment and the Burnett and Normanby catchments produced the lowest loads of total and particulate nitrogen, Sandy Creek in the Plane catchment and Normanby catchments produced the lowest load of dissolved inorganic nitrogen and Sandy Creek in the Plane catchment and South Johnstone catchments produced the lowest loads of dissolved organic nitrogen.
- The monitored annual load of all phosphorus compounds was low in all catchments except in the Burdekin and Fitzroy catchments.
- The highest monitored annual yields of total suspended solids, total nitrogen and total phosphorus were derived from the North Johnstone and South Johnstone catchments. The Tully catchment, Sandy Creek in the Plane catchment and Pioneer catchments also produced relatively high yields of most monitored pollutants during the 2011–2012 monitoring year.
- The lowest monitored annual yields of total suspended solids, total nitrogen and total phosphorus occurred in the Burnett and Normanby catchments with comparatively low yields in the Fitzroy and Burdekin catchments.
- The annual load of the five photosystem II inhibitor herbicides (ametryn, total atrazine, diuron, hexazinone and tebuthiuron) was approximately 4.2 tonnes.

- Photosystem II inhibitor herbicides were detected at all monitored sites.
- The total monitored annual pesticide loads at the end-of-system monitoring sites were, in descending order: 2100 kg of total atrazine; 1100 kg of tebuthiuron; 770 kg diuron; 200 kg of hexazinone; and 48 kg of ametryn.
- Total atrazine and diuron were detected at all sites; tebuthiuron was detected at all sites except in the Herbert catchment and Sandy Creek in the Plane catchment.
- The Fitzroy catchment contributed the largest monitored annual load of total atrazine and tebuthiuron, the Tully catchment contributed the largest loads of diuron and hexazinone and the Burdekin contributed the largest load of ametryn. The largest yield of ametryn was in Sandy Creek in the Plane catchment, diuron in Sandy Creek in the Plane and Tully catchments, hexazinone in the Tully catchment, total atrazine in Barratta Creek in the Haughton catchment, and tebuthiuron in the Fitzroy catchment.

The loads and yields data presented in this report complement monitoring conducted by the Great Barrier Reef Catchment Loads Monitoring Program since 2006. These data have been provided to validate the catchment models used to report on progress against Reef Plan water quality improvement targets. The continuity of the data made available through the Great Barrier Reef Catchment Loads Monitoring Program continues to provide a critical data resource for the effective management of Queensland natural resources.

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7 Appendices

Appendix A Comparison of pesticide extraction methods: solid phase extraction vs. liquid liquid extraction

Background

The Queensland Health Forensic Scientific Services organics laboratory currently analyses water samples from the Great Barrier Reef Catchments Loads Monitoring Program for pesticides. Pesticides in samples from the 2009–2010 and 2010–2011 monitoring years were extracted using a liquid-liquid extraction (LLE) method before analysis with Liquid Chromatography-Mass Spectrometry (LCMS). The LLE method involves physically mixing a solvent with the water sample followed by the separation of the solvent phase from the water sample.

In 2011 the Queensland Health Forensic Scientific Services organics laboratory validated and implemented an automated method that uses solid phase extraction (SPE) to prepare water samples for LCMS analysis. This extraction method involves passing a water sample through a small cartridge containing a solid matrix that extracts the pesticides from the water sample. The pesticides are automatically eluted from the cartridge with a solvent and then analysed for pesticides using LCMS.

As part of the implementation and validation of the SPE method, the Queensland Health Forensic Scientific Services organics laboratory compared the extraction efficiencies of the SPE and LLE methods using 84 Great Barrier Reef Catchments Loads Monitoring Program samples. Preliminary analysis revealed that a larger dataset was required so another 200 Paddock to Reef samples, which included samples from the Great Barrier Reef Catchments Loads Monitoring Program and a Mackay-based paddock run-off study, were analysed. This data was provided to the Department of Science, Information Technology, Innovation and the Arts to assess whether there were any differences in the results provided by the two extraction methods.

Advantages and disadvantages of the solids phase extraction method

Advantages

There are a number of advantages to changing to the SPE method, these include:

- reduced sample volume (250 mL versus 1 L) and hence reduced transport costs and improved workplace health and safety
- faster laboratory turn-around-time (within weeks rather than months)
- the automated method reduces human related error
- there is potential to store sample extracts, providing greater flexibility for selecting only the most valuable samples for analysis and thereby reducing analytical costs without compromising holding

times. There is also the potential to re-run stored extracts for 'new' chemicals in the future should the need arise
- improvement of detection levels - a sample can be double extracted for low-level concentrations, which is particularly important for groundwater analysis.

Disadvantages

There are two main disadvantages to the SPE method:

- the LLE method extracts pesticides from the whole sample i.e. both the sorbed and dissolved fractions, (NOTE this is not a total extraction) whereas the SPE method only extracts from the dissolved fraction. Therefore, there are likely to be differences in the concentrations determined using the two methods.
- the change in methods may prevent or limit the validity of temporal comparisons of the annual pesticide loads. NOTE: This can be overcome with a high quality statistically valid relationship between the concentrations determined by the two methods.

Methods

The concentration data for each pesticide from each extraction method were tested for normality using the Kolmogorov-Smirnov test. The majority of the data for each pesticide significantly ($p \leq 0.05$) deviated from normality. Therefore the non-parametric Wilcoxon signed rank test (one-tailed) was used to determine if there were statistically significant differences between the pesticide concentrations extracted by the two methods. The level of statistical inference was set at ≤ 0.05. Wilcoxon signed rank tests with probabilities ≤ 0.05 indicate that the concentrations of each pesticide quantified using the LLE and SPE methods were significantly different.

For each pesticide the relationship between the concentrations measured by the LLE and SPE methods was determined using linear regression analysis. The level of statistical inference was set at ≤ 0.05. Regression equations with probabilities ≤ 0.05 indicate that the relationship was statistically significant. The gradient of the relationship between LLE and SPE became a conversion factor (bias) able to convert LLE derived concentrations to estimated SPE values. The linear regression was always forced through the origin, even for pesticides where there was a significant difference between the two methods. The statistical reasons for forcing the regression through the origin were:

- generally the data supported this (i.e. the intercept terms were not significantly different to zero)
- it is particularly pertinent for the small sample sizes to be only estimating one parameter (the gradient) rather than estimating both the intercept and the gradient

Where the data did not support forcing through the origin (i.e. the intercept terms were significantly different to zero), the data was still forced because:

- you cannot have a negative concentration
- if the chemical is not present in the sample, the true concentration for both methods will be 0 μg/L
- by not forcing the regression through the origin, the conversion factor will be based on the equation SPE = mx + b which will mean that for all LLE concentrations below the limit of reporting, there will be a positive SPE concentration (i.e. SPE = b).

To test the validity of the derived conversion factors, they were applied to measured LLE pesticide concentrations to convert to an SPE pesticide concentration, which were then compared to the measured SPE concentrations. The conversion factors were considered valid if the converted SPE pesticide concentrations agreed better with the measured SPE values (i.e. a higher percentage of its data were within 30 per cent of the measured SPE concentrations) than the measured LLE pesticide concentrations. The bias was calculated using Great Barrier Reef Catchments Loads Monitoring Program data from the second set of testing by Queensland Health Forensic Scientific Services. The validation was conducted using three datasets: Great Barrier Reef Catchments Loads Monitoring Program data from November 2010 (first set of tests) and from August 2011 (second set of tests) and paddock-scale data (second set of tests).

Results of the validation study

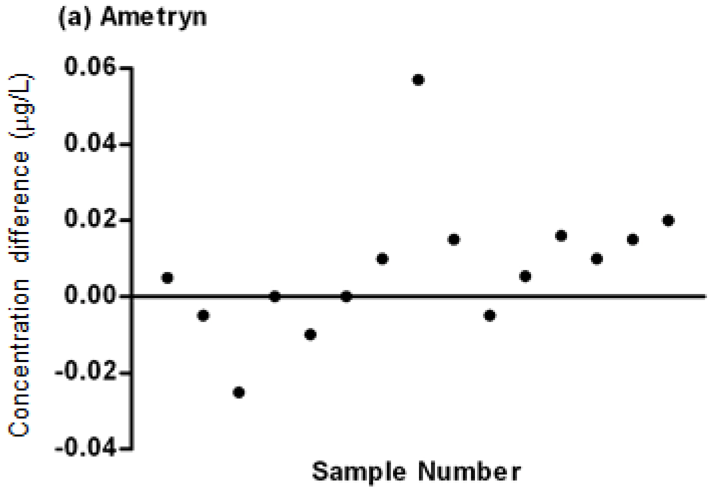
The following are the key outcomes of the above statistical analyses:

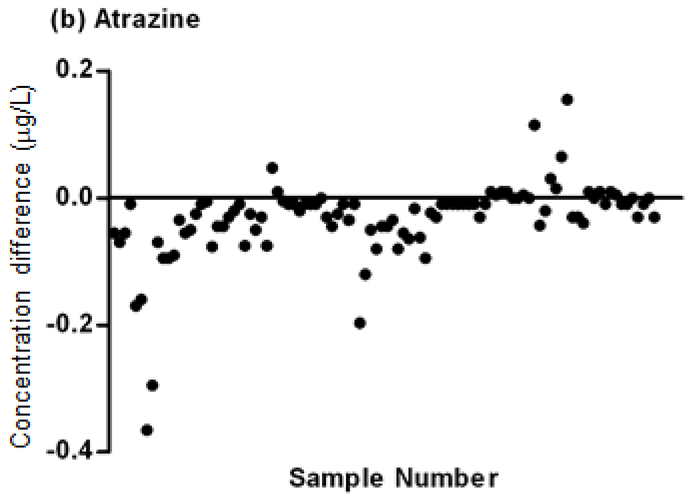
- the pesticide concentrations derived by the LLE and SPE methods were significantly different ($p \leq 0.05$) based on the results of a paired samples t-test (non-parametric) for atrazine (not total atrazine), diuron, hexazinone, desethyl atrazine, imidacloprid and metolachlor (Table 7.1).
- the p-value for ametryn was very close to the significance level ($p = 0.054$, Table 7.1). Figure 7.1(a) shows that the spread of the concentration differences for ametryn were principally greater than zero, and possibly with a larger sample size ($n = 14$), a significant difference between the two methods would be observed.
- tebuthiuron was the only pesticide that indicated a strong agreement between the two methods ($p = 0.133$. Table 7.1). Figure 7.1(e) shows that the differences in concentration are spread fairly evenly around zero. However, it should also be noted that the sample size for this pesticide was relatively small ($n = 16$) compared to some of the other pesticides (e.g. $n = 100$ for atrazine).
- bromacil and desisopropyl atrazine were detected in only three samples each, which was not sufficient to determine a statistical difference between the two methods for these two compounds.
- concentrations determined by the SPE method were, in general, greater than concentrations recovered from LLE (indicated in Figure 7.1 by negative concentration differences). This occurred even though the LLE method is meant to extract a larger fraction (i.e. the dissolved and sorbed fractions) of each pesticide than the SPE method that only extracts the dissolved fraction.

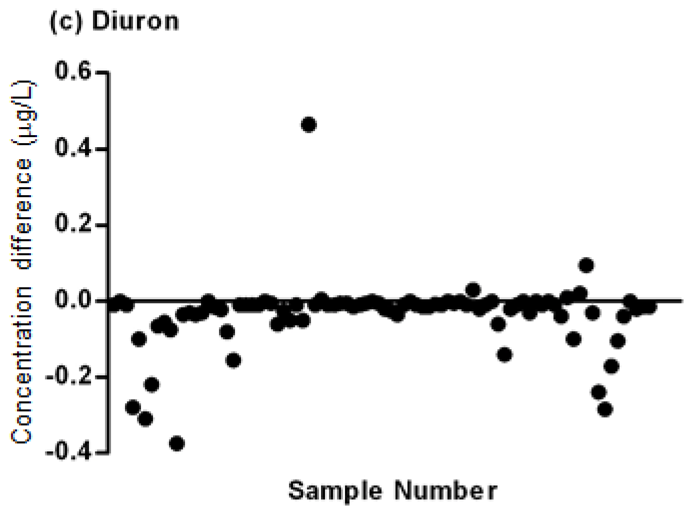
- the differences in pesticide concentrations found between the two extraction methods may be due to the formation of emulsions during the liquid-liquid extraction process (Mary Hodge pers. comm.). Such emulsions do not breakdown, retain some of the pesticides, and therefore may decrease the amount of pesticide extracted by the LLE method. The Queensland Health Forensic Scientific Services organics laboratory has observed that the formation of emulsions is not consistent for all samples, across all sites and temporally within sites.
- the conversion factors ranged from 0.82 for desethyl atrazine to 1.13 for atrazine and imidacloprid (Table 7.1).
- twenty-two tests of the validity of the conversion factors were made (Table 7.1). Sixteen of these were based on Great Barrier Reef Catchment Loads Monitoring Program data and 6 based on paddock-scale data. In 59 per cent of these the conversion factor improved the fit of the data to the measured SPE values and in a further 23 per cent of cases the conversion factors equalled the fit of the data to the measured SPE values. Thus, in 82 per cent of cases use of the conversion factors improved or had no effect on the fit of the data.
- in only four of the 22 cases (18 per cent) the conversion factor did not improve the fit.
- it is therefore recommended that the conversion factors presented in Table 7.1 are applied to the 2009–2010 and 2010–2011 pesticide concentration and loads data so that they are consistent and valid comparisons across years can be made. This will be addressed in a subsequent publication.

Conclusion

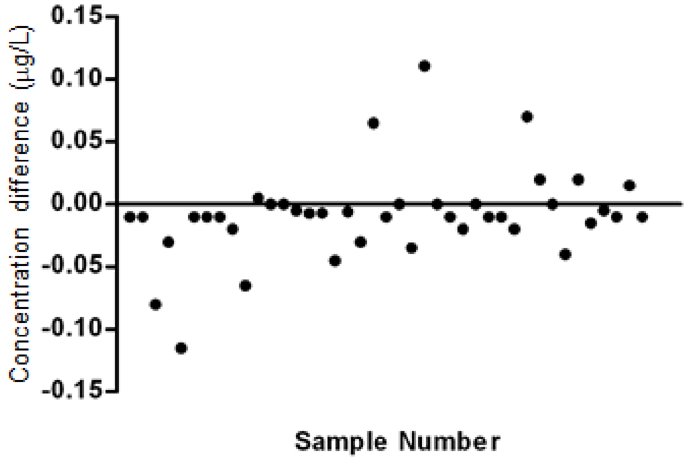
The results presented here indicate that by switching from the LLE to the SPE method, pesticide extraction from water samples will be improved. However, this has implications for the pesticide load calculations that preceded the change in extraction methods, particularly when being compared to pesticide loads calculated after the switch to the SPE extraction method. This issue can be addressed by recalculating the 2009–2010 and 2010–2011 pesticide loads with the conversion factors which would adjust for any differences attributed to the change in the extraction method.


