Water quality signatures of pristine and near-pristine landscapes in the Great Barrier Reef Catchment Area

April 2023 | Report No. 23/12

Authored by: Stephen Lewis, Cassandra James and Zoe Bainbridge

Water quality signatures of pristine and near-pristine landscapes in the Great Barrier Reef Catchment Area

A report for the Paddock to Reef catchment modelling team

Department of Environment and Science

Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) James Cook University Townsville

Phone: (07) 4781 4262

Web: www.jcu.edu.au/tropwater/

ISBN: 978-0-6457422-4-4

The report may be cited as

Lewis S, James C, Bainbridge Z. 2023, 'Water quality signatures of pristine and near-pristine landscapes in the Great Barrier Reef Catchment Area,' Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Report 23/12, James Cook University, Townsville. 68 pp. ISBN: 978-0-6457422-4-4.

Contacts

For more information contact: Stephen Lewis: Stephen.lewis@jcu.edu.au

Acknowledgments

We are grateful to the following colleagues for assisting and providing access to water quality datasets: Craig Thornton and Ken Rohde (*Paddock Monitoring and Modelling, Department of Environment and Science(DES)*), Allan McManus (*formerly Department of Defence*), Andrew Moss (*Aquatic Ecosystem Health, DES*), Lex Cogle (*O-GBR, DES*), Heather Hunter (*formerly NR&W*), Miles Furnas (*formerly AIMS*), Emma Laxton (*J.H & E.S. Laxton – Environmental Consultants*), Rob Bramley (*CSIRO*), Alicia Buckle (*Terrain NRM*), Aaron Davis (*TropWATER, JCU*), Daniel Bloom (*Sunshine Coast Regional Council*) and the DES Water Quality and Investigations team (GBRCLMP).

We thank Dave Waters and the Source Catchments modelling team (Water Quality Modelling, DES Science Division) for supporting this project. Angela Pollett and Shuci Liu are acknowledged for producing upstream catchment land use statistics for some sites, and Lachie Stewart, Cam Dougall, Aditya Singh and Banti Fentie provided modelled daily flow data for ungauged sites. Dr Roger Shaw and Dave Waters provided constructive review of this technical report.

We gratefully acknowledge historical and current water quality monitoring projects, initiatives and organisations, as listed in Table 1 and Appendix 1. We acknowledge the efforts of the Great Barrier Reef catchment area water quality samplers and laboratory staff over the past three decades.

Campus Creek, coastal Brigalow Belt

Front cover: *Russell River at Golden Hole (Image: Aaron Davis)*

Glossary

Be-10	Beryllium-10 radioactive isotope
GBR	Great Barrier Reef
GBRCA	Great Barrier Reef catchment area
GBRCLMP	Great Barrier Reef Catchment Loads Monitoring Program
DIN	Dissolved inorganic nitrogen
DIP	Dissolved inorganic phosphorus
DON	Dissolved organic nitrogen
DOP	Dissolved organic phosphorus
DWC	Dry weather concentration
EMC	Event mean concentration
PN	Particulate nitrogen
PP	Particulate phosphorus
QLUMP	Queensland land use mapping program
TN	Total nitrogen
TP	Total phosphorus

Explanation of terms

'Baseflow' and 'ambient' terms are used interchangeably throughout this document, representing low flow conditions predominately derived from groundwater inputs.

Reference site: There was a notable absence of data from pristine or near-pristine locations for some bioregions. However, monitoring data existed from sites within these bioregions where the catchment area upstream was considered in good condition with relatively minimal evidence of modification in native vegetation. These include lands under Defence jurisdiction and lightly grazed lands. We have termed such sites as 'Reference sites' as they reflect the best possible estimate of a pre-development signature for these bioregions that we have at this time.

TABLE OF CONTENTS

1 INTRODUCTION

Suspended sediment and nutrient loads exported from river basins to the Great Barrier Reef (GBR) provide important data to examine spatial and temporal variability in delivery, understand sediment and nutrient budgets and to determine the level of terrestrial exposure across the GBR lagoon. Indeed, there have been several attempts to estimate sediment and nutrient loads to the Great Barrier Reef over the past four decades (Belperio, 1983; Moss, 1992; Neil and Yu, 1996; Wasson, 1997; Prosser et al., 2001; Neil et al. 2002; Furnas, 2003; Brodie et al., 2003; McKergow et al., 2005a, 2005b; Kroon et al., 2012; McCloskey et al., 2021a, 2021b). The establishment of key river catchment sites sampled by the GBR Catchment Loads Monitoring Program (Queensland Department of Environment and Science) since 2005/2006 (e.g. Joo et al., 2012; Ten Napel et al., 2019) have provided critical measured load data for model calibration. These data have allowed the latest Source Catchment models to produce what is considered the most reliable estimation of current baseline loads for the GBR basins (McCloskey et al., 2021a, 2021b).

Another critical aspect of GBR loads is the estimation of the pre-development or pre-European settlement loads. Accurate knowledge of pre-development load coupled with the current load, provides the anthropogenic load which is a key measure of the change in delivery to the GBR and used for target setting and basin prioritization exercises (e.g. Brodie et al., 2017). Insights on relative changes in suspended sediment loads are provided in sediment core records (Lewis et al., 2014a), coral core records (McCulloch et al., 2003; Lewis et al., 2007, 2018; Saha et al., 2019, 2021; D'Olivo and McCulloch, 2022) and Be-10 derived land denudation rates (Nichols et al., 2014; Croke et al., 2015; Bartley et al., 2015; Mariotti et al., 2021). Modelling pre-development suspended sediment and associated particulate nutrient loads have typically been performed by applying relatively simplistic annual/event mean concentrations from 'reference or pristine' sites coupled with discharge (i.e. to produce a rating curve) as well as considering various biogeomorphological features of the landscape to calculate a natural load (e.g. Neil and Yu, 1996; Furnas, 2003; Brodie et al., 2003; McKergow et al., 2005a; McCloskey et al., 2021a). Similarly for dissolved nutrient loads data from 'reference or pristine' sites are used coupled with discharge to estimate a natural load (e.g. Furnas, 2003; Brodie et al., 2003; McKergow et al., 2005b; Lewis et al., 2014b; McCloskey et al., 2021b). However, the available water quality data from 'reference or pristine' sites are sparse and largely concentrated within the Wet Tropics rainforest region. In that regard, most of the Great Barrier Reef Catchment Area (GBRCA) is modified under agricultural, urban or mining land use (Lewis et al., 2021) and the limited pristine sites typically are averaged to form a single value (e.g. Brodie and Mitchell, 2006; Bartley et al., 2012). This approach results in pristine water quality values that are largely biased to the most dominant monitored pristine bioregion in the GBR (i.e. Wet Tropics) and may not represent other bioregions of the GBRCA.

An example of the disparity in the water quality datasets can be provided using the estimates from the dissolved inorganic nitrogen (DIN) parameter which is one of the key pollutants in the GBR. Brodie and Mitchell (2006) provided DIN concentrations from pristine rainforest and woodlands of northern Australia with an average (mean) of 0.037 mg/L and a median of 0.019 mg/L while Bartley et al. (2012) provide mean and median DIN values of 0.210 and 0.096 mg/L, respectively for pristine forest lands. However, event mean concentrations (EMC) of DIN for the pristine Brigalow scrub site within the Fitzroy Basin have been reported at 1.94 mg/L for the 2010 water year (1^{st} Oct- 30^{th} Sept; Thornton and Elledge, 2013). In the most recent Source Catchments model, the DIN conservation land use EMC values used to calculate pre-development loads varies across the GBR NRM regions and range from 0.03 to 0.16 mg/L (McCloskey et al., 2021b). Clearly, additional water quality data from pristine or reference sites that cover different bioregions are highly desirable to further inform the input model values for the EMCs. The Source Catchments model also captures a dry weather concentration (DWC) for the calculation of loads during baseflow (ambient) periods, which is particularly important for the wetter river catchments where baseflow can potentially contribute up to 50% of the total flow (Puignou Lopez et al. in review).

Fortunately the wealth of water quality monitoring data across the GBRCA continues to increase and previously unavailable datasets for the earlier compilation efforts (i.e. Brodie and Mitchell, 2006; Bartley et al., 2012) have also become available. Hence, for the first time we are able to compile all available water quality datasets from sites considered to be pristine or near-pristine to produce more reliable DWC and EMC values for the different bioregions of the GBRCA.

2 METHODS

2.1 DATA COMPILATION AND PRISTINE CATEGORIES

Water quality sites capturing pristine landscapes within the GBRCA were first identified by the team, including a review of sites earlier identified by the Brodie and Mitchell (2006) and Bartley et al. (2012) studies. The compilation of these raw water quality data included additional data from (i) monitoring programs that have been established since these earlier compilations (e.g. NESP “Project 25”; Burdekin and Wet Tropics Major Investment Program sites); (ii) addition of sites for data poor bioregions considered near-pristine or ‘reference’ (e.g. TropWATER’s sites within the Einasleigh Uplands); and (iii) where data were previously not requested (e.g. Department of Defence Townsville Field Training Area). A summary of the datasets compiled are listed in Table 1.

Where available, we compiled seven separate water quality parameters which included total suspended solids (i.e. suspended sediment), particulate nitrogen (PN), particulate phosphorus (PP), dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP; also termed filterable reactive phosphorus), dissolved organic nitrogen (DON) and dissolved organic phosphorus (DOP).

As water quality parameters can be considerably influenced by natural features within the landscape such as vegetation type, climate, geology and soils (Furnas, 2003; Brodie and Mitchell, 2005), we grouped sites within the seven bioregions that comprise the GBRCA, as shown in Figure 1. While this grouping does not capture the complete natural variability within the GBRCA, we consider this method to be a reasonable balance between the availability of water quality data and the coverage of NRM regions. Indeed, this grouping method addresses the bias associated with the over-representation of sites within the Wet Tropics rainforest. Summary DWC and EMC statistics for each water quality parameter are based on the mean of the site medians of the most undisturbed locations for all sites within each of the bioregions. The QLUMP land use database was used to calculate the upstream catchment area land use statistics for each site, presented in Table 1 and shown in Figure 2 to Figure 9. Sites were then classified into four categories, including:

- “**Pristine**”: – 100% conservation;
- “**Near-pristine**” with some non-intensive land uses – sites utilized include 83 to 99% conservation, with remaining land use non-intensive including wet/dry tropics grazing *and/or* forestry;

- "**Minor intensive**" (pristine with small areas of intensive land use) – sites utilised include 88 to 99% conservation, with remaining land use including 0.5 to 3% intensive (sugar, horticulture, urban) land use;
- "**Reference**" – a combination of conservation *and* grazing (wet forested/dry) land uses. Applied only to regions with limited data availability.

For the Wet Tropics historical sites from the 1990s, a combination of historic (e.g. QLUMP_1999) and current (QLUMP_2022) databases were used to calculate land use statistics, due to the large changes in land use mapping from production forestry to conservation (i.e. conversion of state forests to protected areas in the 1999-2009 period) (DSITI, 2016).

2.2 DATA CLEANING AND FLOW SEPARATION

All datasets were examined and cleaned to ensure that all nutrient parameters, units of measurement, duplicates and below detection values reported were in a consistent format. Nutrient data include results from multiple Queensland laboratories, using kjeldahl, persulfate and UV digestion analytical methods. DIN concentrations reported for the four Barron sites (Freshwater, Kauri, Davies, Clohesy) from the Cogle et al. (2000) study and four Herbert sites (Hawkins, Dalrymple, Crystal, Waterview) from the CSIRO study (Bramley & Roth 2002) do not include nitrite concentrations (i.e. in these cases only, DIN = nitrate + ammonia only); these data have been included in our compilation given that nitrite often makes a very minor contribution to DIN. The reader is referred to the original references listed in Table 1 for the specific analytical methods for each dataset.

Once the data were cleaned and sorted into their respective bioregion, the raw data from each site were separated into baseflow (ambient) and event flow conditions. Daily flow data for each site were obtained using nearby site gauges where available, or modelled (as daily flow) using Source Catchments (McCloskey et al. 2021). Baseflow separation was achieved using a refinement of the Lyne and Hollick digital filter (Lyne & Hollick, 1979); with the alpha parameter set at 0.999 and the number of passes set to 3 using the r package *Hydroevents* (Wasko & Guo, 2022). Binns & Waters (2018) discuss the difficulties of applying a single generic alpha value to all GBR rivers given the climatic variabilities across the basins. Therefore, the results of the initial baseflow separation were plotted against site flow hydrographs for visual review and appropriate adjustments made if required (e.g. data representing the tail-end of an event inaccurately coded as baseflow and therefore reassigned to event). For a smaller number of projects (e.g. Wet Tropics MIPs, Laxton sites), the flow regime at time of sample collection was documented in the original source data file, and this information was used for baseflow separation. Some other programs targeted 'event' or 'baseflow' conditions, and again this information was used to assign baseflow separation. These instances were particularly relevant for sites with small upstream catchment areas where it is difficult to model flow confidently. Flow information used for each site is detailed in Table 1.

Ambient and event flow data were then separately plotted as boxplots for each parameter for the individual sites across each bioregion. The median value of each parameter was calculated for each site. If there were multiple pristine or near-pristine sites within a bioregion, the mean of all the median values was calculated to derive a recommended DWC and EMC for each parameter for each bioregion. These plots are presented in this report within each bioregion section, with the number of discrete water samples for each site represented at the top of each individual box and whisker (for both ambient and event). Individual site summary statistics for TSS, DIN and DIP are also presented in Appendices 2-4.

Table 1. Summary of the water quality datasets compiled in this study. "Upper" catchment sites were treated uniquely to sites located downstream on the same waterway.

Pristine category	Basin	Site (short name)	Map site #	Flow source (Gauging station or modelled flow)	Upstream catchment area (km^2)	Conser-vation (%)	Non-intensive: wet/dry grazing* (%)	Non-intensive: forestry (%)	0.5 - 3% intensive land use (%) (sugar, horti, urban)	Data collection period	Data source
Cape York bioregion											
Near-pristine	Olive-Pascoe	Pascoe R	1	Pascoe R at Garraway	1828	83%	17%			2017 to 2021	GBRCLMP, WQ&I, QDES
Wet Tropics bioregion											
Pristine	Mossman	Mossman R Gorge	4	Mossman R at Mossman	78	100%				1998 to 2003	Laxton and Gittens 2004
Pristine	Mossman									1994 to 1999	Cox et al. 2005
Pristine	Barron	Clohesy R	5	Modelled flow	10	100%				1996 to 1998	Cogle et al. 2000
Pristine	Barron	Davies Ck	6	Modelled flow	44	99.9%	0.1%			1996 to 1999	Cogle et al. 2000
Pristine	Barron	Freshwater Ck	7	Modelled flow	58	94%**				1996 to 1999	Cogle et al. 2000
Pristine	Russell-Mulgrave	Behana Ck	11	Modelled flow	60	100%				2016 to 2020	Davis, Taylor, & Fielke 2020
Pristine	Russell-Mulgrave	Babinda Ck	12	Babinda Ck at Boulders	4	100%				1994 to 1999	Cox et al. 2005
Pristine	Johnstone	Taylor Ck	14	Taylor Ck at Warraker	1.2	100%				1991 to 1996	Hunter et al. 2001
Pristine	Johnstone	Henrietta Ck	15	Flow assigned by data source	19	100%				2021	Terrain NRM (WTMIP) [#]
Pristine	Tully	Tully Valley R/F	19	Flow assigned by data source	1.1	100%				2018 to 2021	Terrain NRM (WTMIP) [#]
Pristine	Tully (Hull)	North Hull R	22	Modelled flow	13	100%				2005 to 2007	Bainbridge et al. 2009
Pristine	Murray	Murray Falls	25	Murray R at Upper Murray	39	100%				2005 to 2007	Bainbridge et al. 2009
Near-pristine	Daintree	Daintree R	2	Daintree R at Bairds	969	90%	10%			1998 to 2003	Laxton and Gittens 2004
Near-pristine	Daintree				913	90%	10%			2019 to 2022	Cox et al. 2005
Near-pristine	Daintree				913	90%	10%			1994 to 1999	Cox et al. 2005
Near-pristine	Daintree	Stewart Ck	3	Modelled flow not available, low flow	180	90%	7.6%	1.9%	0.2%	1994 to 1996	Cox et al. 2005
Near-pristine	Barron	Kauri Ck	8	Modelled flow	16	98%		1.6%		1992 to 1999	Cogle et al. 2000
Near-pristine	Russell-Mulgrave	Little Mulgrave R	9	Modelled flow not available, low flow	72	99%	0.4%			1994 to 1999	Cox et al. 2005
Near-pristine	Russell-Mulgrave	Russell R	13	Modelled flow	125	92%	7.7%		0.4%	1992 to 1999	Cox et al. 2005
Near-pristine					123	92%	7.4%		0.3%	2016 to 2020	Davis, Taylor, & Fielke 2020
Near-pristine	Johnstone	South Johnstone R	16	South Johnstone R Central Mill	333	95%	4%		0.2%	1991 to 1996	Hunter et al. 2001
Near-pristine	Johnstone	Upper Liverpool Ck	17	Flow assigned by data source	36	98%	1.2%		0.3%	2019 to 2021	Terrain NRM (WTMIP) [#]
Near-pristine	Tully	Tully Gorge	18	Modelled flow	505	93%	6.7%			1987 to 2000	Mitchell et al. 2009
Near-pristine				Modelled flow	505	93%	6.7%			1998 to 2003	Laxton and Gittens 2004
Near-pristine				Modelled flow	505	93%	6.7%			2005 to 2007	Bainbridge et al. 2009
Near-pristine				Modelled flow	504	90%	1%	5.7%		1992 to 1999	Cox et al. 2005
Near-pristine				Tully R at Tully Gorge NP	482	96%	1%			2013 to 2021	GBRCLMP, WQ&I, QDES
Near-pristine				Tully R at Tully Gorge NP	482	96%	1%			2018 to 2019	Terrain NRM (WTMIP) [#]

Pristine category	Basin	Site (short name)	Map site #	Flow source (Gauging station or modelled flow)	Upstream catchment area (km²)	Conser -vation (%)	Non-intensive: wet/dry grazing* (%)	Non-intensive: forestry (%)	0.5 - 3% intensive land use (%) (sugar, horti, urban)	Data collection period	Data source
Near-pristine	Herbert	Dalrymple Ck	26	Modelled flow	28	99%		1%		1993 to 1995	Bramley & Muller 1999; Bramley & Roth 2002
Near-pristine	Herbert	Waterview Ck	28	Modelled flow	37	99%	0.3%	0.5%		1992 to 1994	
Near-pristine	Black	Big Crystal Ck	29	Modelled flow	55	99%	0.1%	1.2%		1998 to 2003	Laxton and Gittens 2004
Near-pristine	Black	Little Crystal Ck	31	Modelled flow	14	97%		2.6%	0.4%	1998 to 2003	Laxton and Gittens 2004
Minor-inten	Russell-Mulgrave	Mulgrave R	10	Mulgrave R at Fisheries	363	88%	8.7%	1.5%	1.1%	1992 to 1999	Cox et al. 2005
Minor-inten										2016 to 2020	Davis, Taylor, & Fielke 2020
Minor-inten	Tully	Jarra Ck	20	Modelled flow	181	96%	1.3%		2.6%	1987 to 2000	Mitchell et al. 2009
Minor-inten					181	96%	1.3%		2.6%	2005 to 2007	Bainbridge et al. 2009
Minor-inten	Tully	Bulgun Ck	21	Modelled flow	32	99%			0.9%	2005 to 2007	Bainbridge et al. 2009
Minor-inten	Tully	Davidson Ck	23	Modelled flow	93	98%	2.4%			2005 to 2007	Bainbridge et al. 2009
Minor-inten	Murray	Murray R_Jumbun	24	Murray R at Upper Murray	63	97%	0.4%		2.2%	2005 to 2007	Bainbridge et al. 2009
Minor-inten	Herbert	Hawkins Ck	27	Modelled flow	15	96%	0.5%		4%	1992 to 1995	Bramley & Muller 1999; Bramley & Roth 2002
Minor-inten	Herbert	Crystal Ck	30	Modelled flow	102	94%	0.8%	1.5%	1.8%	1992 to 1994	
Minor-inten	Black	Hen Camp Ck	32	Modelled flow	22	88%	11%		0.9%	2007	Liessman et al. 2007
Einasleigh Uplands bioregion											
Near-pristine	Burdekin	Upper Star R	34	Baseflow program (manual assign)	144	83%	14%		0.3%	early 2000-present	Department of Defence confidential client reports (2002-2022)
Near-pristine	Burdekin	Upper Star R	35	Baseflow program (manual assign)	89	99%					
Near-pristine	Burdekin	Keelbottom Ck	37	Baseflow program (manual assign)	192	91%	6.6%				
Near-pristine	Burdekin	Stake Ck	38	Baseflow program (manual assign)	57	98%	2.2%		0.14%		
Near-pristine	Burdekin	Fanning R	39	Baseflow program (manual assign)	63	98%	1.6%		0.13%		
Reference	Burdekin	Star R	36	Star R at Laroona	1,173	58%	39%				
Reference	Burdekin				1,688	52%	45%	1.2%	0.4%	2005 to 2008	Bainbridge et al. 2014
Reference	Burdekin	Running R	33	Running R at Mt Bradley	682	6%	88%	5.8%	0.1%	2003 to 2008	Bainbridge et al. 2014
Reference	Burdekin	Lolworth Ck	41	Modelled flow	2,295	14%	85%			2004 to 2008	Bainbridge et al. 2014
Reference	Burdekin	Fletcher Ck	40	Modelled flow	884	44%	54%			2004 to 2008	Bainbridge et al. 2014
Reference	Haughton	Reid R	42	Modelled flow	519	3%	97%			2003 to 2008	Bainbridge et al. 2008
Desert Uplands bioregion											
Reference	Burdekin	Cape R	45	Cape River at Taemas	15,860	22%	78%		0.01%	2003 to 2010	Bainbridge et al. 2008, 2014
Reference	Burdekin									2011 to 2013	GBRCLMP, WQ&I, QDES.
Central Queensland Coast bioregion											
Pristine	Pioneer	Impulse Ck	46	Modelled flow	33	100%				2005 to 2007	Event: Rohde et al. 2006, 2008; Baseline: Galea et al.2008;Drewry et al
Pristine	Pioneer	Rawsons Ck (Finch Hatton Gorge)	49	Finch Hatton Ck at Gorge Rd	4	100%				2007 to 2008	Galea et al. 2008; Drewry et al. 2008
										1998 to 2003	Laxton and Gittens 2004
Near-pristine	O'Connell	St Helens Ck	48	Modelled flow	43	98.5%	0.9%		0.6%	2005 to 2008	Event: Rohde et al. 2006, 2008; Baseline: Galea et al. 2008;Drewry et al
Minor-inten	Pioneer	Finch Hatton Ck	50	Finch Hatton Ck at Gorge Rd	24	92%	3.5%		4.2%	2005 to 2007	Rohde et al. 2006, 2008

Pristine category	Basin	Site (short name)	Map site #	Flow source (Gauging station or modelled flow)	Upstream catchment area (km²)	Conser -vation (%)	Non-intensive: wet/dry grazing* (%)	Non-intensive: forestry (%)	0.5 - 3% intensive land use (%) (sugar, horti, urban)	Data collection period	Data source
Brigalow Belt (coastal) bioregion											
Pristine	Ross	Alligator Ck	44	Alligator Ck at Allendale	40	99.9%			0.08%	2007	Liessman et al. 2007
Pristine	Ross	Campus Ck	43	Ephemeral site (manual assign)	2.3	100%				2007	Liessman et al. 2007
Reference	Burdekin	Broken R	47	Broken R at Urannah	2,248	24%	71%	2.7%		2018 to 2021	Bainbridge et al. in review
Brigalow Belt bioregion											
Pristine	Fitzroy	Brigalow forest	51	Local site gauge	0.17	100%				1980 to 2021	Elledge & Thornton, 2017
South East Queensland bioregion											
Near-pristine	Mary	Booloumba Ck	54	Baseflow program (manual assign)	57	98.7%	1.1%	0.07%	0.07%	1995 to 1997	Arthington et al. 1998
Reference	Mary	LIttle Yabba Ck	53	Baseflow program (manual assign)	105	47%	38%	15%		2019-2020	SCRC ##
Reference	Baffle	Baffle Ck	52	Baffle Creek at Mimdale	1401	18%	75%	3.7%	1%	1972 to 2022	SWAN (DNRME)

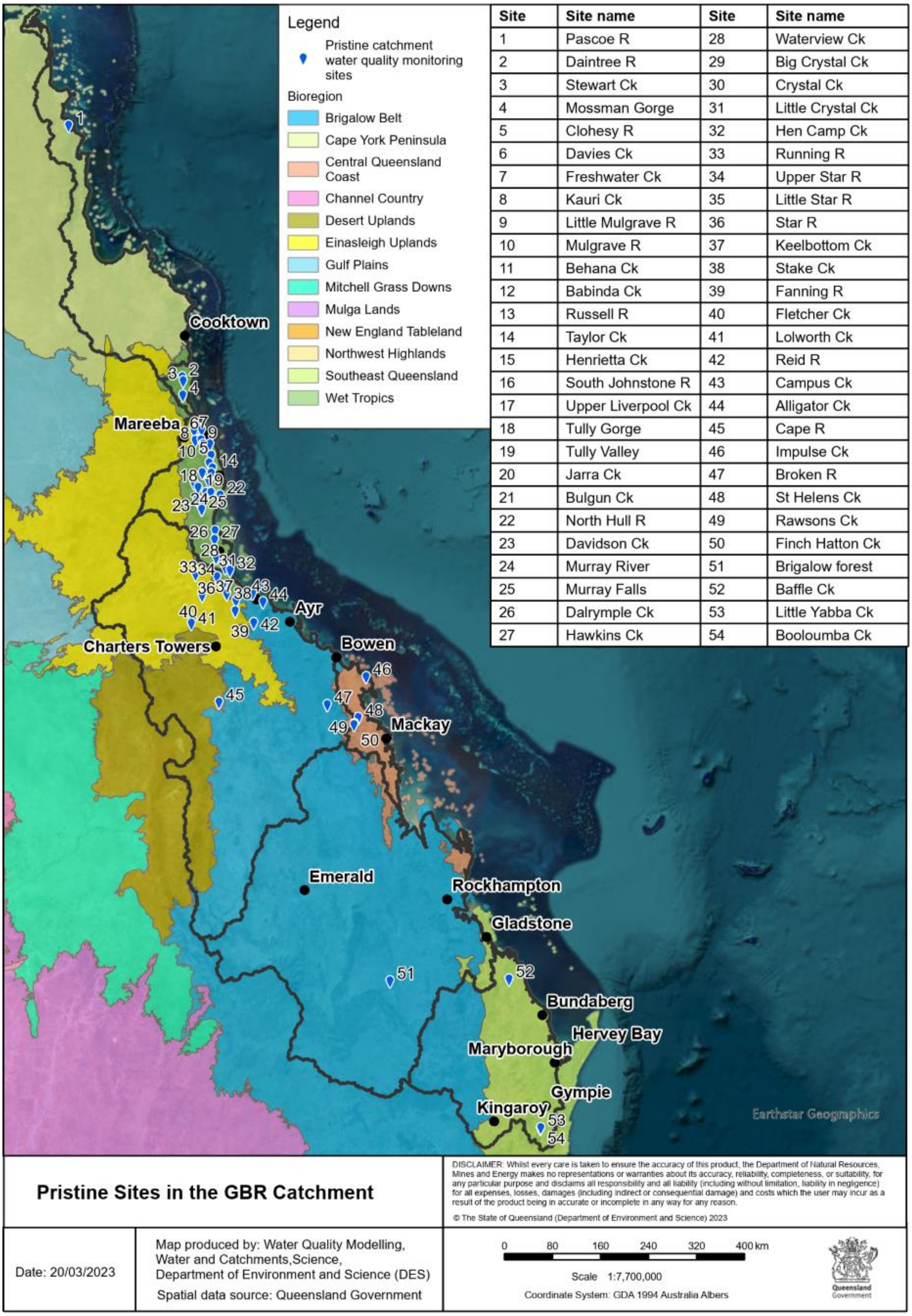
Please note, a breakdown of ambient and event flow samples are provided in Appendices 2-4. Some sites have been sampled by multiple projects, including Mossman R Gorge, Daintree River, Russell River, Tully Gorge, Mulgrave River, Jarra Creek, Star River, Cape River and Rawsons Creek.

* Grazed = Wet Tropics forested, or Dry Tropics open savannah

** Upstream land use includes 5.4% "water"

[#] Data supplied by Terrain Natural Resource Management on behalf of the Wet Tropics Major Integrated Project (WTMIP) consortium.

[##] Data supplied by Sunshine Coast Regional Council (2023). While every care is taken to ensure the accuracy of this data, Sunshine Coast Council makes no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which might be incurred as a result of the data being inaccurate or incomplete in any way and for any reason.



Site	Site name	Site	Site name
1	Pascoe R	28	Waterview Ck
2	Daintree R	29	Big Crystal Ck
3	Stewart Ck	30	Crystal Ck
4	Mossman Gorge	31	Little Crystal Ck
5	Clohesy R	32	Hen Camp Ck
6	Davies Ck	33	Running R
7	Freshwater Ck	34	Upper Star R
8	Kauri Ck	35	Little Star R
9	Little Mulgrave R	36	Star R
10	Mulgrave R	37	Keelbottom Ck
11	Behana Ck	38	Stake Ck
12	Babinda Ck	39	Fanning R
13	Russell R	40	Fletcher Ck
14	Taylor Ck	41	Lolworth Ck
15	Henrietta Ck	42	Reid R
16	South Johnstone R	43	Campus Ck
17	Upper Liverpool Ck	44	Alligator Ck
18	Tully Gorge	45	Cape R
19	Tully Valley	46	Impulse Ck
20	Jarra Ck	47	Broken R
21	Bulgun Ck	48	St Helens Ck
22	North Hull R	49	Rawsons Ck
23	Davidson Ck	50	Finch Hatton Ck
24	Murray River	51	Brigalow forest
25	Murray Falls	52	Baffle Ck
26	Dalrymple Ck	53	Little Yabba Ck
27	Hawkins Ck	54	Booloumba Ck

Figure 1. Identified pristine or near-pristine water quality sites across the GBRCA bioregions.

