Plane Basin Grower Led Water Quality Monitoring Program

Event and Ambient Monitoring Report 2020

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for Reef Catchments (Mackay Whitsunday Isaac) Limited as part of the

Plane Basin Grower Led Water Quality Monitoring and Engagement - Rocky Dam Ck Project Stage 2

and for the Department of Agriculture and Fisheries Enhanced Extension Coordination Project.

This project has been supported by the Queensland Government Reef Water Quality Program and Reef Catchments (Mackay Whitsunday Isaac) Limited.

1.0 Introduction:

The Mackay-Whitsunday region makes up roughly 20% of the total coastline length of all Great Barrier Reef (GBR) catchments. The quality of water entering the GBR lagoon is therefore extremely important to its health and resilience in the Mackay-Whitsunday region. Increased grazing, sugarcane, horticulture, and urban development within the area are all attributed to increased outputs of sediments, nutrients, and pesticides. High concentrations and loads of these sediments, pesticides and nutrients (such as nitrogen and phosphorus) in land-based run-off have been identified as significant contributors to the decline of many of the high-quality attributes which contribute to the universal value of the Reef (Brodie *et al*. 2017; Folkers *et al.* 2014). Increased concentrations of these elements can have a variety of detrimental effects including high algal growth, pollutant build-up in sediments and marine species, reduced light/coral smothering, ecological and metabolic changes in most marine plants and animals and less coral diversity (and therefore more difficulty establishing and growing). Extensive persistence in the environment is also common for some pollutants which can last for decades. Build-up of these pollutants (e.g. pesticides or heavy metals) can adversely affect reproduction, immune systems, and have been known to cause neurological disorders and cancers (GBRMPA n.d.) of aquatic animals. Water quality decline can also have significant impacts to reef-dependent industries such as tourism and fishing. Therefore, reducing or mitigating the risk of land-based run-off will have significant positive effects on the GBR and local waterways. Reef Catchments (Mackay Whitsunday Isaac) Limited secured funding and engaged Sarina Landcare Catchment Management Association Inc. (SLCMA) as part of the Department of Agriculture and Fisheries (DAF) Enhanced Extension Coordination Project.

1.1 Objectives:

The objectives of the Plane Basin Grower Led Water Quality Monitoring Project are to:

1. Assess levels of nutrients and pesticides entering local waterways in the Plane Basin.
2. Identify any catchments where management practice change could best affect a reduction in observed nutrient and pesticide concentrations entering local waterways.
3. Improve our understanding of the potential impacts from certain agricultural practices on the local waterways within the Plane Basin.
4. Provide landholders with firsthand knowledge and experience collecting water samples to help create awareness and ownership of the health of local waterways.

This report presents only analytical data derived from monitored rain events in the Plane Basin during the 2020 wet season. It is highlighted that the fine-scale event-based comparison of concentration differences or changes within events provides an extremely valuable resource.

2.0 Methods

2.1 Monitoring sites

Event sampling locations were determined by Reef Catchments (Mackay Whitsunday Isaac) Limited. in conjunction with DAF and SLCMA within the Plane Creek basin. The Plane Creek basin is the largest of the Mackay-Whitsunday basins (approximately 2500km^2) and includes Sandy Creek, Plane Creek, Rocky Dam Creek, Cape Creek, Marion Creek, Flaggy Rock Creek and Carmila Creek. All of which drain into the Sarina Inlet, Ince Bay and Carmila Coast receiving waters.

Within the Plane Creek basin, one monitoring site was selected at each of the following six waterways: Plane Creek, Rocky Dam Creek, Marion Creek, West Hill Creek and Carmila Creek. All sampling sites were located on the main creek system (i.e., not a smaller tributary) which exhibit extensive sub-catchments of sugarcane land-use. These sites were sampled by SLCMA Officers during rain events.

Additional event-based sampling sites were located on private landholders' properties and were sampled by the landholders themselves. The monitoring sites on landholders' properties typically comprised of drainage channels, gullies, and smaller creek tributaries to allow for a more targeted understanding of their own land-based run-off.

Ambient sampling was also completed across two months (one sample per month) following the event-based sampling at the same SLCMA and landholder sites and an additional four SLCMA sites were selected across the basin. The additional five sites used for ambient water quality monitoring were: Plum Tree Creek, Cherry Tree Creek, Station Creek, Basin Creek and Flaggy Rock Creek (See Appendix).

The project was designed to focus on catchments with a high sugarcane land-use, as the Plane Creek Basin represents the highest area of sugarcane farming within the Mackay-Whitsunday region, and thus the sites selected for sampling reflect this, with the exception of Basin Creek. Basin Creek is traditionally recognised as a more 'untouched'/ natural catchment and therefor used as a control. All samples were collected between January 2020 and May 2020.