(a) Ametryn
0.06
0.04
0.02
0.00
-0.02
-0.04
Concentration difference (μg/L)
Sample Number

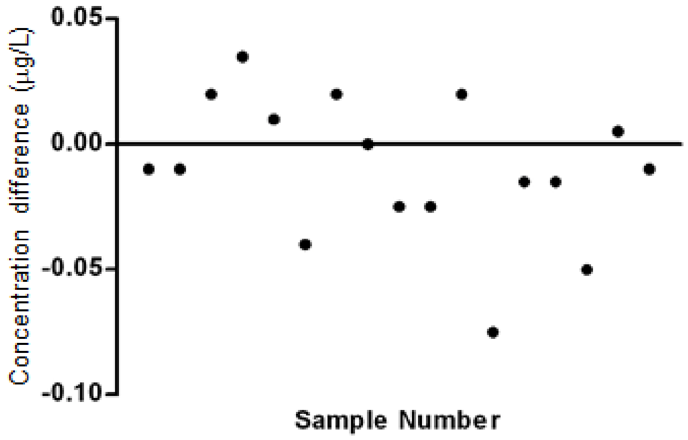

(b) Atrazine
0.2
0.0
-0.2
-0.4
Concentration difference (μg/L)
Sample Number


(c) Diuron
0.6
0.4
0.2
0.0
-0.2
-0.4
Concentration difference (μg/L)
Sample Number

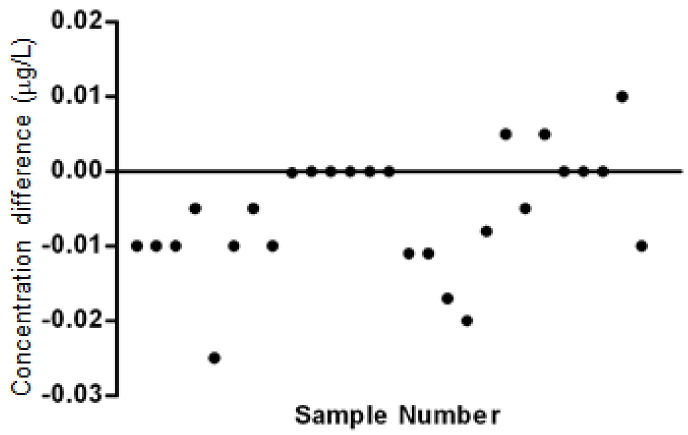
(d) Hexazinone

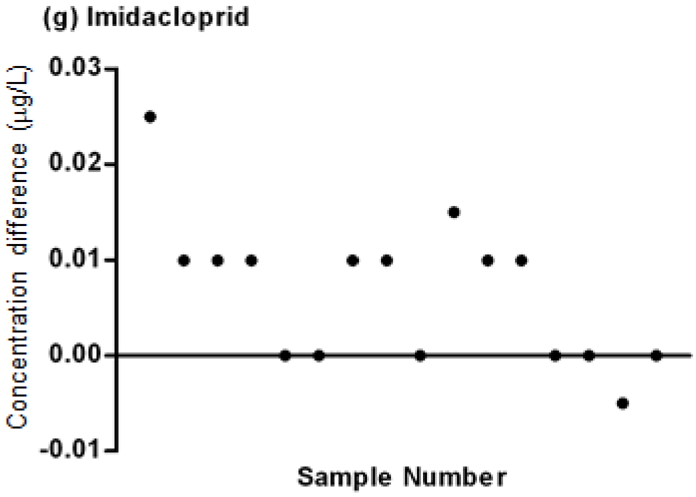


(e) Tebuthiuron



(f) Desethyl atrazine





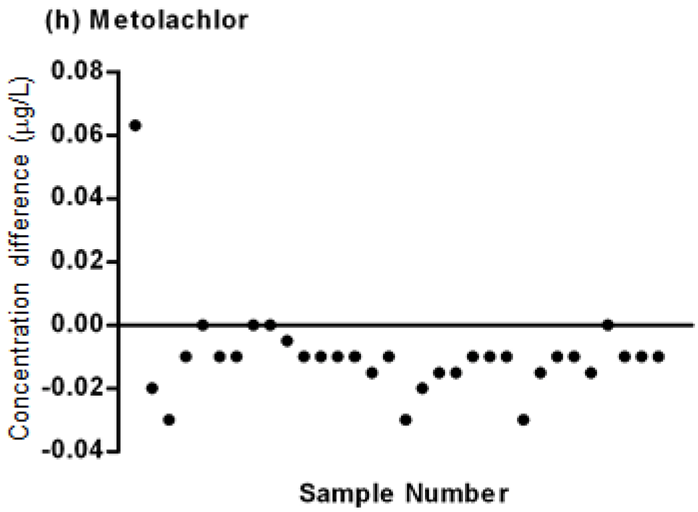


Figure 7.1 Per cent concentration differences between the liquid-liquid extraction (LLE) and solid phase extraction (SPE) methods for the pesticides: (a) ametryn, (b) atrazine, (c) diuron, (d) hexazinone, (e) tebuthiuron, (f) desethyl atrazine, (g) imidacloprid and (h) metolachlor. Positive concentration differences indicate a higher concentration was obtained by the LLE method and a negative value indicates a higher concentration was obtained by the SPE method.

Table 7.1 Summary of the statistical analyses conducted for each pesticide to determine: if the two extraction methods resulted in different pesticide concentrations (test for normality and paired samples t-test), an appropriate conversion factor, validation of the conversion factors (prediction of SPE concentrations based on observed LLE concentrations).

Pesticide		Ametryn	Atrazine	Diuron	Hexazinone	Tebuthiuron	Desethyl atrazine	Imidacloprid	Metolachlor
Statistical analysis									
Test for normality: Kolmogorov Smirnov	p value (SPE)	0.0144	< 0.0001	< 0.0001	< 0.0001	> 0.10	0.0001	> 0.10	< 0.0001
	p value (LLE)	0.0144	< 0.0001	< 0.0001	< 0.0001	> 0.10	0.0012	< 0.0001	< 0.0001
Paired samples t-test (non-parametric): Wilcoxon signed rank test (one-tailed)	p value	0.0538	< 0.0001	< 0.0001	0.0062	0.1328	0.0007	0.0036	< 0.0001
	df	*14*	*99*	*85*	*40*	*16*	*26*	*15*	*31*
Conversion factor									
Linear Regression	*y* (0,0 intercept)	0.92	1.14	1.12	1.13	1.01	0.824	1.13	0.99
	R^2	0.80	0.94	0.97	0.96	0.77	0.46	0.54	0.77
Prediction of SPE concentrations based on observed LLE concentrations (% of samples fitted to the observed SPE ± 30% concentration)									
Aug 2011 data	With bias	80	80	90	73	76	85	81	72
	Without bias	60	69	78	73	76	67	56	25
	n	*15*	*100*	*86*	*41*	*17*	*27*	*16*	*32*
Nov 2010 data	With bias	85	95	94	88	93	85	65	63
	Without bias	90	93	88	88	100	64	88	75
	n	*20*	*43.0*	*34*	*33*	*15*	*33*	*26*	*8*
Paddock scale data	With bias	67	89	82	62	n/a	85	n/a	100
	Without bias	56	70	76	62	n/a	85	n/a	89
	n	*9*	*27*	*17*	*13*	n/a	*20*	n/a	*12*

Appendix B Loads and yields of other PSII pesticides detected by the Great Barrier Reef Catchment Loads Monitoring Program

The Great Barrier Reef Catchment Loads Monitoring Program calculates the monitored annual loads of photosystem II pesticides at eight end-of-system and three sub-catchment monitoring sites. The monitored annual loads of five priority photosystem II pesticides (ametryn, total atrazine, diuron, hexazinone and tebuthiuron) calculated by this program are used to validate pollutant loads modelled under the Reef Water Quality Protection Plan 2009 to monitor progress towards the water quality improvement targets.

All water samples collected for the analysis of pesticides were submitted to Queensland Health Forensic Scientific Services for analysis via LCMS as described in Section 2.5. The LCMS analytical suite is capable of detecting pesticides and their breakdown products which are not modelled under the Reef Water Quality Protection Plan 2009. The results presented in this section of the report are the monitored annual loads and yields of bromacil, metolachlor, prometryn, simazine and terbutryn. The monitored annual loads and yield 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.

The monitored annual loads and yields of these pesticides were calculated using the methods previously described in Section 2.7.2 and Section 2.7.3.

The total monitored annual loads ranged from 0.56 kg for terbutryn to 660 kg for metolachlor (Table 7.2). Overall, the additional pesticides reported here increase the total monitored annual load of pesticides by 742 kg (or approximately 17 per cent) to a total monitored annual load of 4960 kg.

Bromacil was only detected at four end-of-system sites all with small monitored annual loads, the largest load of 6.5 kg occurred at the Pioneer River at Dumbleton Pump Station (71 per cent of the total load of this pesticide) (Table 7.2 and Figure 7.2). Simazine was only detected at six sites including two sub-catchment monitoring sites. The largest monitored annual load of simazine occurred in the Fitzroy catchment (60 kg), which accounted for 87 per cent of the total monitored annual simazine load (Table 7.2 and Figure 7.5). Approximately 82 per cent of the total monitored annual metolachlor load (660 kg) was also derived from the Fitzroy catchment (Table 7.2 and Figure 7.3) with the next largest monitored annual load occurring in the Burdekin catchment (80 kg; 12 per cent). Prometryn was only detected at Burnett River at Ben Anderson Barrage Head Water with a total monitored annual load of 3.0 kg (Table 7.2 and Figure 7.4) and terbutryn was only detected at Sandy Creek at Homebush and had a total monitored annual load of 0.56 kg (Table 7.2 and Figure 7.6).

The yields of the additional chemicals ranged from 0.00009 kg km^{-2} to 0.024 kg km^{-2} (Table 7.3). These are, overall, lower than those for the five priority photosystem II herbicides that are the principal focus of the Great Barrier Reef Catchment Loads Monitoring Program that ranged from 0.000052 kg km^{-2} to 0.29 kg km^{-2} (Table 3.6). Sandy Creek had the highest monitored annual yields for metolachlor (0.024 kg km^{-2}) and terbutryn (0.0017 kg km^{-2}). The Pioneer River had the highest monitored annual yield for bromacil

(0.0044 kg km^{-2}), the Tully River had the highest monitored annual yield for simazine (0.0037 kg km^{-2}) and prometryn was only detected in the Burnett River (0.000091 kg km^{-2}).

Table 7.2 The monitored annual loads calculated for the additional chemicals: bromacil, metolachlor, prometryn, simazine, terbutryn, and atrazine and its metabolites desethyl atrazine, desisopropyl atrazine. Sites in bold are end-of-system sites, all others are sub-catchment sites.

Catchment	Gauging station	River and site name	Monitored area (km^2)	Monitored area of catchment (%)	n	Bromacil (kg)	Metolachlor (kg)	Prometryn (kg)	Simazine (kg)	Terbutryn (kg)	Atrazine (kg)	Desethyl atrazine (kg)	Desisopropyl atrazine (kg)
Johnstone	112004A[B]	North Johnstone River at Tung Oil	925	40	32	NC	NC	NC	2.5	NC	14	NC	NC
Tully	**113006A[B]**	**Tully River at Euramo**	1450	86	73	1.1	1.1	NC	5.4	NC	100	28	14
Herbert	**116001F[L]**	**Herbert River at Ingham**	8581	87	77	NC	11	NC	NC	NC	33	7.5	1.7
Haughton	**119101A[L]**	**Barratta Creek at Northcote**	753	19	93	NC	1.0	NC	0.45	NC	160	39	15
Burdekin	**120001A[L]**	**Burdekin River at Home Hill**	129,939	99	52	NC	80	NC	NC	NC	230	78	26
Pioneer	**125013A[L]**	**Pioneer River at Dumbleton Pump Station**	1485	94	149	6.5	4.6	NC	0.60	NC	160	31	15
Plane	**126001A[B]**	**Sandy Creek at Homebush**	326	13	26	0.90	7.8	NC	NC	0.56	41	9.9	4.5
Fitzroy	**1300000[L]**	**Fitzroy River at Rockhampton**	139,159	98	28	NC	540	NC	60	NC	740	130	110
	130504B[B]	Comet River at Comet Weir	16,457	12	18	NC	290	NC	18	NC	210	74	57
	130206A[B]	Theresa Creek at Gregory Highway	8,485	6	13	NC	180	NC	NC	NC	420	25	13
Burnett	**136014A[L]**	**Burnett River at Ben Anderson Barrage Head Water**	32,891	99	48	0.67	10	3.0	NC	NC	10	NC	NC
Total (end-of-system sites plus the North Johnstone River)			320,000		580	9.2	660	3.0	69	0.56	1500	320	190

Data shaded blue (atrazine, desethyl atrazine and desisopropyl atrazine) have already been incorporated in the calculation of total atrazine as presented in the main body of this report;
n = the number of grab samples used to estimate loads; NC = a load was not calculated as all the concentrations for all samples collected were below the practical quantitation limit;
[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 yields calculated for the additional pesticides: bromacil, metolachlor, prometryn, simazine, terbutryn, and atrazine and its metabolites desethyl atrazine, desisopropyl atrazine. Sites in bold are end-of-system sites, all others are sub-catchment sites.

Catchment	Gauging station	River and site name	Monitored area (km^2)	Monitored area of catchment (%)	n	Bromacil (kg km^{-2})	Metolachlor (kg km^{-2})	Prometryn (kg km^{-2})	Simazine (kg km^{-2})	Terbutryn (kg km^{-2})	Atrazine (kg km^{-2})	Desethyl atrazine (kg km^{-2})	Desisopropyl atrazine (kg km^{-2})
Johnstone	112004A[B]	North Johnstone River at Tung Oil	925	40	32	NC	NC	NC	0.0027	NC	0.016	NC	NC
Tully	**113006A[B]**	**Tully River at Euramo**	1450	86	73	0.00076	0.00076	NC	0.0037	NC	0.070	0.019	0.0094
Herbert	**116001F[L]**	**Herbert River at Ingham**	8581	87	77	NC	0.0013	NC	NC	NC	0.0038	0.00087	0.00020
Haughton	**119101A[L]**	**Barratta Creek at Northcote**	753	19	93	NC	0.0013	NC	0.00060	NC	0.21	0.052	0.020
Burdekin	**120001A[L]**	**Burdekin River at Home Hill**	129,939	99	52	NC	0.00062	NC	NC	NC	0.0017	0.00060	0.00020
Pioneer	**125013A[L]**	**Pioneer River at Dumbleton Pump Station**	1485	94	149	0.0044	0.0031	NC	0.00040	NC	0.11	0.021	0.010
Plane	**126001A[B]**	**Sandy Creek at Homebush**	326	13	26	0.0028	0.024	NC	NC	0.0017	0.13	0.030	0.014
Fitzroy	**1300000[L]**	**Fitzroy River at Rockhampton**	139,159	98	28	NC	0.0039	NC	0.00043	NC	0.0053	0.00092	0.00080
	130504B[B]	Comet River at Comet Weir	16,457	12	18	NC	0.021	NC	NC	NC	0.025	0.0030	0.0015
	130206A[B]	Theresa Creek at Gregory Highway	8,485	6	13	NC	0.018	NC	0.0011	NC	0.026	0.0045	0.0035
Burnett	**136014A[L]**	**Burnett River at Ben Anderson Barrage Head Water**	32,891	99	48	0.000020	0.00031	0.000091	NC	NC	0.00032	NC	NC

Data shaded blue (atrazine, desethyl atrazine and desisopropyl atrazine) have already been incorporated in the calculation of total atrazine as presented in the main body of this report;
NC = no yield was calculated as no load was calculated (refer to Table 7.2), [L] = average load (linear interpolation of concentration) method used to calculate loads; [B] = Beale ratio method used to calculate loads.