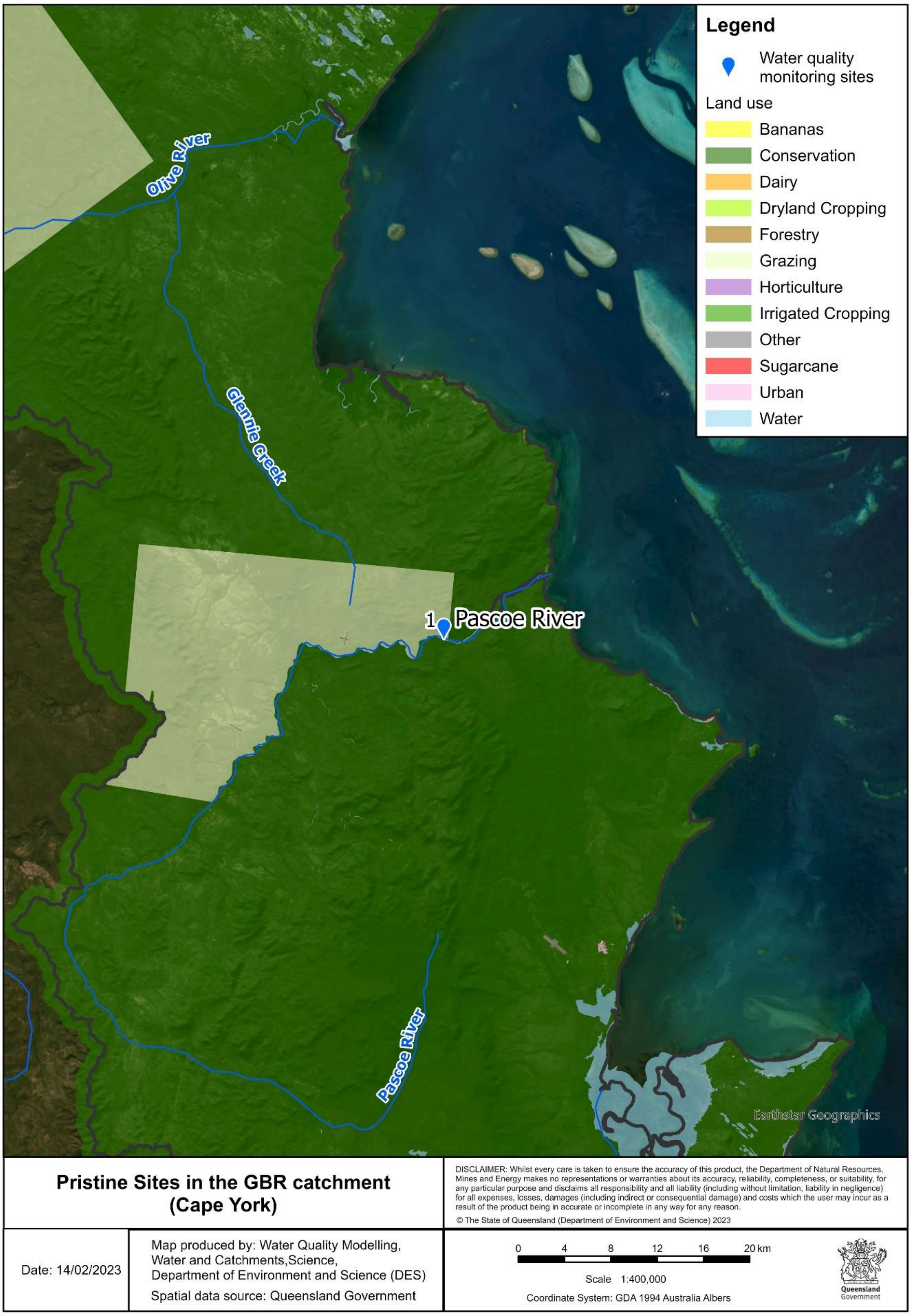


Figure 2. Location and land use of the near-pristine site in the Cape York bioregion.

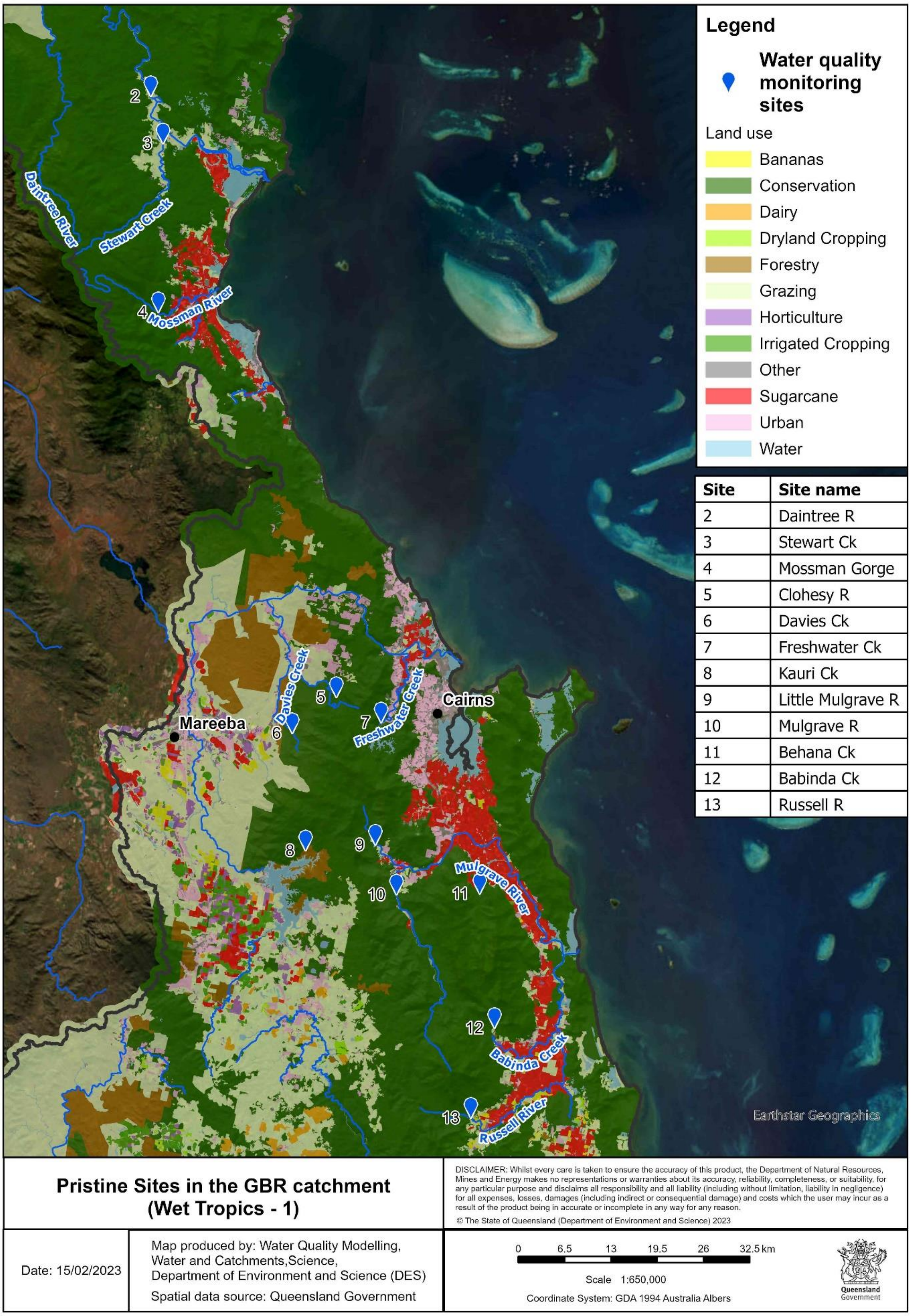


Figure 3. Locations and land use of pristine and near-pristine sites in the northern Wet Tropics bioregion.

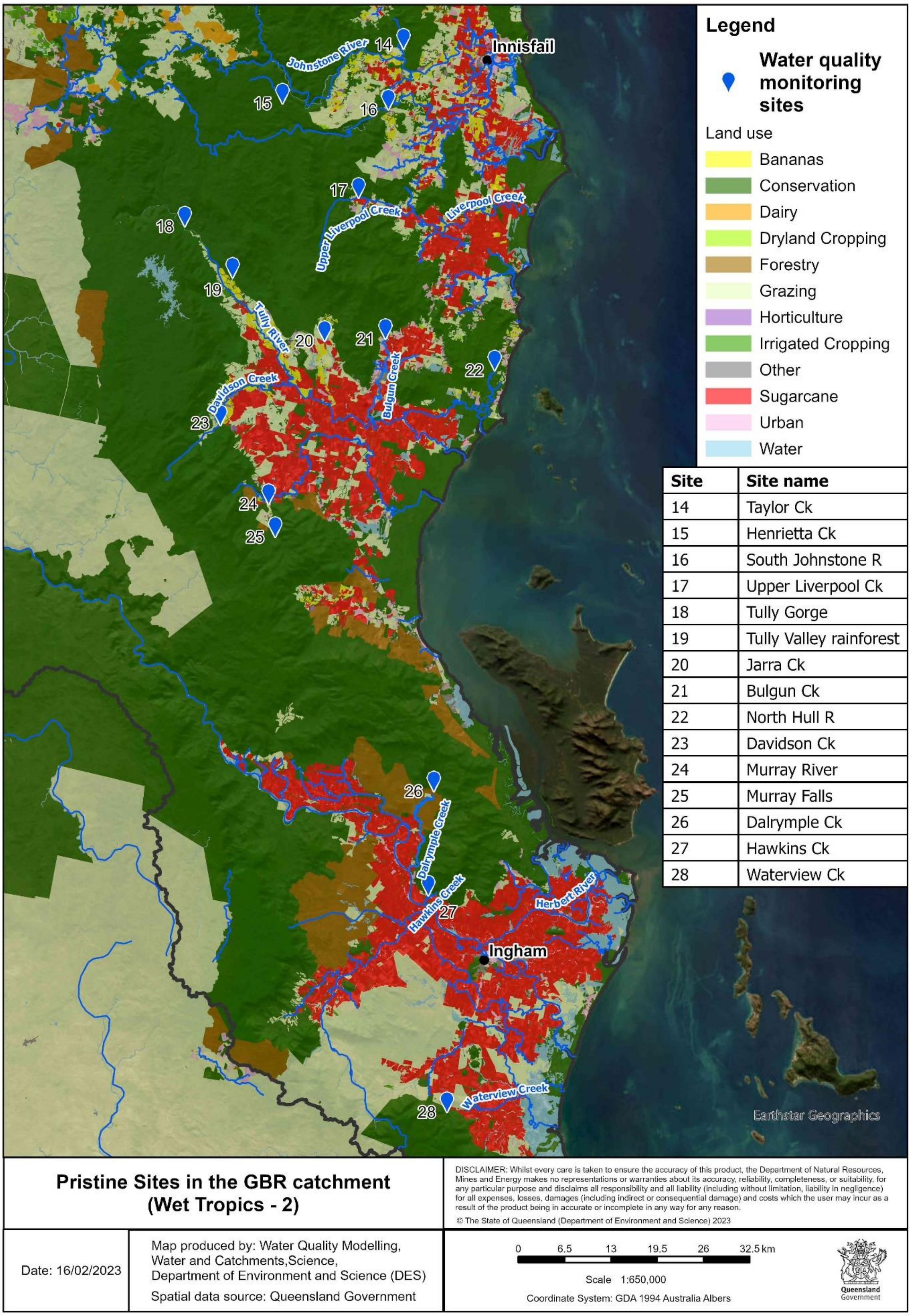


Figure 4. Locations and land use of pristine and near-pristine sites in the southern Wet Tropics bioregion.

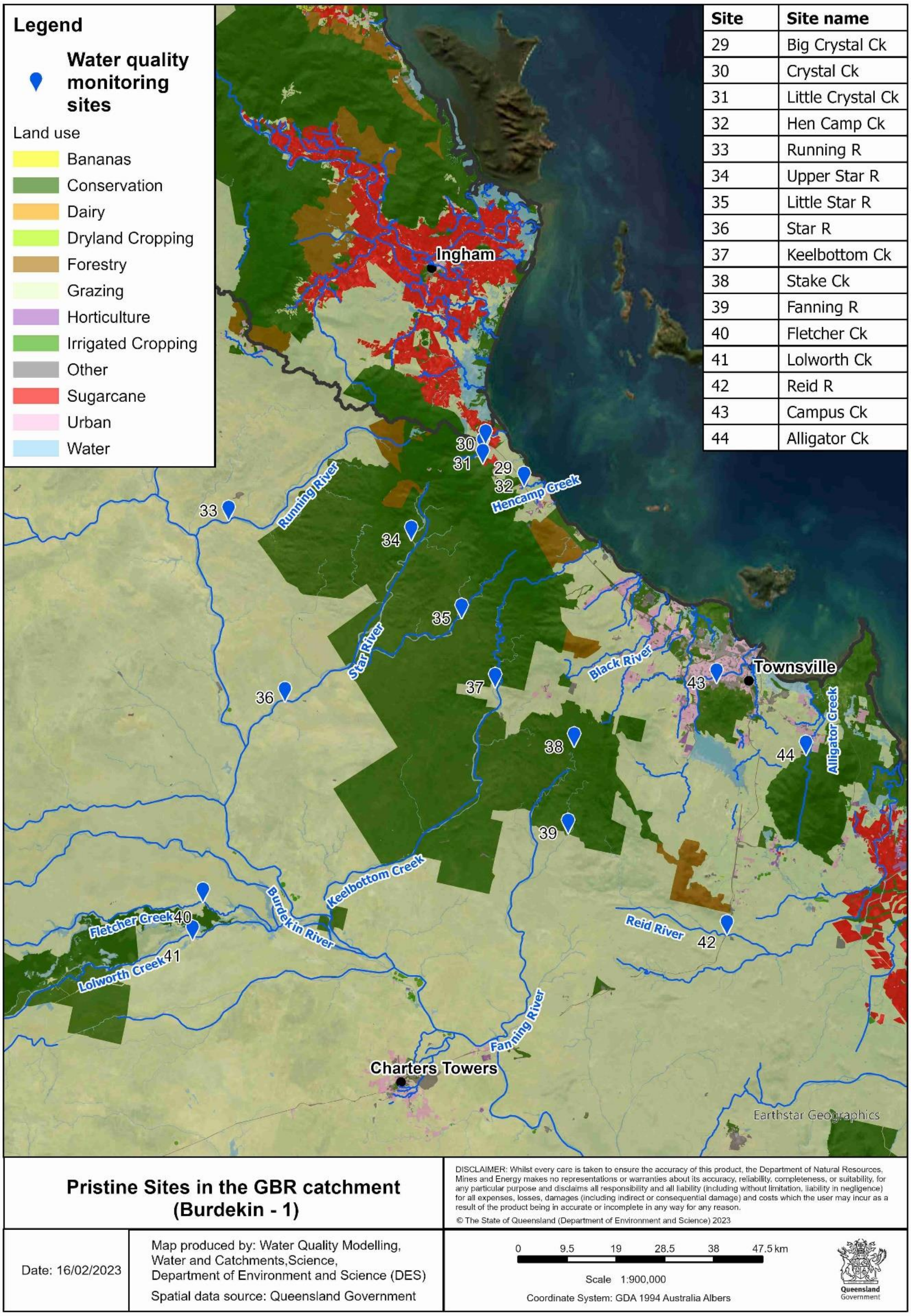


Figure 5. Locations and land use of pristine and near-pristine sites in the Einasleigh Uplands, Wet Tropics (Black basin only) and Brigalow Belt (coastal) bioregions.

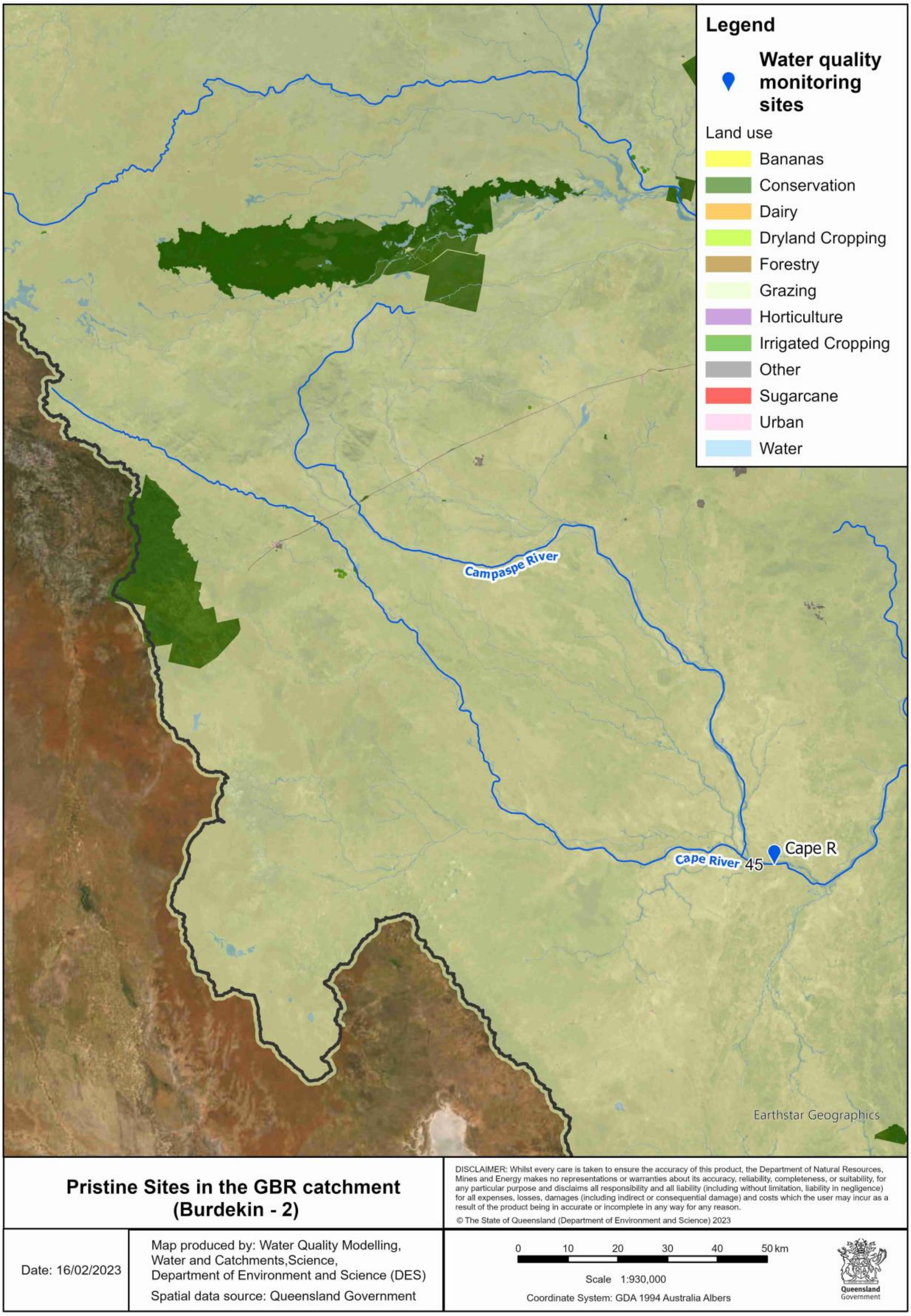


Figure 6. Locations and land use of the reference site in the Desert Uplands bioregion.

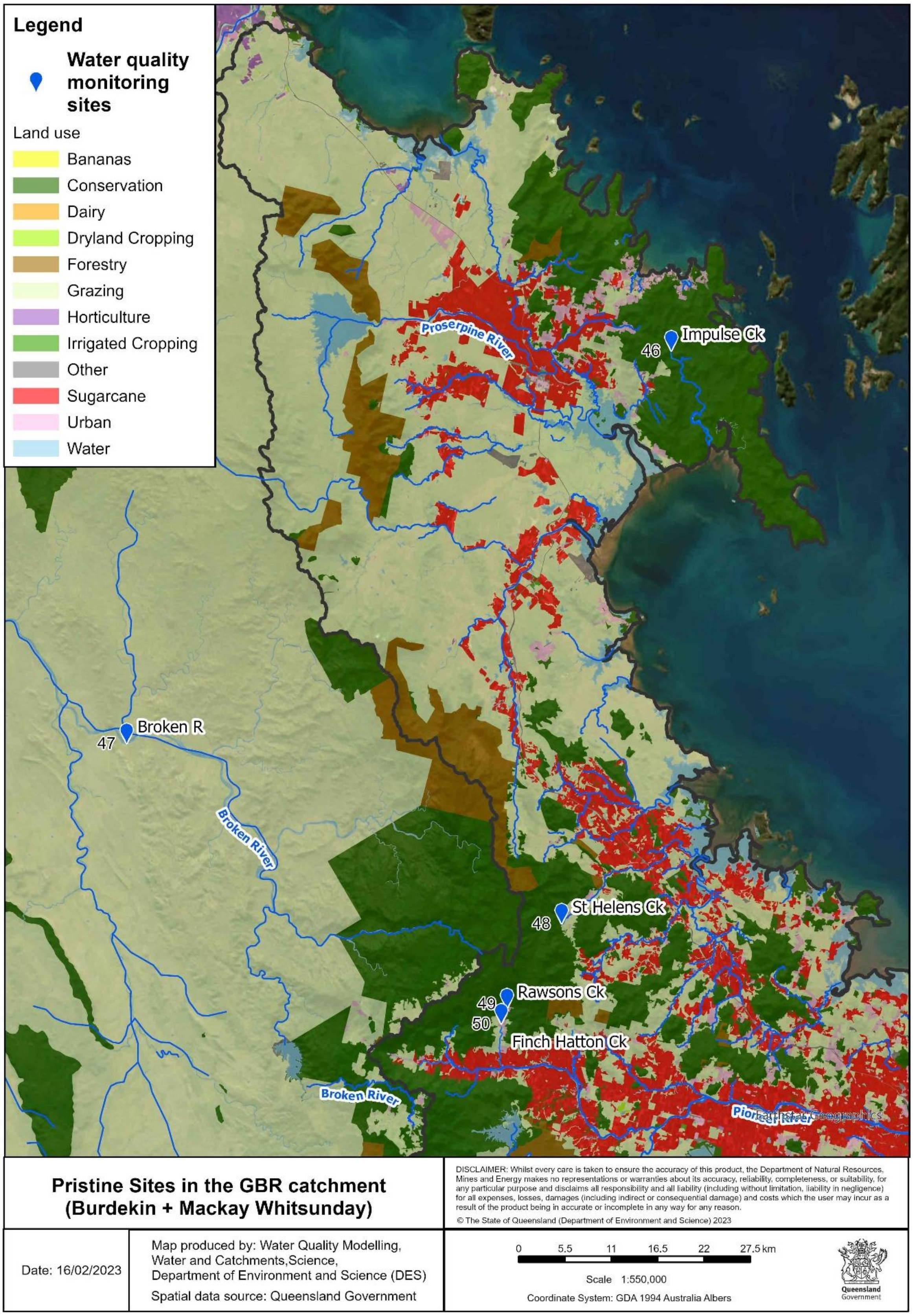


Figure 7. Locations and land use of pristine and near-pristine sites in the Central Queensland Coast and Brigalow Belt (coastal) bioregions.

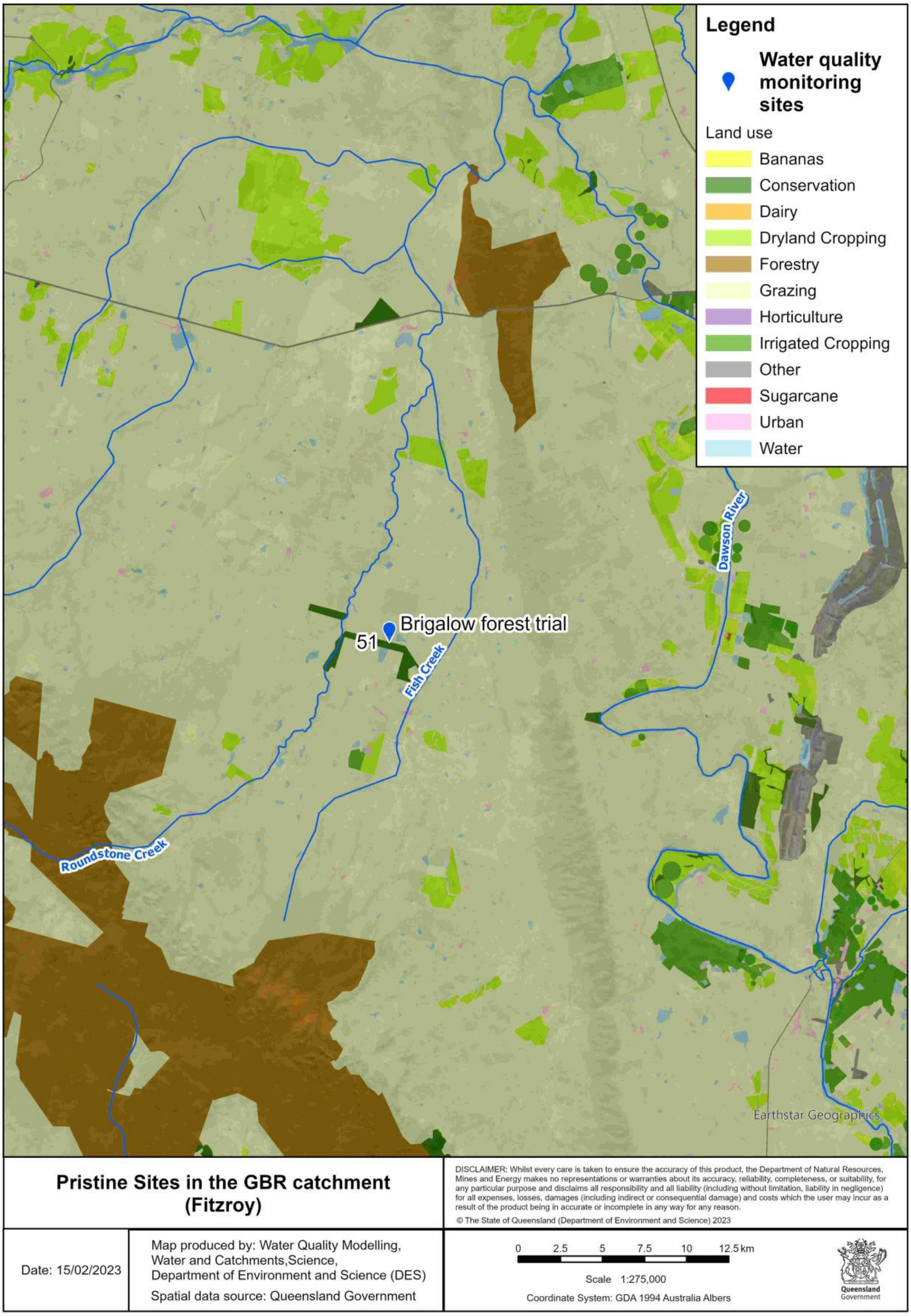


Figure 8. Location and land use of the pristine site in the Brigalow Belt bioregion.

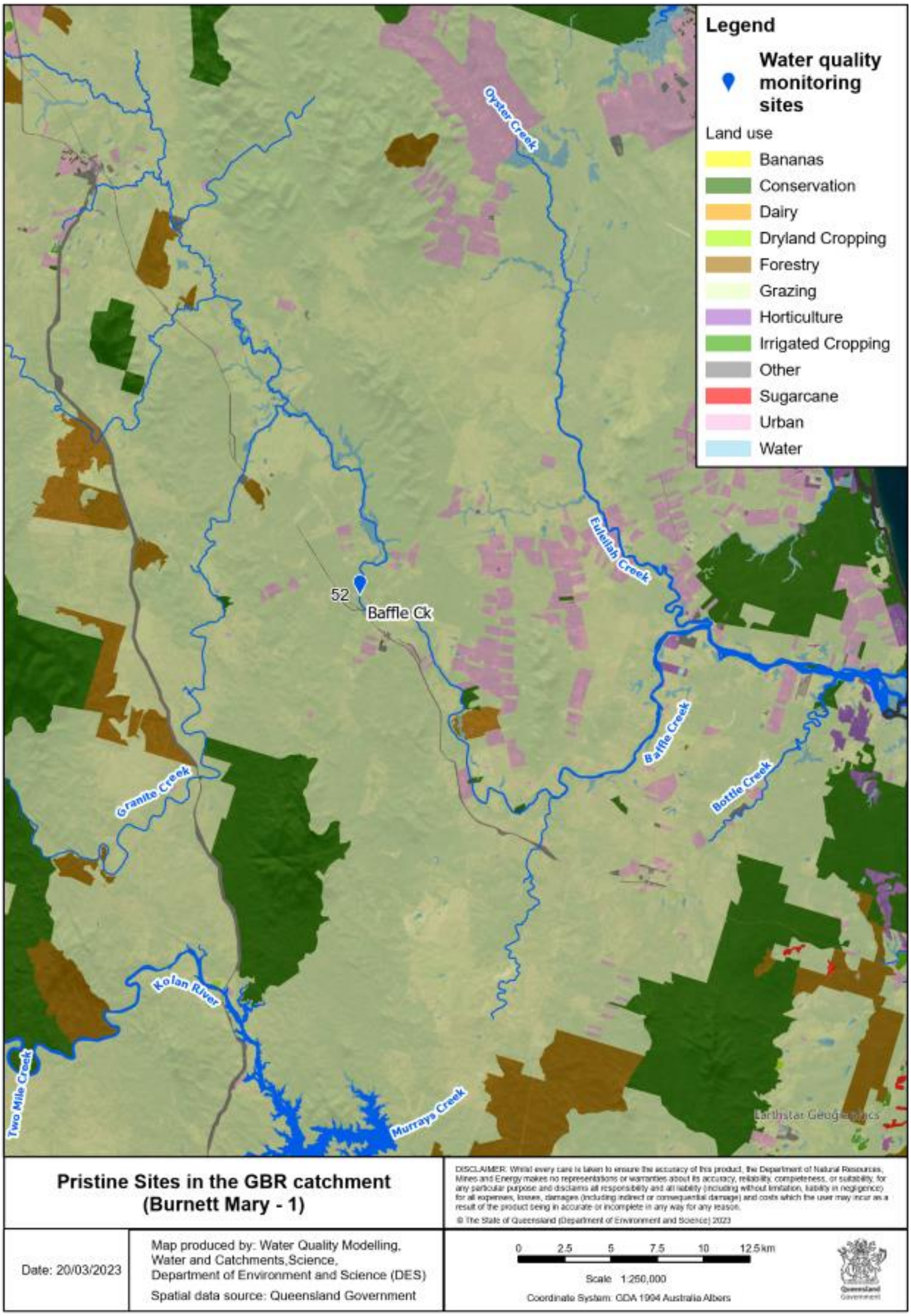


Figure 9. Location and land use of the reference site in the Southeast Queensland bioregion (Baffle basin).