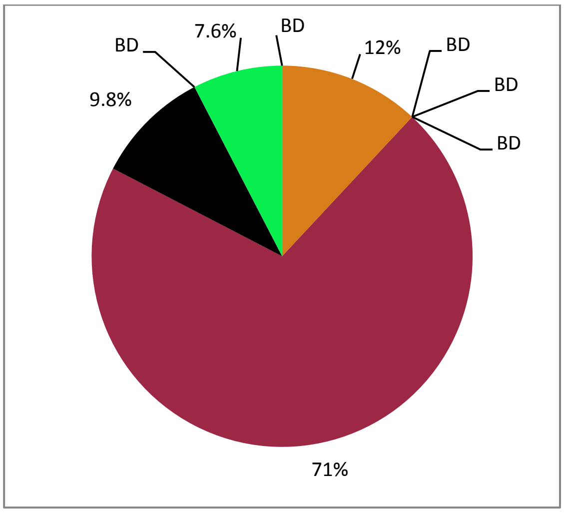


Figure 7.2 Per cent contribution from each end-of-system site (including North Johnstone) to the combined monitored bromacil load.

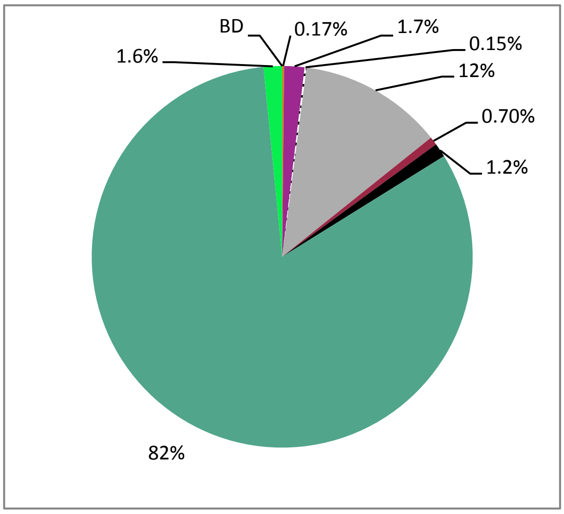


Figure 7.3 Per cent contribution from each end-of-system site (including North Johnstone) to the combined monitored metolachlor load.

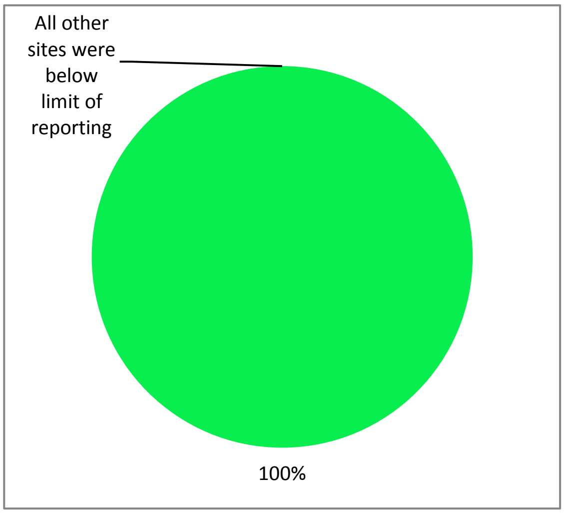


Figure 7.4 Per cent contribution from each end-of-system site (including North Johnstone) to the combined monitored prometryn load.

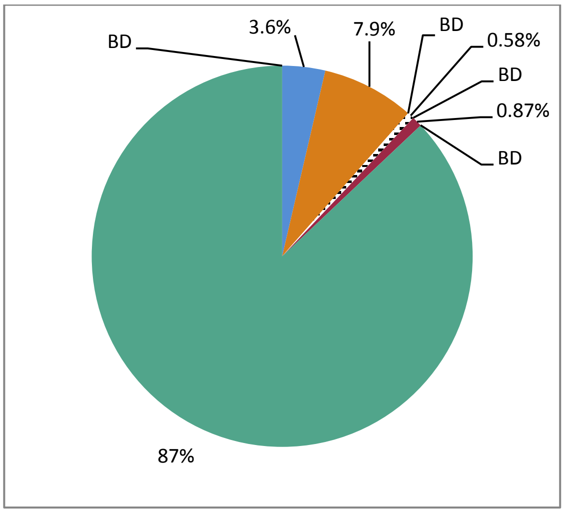


Figure 7.5 Per cent contribution from each end-of-system site (including North Johnstone) to the combined monitored simazine load.

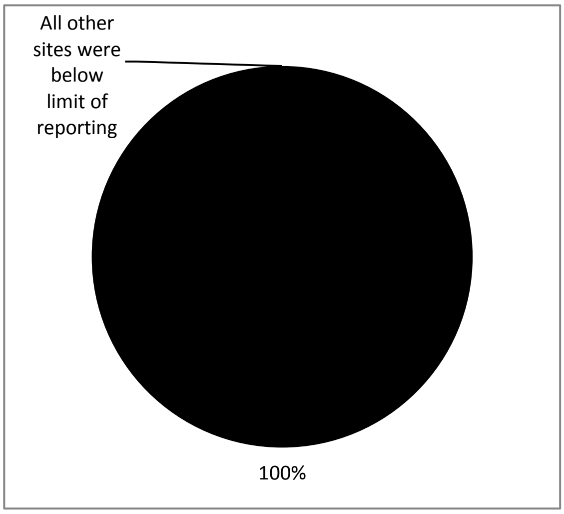


Figure 7.6 Per cent contribution from each end-of-system site (including North Johnstone) to the combined monitored terbutryn load.

Appendix C Discharge data quality

The total period (hours) during the 2011–2012 monitoring year where discharge was calculated from interpolated height data is provided in Table 7.4. Discharge which has been calculated from interpolated height data is assigned a quality code of 59 or 60.

Table 7.4 Per cent of annual discharge period calculated using estimated discharge. Sites in bold are end-of-system sites, all others are sub-catchment sites.

Catchment	Gauging station	River and site name	Time period (hours)	Quality code	Per cent of annual discharge calculate using estimated discharge
Normanby	**105107A[L]**	**Normanby River at Kalpowar Crossing**	0		0
Barron	**110001D[B]**	**Barron River at Myola**	0		0
Johnstone	112004A[B]	North Johnstone River at Tung Oil	37	60	1
	112101B[B]	South Johnstone River at Upstream Central Mill	0		0
Tully	**113006A[L]**	**Tully River at Euramo**	404	60	5
	113015A[B]	Tully River at Tully Gorge National Park	78	60	1
Herbert	**116001F[L/B]**	**Herbert River at Ingham**	0		0
Haughton	**119101A[L]**	**Barratta Creek at Northcote**	105	60	1
Burdekin	**120001A[L]**	**Burdekin River at Home Hill**	0		0
	120002C[B]	Burdekin River at Sellheim	0		0
	120301B[L]	Belyando River at Gregory Development Road	0		0
	120302B[L/B]	Cape River at Taemas	0		0
	120310A[B]	Suttor River at Bowen Development Road	0		0
Pioneer	**125013A[L]**	**Pioneer River at Dumbleton Pump Station**	0		0
Plane	**126001A[B]**	**Sandy Creek at Homebush**	0		0
Fitzroy	**1300000[L]**	**Fitzroy River at Rockhampton**	0		0
	130206A[B]	Theresa Creek at Gregory Highway	0		0
	130504B[B]	Comet River at Comet Weir	0		0
Burnett	**136014A[L]**	**Burnett River at Ben Anderson Barrage Head Water**	0		0
	136002D[B]	Burnett River at Mt Lawless	0		0
	136094A[B]	Burnett River at Jones Weir Tail Water	528	60	6
	136106A[L]	Burnett River at Eidsvold	0		0

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

Appendix D Calculation of discharge

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

Equation 4

$$q = va$$

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

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*. River gauge height was recorded by gauging stations using a float or a pressure sensor at intervals of approximately 15 minutes. Flow velocity was determined for each cross-sectional area at time *t* using a current meter. Flow records were extracted for each site from the Queensland Government electronic data management system (Hydstra).

Appendix E Hydrograph plots of discharge and sample collection points

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

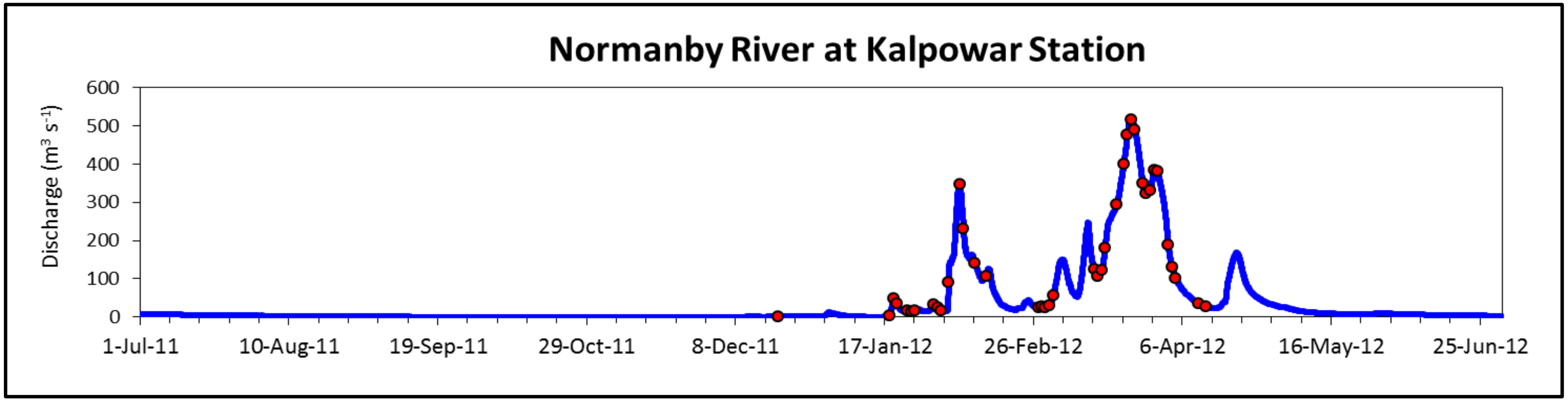


Figure 7.7 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Normanby River at Kalpowar Crossing between 1 July 2011 and 30 June 2012. Representivity rating was good for all analytes.

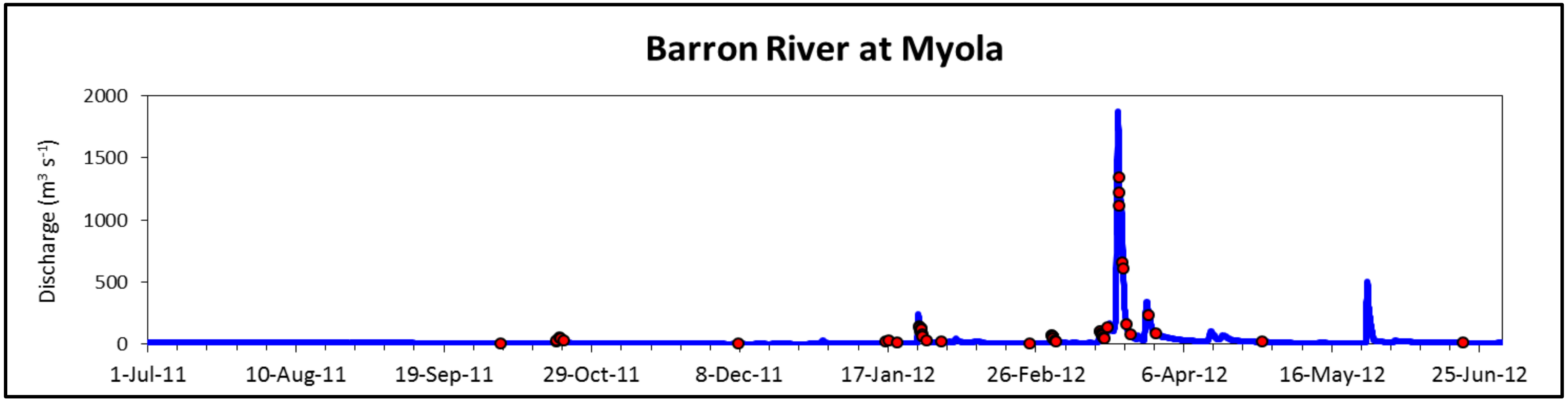


Figure 7.8 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Barron River at Myola between 1 July 2011 and 30 June 2012. Representivity rating was good for all analytes.

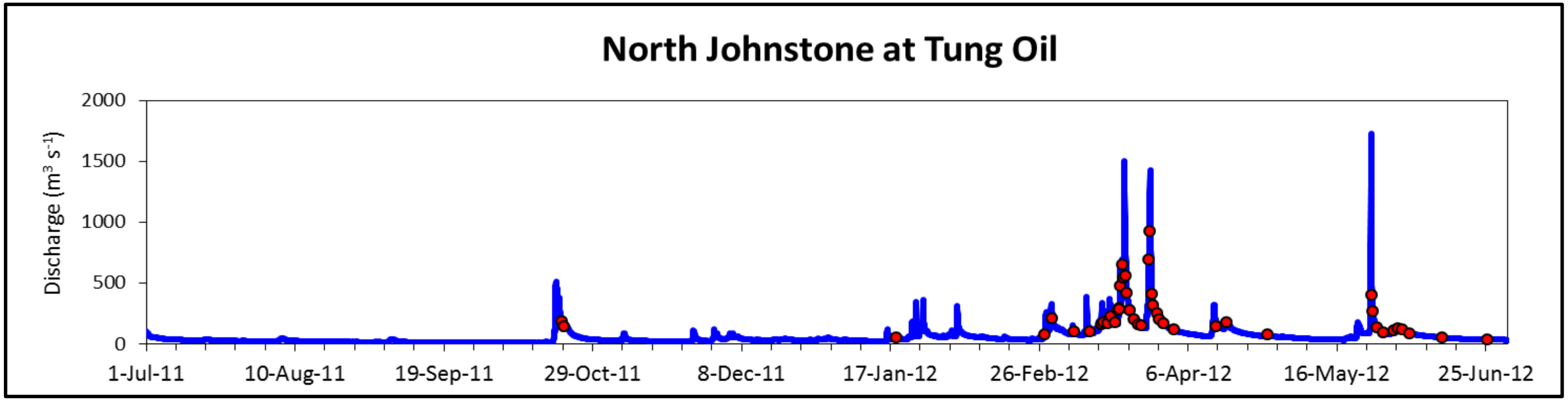


Figure 7.9 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the North Johnstone River at Tung Oil between 1 July 2011 and 30 June 2012. Representivity rating was good for all analytes.

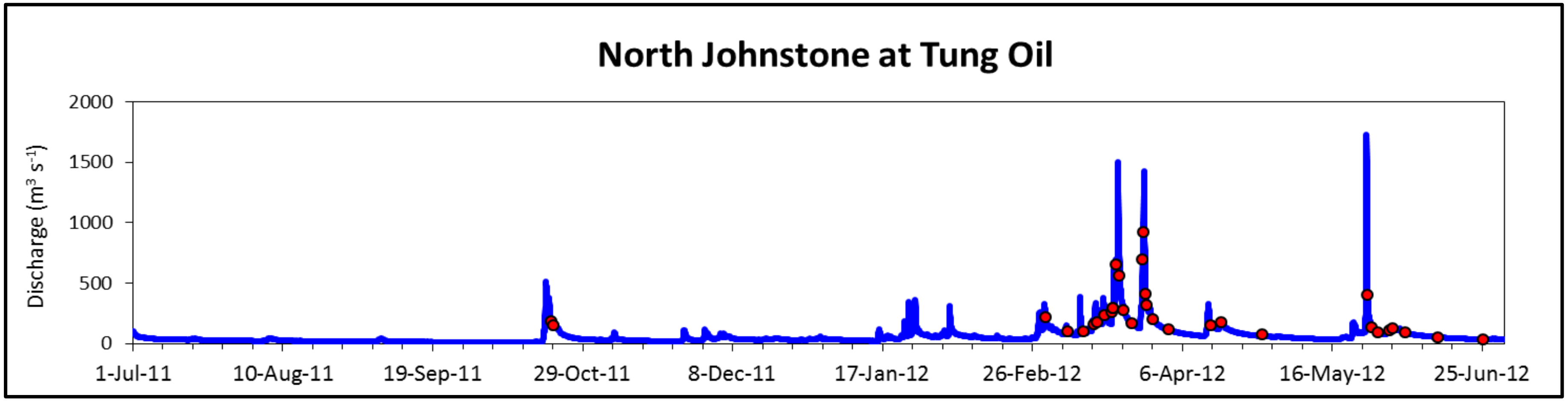


Figure 7.10 Hydrograph showing discharge (blue line) and photosystem II pesticide sample coverage (red circles) for North Johnstone River at Tung Oil between 1 July 2011 and 30 June 2012.

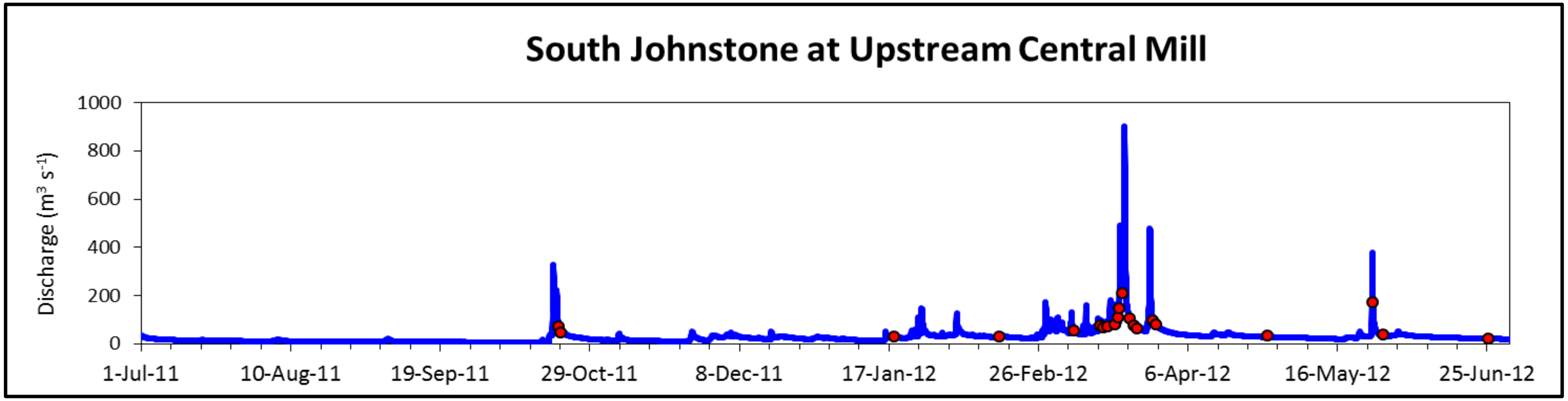


Figure 7.11 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the South Johnstone River at Upstream Central Mill between 1 July 2011 and 30 June 2012. Representivity rating was moderate for all analytes.

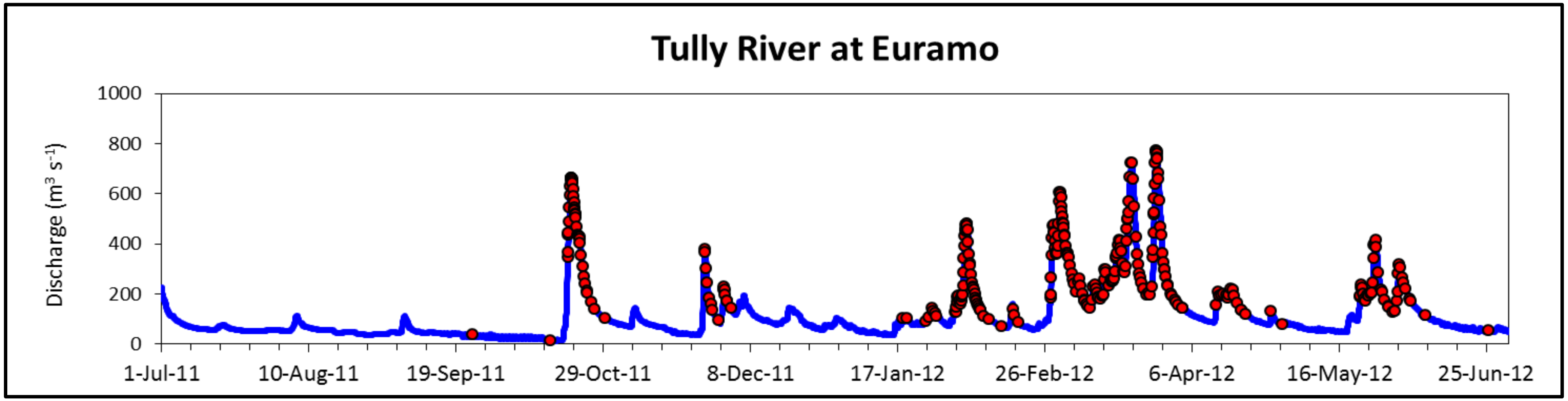


Figure 7.12 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Tully River at Euramo between 1 July 2011 and 30 June 2012. Representivity rating was excellent for all analytes.

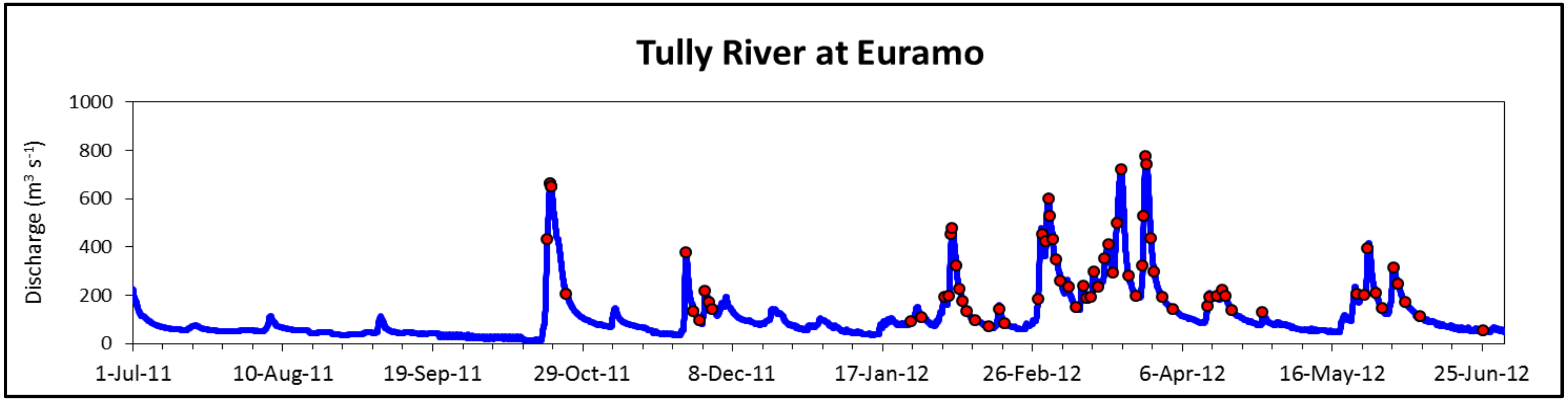


Figure 7.13 Hydrograph showing discharge (blue line) and photosystem II pesticide sample coverage (red circles) for Tully River at Euramo between 1 July 2011 and 30 June 2012.

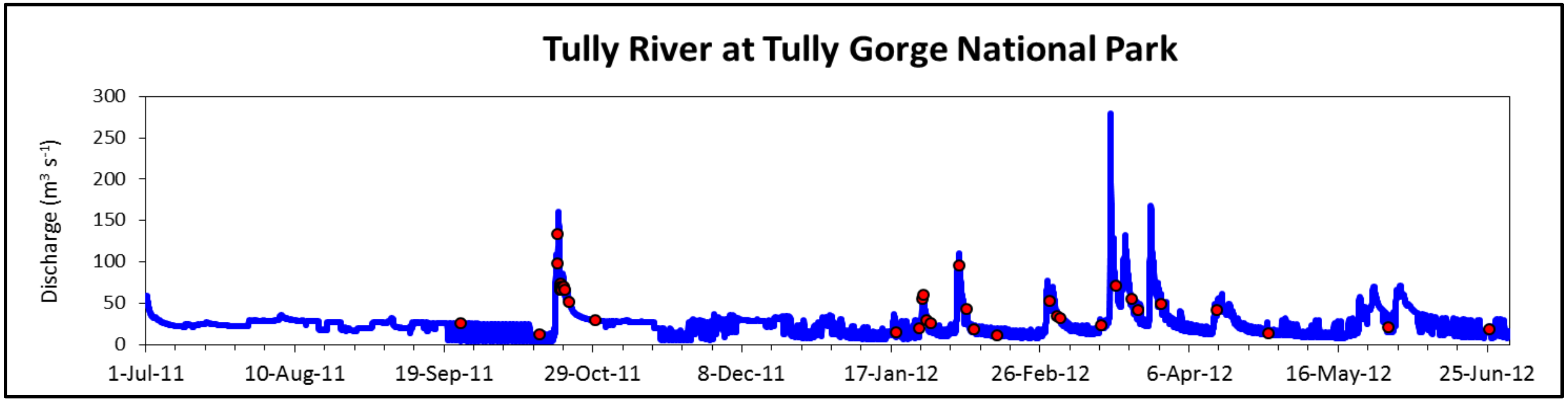


Figure 7.14 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Tully River at Tully Gorge National Park between 1 July 2011 and 30 June 2012. Representivity rating was moderate for all analytes.

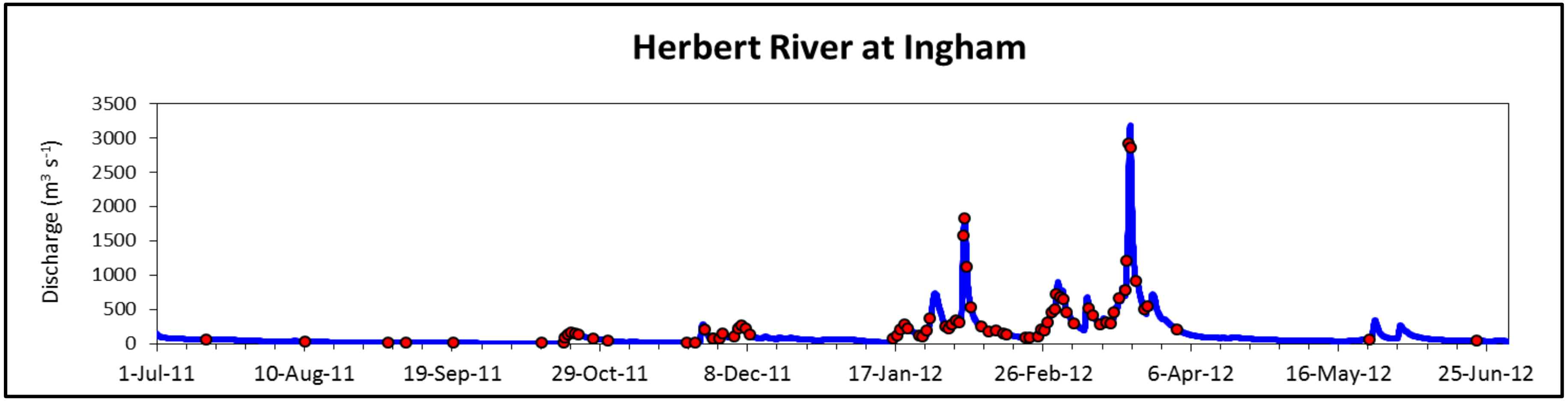


Figure 7.15 Hydrograph showing discharge (blue line) and sample coverage (total suspended solids and total nutrients in (red circles) for Herbert River at Ingham between 1 July 2011 and 30 June 2012. Representivity rating was good for all analytes.