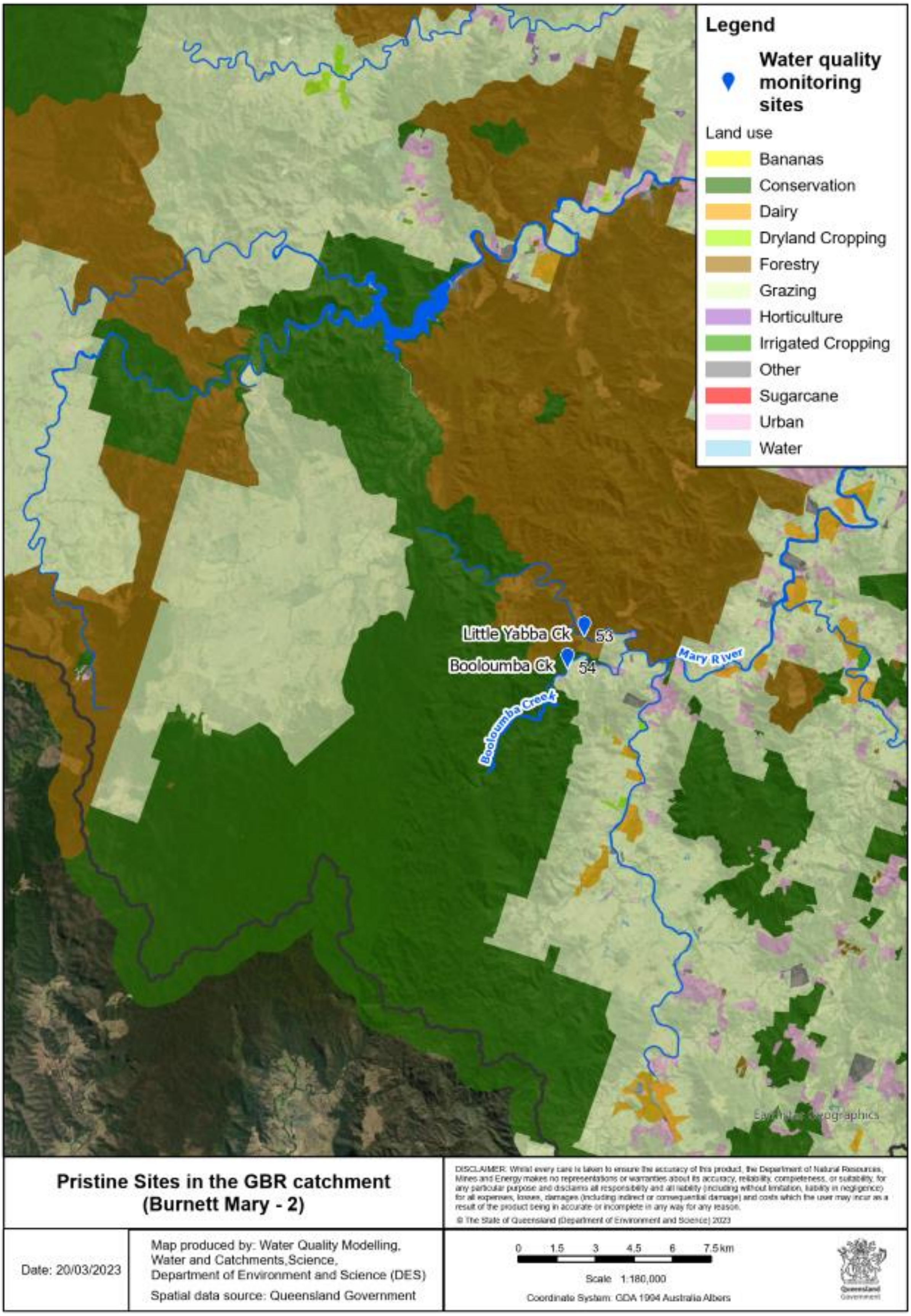


Figure 10. Location and land use of sites in the Southeast Queensland bioregion (Mary basin).

3 RESULTS

3.1 CAPE YORK PENINSULA BIOREGION

The Cape York Peninsula bioregion exclusively covers the Cape York NRM region. The only pristine or near-pristine site identified within the Cape York Peninsula bioregion is the Pascoe River at Wattlehill Station (Figure 2). This site is categorised as Near-pristine.

Based on these data (Figure 11 to Figure 13) we recommend the following DWC and EMC values (in mg/L) for the Cape York Peninsula bioregion in Table 2.

Table 2. Recommended values for the Cape York Peninsula bioregion.

Parameter	Dry weather concentration (mg/L)	Event mean concentration (mg/L)
Suspended sediment	0.5	22
Dissolved inorganic nitrogen	0.005	0.04
Particulate nitrogen	0.015	0.07
Dissolved organic nitrogen	0.07	0.2
Dissolved inorganic phosphorus	0.0005	0.0005
Particulate phosphorus	0.01	0.01
Dissolved organic phosphorus	0.01	0.01

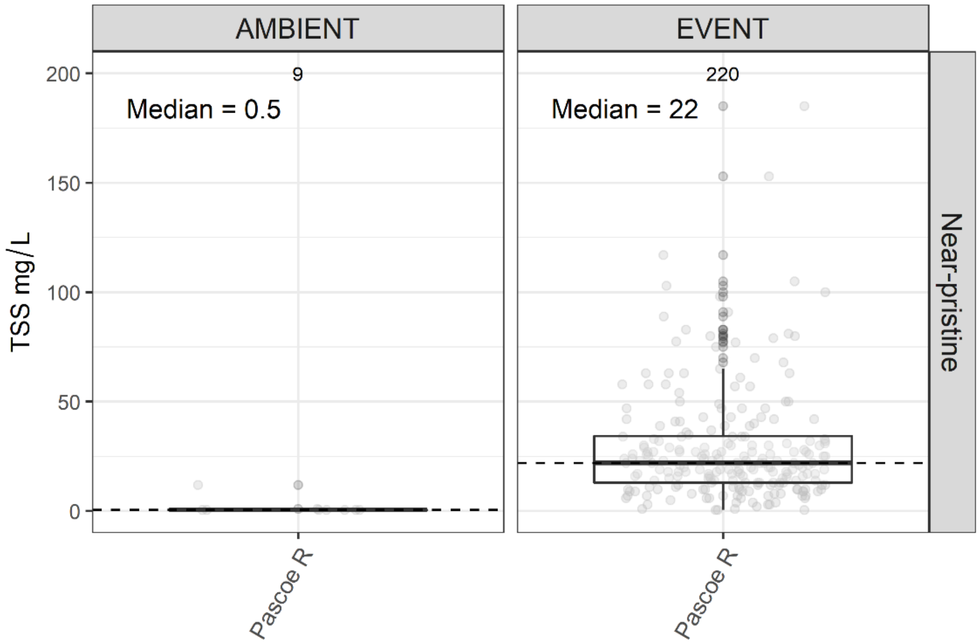


Figure 11. TSS concentrations (mg/L) for the Pascoe River (Near-pristine). Note, the total number of discrete water samples collected per site are displayed at the top of each box and whisker plot, for ambient and event conditions, respectively.

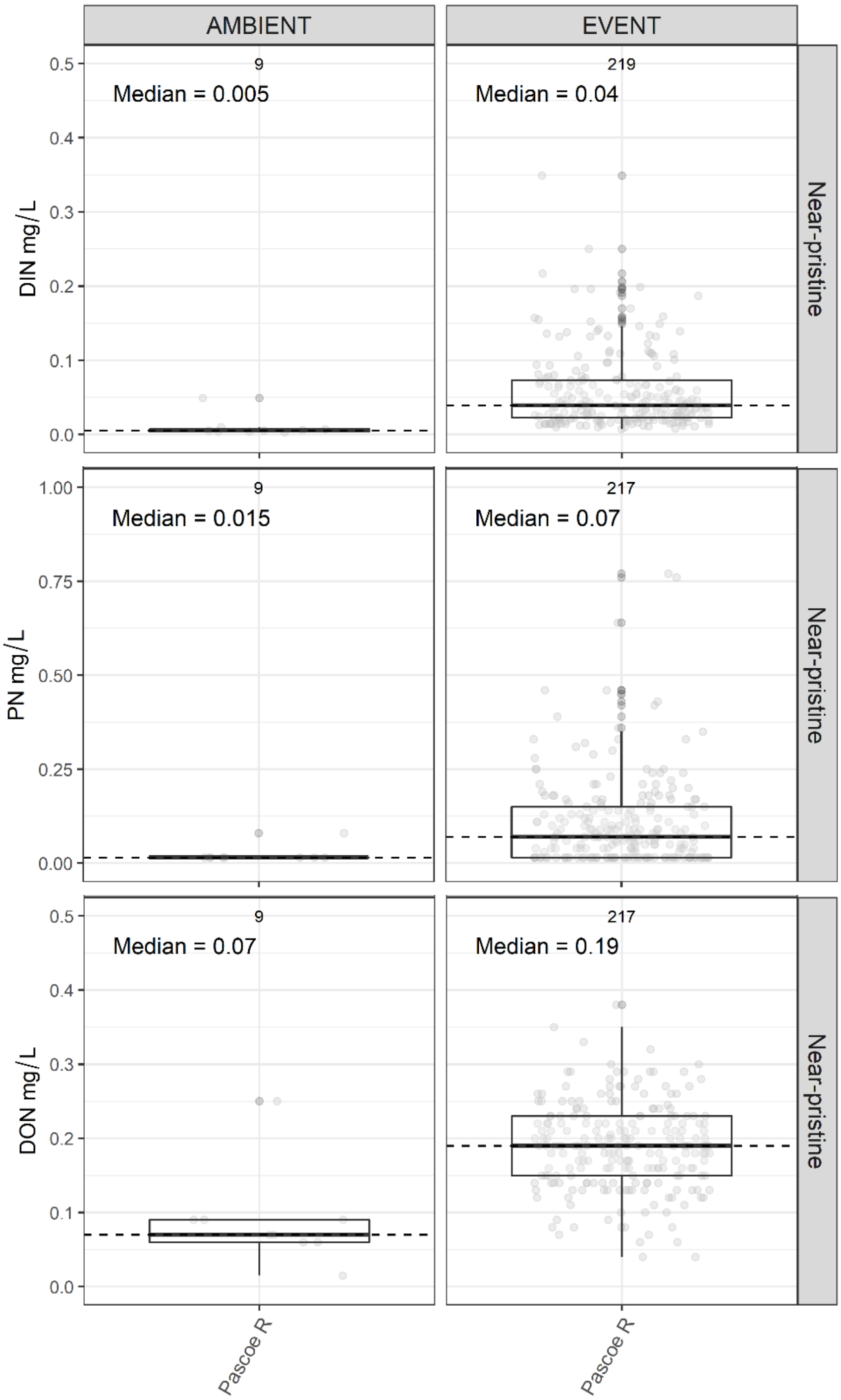


Figure 12. Nitrogen concentrations (mg/L) including dissolved inorganic nitrogen (DIN), particulate nitrogen (PN), and dissolved organic nitrogen (DON) for the Pascoe River (Near-pristine).

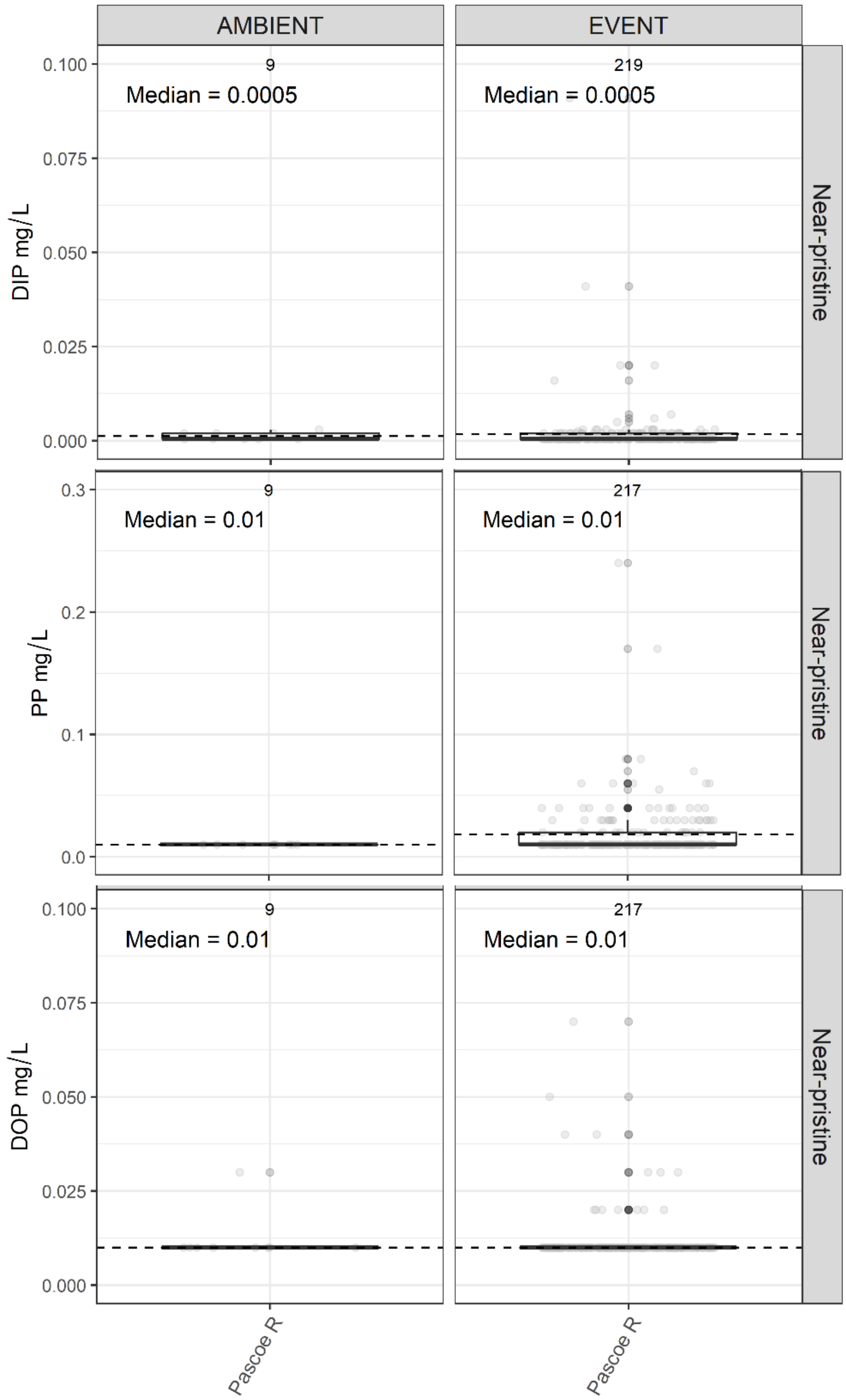


Figure 13. Phosphorus concentrations (mg/L) including dissolved inorganic phosphorus (DIP), particulate phosphorus (PP) and dissolved organic phosphorus (DOP) for the Pascoe River (Near-pristine).

3.2 WET TROPICS BIOREGION

The Wet Tropics bioregion covers large parts of the Wet Tropics NRM region and the northern coastal section of the NQ Dry Tropics NRM region (specifically part of the Black River Basin and coastal section of the Upper Burdekin sub-basin). For this bioregion, we identified 11 Pristine sites, 12 Near-pristine sites, and 8 Minor intensive sites (Table 1 and Figures 3-5).

Using only the Pristine category site data (Figure 14 to Figure 20), we recommend the following DWC and EMC values (in mg/L) for the Wet Tropics bioregion in Table 3.

Table 3. Recommended values for the Wet Tropics bioregion.

Parameter	Dry weather concentration (mg/L)	Event mean concentration (mg/L)
Suspended sediment	1.4	3.3
Dissolved inorganic nitrogen	0.04	0.05
Particulate nitrogen	0.04	0.04
Dissolved organic nitrogen	0.04	0.05
Dissolved inorganic phosphorus	0.005	0.004
Particulate phosphorus	0.02	0.01
Dissolved organic phosphorus	0.006	0.007

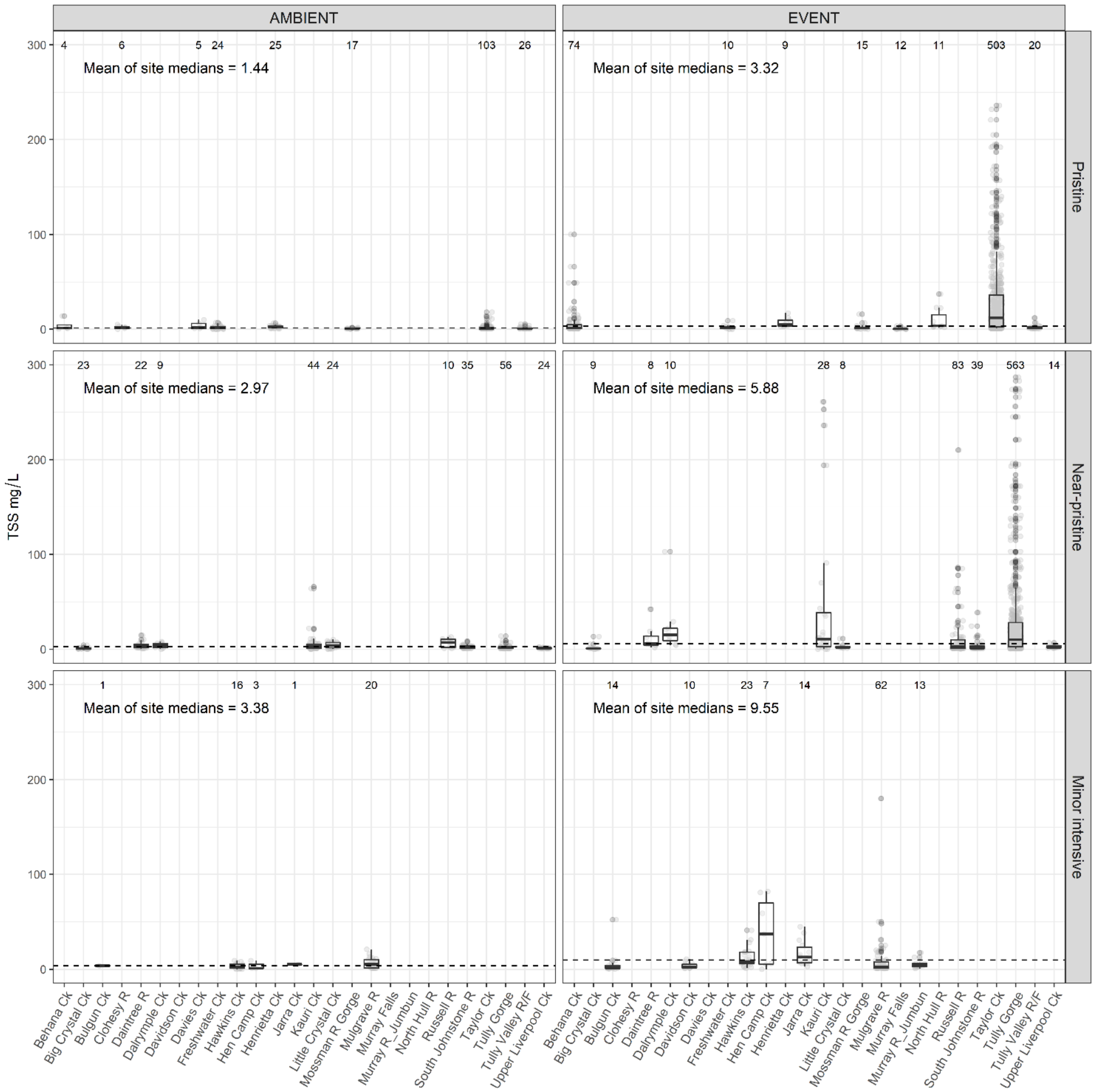


Figure 14. TSS concentrations (mg/L) for Pristine, Near-pristine and Minor intensive categories in the Wet Tropics bioregion.

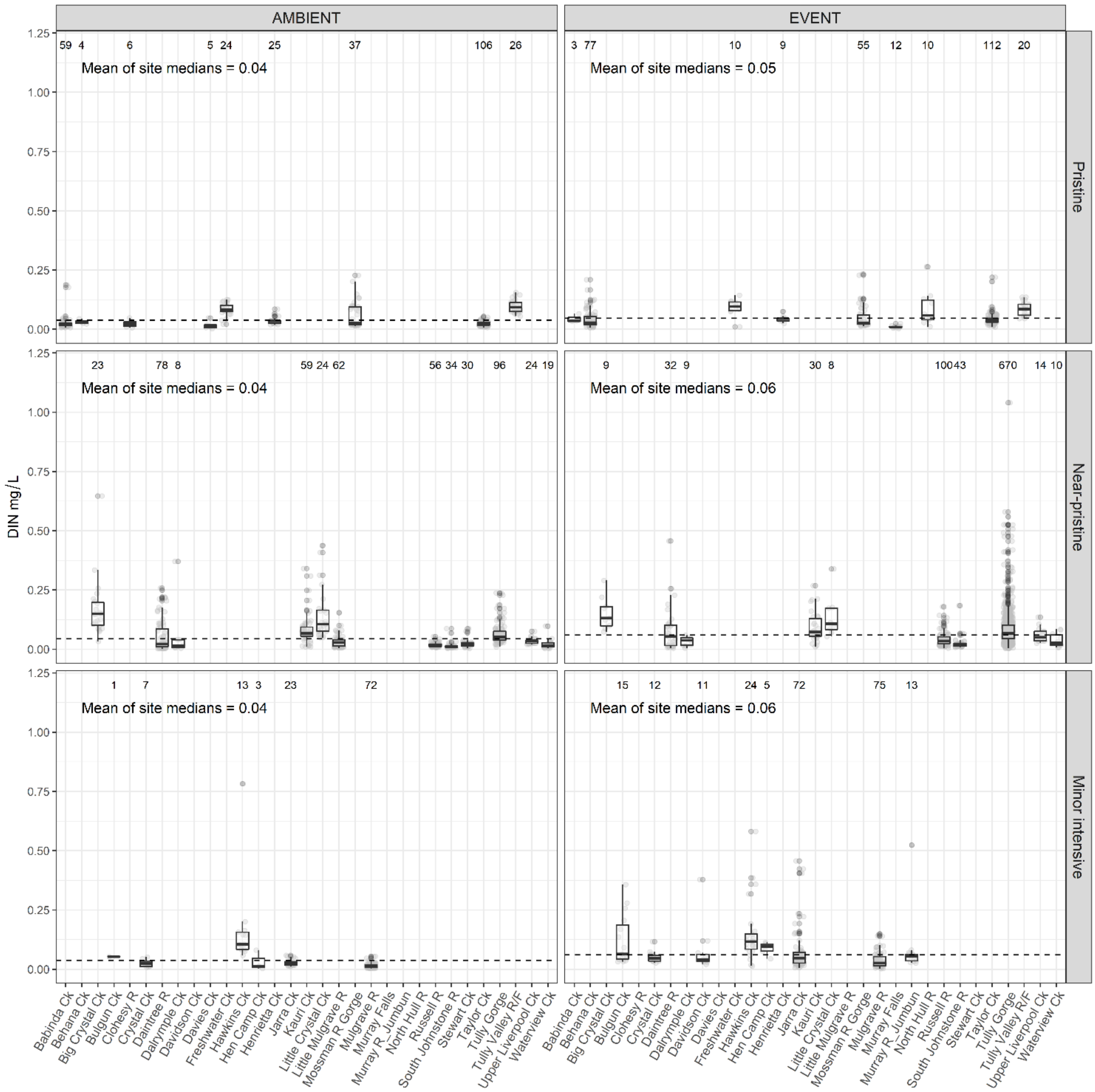


Figure 15. DIN concentrations (mg/L) for Pristine, Near-pristine and Minor intensive categories in the Wet Tropics bioregion.

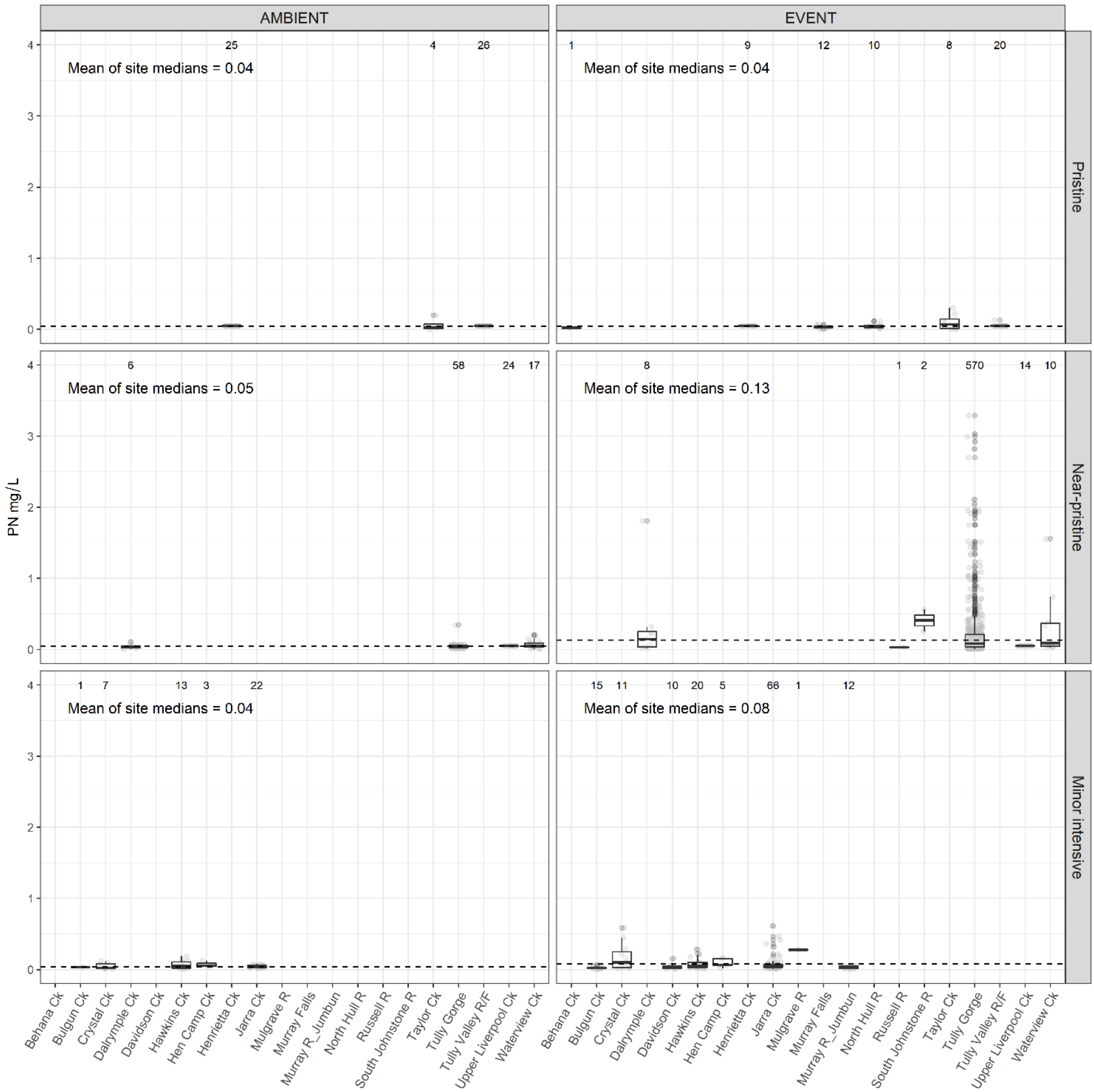


Figure 16. PN concentrations (mg/L) for Pristine, Near-pristine and Minor intensive categories in the Wet Tropics bioregion.

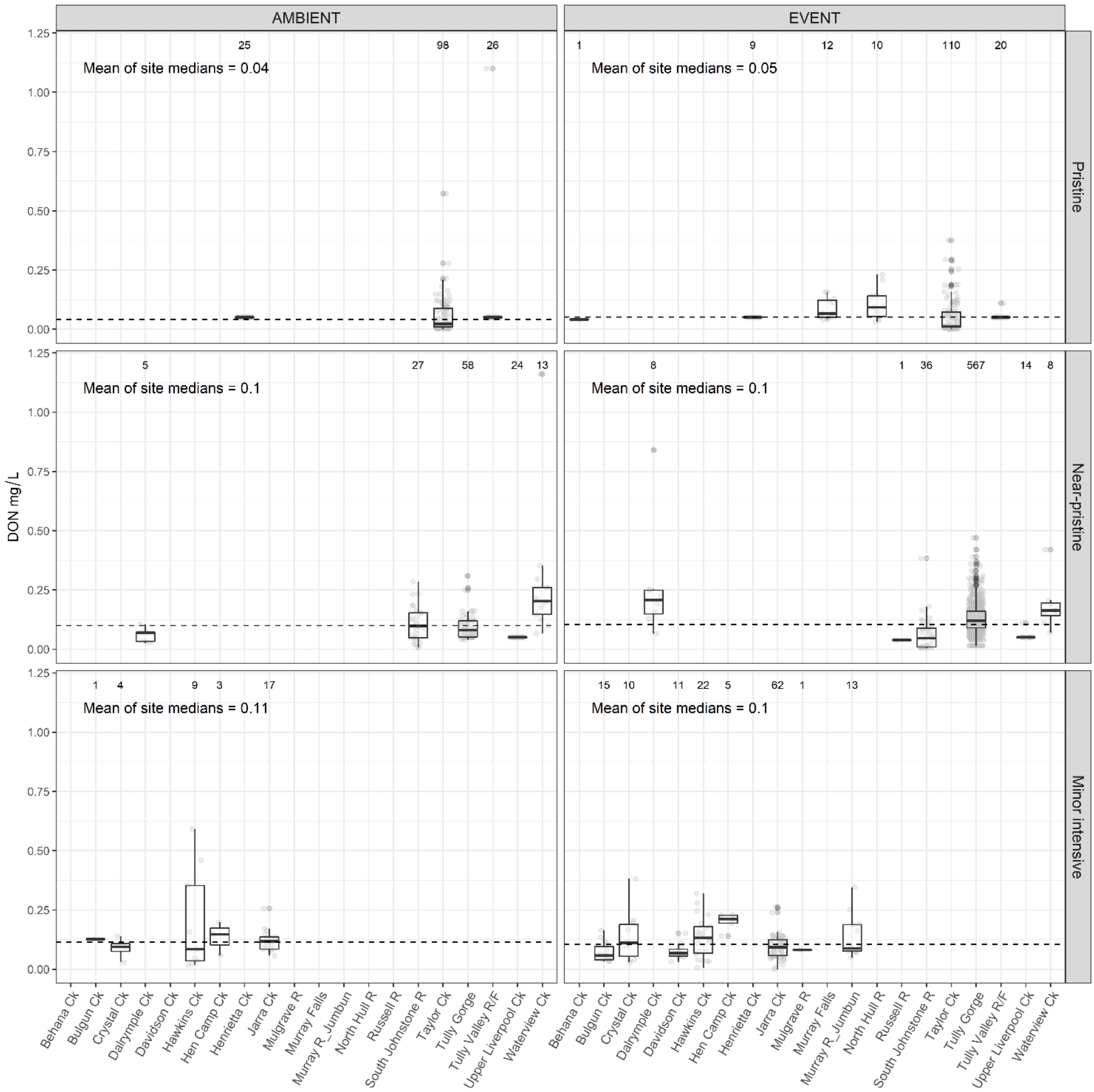


Figure 17. DON concentrations (mg/L) for Pristine, Near-pristine and Minor intensive categories in the Wet Tropics bioregion.