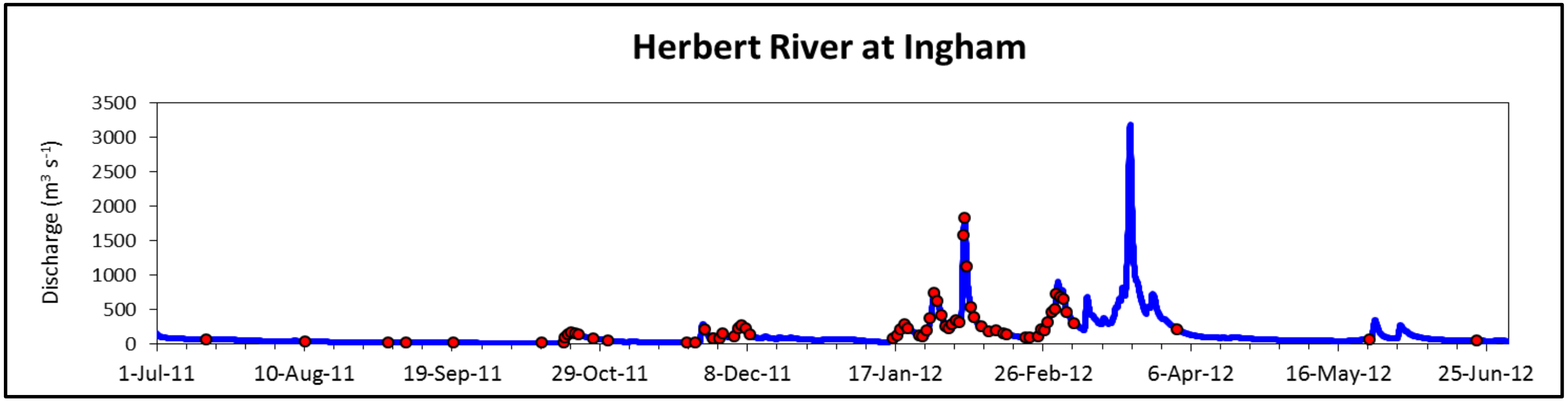


Figure 7.16 Hydrograph showing discharge (blue line) and dissolved and particulate nutrients coverage (red circles) for Herbert River at Ingham between 1 July 2011 and 30 June 2012. Representivity rating was moderate for all analytes.

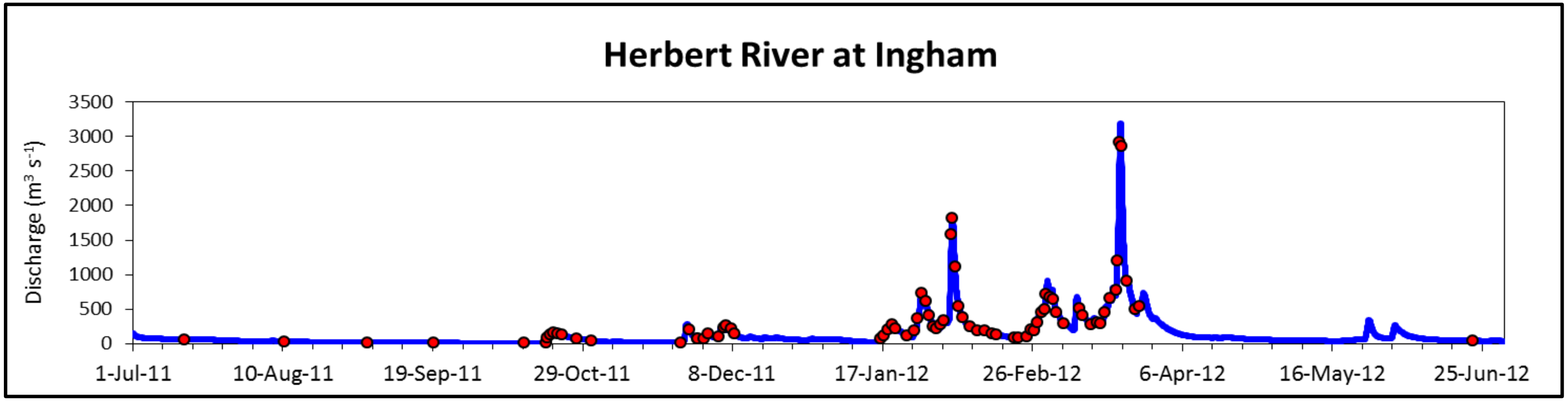


Figure 7.17 Hydrograph showing discharge (blue line) and photosystem II pesticide sample coverage (red circles) for Herbert River at Ingham between 1 July 2011 and 30 June 2012

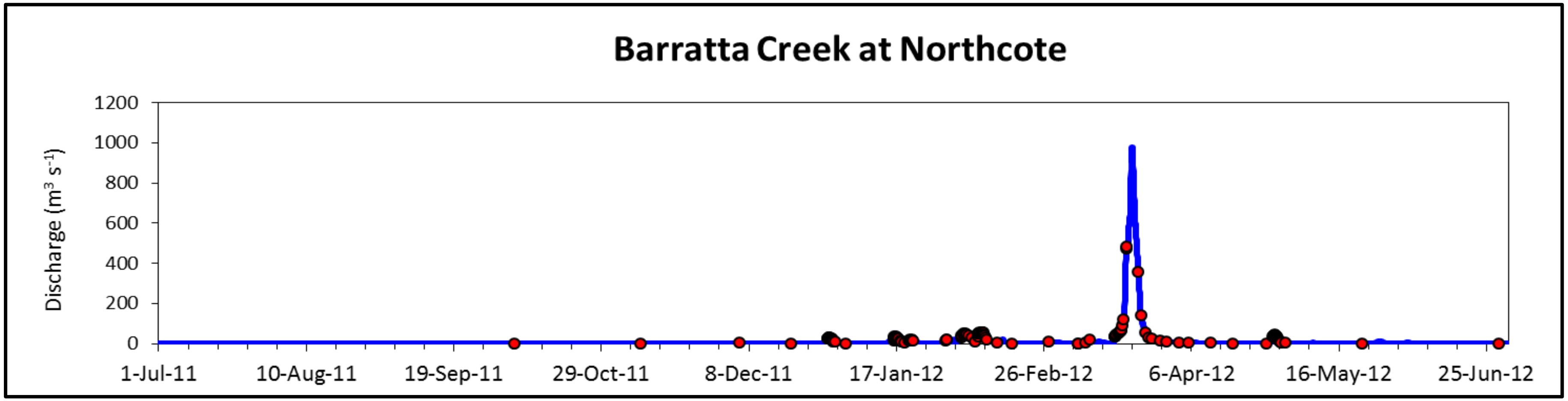


Figure 7.18 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients sample coverage (red circles) in the Barratta Creek at Northcote between 1 July 2011 and 30 June 2012. Representivity rating was excellent for all analytes.

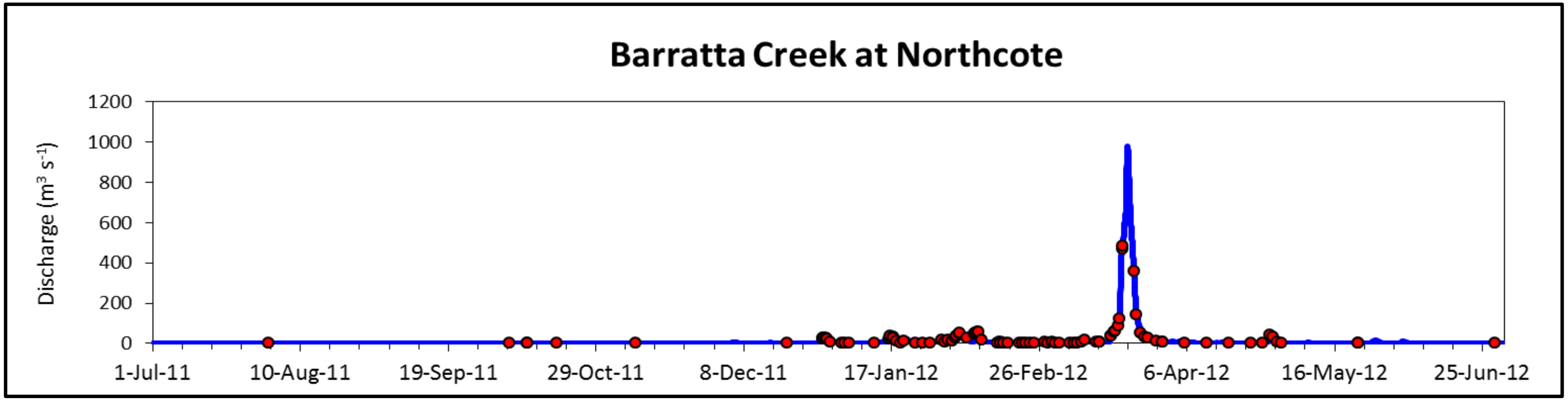


Figure 7.19 Hydrograph showing discharge (blue line) and photosystem II pesticide sample coverage (red circles) for Barratta Creek at Northcote between 1 July 2011 and 30 June 2012.

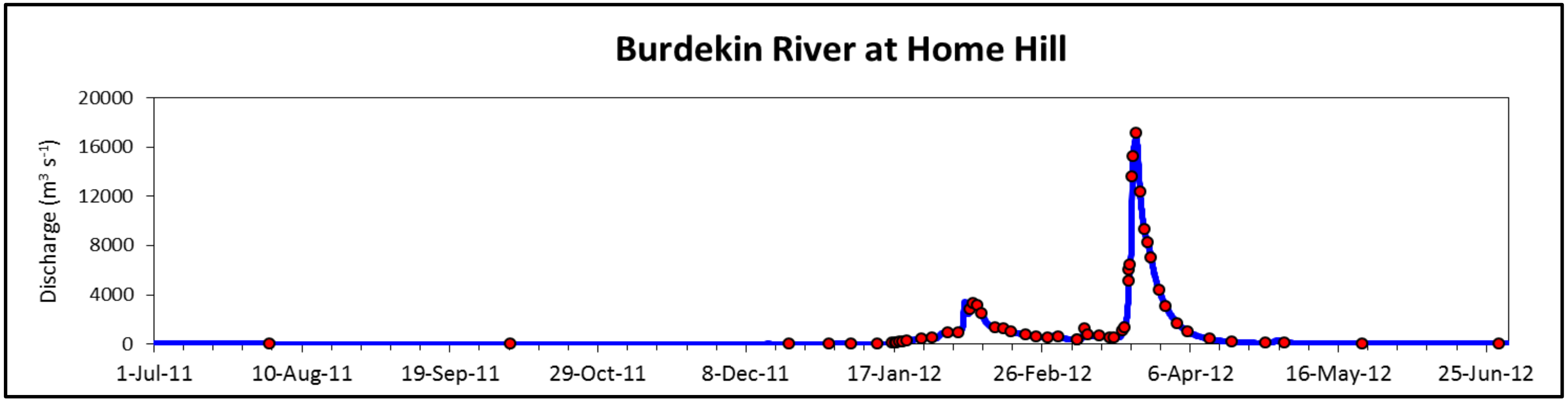


Figure 7.20 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Burdekin River at Home Hill between 1 July 2011 and 30 June 2012. Representivity rating was good for all analytes.

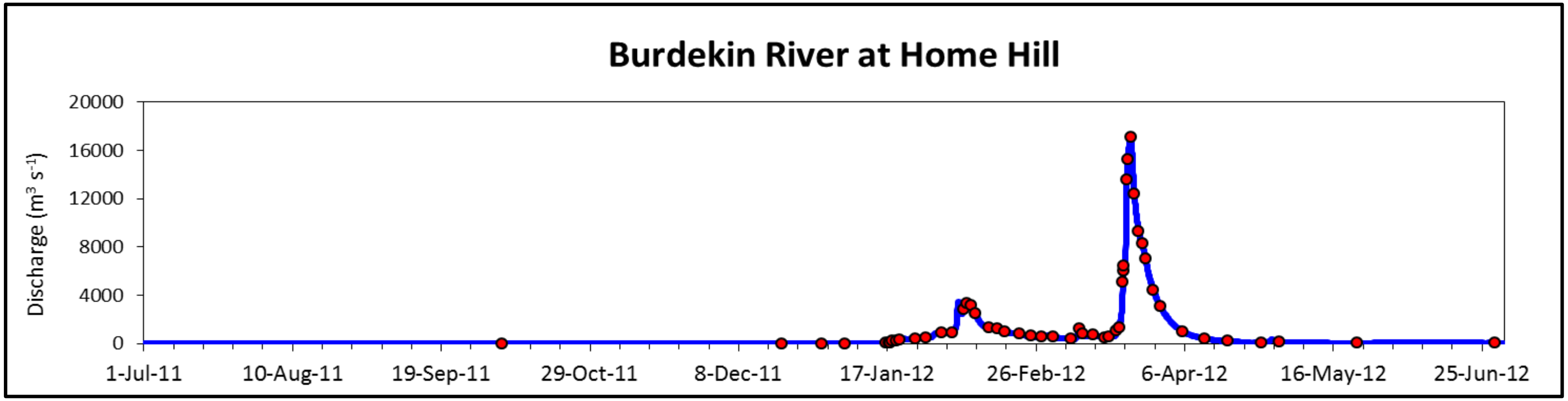


Figure 7.21 Hydrograph showing discharge (blue line) and photosystem II herbicide sample coverage (red circles) for Burdekin River at Home Hill between 1 July 2011 and 30 June 2012.

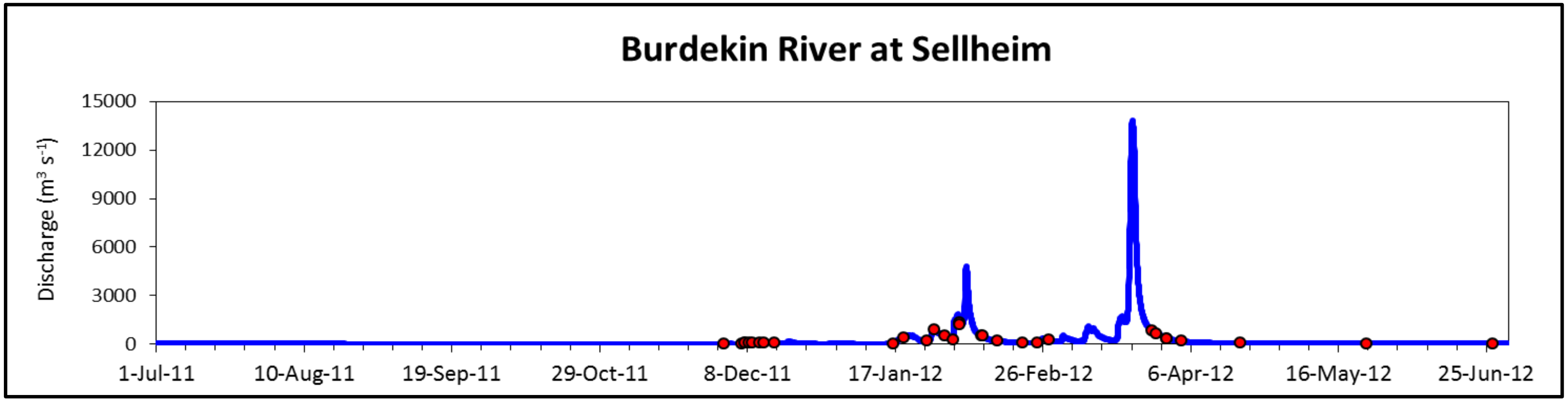


Figure 7.22 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Burdekin River at Sellheim between 1 July 2011 and 30 June 2012. Representivity rating was indicative for all analytes.