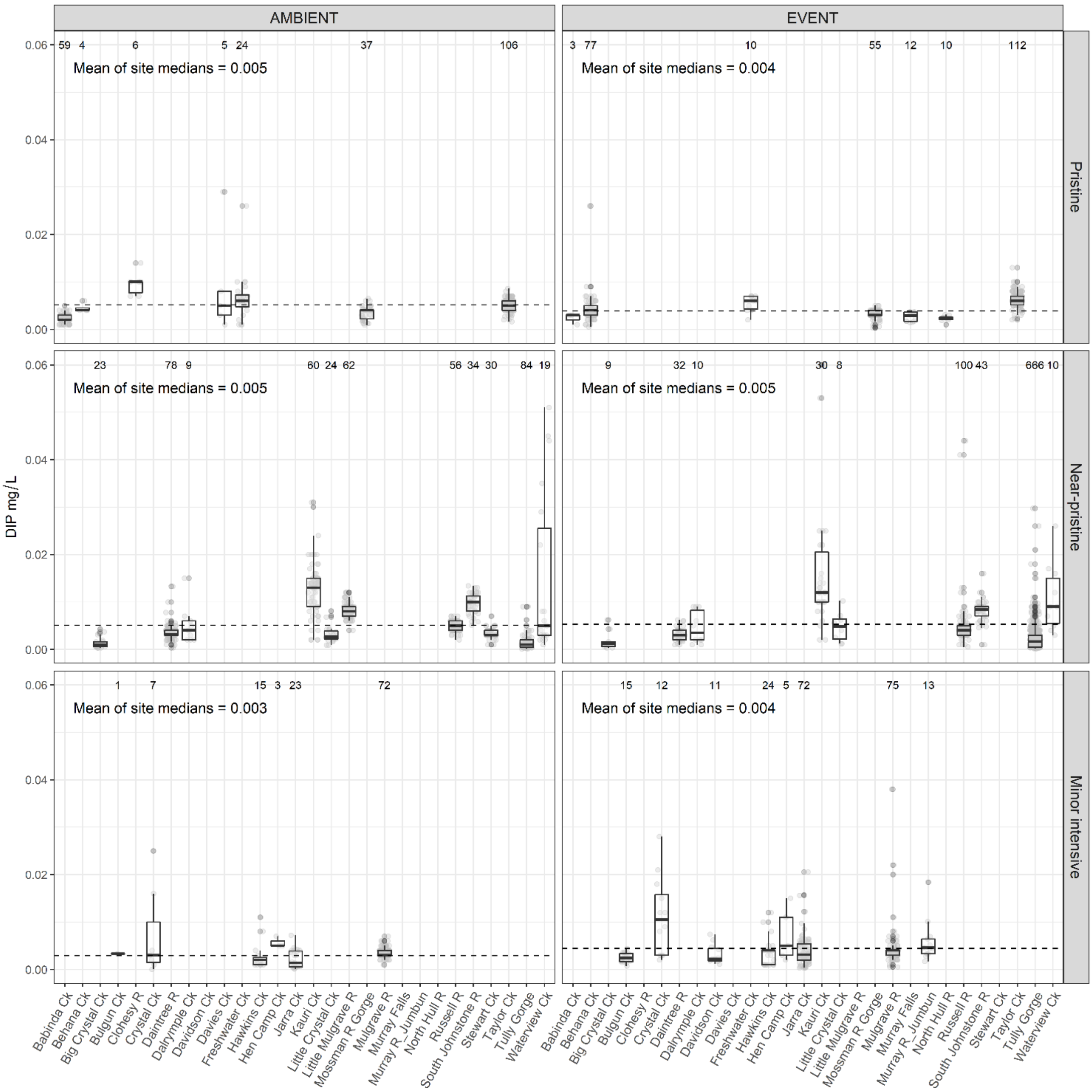


Figure 18. DIP concentrations (mg/L) for Pristine, Near-pristine and Minor intensive categories in the Wet Tropics bioregion.

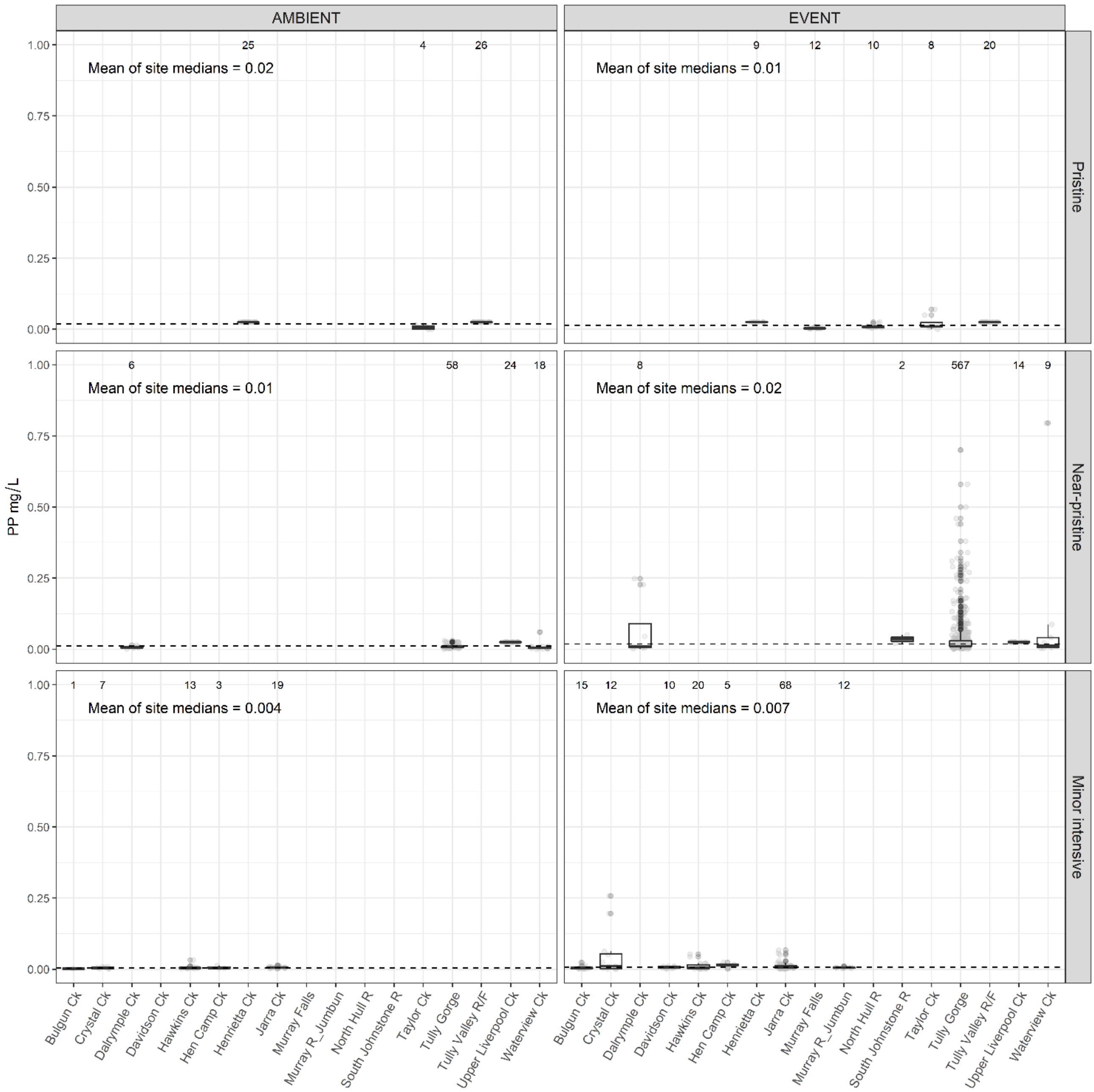


Figure 19. PP concentrations (mg/L) for Pristine, Near-pristine and Minor intensive categories in the Wet Tropics bioregion.

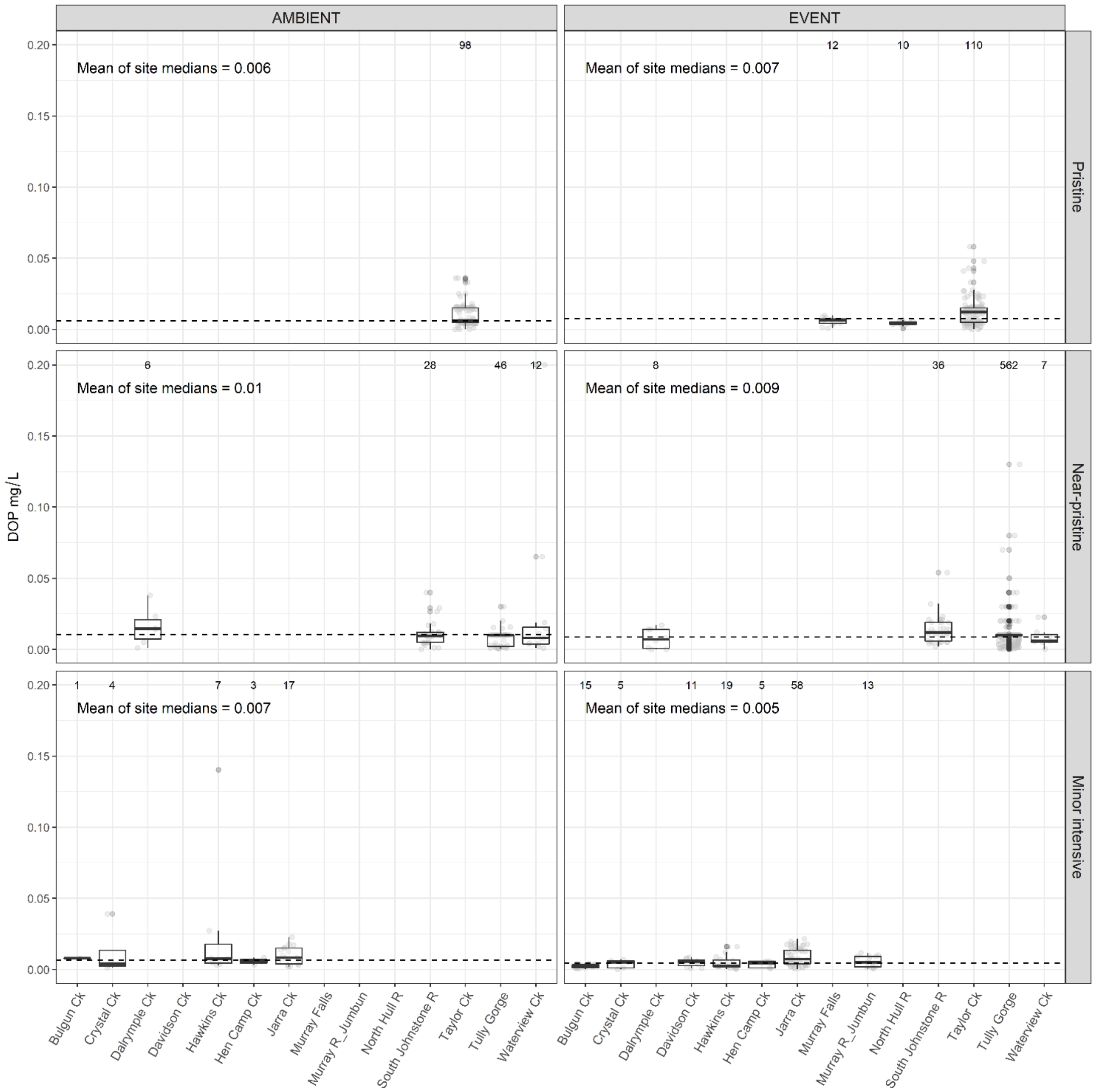


Figure 20. DOP concentrations (mg/L) for Pristine, Near-pristine and Minor intensive categories in the Wet Tropics bioregion.

3.3 EINASLEIGH UPLANDS BIOREGION

The Einasleigh Uplands bioregion covers large parts of the Upper Burdekin sub-basin in the NQ Dry Tropics NRM region and sections of the Daintree and Barron basins within the Wet Tropics NRM region. Four Near-pristine and five Reference sites were identified within the Einasleigh Uplands bioregion (Figure 5).

Based on these data (Figure 21 to Figure 27) we recommend the following DWC and EMC values (in mg/L) for the Einasleigh Uplands bioregion in Table 4, using the Near-pristine sites for DWC and the Reference sites for EMC values. We caution that only Reference sites are available for populating EMC values for this bioregion, and for some basins within this region it may be necessary to default to neighbouring bioregion EMCs. There is also natural variability across this large bioregion, and this is reflected in TSS concentrations (and associated PN/PP) measured at the Reference sites draining the eastern ranges of the Upper Burdekin sub-catchment (Running and Star Rivers) compared to those draining the western ranges (Fletcher and Lolworth Creeks) (Bainbridge et al. 2014).

Table 4. Recommended values for the Einasleigh Uplands bioregion.

Parameter	Dry weather concentration (mg/L)	Event mean concentration (mg/L)
Suspended sediment	5.0	100
Dissolved inorganic nitrogen	0.01	0.08
Particulate nitrogen	0.05	0.24
Dissolved organic nitrogen	0.18	0.30
Dissolved inorganic phosphorus	0.004	0.04
Particulate phosphorus	0.006	0.08
Dissolved organic phosphorus	0.003	0.01

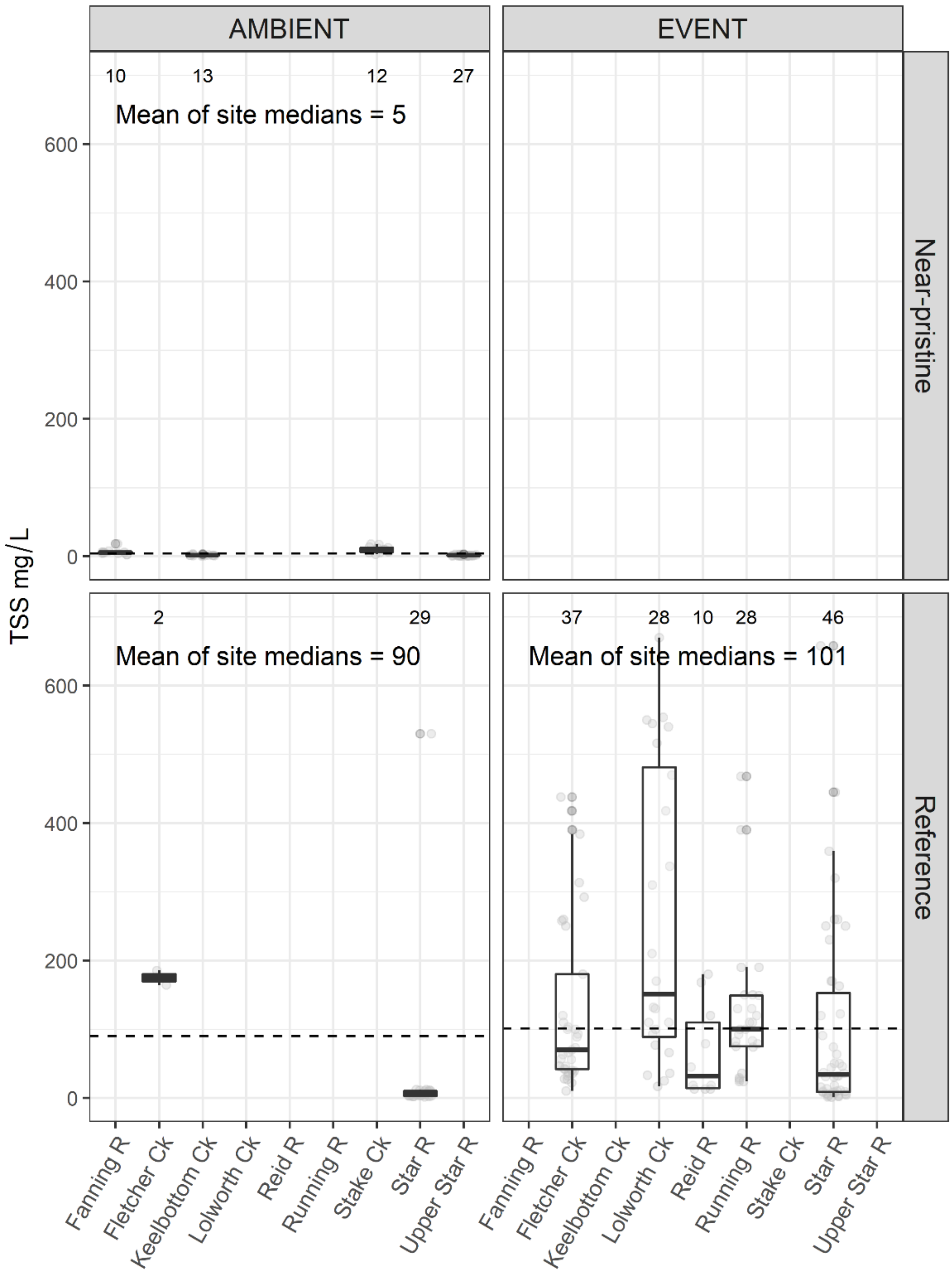


Figure 21. TSS concentrations (mg/L) for Near-pristine and Reference categories in the Einasleigh Uplands bioregion.

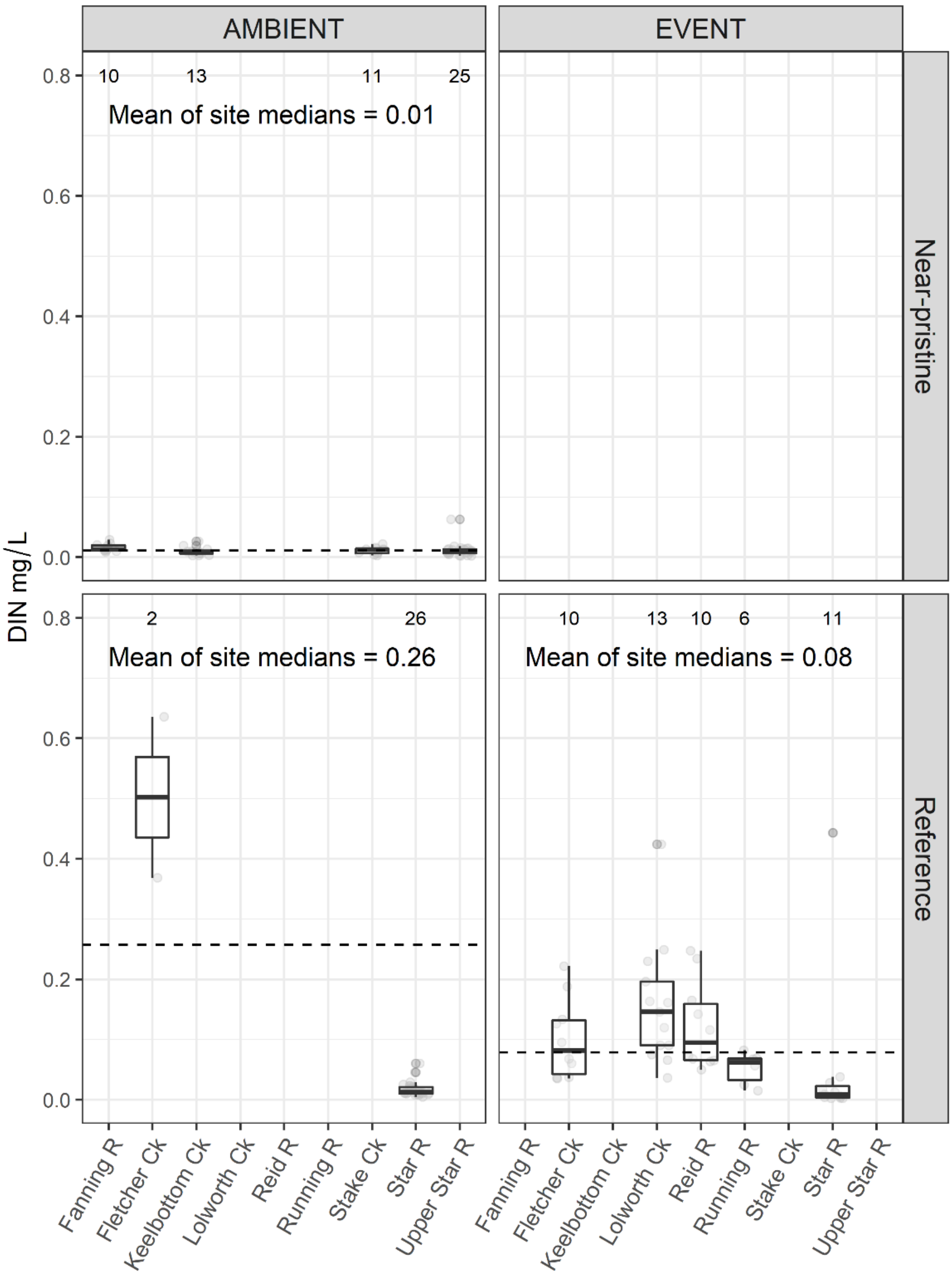


Figure 22. DIN concentrations (mg/L) for Near-pristine and Reference categories in the Einasleigh Uplands bioregion.

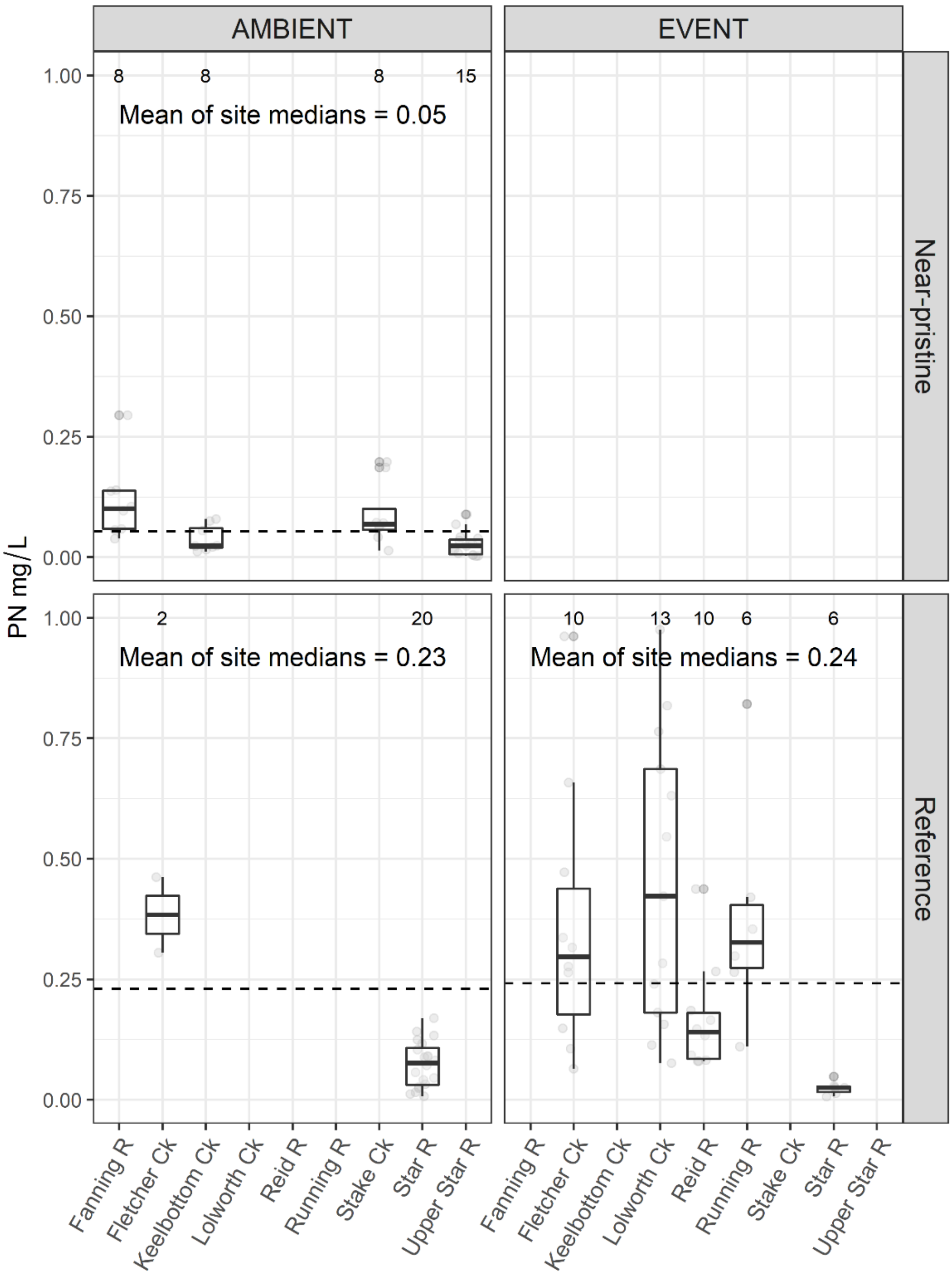


Figure 23. PN concentrations (mg/L) for Near-pristine and Reference categories in the Einasleigh Uplands bioregion.

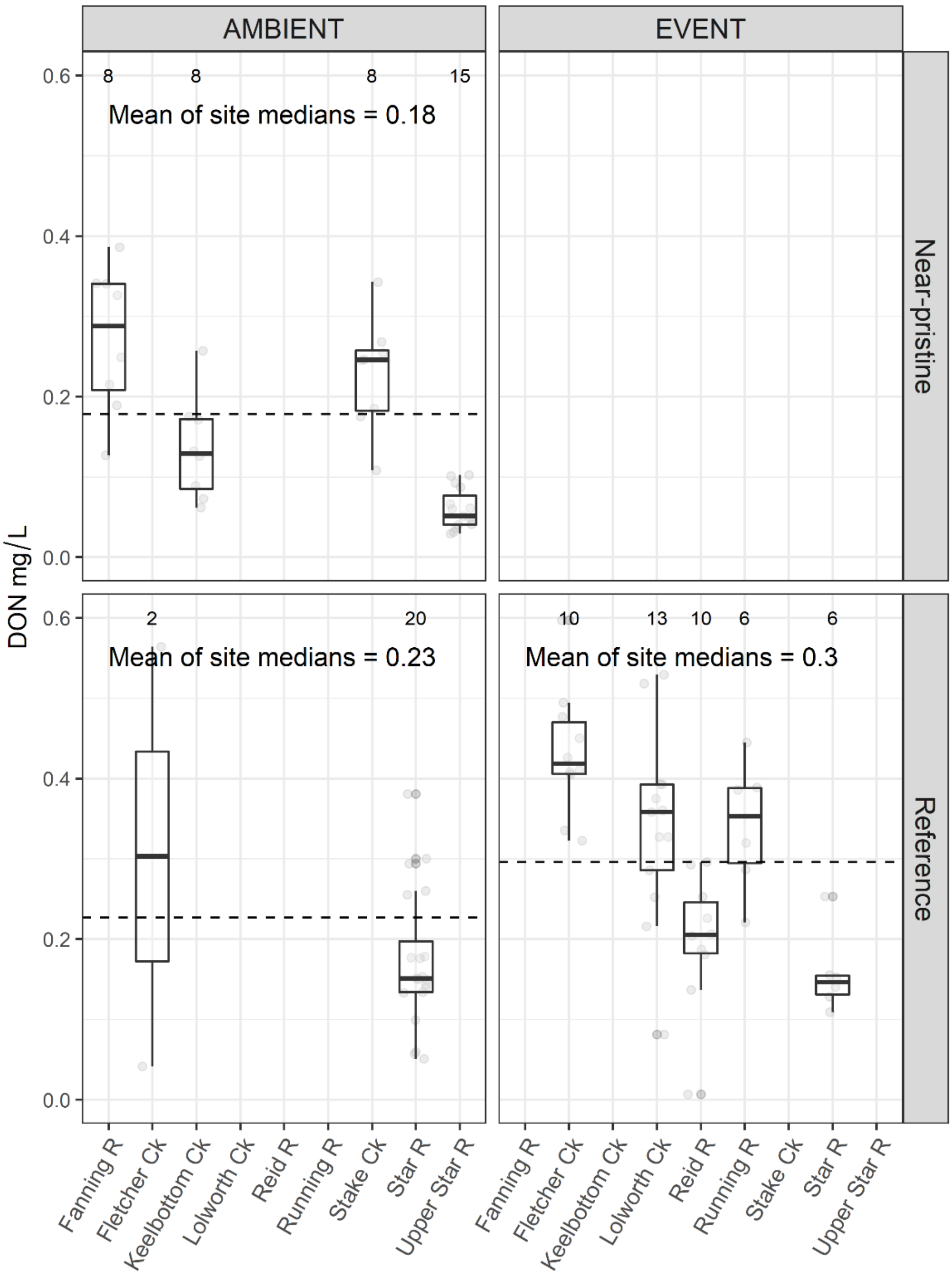


Figure 24. DON concentrations (mg/L) for Near-pristine and Reference categories in the Einasleigh Uplands bioregion.

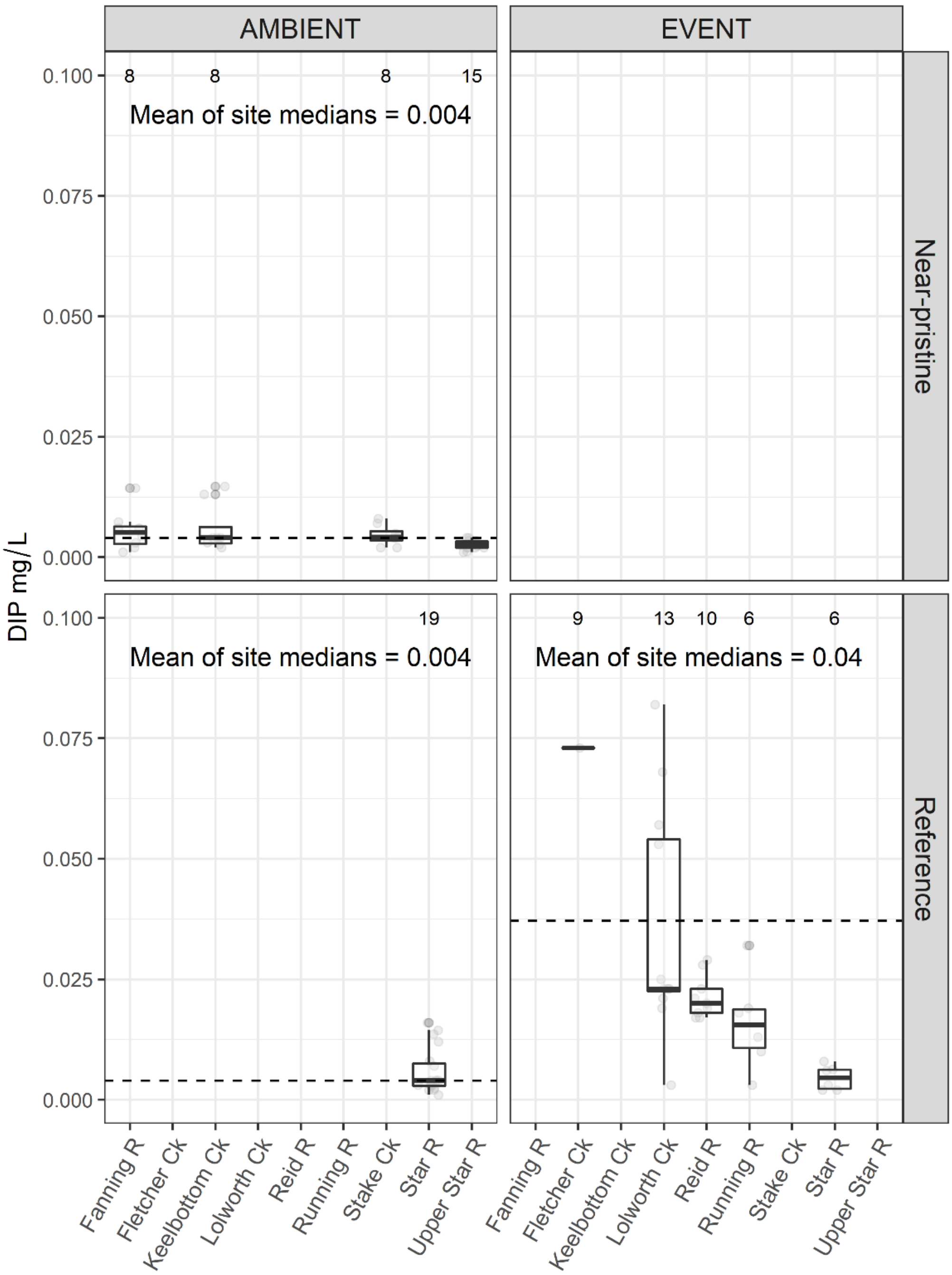


Figure 25. DIP concentrations (mg/L) for Near-pristine and Reference categories in the Einasleigh Uplands bioregion.

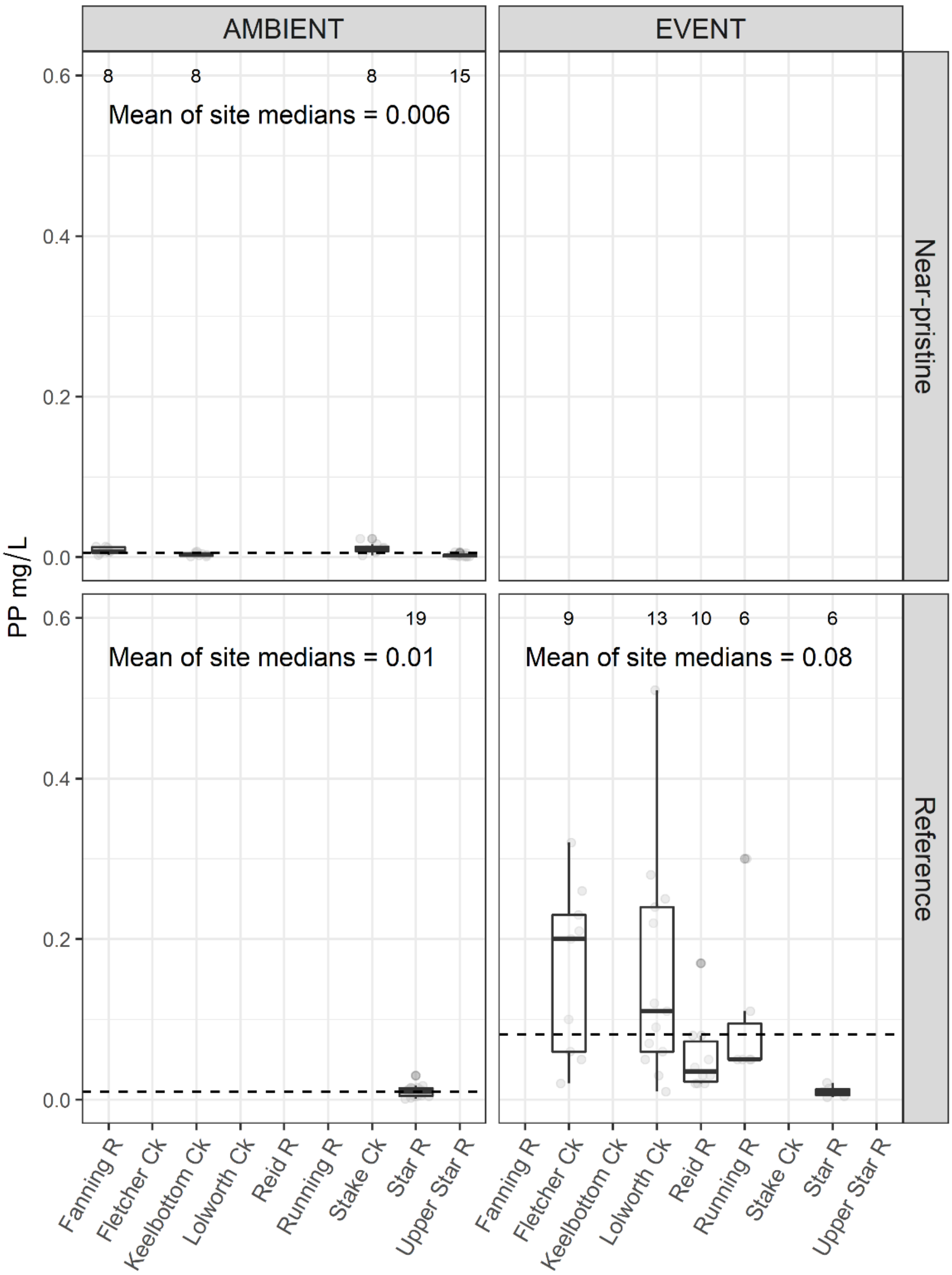


Figure 26. PP concentrations (mg/L) for Near-pristine and Reference categories in the Einasleigh Uplands bioregion.

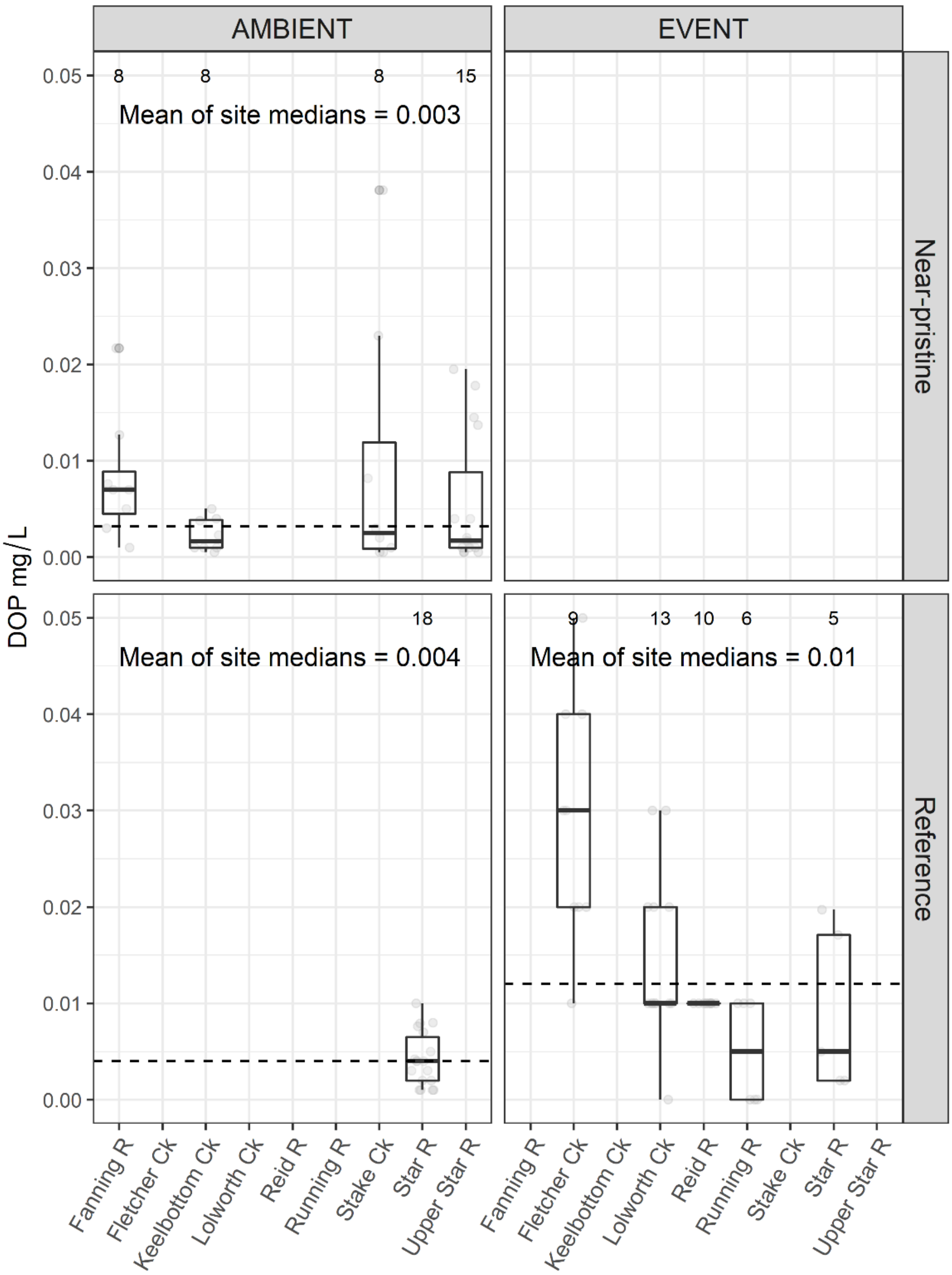


Figure 27. DOP concentrations (mg/L) for Near-pristine and Reference categories in the Einasleigh Uplands bioregion.

3.4 DESERT UPLANDS BIOREGION

The Desert Uplands bioregion covers sections of the Cape and Belyando sub-basins within the NQ Dry Tropics NRM region. The only reference site identified within the Desert Uplands bioregion is the Cape River at Taemas. We note the catchment area is largely grazed and is not pristine, but provides the only reference information for this bioregion (Figure 6).

Based on these data (Figure 28 to Figure 30) we recommend the follow DWC and EMC (in mg/L) for the Desert Uplands bioregion in Table 5. We have a lower level of confidence in these data due to it being based on one, non-Pristine (Reference) site only, and being limited in sample numbers available for the production of a DWC value.

Table 5. Recommended values for the Desert Uplands bioregion.

Parameter	Dry weather concentration (mg/L)	Event mean concentration (mg/L)
Suspended sediment	14	150
Dissolved inorganic nitrogen	0.015	0.019
Particulate nitrogen	0.015	0.40
Dissolved organic nitrogen	0.18	0.33
Dissolved inorganic phosphorus	0.0005	0.007
Particulate phosphorus	0.01	0.10
Dissolved organic phosphorus	0.01	0.01

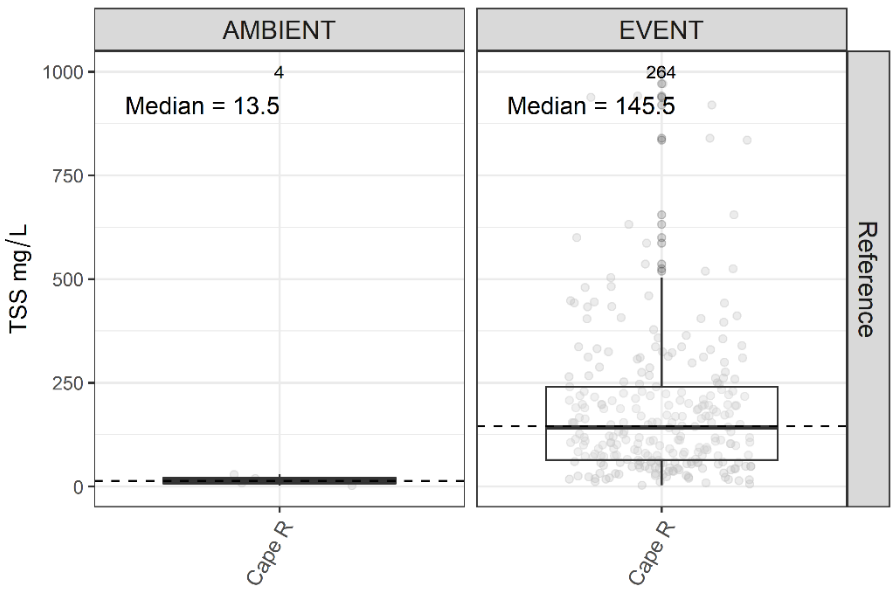


Figure 28. TSS concentrations (mg/L) for the Cape River (Reference) in the Desert Uplands bioregion.

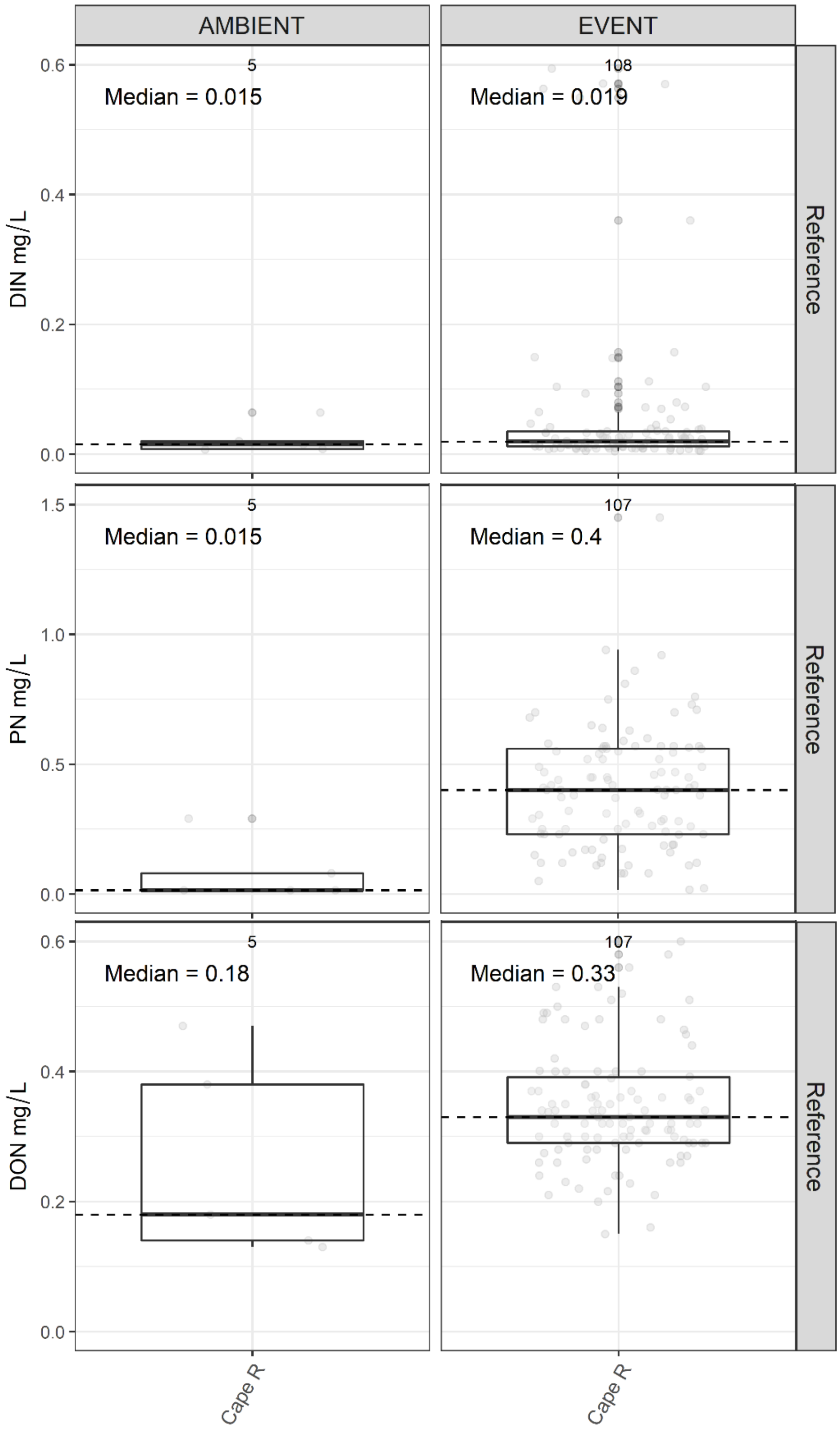


Figure 29. Nitrogen concentrations (mg/L) including dissolved inorganic nitrogen (DIN), particulate nitrogen (PN) and dissolved organic nitrogen (DON) for the Cape River (Reference) in the Desert Uplands bioregion.

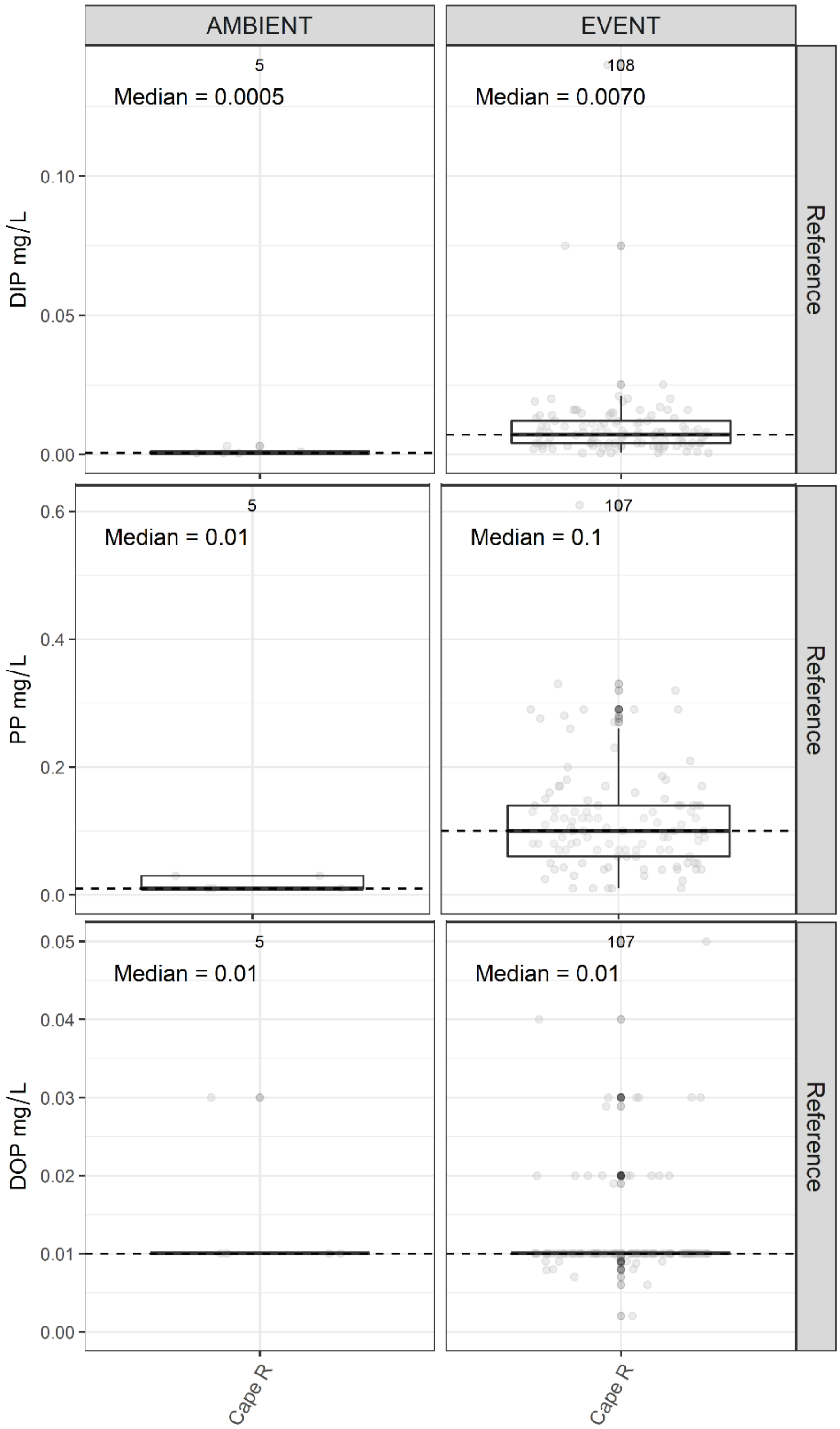


Figure 30. Phosphorus concentrations (mg/L) including dissolved inorganic phosphorus (DIP), particulate phosphorus (PP) and dissolved organic phosphorus (DOP) for the Cape River (Reference) in the Desert Uplands bioregion.

3.5 BRIGALOW BELT BIOREGION

The Brigalow Belt bioregion covers the entire Fitzroy NRM region and large sections of the Burdekin and Burnett Mary NRM regions. The pristine or near-pristine sites identified within the Brigalow Belt bioregion were Alligator Creek, Campus Creek, Broken River (Coastal Brigalow sites) and the Brigalow Forest (part of the Brigalow Catchment Study within the 'inland' Fitzroy catchment). Due to the large variability in the water quality data and the characteristics of these sites (i.e. climate, vegetation) across this bioregion, we have separated out Brigalow Belt (Coastal) sites (Figure 5) from the broader bioregion (Figure 8).

Based on these data (Figure 31 to Figure 36) we recommend the following EMC values (in mg/L) for the Brigalow Belt bioregion in Table 6. Note there were no available data to populate DWC values and so we suggest to apply the values from the Einasleigh Uplands bioregion as these data likely provide the closest indication.

Table 6. Recommended values for the Brigalow Belt bioregion. Values separated to show the coastal Brigalow sites and in brackets the inland Brigalow site. DWC values are populated from the Einasleigh Uplands bioregion.

Parameter	Dry weather concentration (mg/L)	Event mean concentration (mg/L)
Suspended sediment	5.0	6.3 (250)
Dissolved inorganic nitrogen	0.01	0.05 (4.3)
Particulate nitrogen	0.05	0.08 (3.6)
Dissolved organic nitrogen	0.18	0.2 (2.1)
Dissolved inorganic phosphorus	0.004	0.04 (0.1)
Particulate phosphorus	0.006	0.02 (0.4)
Dissolved organic phosphorus	0.003	0.008 (0.02)

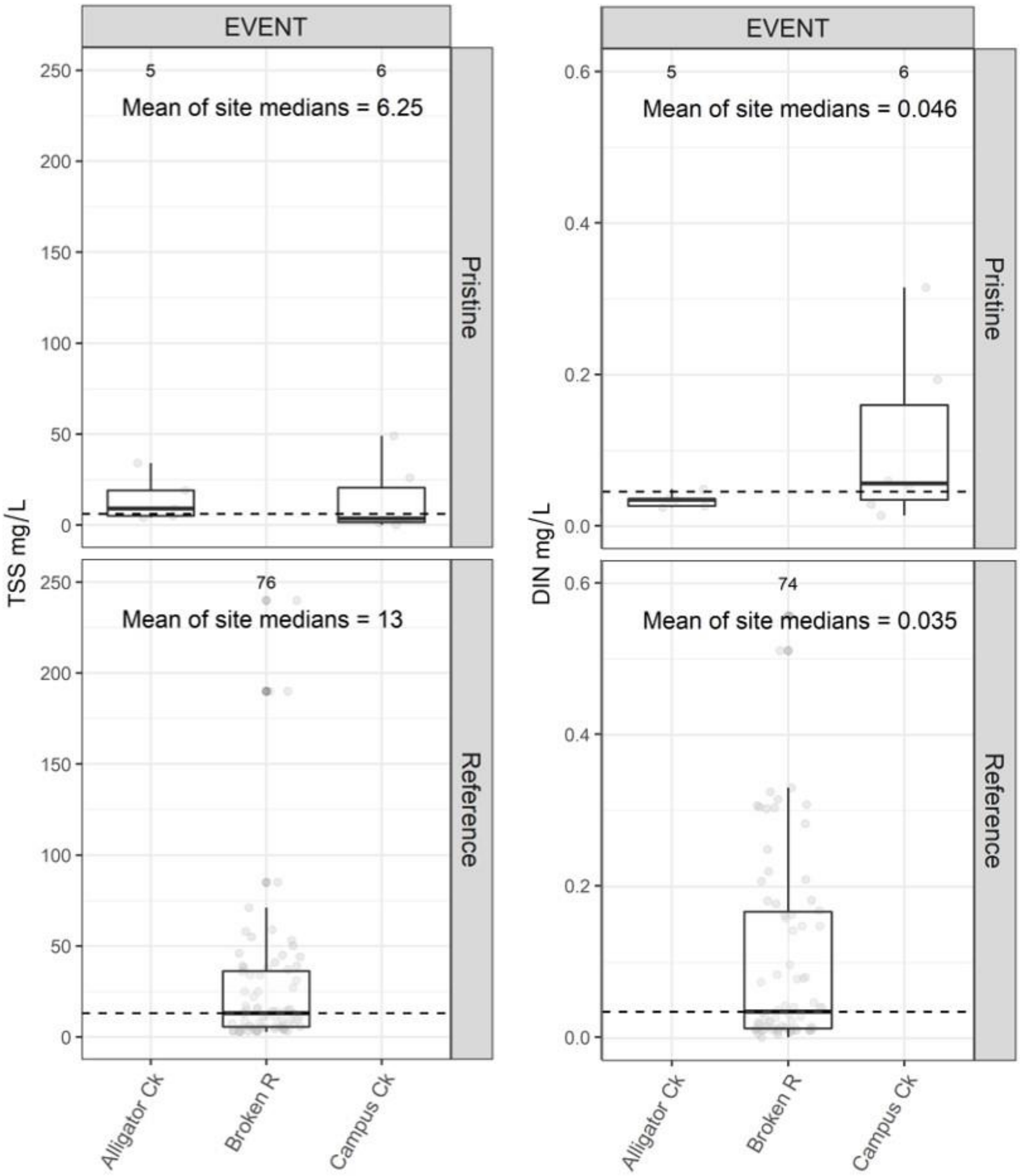


Figure 31. TSS and DIN concentrations (mg/L) for Pristine and Reference categories in the Brigalow Belt (Coastal) bioregion.

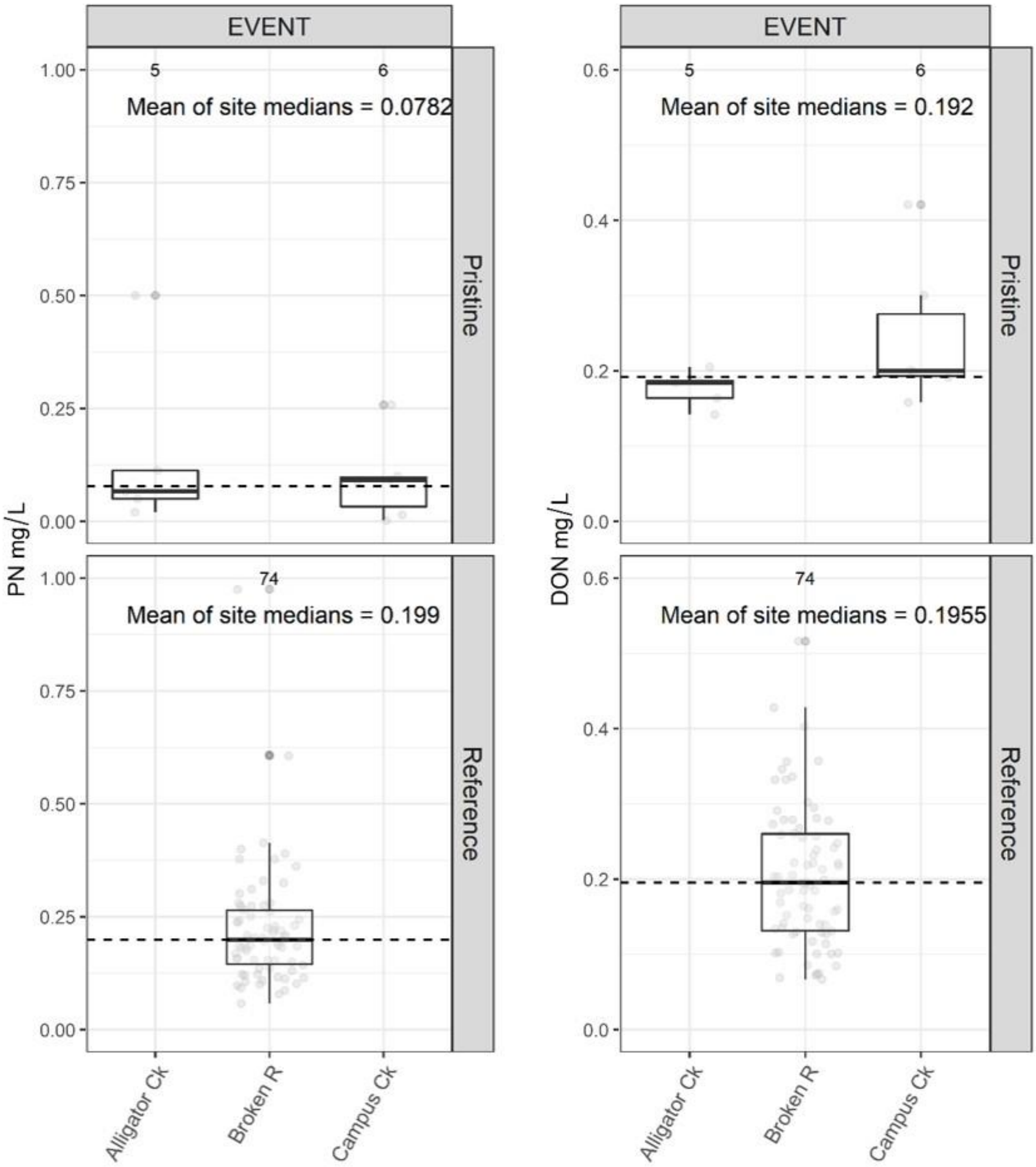


Figure 32. PN and DON concentrations (mg/L) for Pristine and Reference categories in the Brigalow Belt (Coastal) bioregion.

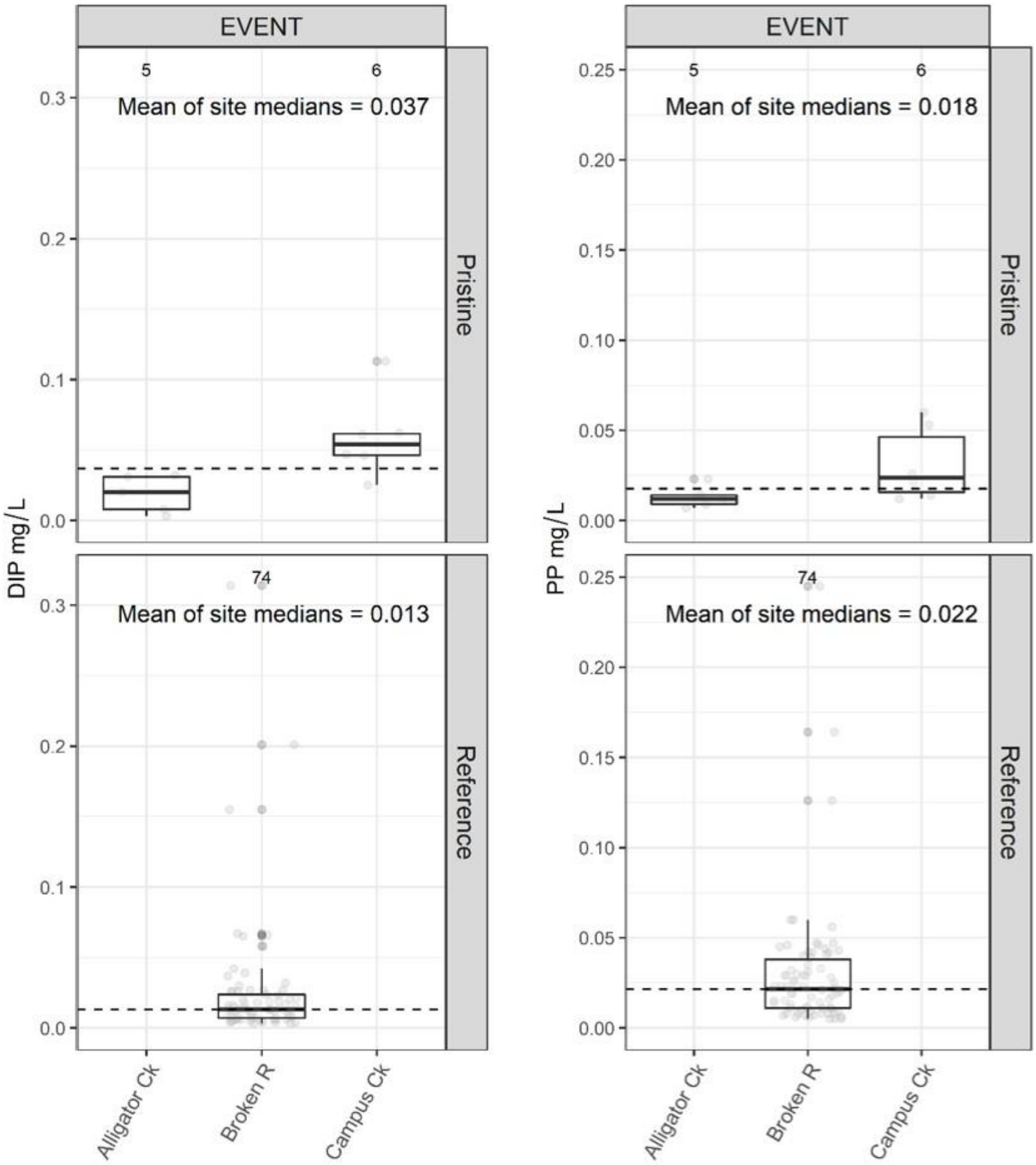


Figure 33. DIP and PP concentrations (mg/L) for Pristine and Reference categories in the Brigalow Belt (Coastal) bioregion.