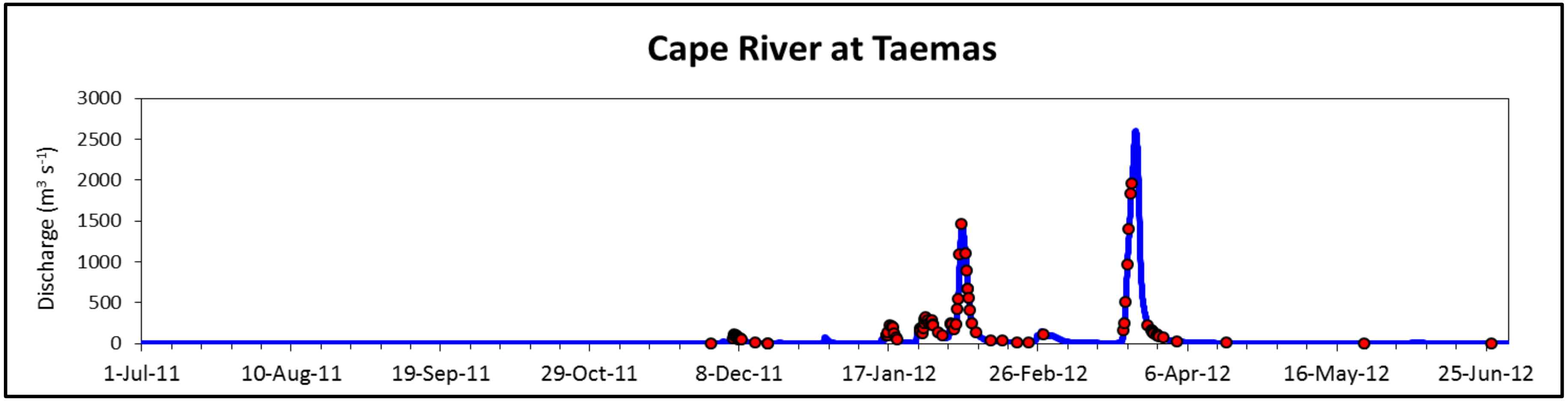


Figure 7.23 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) for Cape River at Taemas between 1 July 2011 and 30 June 2012. Representivity rating was excellent for total suspended solids and good for all other analytes.

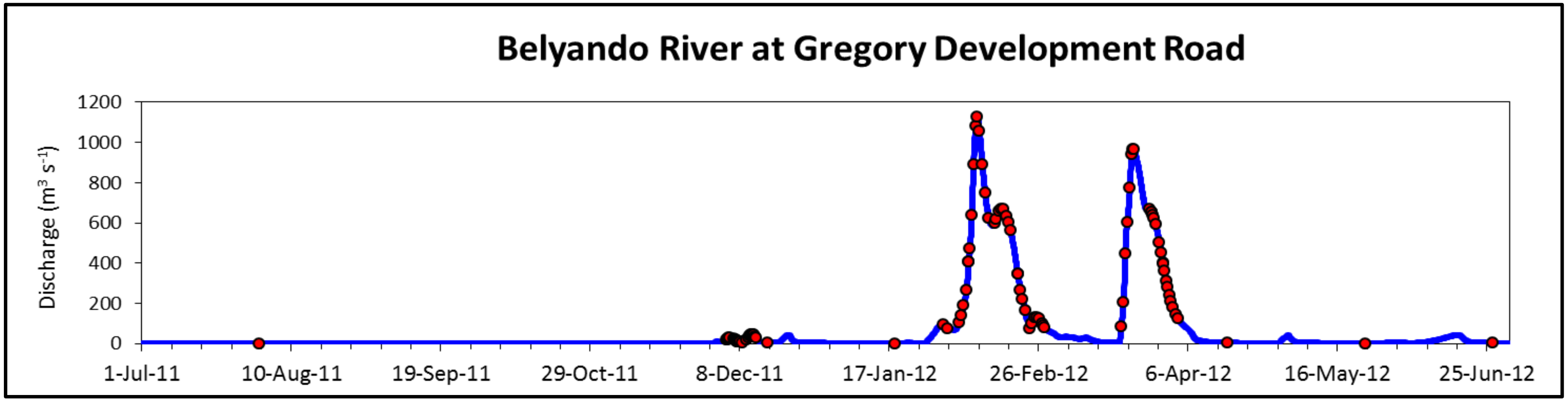


Figure 7.24 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids and total nutrients (red circles) for Belyando River at Gregory Development Road between 1 July 2011 and 30 June 2012. Representivity rating was excellent for all analytes.

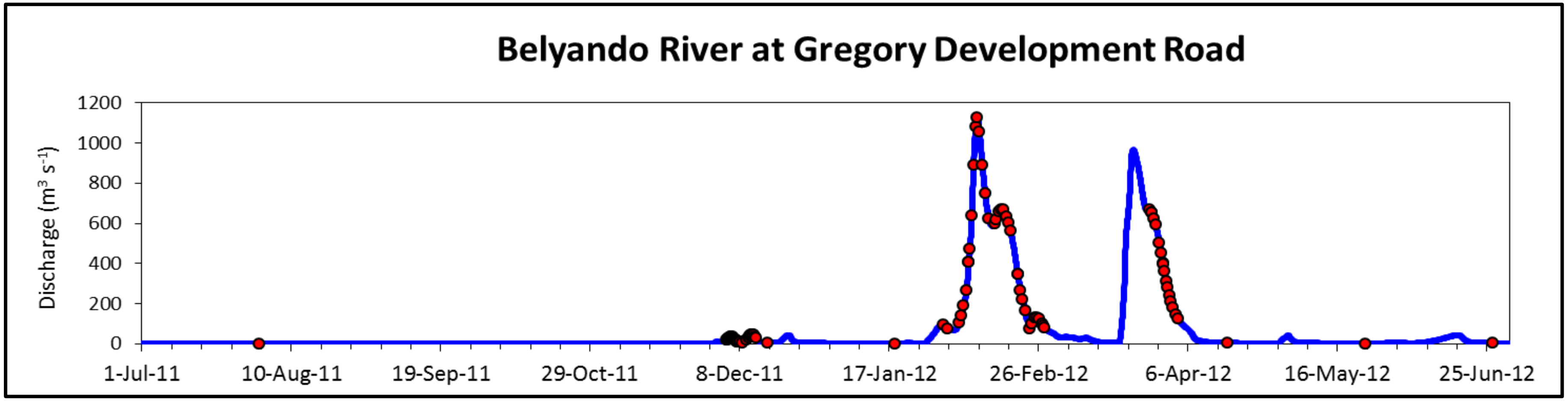


Figure 7.25 Hydrograph showing discharge (blue line) and sample coverage for dissolved and particulate nutrients (red circles) for the Belyando River at Gregory Development Road between 1 July 2011 and 30 June 2012. Representivity rating was good for all analytes.

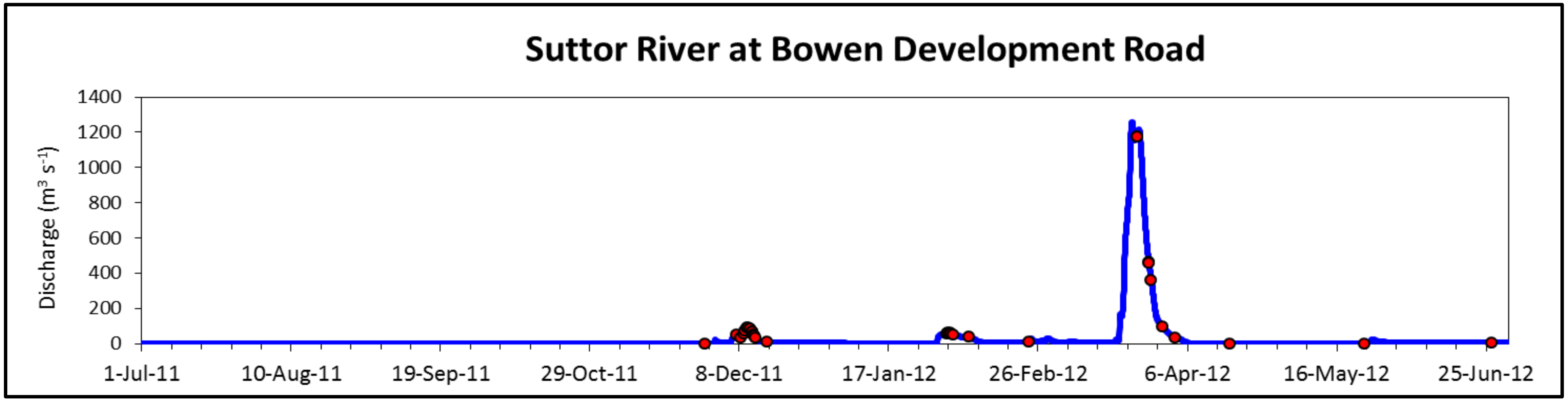


Figure 7.26 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Suttor River at Bowen Development Road between 1 July 2011 and 30 June 2012. Representivity rating was good for all analytes.

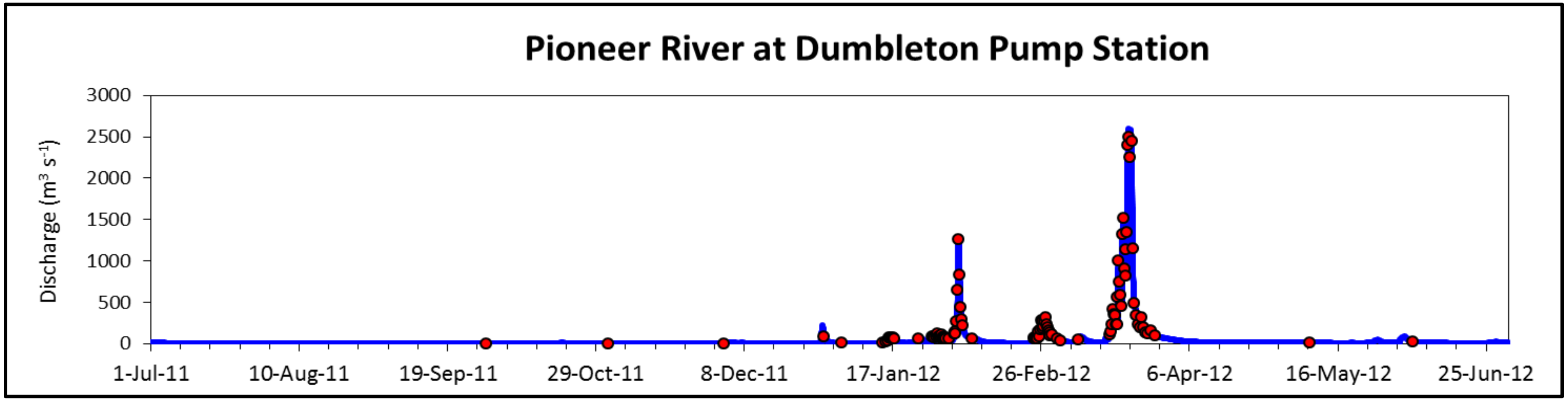


Figure 7.27 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Pioneer River at Dumbleton Pump Station between 1 July 2011 and 30 June 2012. Representivity rating was excellent for all analytes.

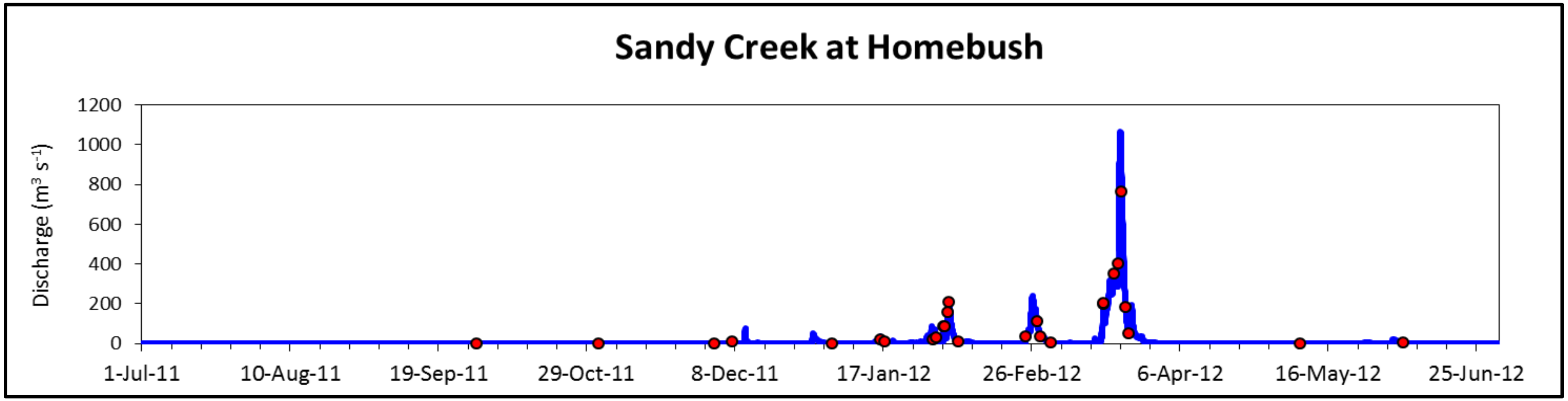


Figure 7.28 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients and photosystem II inhibiting herbicides (red circles) in Sandy Creek at Homebush between 1 July 2011 and 30 June 2012. Representivity rating was good for all analytes (excluding photosystem II herbicides).

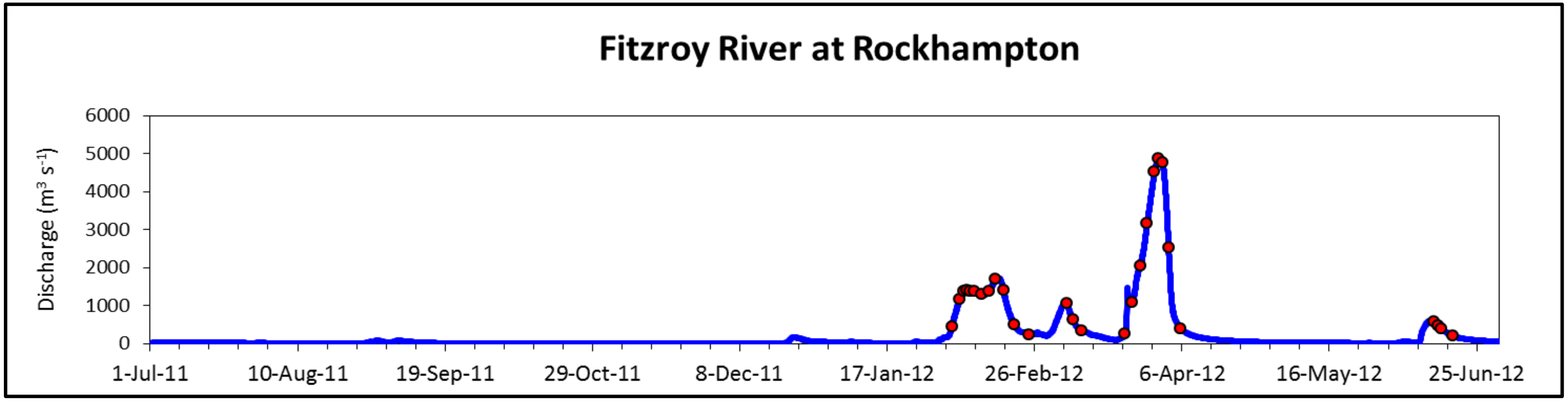


Figure 7.29 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients and photosystem II inhibiting herbicides (red circles) in the Fitzroy River at Rockhampton between 1 July 2011 and 30 June 2012. Representivity rating was good for all analytes (excluding photosystem II herbicides).

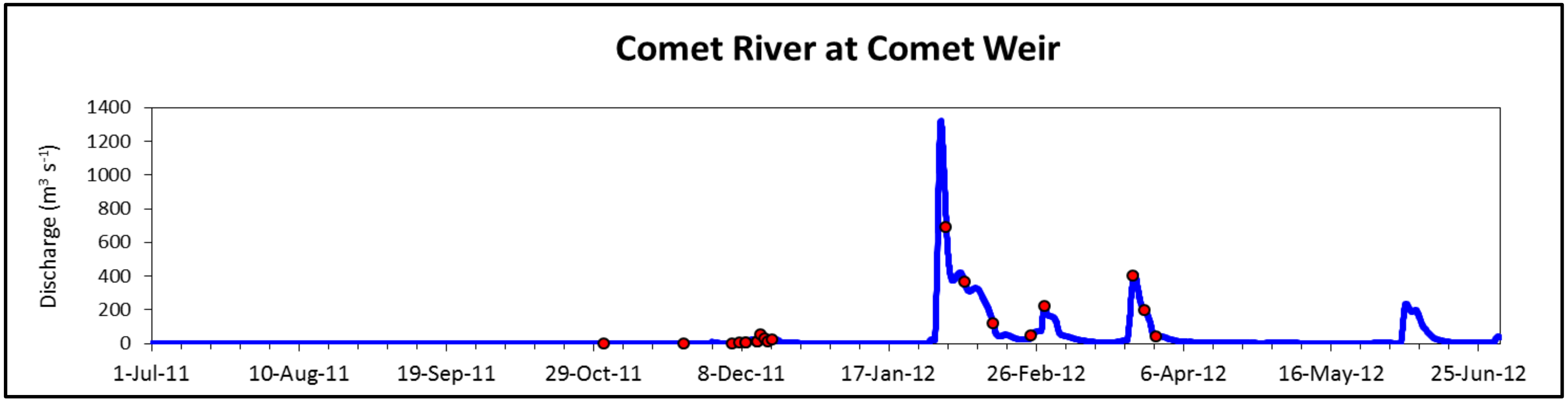


Figure 7.30 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients and photosystem II inhibiting herbicides (red circles) in the Comet River at Comet Weir between 1 July 2011 and 30 June 2012. Representivity rating was moderate for all analytes.

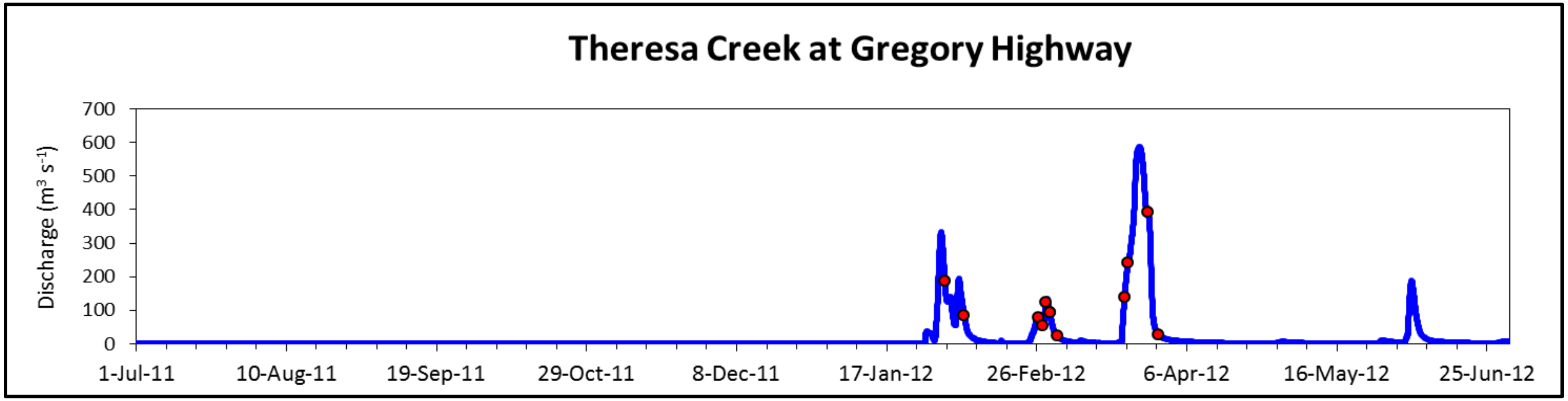


Figure 7.31 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients and photosystem II inhibiting herbicides (red circles) in Theresa Creek at Gregory Highway between 1 July 2011 and 30 June 2012. Representivity rating was moderate for all analytes

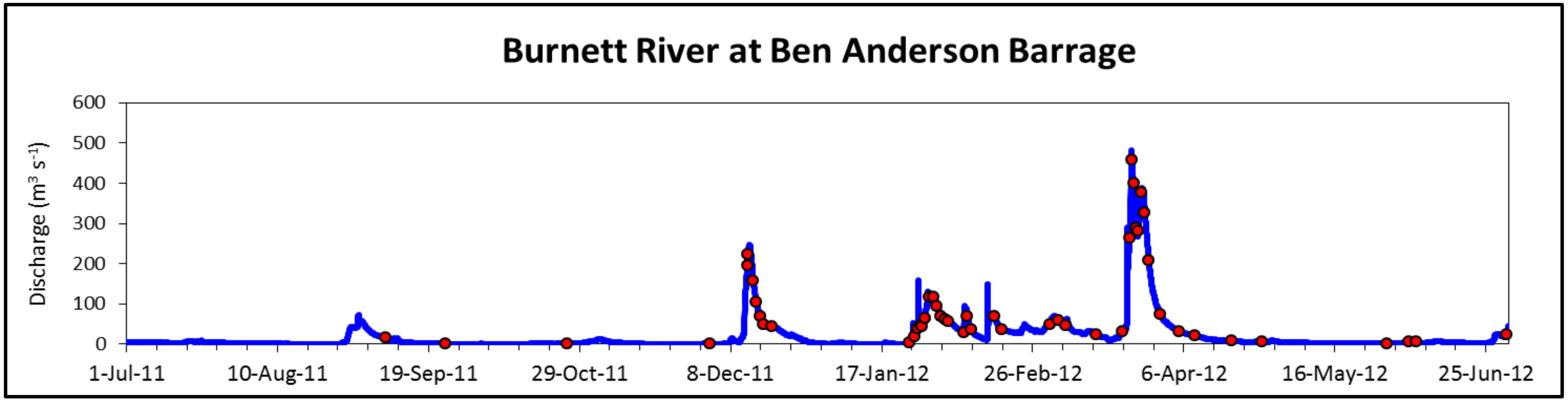


Figure 7.32 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients and photosystem II inhibiting herbicides (red circles) in the Burnett River at Ben Anderson Barrage between 1 July 2011 and 30 June 2012. Representivity rating was good for all analytes (excluding photosystem II herbicides.

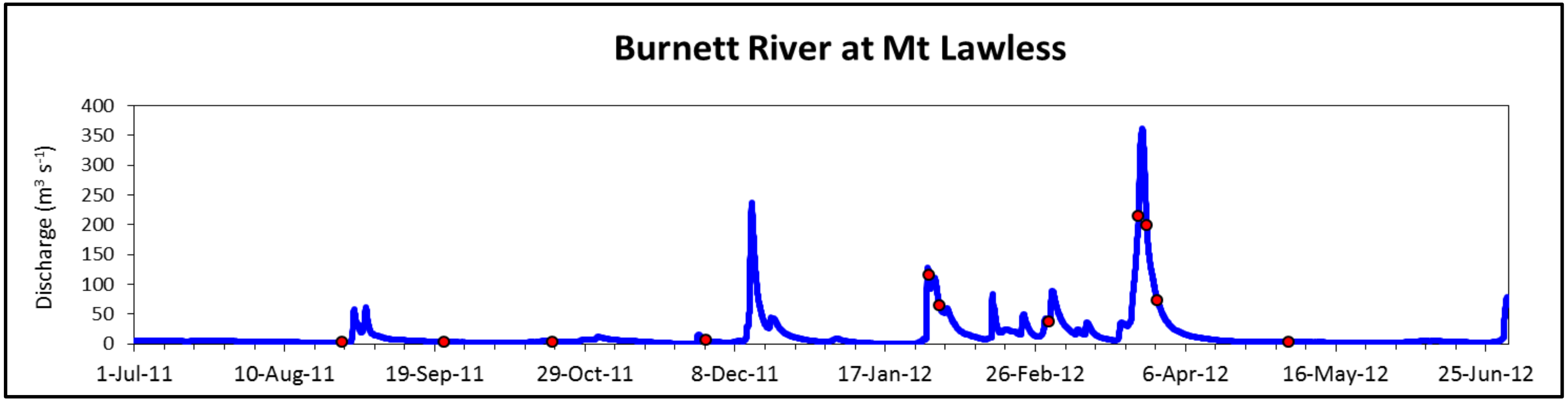


Figure 7.33 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Burnett River at Mt Lawless between 1 July 2011 and 30 June 2012. Representivity rating was indicative for all analytes

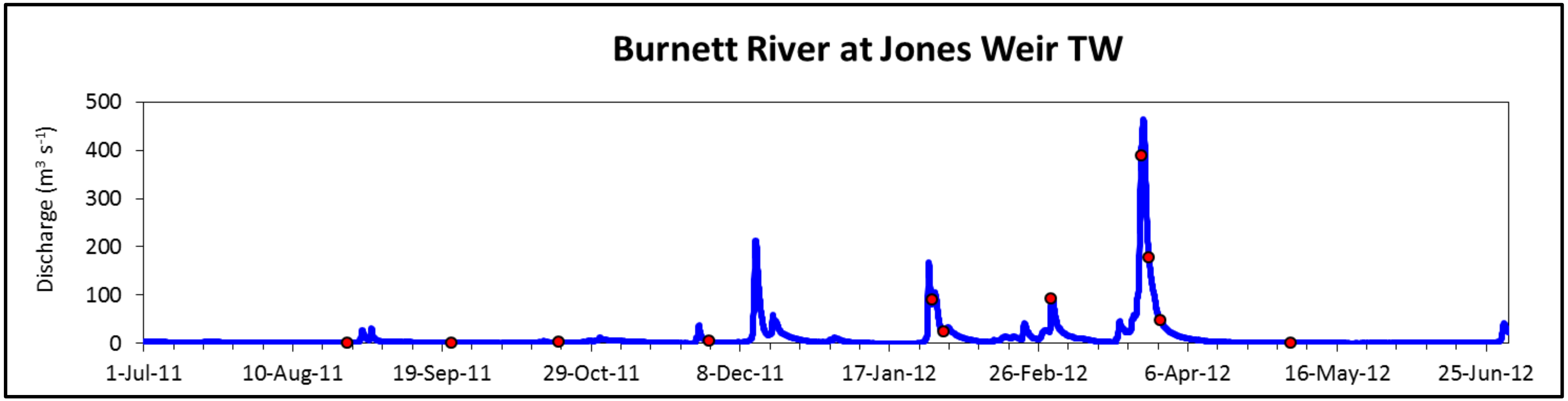


Figure 7.34 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) in the Burnett River at Jones Weir between 1 July 2011 and 30 June 2012. Representivity rating was good for all analytes.

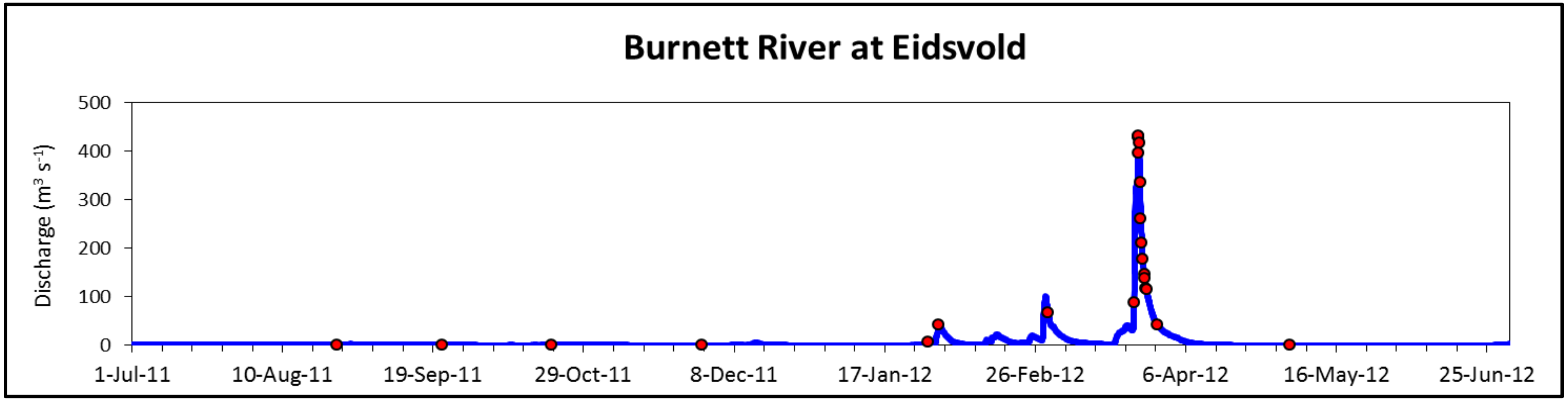


Figure 7.35 Hydrograph showing discharge (blue line) and sample coverage for total suspended solids, total nutrients, dissolved and particulate nutrients (red circles) for Burnett River at Eidsvold between 1 July 2011 and 30 June 2012. Representivity rating was good for all analytes.

Appendix F Calculation of pesticide land use yields

Introduction

Agricultural chemicals, including photosystem II inhibitor 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 chemical. These restrictions may include the crop type, timing and rate which registered chemicals may be applied.

It is possible to use these registered chemical restriction information to determine which agricultural production purposes the priority photosystem II herbicides were registered during the 2011–2012 monitoring year. Together with land use data available through the Australian Collaborative Land Use Mapping Program, registered chemical information may be used to inform the land use yield of photosystem II herbicides calculated by the Great Barrier Reef Catchment Loads Monitoring Program.