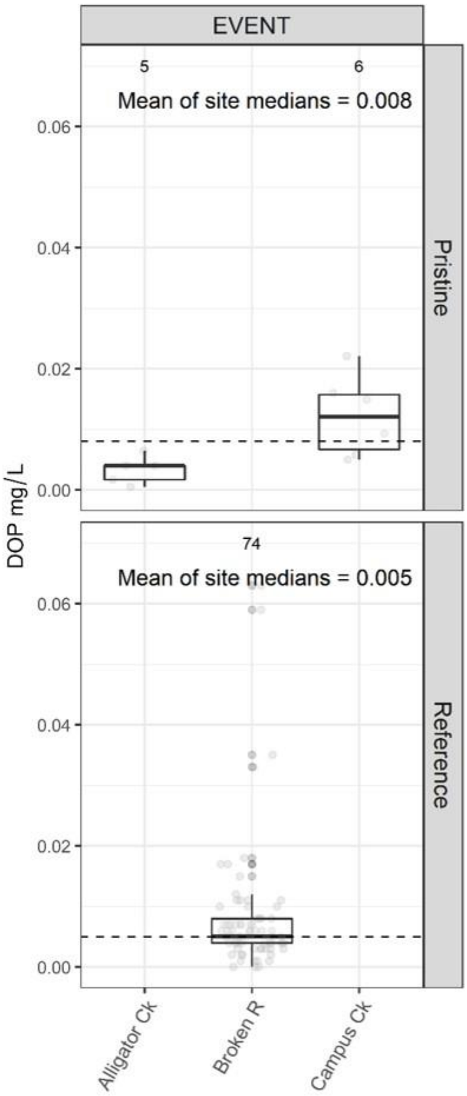


Figure 34. DOP concentrations (mg/L) for Pristine and Reference categories in the Brigalow Belt (Coastal) bioregion.

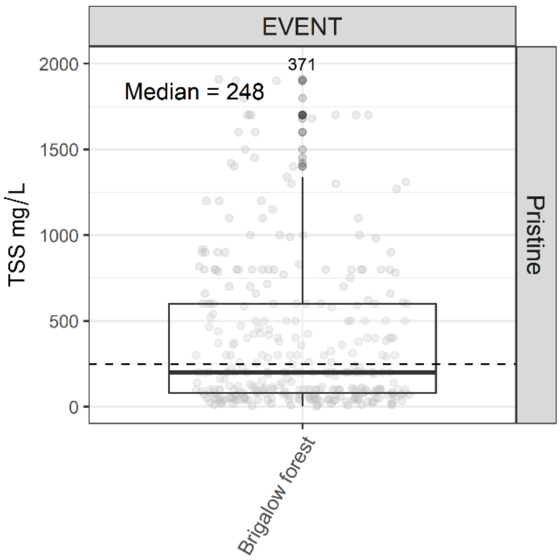


Figure 35. TSS concentrations (mg/L) for the Brigalow forest (Pristine) in the Brigalow Belt bioregion.

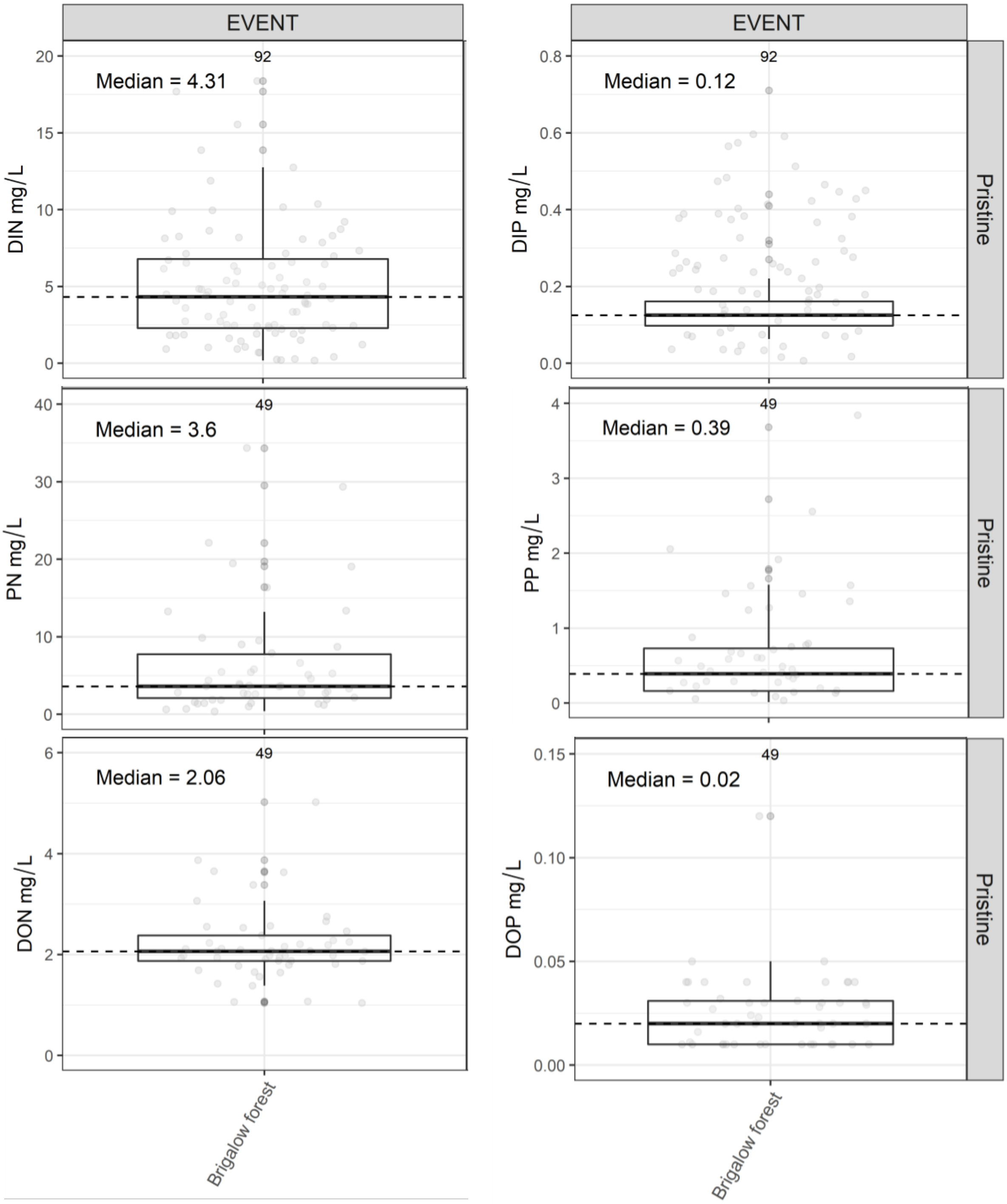


Figure 36. DIN, DIP, PN, PP, DON and DOP concentrations (mg/L) for the Brigalow forest (Pristine) in the Brigalow Belt bioregion.

3.6 CENTRAL QUEENSLAND COAST BIOREGION

The Central Queensland Coast bioregion exclusively covers the Mackay Whitsunday NRM region. The Pristine, Near-pristine and Minor intensive sites identified within the Central Queensland Coast bioregion included Impulse Creek (Pristine), St Helens Creek (Near-pristine), Finch Hatton Ck (Minor intensive) and its upper tributary Rawson's Creek (Pristine) (Figure 7).

Based on these data (Figure 37 to Figure 43) we recommend the following DWC and EMC values (in mg/L) for the Central Queensland Coast bioregion in Table 7.

Table 7. Recommended values for the Central Queensland Coast bioregion.

Parameter	Dry weather concentration (mg/L)	Event mean concentration (mg/L)
Suspended sediment	1.0	2.3
Dissolved inorganic nitrogen	0.05	0.08
Particulate nitrogen	0.03	0.06
Dissolved organic nitrogen	0.07	0.11
Dissolved inorganic phosphorus	0.006	0.01
Particulate phosphorus	0.003	0.01
Dissolved organic phosphorus	0.007	0.007

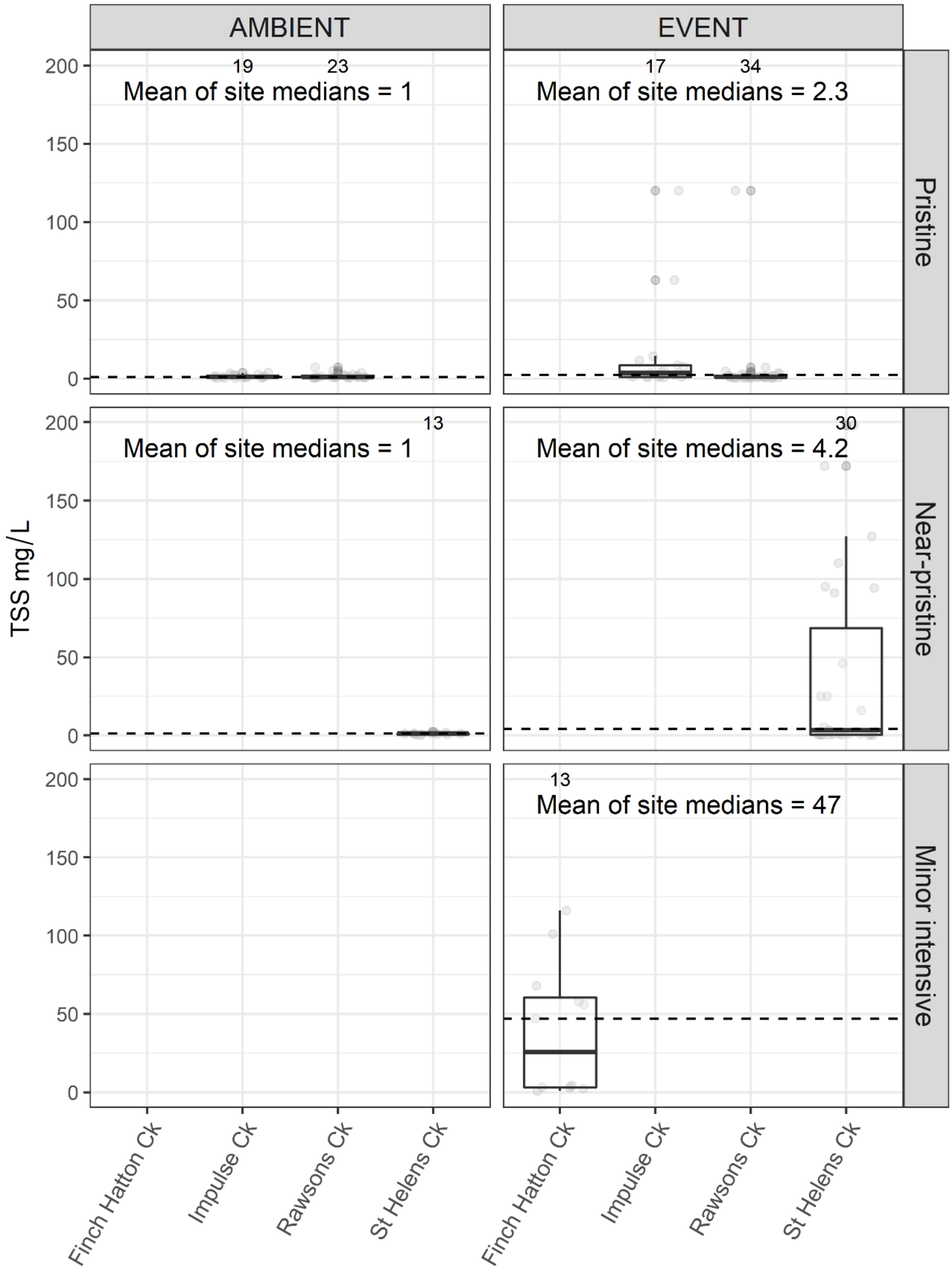


Figure 37. TSS concentrations (mg/L) for Pristine, Near-pristine and Minor intensive categories in the Central Queensland Coast bioregion.

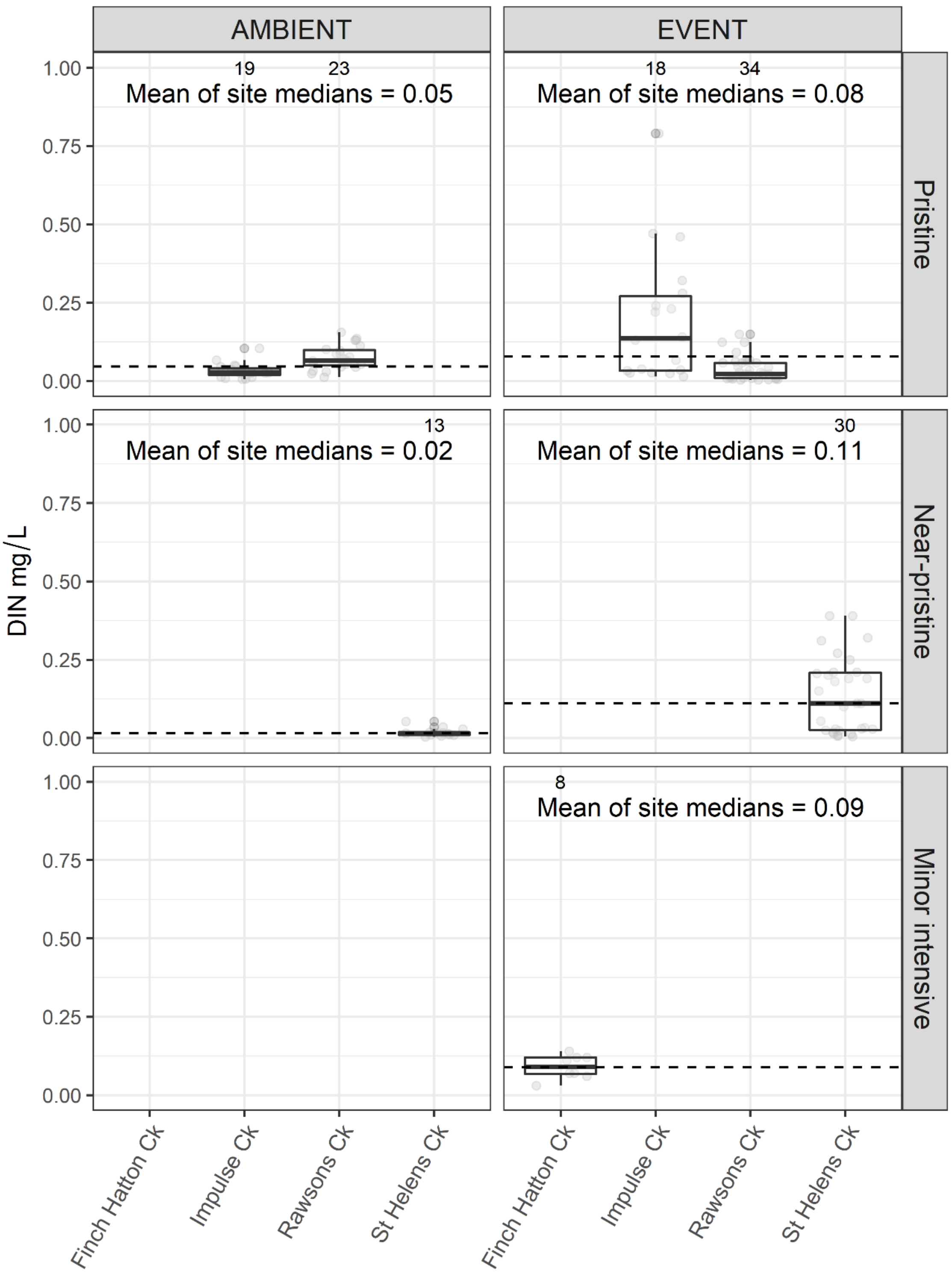


Figure 38. DIN concentrations (mg/L) for Pristine, Near-pristine and Minor intensive categories in the Central Queensland Coast bioregion.

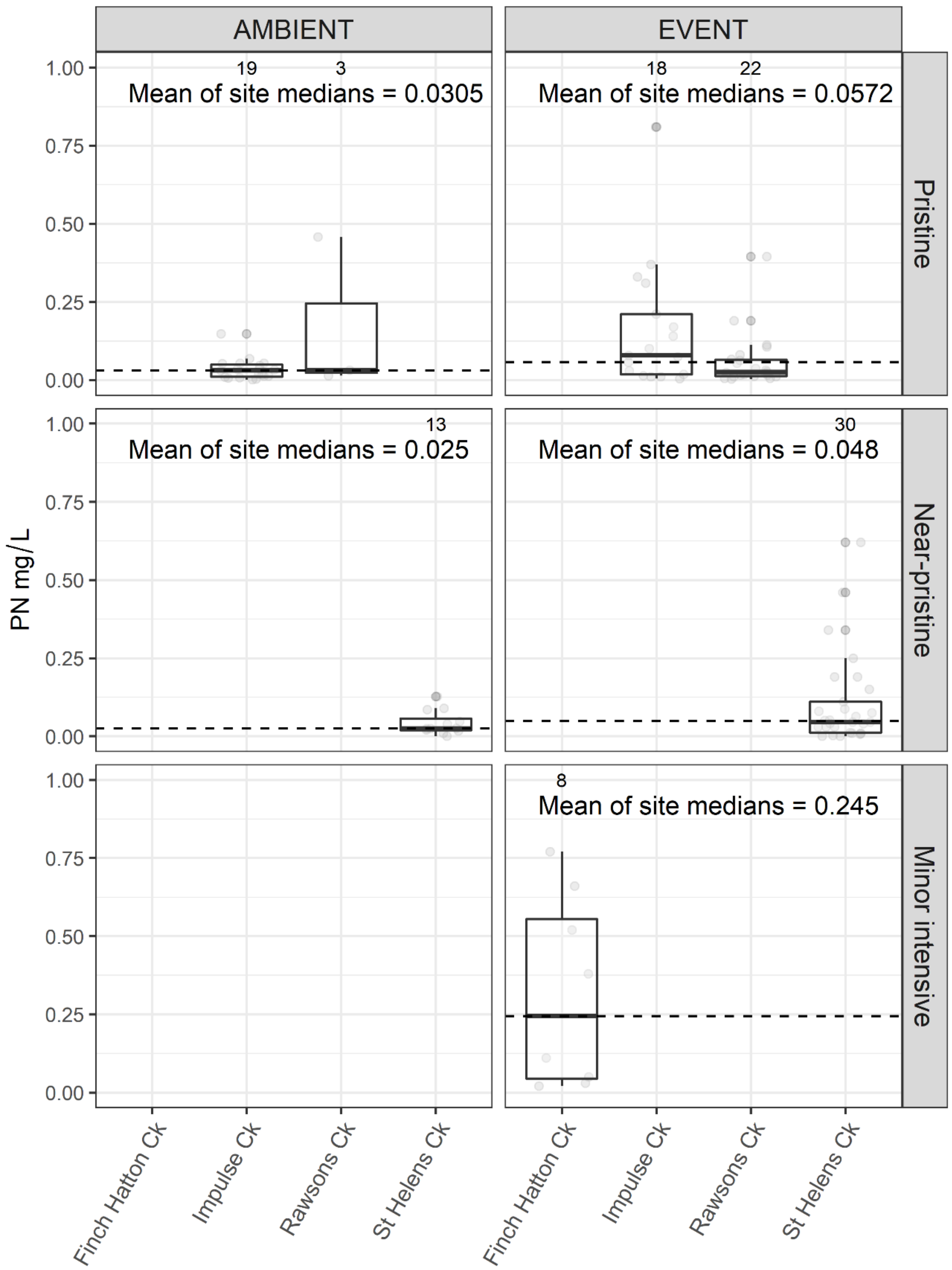


Figure 39. PN concentrations (mg/L) for Pristine, Near-pristine and Minor intensive categories in the Central Queensland Coast bioregion.

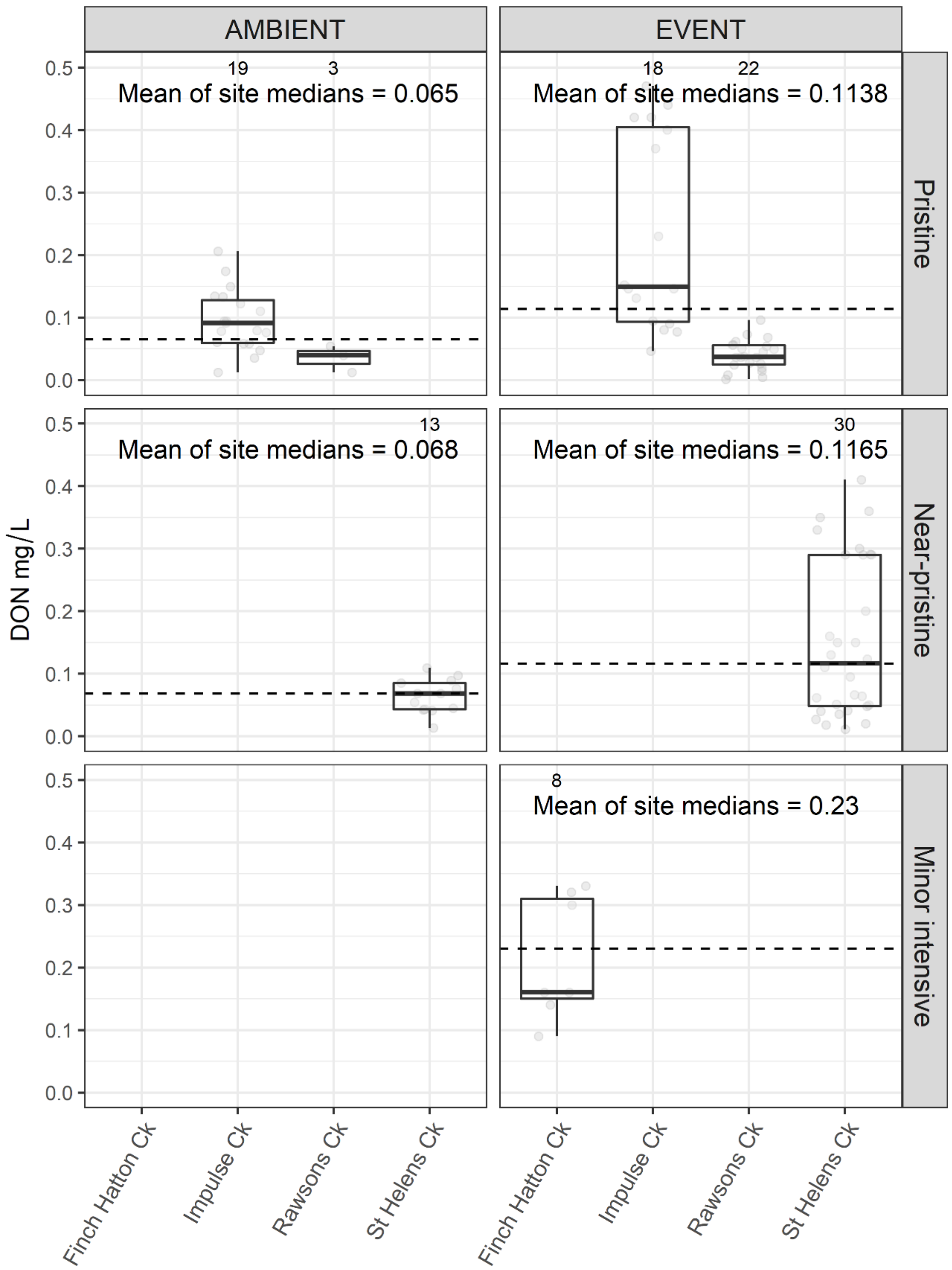


Figure 40. DON concentrations (mg/L) for Pristine, Near-pristine and Minor intensive categories in the Central Queensland Coast bioregion.

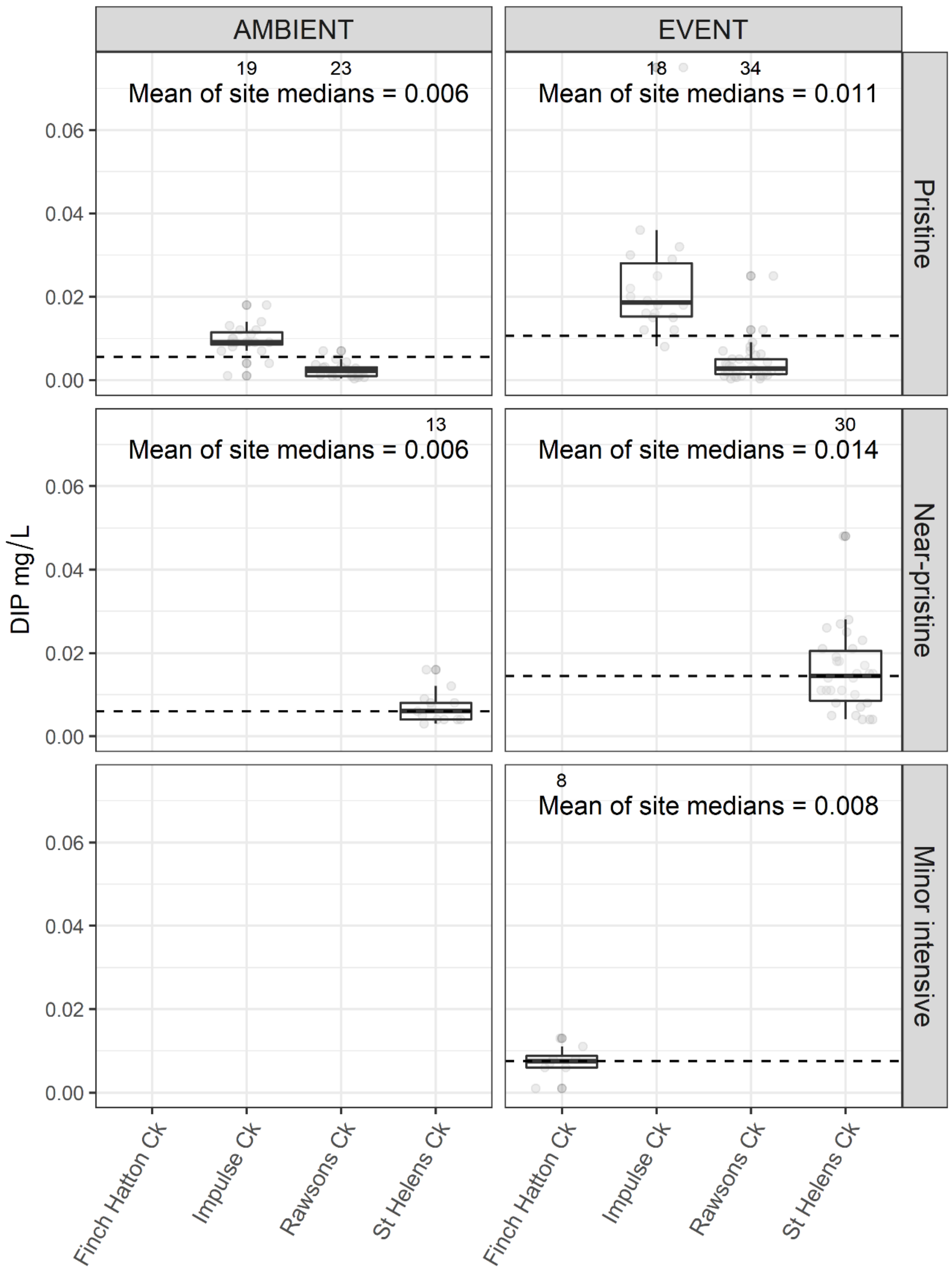


Figure 41. DIP concentrations (mg/L) for Pristine, Near-pristine and Minor intensive categories in the Central Queensland Coast bioregion.

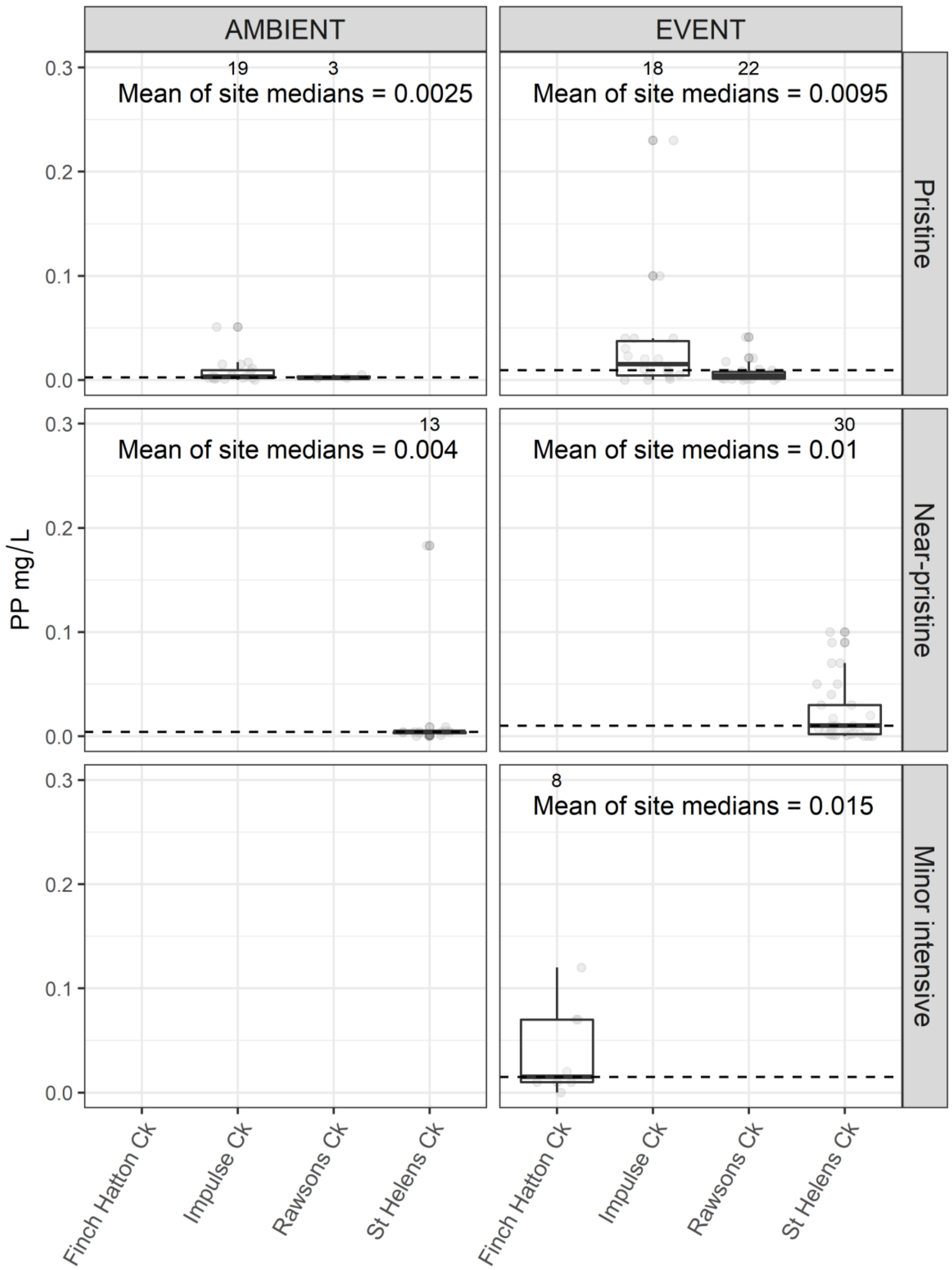


Figure 42. PP concentrations (mg/L) for Pristine, Near-pristine and Minor intensive categories in the Central Queensland Coast bioregion.