The calculation of pesticide land use yields presented in Appendix F differs to the pesticide yields presented in Section 3.4 of this report. In Section 3.4, pesticide yields were calculated using the total monitored catchment area which in many instances is much larger than the land area used for the agricultural production purposes for which specific photosystem II inhibitor herbicides may also be registered. As such, the yields presented in Section 3.4 are likely to be an underestimate of the true yield, as not all of the catchment has pesticides applied to it. For example, in the Tully catchment 72 per cent of land use is conservation and protected areas, where in theory there would be no pesticide use. Due to this potential underestimation, pesticide land use yields were calculated to complement pesticide loads and yields data reported in Section 3.4 of this report.

Method

In each catchment/sub-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 (ACLUMP) sourced through the Queensland Government Information Service (QGIS). 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., urban, mining, conservation and water were not used). Aggregated land use categories used in the calculation of land use yields for the photosystem II herbicides are presented in Table 7.5.

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 (i.e. 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 pesticide land use yields (LUY) in each catchment were calculated using Equation 5:

Equation 5

LUY = annual monitored pesticide load/LUA

where LUA is the total land use area in each catchment based on the aggregated land use categories to which a photosystem II herbicide may be applied.

The LUA was determined by:

Equation 6

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

Thus the resulting land use yields (kg km^{-2}) are the yields of pesticide from the monitored area in each aggregated land use category in each catchment.

These estimates are still likely to underestimate 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 contribute to the load or yield. At this point the spatial resolution for rainfall in the Great Barrier Reef catchments is not sufficient to permit this type of calculation of yields. It is also acknowledged that pesticides may not be applied annually which is the temporal interval reported here.

Table 7.5 Binary codes indicating which photosystem II inhibiting herbicides are registered for the aggregated land use categories in the Great Barrier Reef catchments.

Application units ratio	Cropping	Forestry	Grazing	Horticulture	Sugarcane
Ametryn	0	0	0	1	1
Total atrazine	1	1	1	1	1
Diuron	1	0	0	1	1
Hexazinone	0	1	1	0	1
Tebuthiuron	0	0	1	0	0

Results

Land use yields are presented in Table 7.6. The Burdekin catchment had the highest land use yield of ametryn (0.19 kg km^{-2}) which was six times greater than the other catchments. Tully had the largest land use yields for the remaining four photosystem II herbicides (Table 7.6). The total atrazine land use yield in the Tully catchment (0.47 kg km^{-2}) was approximately 1.6 times larger than in the Barratta catchment (0.29 kg km^{-2}), the catchment with the next largest land use yield. The land use yield of diuron in the Tully catchment (1.1 kg km^{-2}) was twice that of the Herbert catchment (0.53 kg km^{-2}), the catchment with the next largest land use yield. The hexazinone and tebuthiuron land use yields were at least 6 times larger in the Tully catchment, 0.37 kg km^{-2} and 0.059 kg km^{-2}, respectively, than any other monitored catchment.

The ratio of catchment yield to land use yield for the photosystem II herbicides varied greatly between catchments particularly where the total registered area for the application of a photosystem II herbicide was small relative to the total monitored catchment area. Generally the ratio of catchment yield to land use yield was low for total atrazine, hexazinone and tebuthiuron (Table 7.6). The ratio of catchment yield to land use yield for diuron varied between 2.1 at Sandy Creek in the Plane catchment and 89 in the Burdekin catchment. For ametryn, the ratio varied between 2.1 in Sandy Creek in the Plane catchment to 1100 in the Burdekin catchment. These increases are likely to be driven by the small registered land use for application of diuron and ametryn in the Burdekin catchment relative to the total monitored catchment area. These differences further indicate the potential underestimation of photosystem II herbicide yield when calculated based on the total monitored catchment area.

With two exceptions (total atrazine and hexazinone at Barratta Creek in the Haughton catchment) the land use yields are always larger than the average catchment yields. The size of the increase varied with the pesticide and the catchment.

Table 7.6 Herbicide yields for five priority photosystem II herbicides and land use yields.

River and site name	PSII herbicide	Catchment yield (kg km^{-2})	Land use yield (kg km^{-2})	Ratio of catchment yield to land use yield	Registered land use types
North Johnstone River at Tung Oil	Ametryn	NC	NC	NC	Horticulture and sugarcane
	Total atrazine	0.016	0.035	2.3	Cropping, forestry, grazing, horticulture and sugarcane
	Diuron	0.017	0.47	28	Cropping, horticulture and sugarcane
	Hexazinone	NC	NC	NC	Forestry, grazing and sugarcane
	Tebuthiuron	0.00032	0.00080	2.5	Grazing
Tully River at Euramo	Ametryn	0.0043	0.029	6.8	Horticulture and sugarcane
	Total atrazine	0.11	0.47	4.4	Cropping, forestry, grazing, horticulture and sugarcane
	Diuron	0.17	1.1	6.8	Cropping, horticulture and sugarcane
	Hexazinone	0.068	0.37	5.5	Forestry, grazing and sugarcane
	Tebuthiuron	0.0030	0.059	20	Grazing
Herbert River at Ingham	Ametryn	0.00043	0.015	35	Horticulture and sugarcane
	Total atrazine	0.0054	0.0078	1.4	Cropping, forestry, grazing, horticulture and sugarcane
	Diuron	0.017	0.53	31	Cropping, horticulture and sugarcane
	Hexazinone	0.0057	0.0082	1.4	Forestry, grazing and sugarcane
	Tebuthiuron	NC	NC	NC	Grazing
Barratta Creek at Northcote	Ametryn	0.0029	0.016	5.6	Horticulture and sugarcane
	Total atrazine	0.29	0.29	1.0	Cropping, forestry, grazing, horticulture and sugarcane
	Diuron	0.080	0.39	4.9	Cropping, horticulture and sugarcane
	Hexazinone	0.0039	0.0040	1.0	Forestry, grazing and sugarcane
	Tebuthiuron	0.0017	0.0022	1.3	Grazing
Burdekin River at Home Hill	Ametryn	0.00018	0.19	1100	Horticulture and sugarcane
	Total atrazine	0.0028	0.0029	1.1	Cropping, forestry, grazing, horticulture and sugarcane
	Diuron	0.00022	0.020	89	Cropping, horticulture and sugarcane
	Hexazinone	NC	NC	NC	Forestry, grazing and sugarcane
	Tebuthiuron	0.0018	0.0019	1.1	Grazing
Pioneer River at Dumbleton Pump Station	Ametryn	0.0059	0.028	4.8	Horticulture and sugarcane
	Total atrazine	0.15	0.18	1.3	Cropping, forestry, grazing, horticulture and sugarcane
	Diuron	0.091	0.44	4.8	Cropping, horticulture and sugarcane
	Hexazinone	0.018	0.023	1.3	Forestry, grazing and sugarcane
	Tebuthiuron	0.00061	0.0018	2.9	Grazing
Sandy Creek at Homebush	Ametryn	0.0089	0.019	2.1	Horticulture and sugarcane
	Total atrazine	0.18	0.20	1.1	Cropping, forestry, grazing, horticulture and sugarcane
	Diuron	0.17	0.35	2.1	Cropping, horticulture and sugarcane
	Hexazinone	0.050	0.055	1.1	Forestry, grazing and sugarcane
	Tebuthiuron	NC	NC	NC	Grazing

River and site name	PSII herbicide	Catchment yield (kg km^{-2})	Land use yield (kg km^{-2})	Ratio of catchment yield to land use yield	Registered land use types
Fitzroy River at Rockhampton	Ametryn	NC	NC	NC	Horticulture and sugarcane
	Total atrazine	0.0074	0.0079	1.1	Cropping, forestry, grazing, horticulture and sugarcane
	Diuron	0.00047	0.0072	15	Cropping, horticulture and sugarcane
	Hexazinone	NC	NC	NC	Forestry, grazing and sugarcane
	Tebuthiuron	0.0064	0.0080	1.3	Grazing
Burnett River at Ben Anderson Barrage Head Water	Ametryn	NC	NC	NC	Horticulture and sugarcane
	Total atrazine	0.00032	0.00034	1.1	Cropping, forestry, grazing, horticulture and sugarcane
	Diuron	0.00037	0.0091	24	Cropping, horticulture and sugarcane
	Hexazinone	0.00017	0.00019	1.1	Forestry, grazing and sugarcane
	Tebuthiuron	0.000052	0.000067	1.3	Grazing

NC = a load was not calculated as all the concentrations for all samples collected were below the practical quantitation limit

Appendix G Representitivity rating of all calculated loads data

Table 7.7 The number of samples collected and the representitivity rating for monitored sites in 2011–2012. Sites in bold are end-of-system sites, all others are sub-catchment sites.

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**	**Normanby River at Kalpowar Crossing**	39	good	39	good	39	good	39	good	39	good	39	good
Wet Tropics	Barron	**110001D**	**Barron River at Myola**	48	good	48	good	46	good	48	good	48	good	48	good
	Johnstone	112004A	North Johnstone River at Tung Oil[$]	45	good	45	good	45	good	45	good	45	good	45	good
		112101B	South Johnstone River at Upstream Central Mill[$]	21	moderate	21	moderate	21	moderate	21	moderate	21	moderate	21	moderate
	Tully	**113006A**	**Tully River at Euramo**	311	excellent	303	excellent	302	excellent	302	excellent	302	excellent	302	excellent
		113015A	Tully River at Tully Gorge National Park	38	moderate	38	moderate	38	moderate	38	moderate	38	moderate	38	moderate
	Herbert	**116001F**	**Herbert River at Ingham**	79	good	84	good	69	moderate	69	moderate	69	moderate	69	moderate
Burdekin	Haughton	**119101A**	**Barratta Creek at Northcote**	114	excellent	111	excellent	109	excellent	109	excellent	109	excellent	109	excellent
	Burdekin	**120001A**	**Burdekin River at Home Hill**	55	good	52	good	52	good	52	good	52	good	52	good
		120002C	Burdekin River at Sellheim	31	indicative	32	indicative	29	indicative	29	indicative	29	indicative	29	indicative
		120301B	Belyando River at Gregory Development Road	102	excellent	103	excellent	65	good	65	good	65	good	65	good
		120302B	Cape River at Taemas	91	excellent	80	good	79	good	79	good	79	good	79	good
		120310A	Suttor River at Bowen Development Road	32	good	29	good	29	good	29	good	29	good	29	good
Mackay Whitsunday	Pioneer	**125013A**	**Pioneer River at Dumbleton Pump Station**	100	excellent	92	excellent	88	excellent	92	excellent	92	excellent	92	excellent
	Plane	**126001A**	**Sandy Creek at Homebush**	27	good	27	good	27	good	27	good	27	good	27	good
Fitzroy	Fitzroy	**1300000**	**Fitzroy River at Rockhampton**	28	good	28	good	28	good	28	good	28	good	28	good
		130206A	Theresa Creek at Gregory Highway	12	moderate	12	moderate	12	moderate	12	moderate	12	moderate	12	moderate
		130504B	Comet River at Comet Weir	20	moderate	20	moderate	20	moderate	20	moderate	20	moderate	20	moderate
Burnett Mary	Burnett	**136014A**	**Burnett River at Ben Anderson Barrage Head Water**	50	good	50	good	49	good	50	good	50	good	50	good
		136002D	Burnett River at Mt Lawless	11	indicative	11	indicative	11	indicative	11	indicative	11	indicative	11	indicative
		136094A	Burnett River at Jones Weir Tail Water	11	good	11	good	11	good	11	good	11	good	11	good
		136106A	Burnett River at Eidsvold	23	good	23	good	23	good	23	good	23	good	23	good

n = number of concentration data points used in the calculation of loads; TSS = total suspended solids; TN = total nitrogen; PN = particulate nitrogen; NO_x-N = oxidised nitrogen as N; NH_4-N = ammonium nitrogen as N; DIN = dissolved inorganic nitrogen (DIN = (NO_x-N) + (NH_4-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.

Table 7.8 The number of samples collected and the representivity rating for monitored sites in 2011–2012. Sites in bold are end-of-system sites, all others are sub-catchment sites.

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**	**Normanby River at Kalpowar Crossing**	39	good	39	good	39	good	39	good	39	good
Wet Tropics	**Barron**	**110001D**	**Barron River at Myola**	46	good	48	good	48	good	46	good	46	good
	Johnstone	112004A	North Johnstone River at Tung Oil[$]	45	good	45	good	45	good	45	good	45	good
		112101B	South Johnstone River at Upstream Central Mill[$]	21	moderate	21	moderate	21	moderate	21	moderate	21	moderate
	Tully	**113006A**	**Tully River at Euramo**	302	excellent	304	excellent	302	excellent	302	excellent	302	excellent
		113015A	Tully River at Tully Gorge National Park	38	moderate	38	moderate	38	moderate	38	moderate	38	moderate
	Herbert	**116001F**	**Herbert River at Ingham**	69	moderate	84	good	69	moderate	69	moderate	69	moderate
Burdekin	**Haughton**	**119101A**	**Barratta Creek at Northcote**	109	excellent	111	excellent	109	excellent	109	excellent	109	excellent
	Burdekin	**120001A**	**Burdekin River at Home Hill**	52	good	52	good	52	good	52	good	52	good
		120002C	Burdekin River at Sellheim	29	indicative	32	indicative	29	indicative	29	indicative	29	indicative
		120301B	Belyando River at Gregory Development Road	65	good	103	excellent	65	good	65	good	65	good
		120302B	Cape River at Taemas	79	good	80	good	79	good	79	good	79	good
		120310A	Suttor River at Bowen Development Road	29	good	29	good	29	good	29	good	29	good
Mackay Whitsunday	**Pioneer**	**125013A**	**Pioneer River at Dumbleton Pump Station**	88	excellent	92	excellent	92	excellent	88	excellent	88	excellent
	Plane	**126001A**	**Sandy Creek at Homebush**	27	good	27	good	27	good	27	good	27	good
Fitzroy	**Fitzroy**	**1300000**	**Fitzroy River at Rockhampton**	28	good	28	good	28	good	28	good	28	good
		130206A	Theresa Creek at Gregory Highway	12	moderate	12	moderate	12	moderate	12	moderate	12	moderate
		130504B	Comet River at Comet Weir	20	moderate	20	moderate	20	moderate	20	moderate	20	moderate
Burnett Mary	**Burnett**	**136014A**	**Burnett River at Ben Anderson Barrage Head Water**	49	good	50	good	50	good	49	good	49	good
		136002D	Burnett River at Mt Lawless	11	indicative	11	indicative	11	indicative	11	indicative	11	indicative
		136094A	Burnett River at Jones Weir Tail Water	11	good	11	good	11	good	11	good	11	good
		136106A	Burnett River at Eidsvold	23	good	23	good	23	good	23	good	23	good

n = the number of concentration data points used for the load calculation; TSS = total suspended solids; TN = total nitrogen; PN = particulate nitrogen; NO_x-N = oxidised nitrogen as N; NH_4-N = ammonium nitrogen as N; DIN = dissolved inorganic nitrogen (DIN = (NO_x-N) + (NH_4-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.