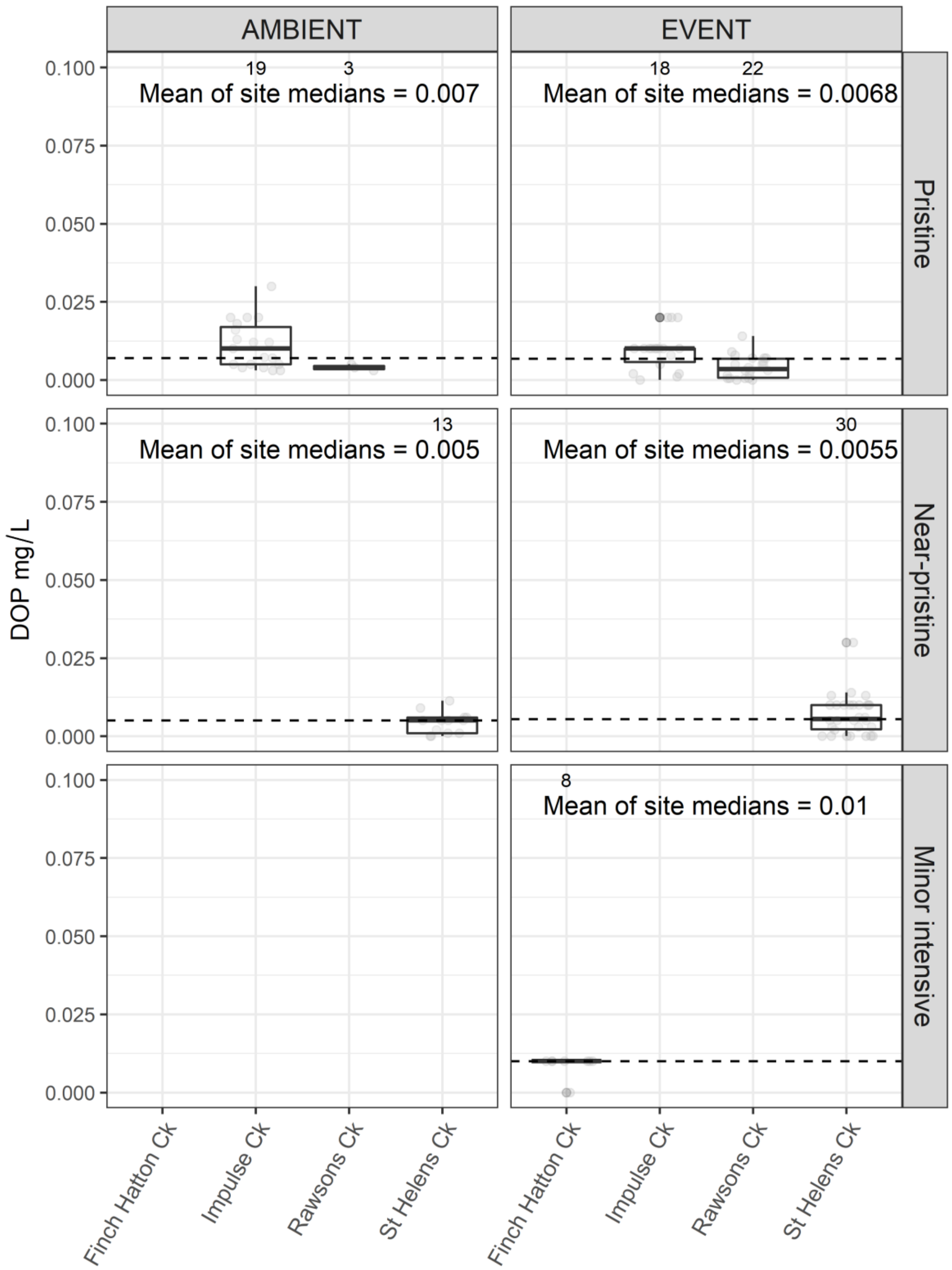


Figure 43. DOP concentrations (mg/L) for Pristine, Near-pristine and Minor intensive categories in the Central Queensland Coast bioregion.

3.7 SOUTH EAST QUEENSLAND BIOREGION

The South East Queensland bioregion covers parts of the Burnett Mary NRM region including the Baffle, Kolan, Burrum and Mary basins. There are only three sites identified within the South East Queensland bioregion, including two Mary basin sites of Booloumba Ck (Near-pristine) and Little Yabba Ck (Reference), and Baffle Creek at Mimdale (Reference) (Figures 9 and 10). Only three parameters are available for these sites including TSS, DIN and DIP.

Based on these data (Figure 44 to Figure 46) we recommend the following TSS, DIN and DIP DWC and EMC values (in mg/L) for the Southeast Queensland bioregion in Table 8. We have a lower level of confidence in these data due to it being collected primarily from Reference sites in low flow conditions, and being limited in sample numbers available for the production of DIN and DIP values. At this stage, we recommend using the Central Queensland Coast bioregion values for the other parameters, which is the closest neighbouring coastal area.

Table 8. Recommended values for the South East Queensland bioregion. The Central Queensland Coast bioregion TSS, DIN and DIP values are shown in brackets for comparison, and recommended for the remaining parameters.

Parameter	Dry weather concentration (mg/L)	Event mean concentration (mg/L)
Suspended sediment	5 (1)	30 (2.3)
Dissolved inorganic nitrogen	0.01 (0.05)	0.05 (0.08)
Particulate nitrogen	0.03	0.06
Dissolved organic nitrogen	0.07	0.11
Dissolved inorganic phosphorus	0.006 (0.006)	0.01
Particulate phosphorus	0.003	0.01
Dissolved organic phosphorus	0.007	0.007

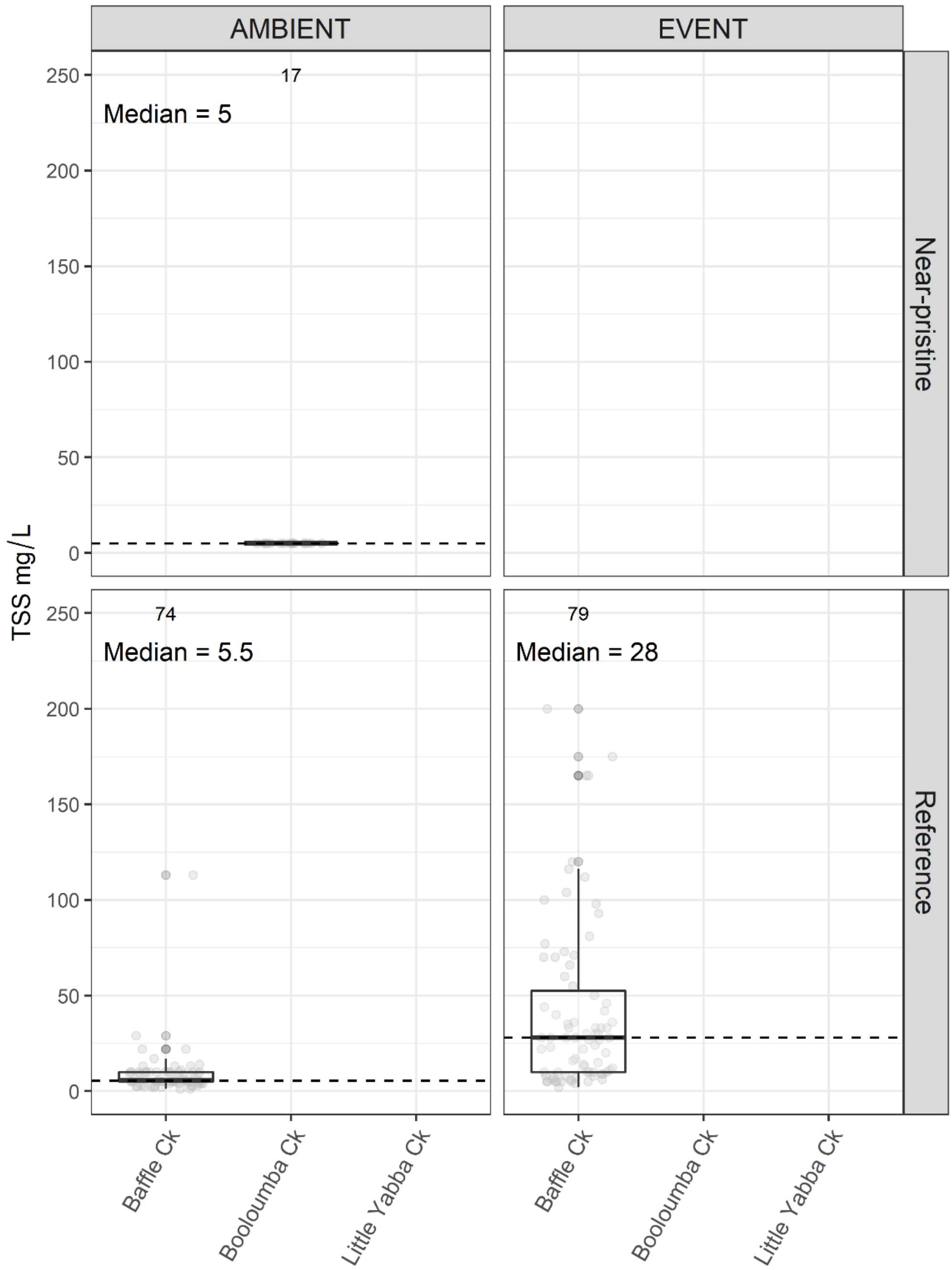


Figure 44. TSS concentrations (mg/L) for the Near-pristine and Reference categories in the South East Queensland bioregion.

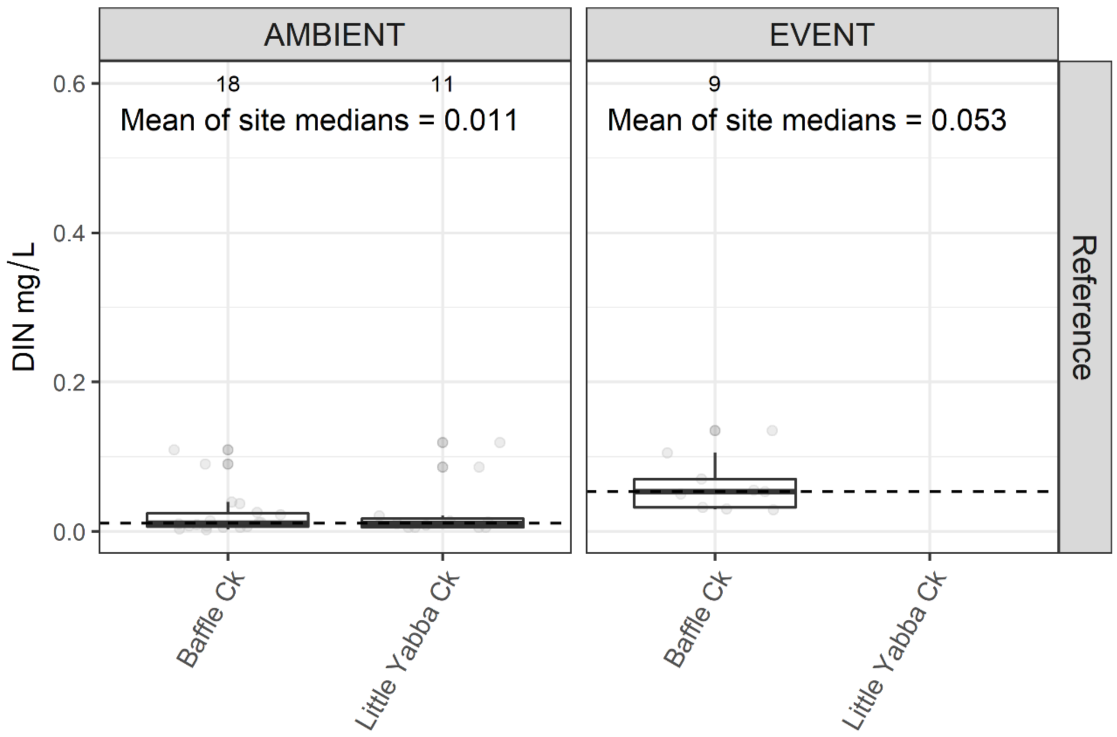


Figure 45. DIN concentrations (mg/L) for the Reference category in the South East Queensland bioregion.

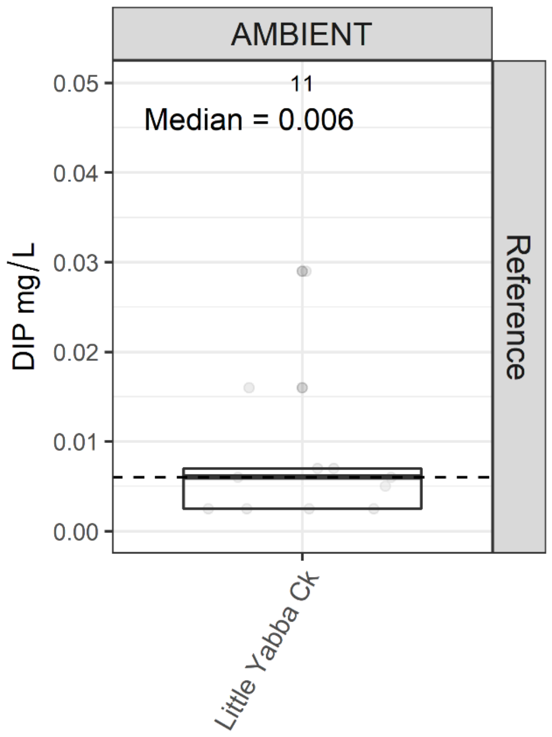


Figure 46. FRP concentrations (mg/L) for the Reference category in the South East Queensland bioregion.

4 DISCUSSION

To our knowledge, this compilation represents the most comprehensive dataset on water quality from Pristine and Near-pristine/Reference locations gathered to date, from the various bioregions of the GBRCA. On a spatial scale, it highlights the large discrepancies in either water quality monitoring efforts or the lack of suitable pristine locations within the bioregions of the GBRCA. Specifically, the Southeast Queensland, Desert Uplands, Brigalow and Cape York bioregions are poorly represented in terms of monitoring sites. In contrast, the Wet Tropics has an abundance of data allowing more detailed analysis of spatial variability in water quality data and the influence of varying levels of non-intensive and intensive land uses on each water quality parameter. We recommend that suitable pristine to near-pristine monitoring sites from these poorly represented bioregions be established and sampled over baseflow and event flow conditions. Additional data from these bioregions would provide much more confidence in the derivation of the EMC and DWC values.

The suspended sediment results show high variability across the bioregions (Table 9), which is likely explained by the differences in climate/rainfall, geomorphology, soil type and vegetation cover (e.g. Bainbridge et al., 2014). The lower values coincide with the wetter bioregions of the Wet Tropics, Central Queensland Coast and the coastal Brigalow Belt while the highest values occur in the drier bioregions located further inland including the Einasleigh and Desert Uplands, and the inland Brigalow Belt. The bioregions with intermediate suspended sediment values include Cape York (i.e. EMC) and the South East Queensland (Burnett Mary) bioregions. We note that during elevated event flow conditions that the TSS concentrations for Pristine/Near-pristine sites can display high variability (i.e. see Pascoe River site Figure 11 and Taylor Creek site in Figure 14). These higher TSS concentrations likely represent periods of either first flush conditions or the result of very heavy rainfall, which leads to bank slumping; hence, those concentrations are outliers where the mean and median values reflect the much lower concentrations that predominately occur during event flows.

Table 9. Summary of suspended sediment values for each bioregion.

Bioregion	Dry weather concentration (mg/L)	Event mean concentration (mg/L)
Cape York	0.5	22
Wet Tropics	1.4	3.3
Einasleigh Uplands	5.0	100
Desert Uplands	14	150
Brigalow Belt coastal (Brigalow Belt)	5.0	6.3 (250)
Central Queensland Coast	1.0	2.3
South East Queensland	5	30

The dissolved inorganic nitrogen results across the Pristine, Near-pristine and Minor intensive sites from the Wet Tropics bioregion (Figure 14) show little variability in the mean concentrations which demonstrate that Near-Pristine and Minor Intensive sites have the potential to be used to provide EMC and DWC values in bioregions where no genuine Pristine monitoring sites currently exist. Some caution needs to be applied on the level of intensive cropping upstream given the strong relationship between DIN concentration and upstream cropping area shown by several studies (e.g. Hunter and Walton, 2008; Rohde et al., 2008; Bainbridge et al., 2009; Mitchell et al., 2009). On a spatial scale, there is some variability in the recommended DWC DIN values across the bioregions ranging from 0.005 mg/L in the Cape York bioregion to 0.05 mg/L for the Central Queensland Coast bioregion (Table 10). The reason for the variability is unclear but is likely related to groundwater sources as well as variability in rainfall, vegetation and soils. The recommended EMC values for DIN have much lower variability and range from 0.04 to 0.08 mg/L with two exceptions including the very low value from the Desert Uplands (0.019 mg/L) and the highly elevated value from the inland Brigalow Belt (4.3 mg/L). The lower value from the Desert Uplands may reflect the high level of leaching in this dry bioregion and/or the rainout effect of solutes in this inland area. The elevated values that occur in the inland Brigalow Belt result from the legume vegetation (Acacia harpophylla) dominating this bioregion (see Elledge and Thornton, 2017).

Table 10. Summary of dissolved inorganic nitrogen values for each bioregion.

Bioregion	Dry weather concentration (mg/L)	Event mean concentration (mg/L)
Cape York	0.005	0.04
Wet Tropics	0.04	0.05
Einasleigh Uplands	0.01	0.08
Desert Uplands	0.015	0.019
Brigalow Belt coastal (Brigalow Belt)	0.01	0.05 (4.3)
Central Queensland Coast	0.05	0.08
South East Queensland	0.01	0.05

Similarly to the suspended sediment data, the variability in the particulate nitrogen and particulate phosphorus EMC values across the bioregions (Table 11) is likely related to the rainfall/climate and vegetation cover. This is shown by the lower values coinciding with the wetter bioregions (e.g. Wet Tropics, Central Queensland Coast, Cape York) and higher values occurring in the drier bioregions (Einasleigh Uplands, Desert Uplands, inland Brigalow Belt). High variability of particulate nutrient concentrations has been noted across different soil types within the GBRCA (e.g. Burton et al., 2015), and there is also an influence of geology/soil type on the particulate phosphorus concentrations across the sites such as in the Einasleigh Uplands (i.e. higher concentrations draining the western basaltic-dominated ranges and lower concentrations draining the granitic eastern ranges: Figure 26).

Table 11. Summary of particulate nitrogen (PN) and particulate phosphorus (PP) values for each bioregion.

Bioregion	**PN**		**PP**	
	Dry weather concentration (mg/L)	**Event mean concentration (mg/L)**	**Dry weather concentration (mg/L)**	**Event mean concentration (mg/L)**
Cape York	0.015	0.07	0.01	0.01
Wet Tropics	0.04	0.04	0.02	0.01
Einasleigh Uplands	0.05	0.24	0.006	0.08
Desert Uplands	0.015	0.40	0.01	0.10
Brigalow Belt coastal (Brigalow Belt)	0.05	0.08 (3.6)	0.006	0.02 (0.4)
Central Queensland Coast	0.003	0.06	0.003	0.01
South East Queensland	0.03	0.06	0.003	0.01

Interestingly, the mean DWC and EMC values of dissolved organic nitrogen doubled between the Wet Tropics bioregion Pristine sites and both the Near-pristine and Minor intensive sites (Figure 17). Dissolved organic nitrogen is generally considered a 'natural form' in the landscape (Brodie and Mitchell, 2005) and this change in concentration between the Pristine and Near-pristine/Minor intensive sits is unexpected and warrants further study to examine the various components of this nutrient species. While the Wet Tropics mean values for dissolved organic nitrogen did not notably change between the DWC and EMC values (also evident for the Near-pristine and Minor intensive sites), the results across the bioregions generally show an increase in dissolved organic nitrogen concentrations under event flow conditions (Table 12). Dissolved organic nitrogen can display high variability across sites within individual bioregions (e.g. see Figures 24 and 40) which may reflect differences in rainfall/climate, vegetation and soil composition. Indeed, there is wide variability in dissolved organic DWC and EMC values across the bioregions, which is similarly likely related to rainfall/climate, vegetation and soil composition (Table 12). A better understanding of this variability in the concentrations of dissolved organic nitrogen is needed at a finer scale so that this parameter can be modelled with more confidence.

Table 12. Summary of dissolved organic nitrogen values for each bioregion.

Bioregion	Dry weather concentration (mg/L)	Event mean concentration (mg/L)
Cape York	0.07	0.20
Wet Tropics	0.04	0.05
Einasleigh Uplands	0.18	0.30
Desert Uplands	0.18	0.33
Brigalow Belt coastal (Brigalow Belt)	0.18	0.2 (2.1)
Central Queensland Coast	0.07	0.11
South East Queensland	0.07	0.11

For all bioregions, with the exception of Cape York and Wet Tropics, the EMC values for dissolved inorganic phosphorus are an order of magnitude higher than the DWC values (Table 13). This may be a result of the differences between the wetter and drier bioregions, although more research is required to understand this result. Indeed, the mean dissolved inorganic phosphorus results across the Pristine, Near-Pristine and Minor intensive sites show little variability, although large variability in dissolved inorganic phosphorus concentrations is evident between the individual site data (Figure 18). Order of magnitude differences in dissolved inorganic phosphorus are also present in the mean DWC and EMC values across the different bioregions (Table 13). This variability is likely the result of the different geologies/soil types across the bioregions/sites where basaltic soils can be associated with elevated dissolved inorganic phosphorus concentrations. Indeed, this is shown in the dissolved inorganic phosphorus EMC data for the sites in the Einasleigh Uplands bioregion where the sites that drain the western basalt ranges (i.e. Fletcher and Lolworth Creeks) have much higher concentrations than the sites that drain the eastern granitic ranges (i.e. Star and Running Rivers) (Figure 25). Similarly variability is also observed in the Pristine data from the Central Queensland Coast region (Figure 41).

Table 13. Summary of dissolved inorganic phosphorus values for each bioregion.

Bioregion	Dry weather concentration (mg/L)	Event mean concentration (mg/L)
Cape York	0.0005	0.0005
Wet Tropics	0.005	0.004
Einasleigh Uplands	0.004	0.04
Desert Uplands	0.0005	0.007
Brigalow Belt coastal (Brigalow Belt)	0.004	0.04 (0.1)
Central Queensland Coast	0.006	0.01
South East Queensland	0.006	0.01

The DWC and EMC values for dissolved organic phosphorus are uniformly low across the different bioregions (Table 14). In the Wet Tropics bioregion, the concentrations of dissolved organic phosphorus show little variability between site or with land use change (e.g. Figure 20); however, some variability is evident in the sites within the Einasleigh Uplands with generally higher concentrations in the landscapes that drain basaltic soils (Figure 27).

Table 14. Summary of dissolved organic phosphorus values for each bioregion.

Bioregion	Dry weather concentration (mg/L)	Event mean concentration (mg/L)
Cape York	0.01	0.01
Wet Tropics	0.006	0.007
Einasleigh Uplands	0.003	0.01
Desert Uplands	0.01	0.01
Brigalow Belt coastal (Brigalow Belt)	0.003	0.008 (0.02)
Central Queensland Coast	0.007	0.007
South East Queensland	0.007	0.007

5 CONCLUSIONS

This report has provided recommended DWC and EMC values for the seven bioregions within the GBRCA that can be considered for use in the Source Catchments model. The compilation of available water quality data from pristine and near-pristine monitoring sites within the GBRCA reveal distinct variations in concentrations of the parameters across DWC and EMC values, bioregions and even across individual sites within bioregions. These variations are likely explained by variability within the GBRCA related to rainfall/climate, vegetation, ground cover and geology/soil type. However, further investigation is required to understand some of the variability between sites and bioregions for certain parameters. In particular, the variability of dissolved organic nitrogen concentrations across individual sites and bioregions need to be better understood including the concentration increases within the Wet Tropics bioregion due to the apparent transition from the Pristine to Near-pristine/Minor intensive sites.

This compilation has also demonstrated the lack of suitable water quality monitoring data from Pristine/Near-pristine sites for several of the bioregions within the GBRCA, most critically within the Burnett Mary region. Potential Pristine/Near-pristine sites within this region should be identified and monitored over a couple of seasons (both wet and dry) to produce a more robust set of data from this bioregion. Additional data from the inland Brigalow, Desert Uplands and Cape York bioregions would also be beneficial. Additional data from such bioregions would yield much higher confidence in the recommended DWC/EMC values for the Source Catchment model, and provide new insights on the local and regional variability for certain water quality parameters. Another useful exercise would be to identify and monitor Pristine sites of 'geological end members' (i.e. basalt versus granitic dominated areas) within the one bioregion to better quantify the influence of geological sources on the water quality parameters of interest.

REFERENCES

Arthington, A.H., Pusey, B.J., Mackay, S.J. & Kennard, M.J. 1998. Water quality data collected through projects funded by the Land and Water Resources Research and Development Corporation (LWRRDC). Australian Rivers Institute, Griffith University.

Bainbridge, Z., Lewis, S., Davis, A., Brodie, J. 2008. *Event-based community water quality monitoring in the Burdekin Dry Tropics NRM Region: 2007/08 wet season update*. ACTFR Report No. 08/19 for the North Queensland Dry Tropics. Australian Centre for Tropical Freshwater Research, James Cook University, Townsville. 51pp.

Bainbridge, Z.T., Brodie, J.E., Faithful, J.W., Sydes, D.A., Lewis, S.E. 2009. Identifying the land-based sources of suspended sediments, nutrients and pesticides discharged to the Great Barrier Reef from the Tully–Murray Basin, Queensland, Australia. *Marine and Freshwater Research* 60(11).

Bainbridge, Z.T., Lewis, S.E., Smithers, S.G., Kuhnert, P.M., Henderson, B.L., Brodie, J.E. 2014. Fine-suspended sediment and water budgets for a large, seasonally dry tropical catchment: Burdekin River catchment, Queensland, Australia. *Water Resources Research* 50(11).

Bartley, R., Speirs, W.J., Ellis, T.W. and Waters, D.K., 2012. A review of sediment and nutrient concentration data from Australia for use in catchment water quality models. *Marine Pollution Bulletin 65*(4-9), 101-116.

Bartley, R., Croke, J., Bainbridge, Z.T., Austin, J.M. and Kuhnert, P.M., 2015. Combining contemporary and long-term erosion rates to target erosion hot-spots in the Great Barrier Reef, Australia. *Anthropocene 10*, 1-12.

Belperio, A.P. 1983. *Late Quaternary terrigenous sedimentation in the Great Barrier Reef lagoon*. In: Baker, J.T. Carter, R.M. Sammarco, P.W. Stark, K.P. (Eds) Proceedings: Inaugural Great Barrier Reef Conference, Townsville, August 28 to September 2, 1983. JCU Press, pp. 71-76.

Binns, P. and Waters, D. 2018. Baseflow separation - Refinement of the Lyne & Hollick baseflow separation methodology using historical water quality data from Great Barrier Reef catchments. Technical Report, Queensland Department of Natural Resources, Mines and Energy, Toowoomba, 30pp.

Bramley, R.G.V. and Muller, D.E. 1999. *Water quality in the Lower Herbert River – The CSIRO Dataset*. CSIRO Land and Water Technical Report 16/99, CSIRO, Canberra.

Bramley, R. and Roth, C. 2002. Land-use effects on water quality in an intensively managed catchment in the Australian humid tropics. *Marine and Freshwater Research* 53, 931-940.

Brodie, J.E. and Mitchell, A.W. 2005. *Nutrients in Australian tropical rivers: changes with agricultural development and implications for receiving environments.* Marine and Freshwater Research 56, 279-302.

Brodie, J.E. and Mitchell, A.W. 2006. *Sediments and nutrients in north Queensland tropical streams: changes with agricultural development and pristine condition status* (Vol. 62). Townsville: CRC Reef Research Centre.

Brodie, J. McKergow, L.A. Prosser, I.P. Furnas, M. Hughes, A.O. Hunter, H. 2003. *Sources of sediment and nutrient exports to the Great Barrier Reef World Heritage Area*. ACTFR Report No. 03/11, Australian Centre for Tropical Freshwater Research, James Cook University, Townsville, 208 p.

Brodie, J., Baird, M., Waterhouse, J., Mongin, M., Skerratt, J., Robillot, C., Smith, R., Mann, R., Warne, M., 2017. *Development of basin-specific ecologically relevant water quality targets for the Great Barrier Reef*. TropWATER Report No. 17/38, James Cook University, Published by the State of Queensland, Brisbane, Australia. 68 pp.

Burton J, Moody P, DeHayr R, Chen C, Lewis S, Olley J. (2015). Sources of bioavailable particulate nutrients: Phase 1 (RP128G). Department of Science, Information Technology and Innovation.

Cogle, A.L., Langford, P., Kistle, S., Ryan, T., Dougall, A., Russell, D., Best, E. 2000. *Natural Resources of the Barron River Catchment 2. Water quality, land use and land management interactions*. QI00033, Department of Natural Resources, Mareeba. 87pp.

Cox, M.E., Moss, A., Smyth, G.K. 2005. Water quality condition and trend in North Queensland waterways. *Marine Pollution Bulletin* 51(1-4).

Croke, J., Bartley, R., Chappell, J., Austin, J.M., Fifield, K., Tims, S.G., Thompson, C.J., Furuichi, T. 2015. 10Be-derived denudation rates from the Burdekin catchment: the largest contributor of sediment to the Great Barrier Reef. *Geomorphology 241*, 122-134.

Davis, A.M., Taylor, B. and Fielke, S. 2020. *'Project 25': Engaging with farmers and demonstrating water quality outcomes to create confidence in on-farm decision-making.* Report to the National Environmental Science Program. Reef and Rainforest Research Centre Limited, Cairns (83pp.).

D'Olivo, J.P. and McCulloch, M. 2022. Impact of European settlement and land use changes on Great Barrier Reef river catchments reconstructed from long-term coral Ba/Ca records. *Science of The Total Environment 830*, p.154461.

Drewry, J., Higham, W., Mitchell, C. 2008. Water Quality Improvement Plan. *Final report for Mackay Whitsunday region.* Mackay Whitsunday Natural Resource Management Group, Mackay.

DSITI. 2016. *Land use Summary 1999–2015: Wet Tropics NRM region*, Department of Science, Information Technology and Innovation, Queensland Government, Brisbane, 34 pp.

Elledge, A. and Thornton, C. 2017. Effect of changing land use from virgin brigalow (Acacia harpophylla) woodland to a crop or pasture system on sediment, nitrogen and phosphorus in runoff over 25 years in subtropical Australia. *Agriculture, Ecosystems & Environment* 239, 119-131.

Furnas, M. 2003. *Catchments and corals: Terrestrial runoff to the Great Barrier Reef.* Australian Institute of Marine Science, Townsville, 334 pp.

Galea, L., Pepplinkhouse, D., Loft, F., Folkers, A. 2008. *Mackay Whitsunday Healthy Waterways Baseline Monitoring Program Regional Report 2008*. Queensland Department of Natural Resources and Water for the Mackay Whitsunday Natural Resource Management Group, Australia, 66 pp. ISBN 978-1-7417-2923-8.

Hunter, H.M, Sologinkin, SJ., Choy, S.C., Hooper, A.R., Allen, W.S., Raymond, M.A.A., Peeters, J. 2001. *Water management in the Johnstone Basin*. Natural Heritage Trust Project No. 952194. Department of Natural Resources and Mines, Brisbane. 106 pp.

Joo, M., Raymond, M.A.A., McNeil, V.H., Huggins, R., Turner, R.D.R., Choy, S. 2012. Estimates of sediment and nutrient loads in 10 major catchments draining to the Great Barrier Reef during 2006–2009. *MPB* 65, 150-166.

Kroon, F.J., Kuhnert, P.M., Henderson, B.L., Wilkinson, S.N., Kinsey-Henderson, A., Brodie, J.E., Turner, R.D.R. 2012. River loads of suspended solids, nitrogen, phosphorus and herbicides delivered to the Great Barrier Reef lagoon, *Marine Pollution Bulletin,* 65, 167-181.

Laxton, J.H. and Gittins, R. 2004. *Water Quality of Pristine sections of Rivers of Eastern Australia draining to the Tasman Sea*. Private research Project, October 2004. J.H. & E.S. Laxton – Environmental Consultants P/L, Sydney. 204 pp.

Liessman, L., Lewis, S., Bainbridge, Z., Butler, B., Brodie, J., Faithful, J., Maughan, M. 2007. *Event-based water quality monitoring of the Ross and Black Basins during the 2006/07 Wet Season*. ACTFR Technical Report No. 07/09 for the Creek to Coral Ross Black WQIP, James Cook University, Townsville. 71pp.

Lewis, S.E. Shields, G.A. Kamber, B.S. Lough, J.M. 2007. A multi-trace element coral record of land-use changes in the Burdekin River catchment, NE Australia. *Palaeogeograpahy, Palaeoclimatology, Palaeoecology* 246: 471-487.

Lewis, S.E. Olley, J. Furuichi, T. Sharma, A. Burton, J. 2014a. Complex sediment deposition history on a wide continental shelf: implications for the calculation of accumulation rates on the Great Barrier Reef. *Earth and Planetary Science Letters* 393, 146-158.

Lewis, S., Brodie, J., Endo, G., Lough, J. Furnas, M. & Bainbridge, Z. 2014b. Synthesizing historical land use change, fertiliser and pesticide usage and pollutant load data in the regulated catchments to quantify baseline and changing loads exported to the Great Barrier Reef. Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Technical Report 14/20, James Cook University, Townsville, 105 pp.

Lewis, S.E. Lough, J.M. Cantin, N.E. Matson, E.G. Kinsley, L. Bainbridge, Z.T. Brodie, J.E. 2018. A critical evaluation of coral Ba/Ca, Mn/Ca and Y/Ca ratios as indicators of terrestrial input: new data from the Great Barrier Reef, Australia. *Geochimica et Cosmochimica Acta* 237, 131-154.

Lewis, S.E., Bartley, R., Wilkinson, S.N., Bainbridge, Z.T., Henderson, A.E., James, C.S., Irvine, S.A., Brodie, J.E. 2021. Land use change in the river basins of the Great Barrier Reef, 1860 to 2019: A foundation for understanding environmental history across the catchment to reef continuum. *Marine Pollution Bulletin* 166, 112193.

Lyne, V.D. and Hollick, M. 1979. Stochastic time-variable rainfall–runoff modelling, in 'National Conference Publication', Institution of Engineers Australia, pp. 89–93.

Mariotti, A., Croke, J., Bartley, R., Kelley, S.E., Ward, J., Fülöp, R.H., Rood, A.H., Rood, D.H., Codilean, A.T., Wilcken, K. and Fifield, K., 2021. Pre-development denudation rates for the Great Barrier Reef catchments derived using 10Be. *Marine Pollution Bulletin* 172, p.112731.

Mitchell, A., Reghenzani, J., Faithful, J., Furnas, M., Brodie, J. 2009. Relationships between land use and nutrient concentrations in streams draining a 'wet-tropics' catchment in northern Australia. *Marine and Freshwater Research* 60 (11).

Moss, A.J., Rayment, G.E., Reilly, N., Best, E.K. 1992. *A preliminary assessment of sediment and nutrient exports form Queensland coastal catchments*. Department Of Primary Industries*,* Queensland.

Neil, D.T. Yu, B. 1996. Fluvial sediment yield to the Great Barrier Reef Lagoon: Spatial patterns and the effect of land use. **In:** Hunter, H.M. Eyles, A.G. Rayment, G.E. (eds). *Downstream effects of land use*. Department of Natural Resources, Queensland, Australia, pp 281-286.

Neil, D.T. Orpin, A.R. Ridd, P.V. Yu, B. 2002. Sediment yield and impacts from river catchments to the Great Barrier Reef lagoon. *Marine and Freshwater Research* 53, 733-752.

Nichols, K.K., Bierman, P.R. and Rood, D.H., 2014. 10Be constrains the sediment sources and sediment yields to the Great Barrier Reef from the tropical Barron River catchment, Queensland, Australia. *Geomorphology 224*, 102-110.

Puignou Lopez, O. Lewis, S. James, C. Davis, A. Mackay, S. (in review). Hydrology of the Great Barrier Reef catchment area along a latitudinal gradient: Upscaling discharge to reflect catchment inputs. Journal of Hydrology.

Rohde, K., Masters, B., Brodie, J., Faithful, J., Noble, R., Carroll, C. 2006. *Fresh and Marine Water Quality in the Mackay Whitsunday Region 2004/2005*. Mackay Whitsunday Natural Resource Management Group, Mackay, Australia. 91pp.

Rohde, K., Masters, B., Fries, N., Noble, R., Carroll, C. 2008. *Fresh and Marine Water Quality in the Mackay Whitsunday Region 2004/05 to 2006/07*. Queensland Department of Natural Resources and Water for the Mackay Whitsunday Natural Resource Management Group, Mackay, 135pp. ISBN 978-1-7417-2922-1.

Prosser, I.P. Rustomji, P. Young, W.J. Moran, C.J. Hughes, A. 2001. *Constructing river basin sediment budgets for the National Land and Water Resources Audit*. CSIRO Land and Water Technical Report 15/01, CSIRO, Canberra.

Saha, N. Webb, G.E. Zhao, J-x. Nguyen, A. Lewis, S.E. Lough, J. 2019. Coral-based high-resolution rare earth element proxy for terrestrial sediment discharge affecting coastal seawater quality, Great Barrier Reef. *Geochimica et Cosmochimica Acta* 254, 173-191.

Saha, N. Webb, G.E. Zhao, J-x. Lewis, S.E. Nguyen, A. Feng, Y. 2021. Spatiotemporal variation of rare earth elements from river to reef continuum aids monitoring of terrigenous sources in the Great Barrier Reef. *Geochimica et Cosmochimica Acta* 299, 85-112.

SWAN, 2022. Surface water ambient network – Water Quality, Queensland Department of Natural Resources and Mines.

Ten Napel, M., Wallace, R., Neelamraju, C., Ferguson, B., Orr, D., Simpson, S., Strauss, J., Anderson, L., Roberts, C., Welk, K., Fisher, S., Huggins, R., Turner, R. D.R., and Mann, R.M. 2019. *Great Barrier Reef Catchment Loads Monitoring Program Report Summary 2017-2018*, Department of Environment and Science, Brisbane, Australia.

Thornton, C.M. and Elledge, A.E. (2013). *Runoff of Nitrogen, Phosphorus and Sediment from Pasture Legumes: An Enhancement to Reef Catchment Modelling (Project RRRD009)*. Report to the Reef Rescue Research and Development Program. Reef and Rainforest Research Centre Limited, Cairns (85 pp.). ISBN: 978-1-925088-11-3.

Wasko, C. and Guo, D. 2022. Understanding event runoff coefficient variability across Australia using the hydroEvents R package. *Hydrol. Process* 36, e14563.

Wasson, R.J. 1997. *Run-off from the land to the rivers and the sea*. Proc Great Barrier Reef Conf, Townsville, November 1996, pp 23-41.

Appendix 1. Additional water quality site details including locational details, original site names and study details.

Pristine category	Basin	Site (short name)	Original study site name	Lat	Long	Study period	Project/organisation	Data source
NP	Olive-Pascoe	Pascoe R	Pascoe River at Wattlehill St	-12.55252	143.19764	2017 to 2021	GBRCLMP, WQ&I, QDES	
P	Mossman	Mossman R Gorge	Upper Mossman River	-16.47386	145.33189	1998 to 2003	Laxton private research	Laxton and Gittens 2004
P	Mossman	Mossman R Gorge	Mossman R 14.35km u/s mouth (218779)	-16.47150	145.33160	1994 to 1999	EPA ambient WQ	Cox et al. 2005
P	Barron	Davies Ck	Davies Ck	-16.98664	145.56437	1996 to 1999	NHT Barron (DNR)	Cogle et al. 2000
P	Barron	Clohesy R	Clohesy R (upper Clohesy R Road)	-16.93517	145.61701	1996 to 1998		
P	Barron	Freshwater Ck	Freshwater Ck	-16.96107	145.67906	1996 to 1999		
P	Russell-Mulgrave	Babinda Ck	Babinda Ck 17.7km u/s mouth (798820)	-17.33190	145.87080	1994 to 1999	EPA ambient WQ	Cox et al. 2005
P	Russell-Mulgrave	Behana Ck	Behana Ck at National Park	-17.16422	145.83230	2016 to 2020	NESP 'Project 25'	Davis, Taylor, & Fielke 2020
P	Johnstone	Taylor Ck	Taylor Ck Warraker (112005A)	-17.51806	145.91317	1991 to 1996	NHT Johnstone (DNR)	Hunter et al. 2001
P	Johnstone	Henrietta Ck	Henrietta Creek (MIP_LSM_J10)	-17.60393	145.76207	2021	WTMIP consortium	Terrain NRM (WTMIP)
P	Tully	Tully Valley R/F	Tully Valley rainforest (MIP_LSM_T2)	-17.83066	145.72115	2018 to 2021		
P	Tully (Hull)	North Hull R	North Hull River	-17.91154	146.07955	2005 to 2007	Tully WQIP (Terrain/ACTFR)	Bainbridge et al. 2009
P	Murray	Murray Falls	Murray River (Murray Falls)	-18.15209	145.81430	2005 to 2007		
NP	Daintree	Daintree R	Upper Daintree	-16.23067	145.29817	1998 to 2003	Laxton private research	Laxton and Gittens 2004
NP	Daintree	Daintree R	Daintree R 30.3km u/s mouth (DSC site DRA)	-16.19880	145.29220	2019 to 2022	EPA ambient WQ	Cox et al. 2005
NP	Daintree	Daintree R	Daintree R 32.4km u/s mouth (Crebb Track crossing) (164101)	-16.19860	145.29240	1994 to 1999		
NP	Daintree	Stewart Ck	Stewart Ck 0.15km u/s mouth (198017)	-16.25690	145.31480	1994 to 1996		
NP	Barron	Kauri Ck	Kauri Ck	-17.13330	145.59821	1992 to 1999	NHT Barron (DNR)	Cogle et al. 2000
NP	Russell-Mulgrave	Little Mulgrave R	L.Mulgrave R 6.0km u/s mouth (607068)	-17.11660	145.68880	1994 to 1999	EPA ambient WQ	Cox et al. 2005
NP	Russell-Mulgrave	Russell R	Russell R 42.0km u/s mouth (784713)	-17.45340	145.85940	1992 to 1999		
NP	Russell-Mulgrave	Russell R	Russell R at Golden Hole	-17.44874	145.85267	2016 to 2020	NESP 'Project 25'	Davis, Taylor, & Fielke 2020
NP	Johnstone	Upper Liverpool Ck	Upper Liverpool Ck (MIP_SM_J11)	-17.71267	145.87548	2019 to 2021	WTMIP consortium	Terrain NRM (WTMIP)
NP	Johnstone	South Johnstone R	South Johnstone R (Corsi's)	-17.59717	145.90199	1991 to 1996	NHT Johnstone (DNR)	Hunter et al. 2001
NP	Tully	Tully Gorge	Tully-Upper	-17.76493	145.63932	1987 to 2000	AIMS long term monitoring	Mitchell et al. 2009
NP	Tully	Tully Gorge	Upper Tully River	-17.78603	145.67256	1998 to 2003	Laxton private research	Laxton and Gittens 2004
NP	Tully	Tully Gorge	Tully Gorge	-17.78397	145.67254	2005 to 2007	Tully WQIP (Terrain/ACTFR)	Bainbridge et al. 2009
NP	Tully	Tully Gorge	Tully Gorge (GBRCLMP)	-17.77252	145.65100	1992 to 1999	GBRCLMP, WQ&I, QDES	
NP	Tully	Tully Gorge	Tully Gorge (MIP_LSM_T1)	-17.77252	145.65100	2013 to 2021	WTMIP consortium	Terrain NRM (WTMIP)
NP	Tully	Tully Gorge	Tully R 71.0km u/s mouth (591331)	-17.78410	145.67240	2018 to 2019	EPA ambient WQ	Cox et al. 2005
NP	Herbert	Waterview Ck	Waterview Ck - Jourama	-18.85271	146.12515	1992 to 1994	CSIRO Herbert	Bramley & Muller 1999; Bramley & Roth 2002
NP	Herbert	Dalrymple Ck	Dalrymple Ck - Forestry	-18.45067	146.06070	1993 to 1995		
NP	Black	Big Crystal Ck	Big Crystal Ck	-18.96766	146.28434	1998 to 2003	Laxton private research	Laxton and Gittens 2004
NP	Black	Little Crystal Ck	Little Crystal Ck	-18.98712	146.28609	1998 to 2003		
MI	Russell-Mulgrave	Mulgrave R	Mulgrave R 53.5km u/s mouth (665968)	-17.20740	145.74620	1992 to 1999	EPA ambient WQ	Cox et al. 2005
MI	Russell-Mulgrave	Mulgrave R	Mulgrave R at Fisheries	-17.17666	145.72338	2016 to 2020	NESP 'Project 25'	Davis, Taylor, & Fielke 2020

Pristine category	Basin	Site (short name)	Original study site name	Lat	Long	Study period	Project/organisation	Data source
MI	Tully	Bulgun Ck	Bulgun Creek	-17.88704	145.93118	2005 to 2007	Tully WQIP (Terrain/ACTFR)	Bainbridge et al. 2009
MI	Tully	Jarra Ck	Jarra Creek	-17.89752	145.85104	1987 to 2000	AIMS long term monitoring	Mitchell et al. 2009
MI	Tully	Jarra Ck	Jarra Creek	-17.89800	145.85126	2005 to 2007		
MI	Tully	Davidson Ck	Davidson Creek (Fishtail)	-18.01829	145.72598	2005 to 2007	Tully WQIP (Terrain/ACTFR)	Bainbridge et al. 2009
MI	Murray	Murray R_Jumbun	Murray River (Jumbun)	-18.11118	145.80087	2005 to 2007		
MI	Herbert	Hawkins Ck	Hawkins Ck	-18.58263	146.06856	1992 to 1995	CSIRO Herbert	Bramley & Muller 1999; Bramley & Roth 2002
MI	Herbert	Crystal Ck	Crystal Ck (Bruce Hwy)	-18.95269	146.28728	1992 to 1994		
MI	Black	Hen Camp Ck	Hen Camp Ck (Bruce Hwy)	-19.01858	146.36678	2007	Townsville WQIP (TCC)	Liessman et al. 2007
NP	Burdekin	Upper Star R	Star R (S01)	-19.13470	146.17020			
NP	Burdekin	Little Star R	Little Star R (S03)	-19.26070	146.27910			
NP	Burdekin	Keelbottom Ck	Keelbottom Ck (S06)	-19.37460	146.35530	early 2000-present	Townsville Field Training Area	Department of Defence conf. reports (2002-2022)
NP	Burdekin	Stake Creek	Fanning R (Stake S12)	-19.46230	146.51360			
NP	Burdekin	Fanning R	Fanning R (S26)	-19.61380	146.52070			
R	Burdekin	Star R	Star R (SO4: Laroona)	-19.361	146.085 146.085	146.085		
R	Burdekin	Running R	Running R (Ewan Hills)	-19.13490	145.82953	2003 to 2008		
R	Burdekin	Star R	Star River (Kirkland Downs)	-19.43982	145.97000	2005 to 2008		
R	Burdekin	Lolworth Ck	Lolworth Ck (Lockwall)	-19.87217	145.84722	2004 to 2008	Burdekin community water quality monitoring (NQDT/ACTFR, JCU)	Bainbridge et al. 2014
R	Burdekin	Fletcher Ck	Fletcher Ck (FletcherVale)	-19.80433	145.85883	2004 to 2008		
R	Haughton	Reid R	Reid R (Flinders Hwy)	-19.75822	146.83610	2003 to 2008		Bainbridge et al. 2008
R	Burdekin	Cape R	Cape R at Taemas	-20.99944	146.42722	2003 to 2010		Bainbridge et al. 2008, 2014
R	Burdekin	Cape R	Cape R at Taemas	-20.99944	146.42722	2011 to 2013	GBRCLMP, WQ&I, QDES.	
P	Pioneer	Impulse Ck	Impulse Ck	-20.35312	148.72640	2005 to 2007	Mackay Whitsunday Healthy Waterways: Event/baseline (DNRM/Reef Catchments)	Event: Rohde et al. 2006, 2008; Baseline: Galea et al. 2008; Drewry et al. 2008
P	Pioneer	Rawsons Ck	Baseline: Rawsons Ck (Finch Hatton Ck)	-21.06733	148.63725	2007 to 2008		
P	Pioneer		Finch Hatton Ck	-21.07189	148.63783	1998 to 2003	Laxton Private Consulting	Laxton and Gittens 2004
NP	O'Connell	St Helens Ck	St Helens Ck	-20.97454	148.68744	2005 to 2008	Mackay Whitsunday Healthy Waterways: Event/baseline (DNRM/Reef Catchments)	Event: Rohde et al. 2006, 2008; Baseline: Galea et al. 2008; Drewry et al. 2008
MI	Pioneer	Finch Hatton Ck	Event: Finch Hatton Ck (Braithewaites Crossing)	-21.08875	148.63360	2005 to 2007		
P	Ross	Alligator Ck	Alligator Ck (U/S at NP)	-19.42991	146.94338	2007	Townsville WQIP (TCC/ACTFR, JCU)	Liessman et al. 2007
P	Ross	Campus Ck	Campus Ck, JCU	-19.32283	146.76296	2007		
R	Burdekin	Broken R	Broken River at Mt Sugarloaf gauge	-20.84327	148.16533	2018 to 2022	Burdekin MIPs (NQDT/TropWATER, JCU)	Bainbridge et al. in review
P	Fitzroy	Brigalow forest	Brigalow trial – natural site	-24.80000	149.78333	1980 to 2021	WDES Paddock Monitoring & Modelling	Elledge & Thornton, 2017
NP	Mary	Booloumba Ck	Booloumba Ck at Booloumba Ck Rd	-26.63189	152.65245	1995 to 1997	Griffith Uni (LWRRDC)	Arthington et al. 1998
R	Mary	Little Yabba Ck	Little Yabba Ck	-26.62010	152.65699	2019-2020	Mary R nutrient investigation	Sunshine Coast Regional Council
R	Baffle	Baffle Ck	Baffle Ck at Mimdale	-24.51364	151.73628	1972 to 2022	SWAN (DNRME)	
Pristine categories: P= Pristine NP= Near-pristine MI=Near-pristine with minor intensive land use R= Reference.								

APPENDIX 2. SUMMARY TSS CONCENTRATION (MG/L) STATISTICS BY SITE

Site name	Ambient flow				Event flow			
	count	mean	median	sd	count	mean	median	sd
Alligator Ck	1	1.0	1.0	NA	5	14	9.0	13
Babinda Ck	0				0			
Baffle Ck	74	8.7	5.5	13	79	41	28	44
Behana Ck	4	4.2	1.2	6.6	74	7.1	1.4	16
Big Crystal Ck	23	0.8	0.5	0.9	9	2.5	0.7	4.4
Booloumba Ck	17	5.0	5.0	0	0			
Brigalow forest	0				371	1080	248	2212
Broken R	0				76	27	13	41
Bulgun Ck	1	3.4	3.4	NA	14	6.1	1.2	14
Campus Ck	0				6	14	3.5	20
Cape R	4	15	14	12	264	212	146	246
Clohesy R	6	2.2	2.0	1.7	0			
Crystal Ck	0				0			
Daintree R	22	3.8	2.6	3.6	8	12	5.9	13
Dalrymple Ck	9	4.0	4.0	2.9	10	66	18	134
Davidson Ck	0				10	3.7	1.9	3.4
Davies Ck	5	4.0	2.0	3.9	0			
Fanning R	10	6.2	5.4	4.5	0			
Finch Hatton Ck	0				13	52	47	62
Fletcher Ck	2	175	175	15	37	129	70	127
Freshwater Ck	24	2.1	1.5	2.0	10	2.3	1.5	2.7
Hawkins Ck	16	3.1	2.5	2.9	23	12	8.0	10
Hen Camp Ck	3	3.7	1.0	4.6	7	39	37	36
Henrietta Ck	25	2.6	2.8	1.4	9	7.1	5.0	4.9
Impulse Ck	19	1.4	1.1	1.0	17	15	3.6	31
Jarra Ck	1	5.0	5.0	NA	14	17	13	13
Kauri Ck	44	7.0	3.0	13.6	28	48	11	82
Keelbottom Ck	13	1.6	1.5	0.7	0			
Little Crystal Ck	24	4.1	3.8	3.1	8	3.1	1.9	3.4
Little Mulgrave R	0				0			
Little Yabba Ck	0				0			
Lolworth Ck	0				28	445	260	627
Mossman R Gorge	17	0.8	0.6	0.4	15	2.5	1.1	4.1
Mulgrave R	20	6.5	5.0	5.9	62	9.6	2.6	24
Murray Falls	0				12	0.7	0.4	1.0
Murray R	0				13	5.3	3.6	4.8
North Hull R	0				11	10	3.6	12
Pascoe R	9	1.8	0.5	3.8	220	29	22	26
Rawsons Ck	23	1.6	0.9	1.7	34	4.9	1.0	20
Reid R	0				10	67	32	67
Running R	0				28	235	110	363
Russell R	10	6.4	7.0	4.6	83	14	3.0	30
South Johnstone R	35	2.8	3.0	1.8	39	4.1	1.0	7.3
St Helens Ck	13	1.0	1.0	0.6	30	103	4.2	297
Stake Ck	12	10.0	9.9	4.8	0			
Star R	29	138	5.3	361	46	99	34	140
Stewart Ck	0				0			
Taylor Ck	103	1.9	1.0	2.7	503	34	12	79
Tully Gorge	56	2.2	1.6	2.4	563	35	10	68
Tully Valley R/F	26	1.1	0.5	1.2	20	2.3	1.6	2.7
Upper Liverpool Ck	24	1.2	1.2	0.6	14	2.7	2.0	1.6
Upper Star R	27	1.4	1.4	0.7	0			
Waterview Ck	0				0			

APPENDIX 3. SUMMARY DIN CONCENTRATION (MG/L) STATISTICS BY SITE

Site name	Ambient flow				Event flow			
	count	mean	median	sd	count	mean	median	sd
Alligator Ck	1	0.02	0.02	NA	5	0.03	0.04	0.01
Babinda Ck	59	0.03	0.02	0.03	3	0.04	0.04	0.02
Baffle Ck	18	0.02	0.01	0.03	9	0.06	0.05	0.04
Behana Ck	4	0.03	0.03	0.01	77	0.04	0.03	0.04
Big Crystal Ck	23	0.17	0.15	0.12	9	0.15	0.13	0.07
Booloumba Ck	0				0			
Brigalow forest	0				92	5.0	4.3	3.8
Broken R	0				74	0.10	0.04	0.13
Bulgun Ck	1	0.053	0.053	NA	15	0.12	0.06	0.11
Campus Ck	0				6	0.11	0.06	0.12
Cape R	5	0.02	0.02	0.02	108	0.06	0.02	0.12
Clohesy R	6	0.02	0.02	0.02	0			
Crystal Ck	7	0.02	0.02	0.02	12	0.05	0.05	0.02
Daintree R	78	0.06	0.02	0.07	32	0.08	0.05	0.10
Dalrymple Ck	8	0.06	0.01	0.13	9	0.03	0.04	0.02
Davidson Ck	0				11	0.08	0.04	0.10
Davies Ck	5	0.02	0.01	0.02	0			
Fanning R	10	0.02	0.01	0.01	0			
Finch Hatton Ck	0				8	0.09	0.09	0.04
Fletcher Ck	2	0.50	0.50	0.19	10	0.10	0.08	0.07
Freshwater Ck	24	0.08	0.08	0.03	10	0.09	0.10	0.04
Hawkins Ck	13	0.17	0.11	0.19	24	0.15	0.12	0.13
Hen Camp Ck	3	0.03	0.01	0.04	5	0.09	0.10	0.03
Henrietta Ck	25	0.04	0.04	0.02	9	0.05	0.05	0.01
Impulse Ck	19	0.03	0.03	0.02	18	0.20	0.14	0.21
Jarra Ck	23	0.03	0.02	0.01	72	0.08	0.05	0.10
Kauri Ck	59	0.08	0.07	0.06	30	0.09	0.07	0.06
Keelbottom Ck	13	0.01	0.01	0.01	0			
Little Crystal Ck	24	0.15	0.11	0.11	8	0.14	0.11	0.09
Little Mulgrave R	62	0.03	0.03	0.03	0			
Little Yabba Ck	11	0.03	0.01	0.04	0			
Lolworth Ck	0				13	0.16	0.15	0.10
Mossman R Gorge	37	0.06	0.03	0.06	55	0.05	0.03	0.05
Mulgrave R	72	0.01	0.01	0.01	75	0.04	0.03	0.03
Murray Falls	0				12	0.01	0.01	0.01
Murray R_Jumbun	0				13	0.09	0.05	0.13
North Hull R	0				10	0.09	0.06	0.08
Pascoe R	9	0.01	0.01	0.01	219	0.06	0.04	0.05
Rawsons Ck	23	0.07	0.06	0.04	34	0.02	0.04	0.04
Reid R	0				10	0.12	0.09	0.07
Running R	0				6	0.05	0.06	0.03
Russell R	56	0.02	0.02	0.01	100	0.04	0.03	0.03
South Johnstone R	34	0.02	0.01	0.02	43	0.03	0.02	0.03
St Helens Ck	13	0.02	0.02	0.01	30	0.14	0.11	0.12
Stake Ck	11	0.01	0.01	0.01	0			
Star R	26	0.02	0.01	0.01	11	0.05	0.01	0.13
Stewart Ck	30	0.03	0.02	0.02	0			
Taylor Ck	106	0.02	0.02	0.01	112	0.04	0.04	0.03
Tully Gorge	96	0.07	0.05	0.05	670	0.09	0.07	0.09
Tully Valley R/F	26	0.10	0.09	0.03	20	0.09	0.09	0.03
Upper Liverpool Ck	24	0.03	0.04	0.01	14	0.06	0.05	0.03
Upper Star R	25	0.01	0.01	0.01	0			
Waterview Ck	19	0.02	0.02	0.02	10	0.04	0.03	0.03

APPENDIX 4. SUMMARY DIP CONCENTRATION (MG/L) STATISTICS BY SITE

Site name	Ambient flow				Event flow			
	count	mean	median	sd	*count*	mean	median	sd
Alligator Ck	*1*	0.011	0.011	NA	*5*	0.019	0.020	0.013
Babinda Ck	*59*	0.002	0.002	0.001	*3*	0.002	0.003	0.001
Baffle Ck	*0*				*0*			
Behana Ck	*4*	0.005	0.004	0.001	*77*	0.004	0.004	0.003
Big Crystal Ck	*23*	0.020	0.001	0.089	*9*	0.002	0.001	0.002
Booloumba Ck	*0*				*0*			
Brigalow forest	*0*				*92*	0.146	0.125	0.087
Broken R	*0*				*74*	0.025	0.013	0.045
Bulgun Ck	*1*	0.003	0.003	NA	*15*	0.002	0.002	0.001
Campus Ck	*0*				*6*	0.059	0.054	0.030
Cape R	*5*	0.001	0.001	0.001	*108*	0.010	0.007	0.015
Clohesy R	*6*	0.010	0.010	0.003	*0*			
Crystal Ck	*7*	0.007	0.003	0.009	*12*	0.011	0.011	0.008
Daintree R	*78*	0.004	0.003	0.002	*32*	0.003	0.003	0.001
Dalrymple Ck	*9*	0.005	0.004	0.004	*10*	0.005	0.004	0.003
Davidson Ck	*0*				*11*	0.003	0.002	0.002
Davies Ck	*5*	0.009	0.005	0.011	*0*			
Fanning R	*10*	0.005	0.004	0.004	*0*			
Finch Hatton Ck	*0*				*8*	0.008	0.008	0.004
Fletcher Ck	*2*	0.096	0.096	0.049	*10*	0.125	0.130	0.024
Freshwater Ck	*24*	0.007	0.006	0.005	*10*	0.006	0.006	0.002
Hawkins Ck	*15*	0.003	0.002	0.003	*24*	0.004	0.004	0.003
Hen Camp Ck	*3*	0.006	0.005	0.001	*5*	0.007	0.005	0.006
Henrietta Ck	*0*				*0*			
Impulse Ck	*19*	0.010	0.009	0.004	*18*	0.023	0.019	0.015
Jarra Ck	*23*	0.002	0.001	0.002	*72*	0.004	0.003	0.004
Kauri Ck	*60*	0.013	0.013	0.006	*30*	0.017	0.012	0.015
Keelbottom Ck	*14*	0.004	0.003	0.004	*0*			
Little Crystal Ck	*24*	0.003	0.003	0.002	*8*	0.005	0.005	0.003
Little Mulgrave R	*62*	0.008	0.008	0.002	*0*			
Little Yabba Ck	*11*	0.01	0.01	0.01	*0*			
Lolworth Ck	*0*				*13*	0.042	0.023	0.035
Mossman R Gorge	*37*	0.003	0.004	0.001	*55*	0.003	0.003	0.001
Mulgrave R	*72*	0.004	0.003	0.001	*75*	0.005	0.004	0.005
Murray Falls	*0*				*12*	0.003	0.003	0.001
Murray R_Jumbun	*0*				*13*	0.006	0.005	0.004
North Hull R	*0*				*10*	0.002	0.002	0.001
Pascoe R	*9*	0.001	0.001	0.001	*219*	0.002	0.001	0.007
Rawsons Ck	*23*	0.002	0.002	0.002	*34*	0.004	0.003	0.005
Reid R	*0*				*10*	0.030	0.021	0.026
Running R	*0*				*6*	0.016	0.016	0.010
Russell R	*56*	0.005	0.005	0.001	*100*	0.005	0.004	0.006
South Johnstone R	*34*	0.010	0.010	0.002	*43*	0.008	0.008	0.002
St Helens Ck	*13*	0.007	0.006	0.004	*30*	0.015	0.015	0.009
Stake Ck	*12*	0.004	0.004	0.002	*0*			
Star R	*26*	0.006	0.004	0.005	*13*	0.003	0.002	0.002
Stewart Ck	*30*	0.003	0.003	0.001	*0*			
Taylor Ck	*106*	0.005	0.005	0.001	*112*	0.006	0.006	0.002
Tully Gorge	*84*	0.002	0.001	0.002	*666*	0.002	0.002	0.003
Tully Valley R/F	*0*				*0*			
Upper Liverpool Ck	*0*				*0*			
Upper Star R	*27*	0.002	0.002	0.001	*0*			
Waterview Ck	*19*	0.015	0.005	0.017	*10*	0.011	0.009	0.007