2.2 Sample methods

All water samples analysed for the Plane Basin Grower Led Water Quality Monitoring were obtained following methods outlined in the Environmental Protection (Water) Policy Monitoring and Sampling Manual (DES 2018) and in accordance with field methods developed for the Great Barrier Reef Catchment Loads Monitoring Program.

SLCMA, in accordance with Reef Catchments (Mackay Whitsunday Isaac) Limited developed and tailored a training package which was delivered to all participating landholders and samplers involved. The training consisted of background information and objectives for the project, water sampling collection and manual grab sampling, sample preservation and contamination controls. The process for sampling was designed to be simple, quick, and efficient to encourage landholders to sample for multiple events and in the future.

Manual grab samples were collected by trained SLCMA Officers, and local landholders across the catchment using a clean bucket to collect the water (and after rinsing three times). before decanting into sample bottles. Participating landholders were instructed to commence sampling when adequate local rainfall had resulted in enough run-off to create flow within drains, gullies or creeks on the property (typically >20mm). Sample collection occurred as close to the "rise", "peak" and "fall" of these rainfall events. Rise represented the initial rise of the local waterway, peak represented the middle (or peak) of the rise of the local waterway, and fall represented when the waterway height was falling and close to ambient height.

The SLCMA Officer sampled all the other 'whole of catchment' sample sites and collected landholder samples for dispatch to the laboratory, following collection of water samples by landholders. Each sample consisted of three sample bottles, corresponding to the tested parameters (nutrients and pesticides).

2.3 Sample analysis

Analysis of all samples was undertaken by ALS Environmental, Stafford. The laboratory is accredited by the National Association of Testing Authorities (NATA, Australia). All samples were analysed for 87 pesticides (See appendix) and total/dissolved nutrients (nitrogen and phosphorus).

2.4 Comparison with water quality guidelines and water quality objectives

The majority of pesticide water quality guideline values were sourced from Part 1 (amended) and Part 2 of the "Proposed Aquatic Ecosystem Protection Guideline Values for Pesticides used in the Great Barrier Reef catchment area"(King *et al.* 2017), using the guideline value associated with protecting 95% of species for that specific pesticide. The remaining pesticide guideline values were derived from ANZECC and ARMCANZ (2000). If pesticide guideline values could not be found in the previous documents, water quality objectives were taken from the Water Quality Improvement Plan's (2014-2021) target value for event-based water quality objectives relevant to the specific catchment. For samples which returned values below the limit of reporting (LOR), the LOR was halved (e.g. if the LOR was <0.01, then the value used was 0.005). The limit of reporting (LOR) is the limit of detection for that specific analyte, or the lowest concentration that can be confidently measured within the specified limits of precision and accuracy.

Dissolved inorganic nitrogen and filterable reactive phosphorus water quality objective values were similarly extracted from the Mackay Whitsunday Water Quality Improvement Plan's (2014-2021) target value for event-based water quality objectives relevant to the specific catchment. (Folkers *et al.* 2014)

Ambient sample data were compared against the same guidelines and objectives respectively, however ambient water quality objectives were used opposed to event-based objectives.

3.0 Event based results and discussion

3.1 Rainfall, events, and sampling summary

All event sampling occurred between 29/01/2020 and 09/03/2020. This period allowed all six creeks to be sampled for either three or four events (Table 1). Plane Creek and Marion Creek were sampled 1 fewer event (see Figure 2) due to low rainfall conditions and site accessibility within their respective catchments.

Table 1: 2020 event sampling details.

Date	Creeks sampled	Event #
29/01/2020	Plane Creek, Rocky Dam Creek, Marion Creek, West Hill Creek, Carmila Creek	1 - Peak
03/02/2020	Plane Creek, Rocky Dam Creek, Marion Creek, West Hill Creek, Carmila Creek	1 - Fall
18/02/2020	Rocky Dam Creek, West Hill Creek, Carmila Creek	2- Peak
20/02/2020	Rocky Dam Creek, West Hill Creek, Carmila Creek	2 - Fall
24/02/2020	Plane Creek, Rocky Dam Creek, Marion Creek, West Hill Creek, Carmila Creek	3- Peak
26/02/2020	Plane Creek, Rocky Dam Creek, Marion Creek, West Hill Creek, Carmila Creek	3 - Fall
04/03/2020	Plane Creek, Rocky Dam Creek, Marion Creek, West Hill Creek, Carmila Creek	4- Peak
09/03/2020	Plane Creek, Rocky Dam Creek, Marion Creek, West Hill Creek, Carmila Creek	4 - Fall

Rainfall data has been sourced from the Australian Government Bureau of Meteorology, Plane Creek Sugar Mill Station 33059 (Plane Creek), Koumala Hatfields Road Station 33038 (Rocky Dam Creek), Orkabie West Hill Station 33095 (Marion and West Hill Creek) and The Valley Station 33071 (Carmila Creek). Daily rainfall during each sample period is provided below in Figure 1, 2, 3 and 4.

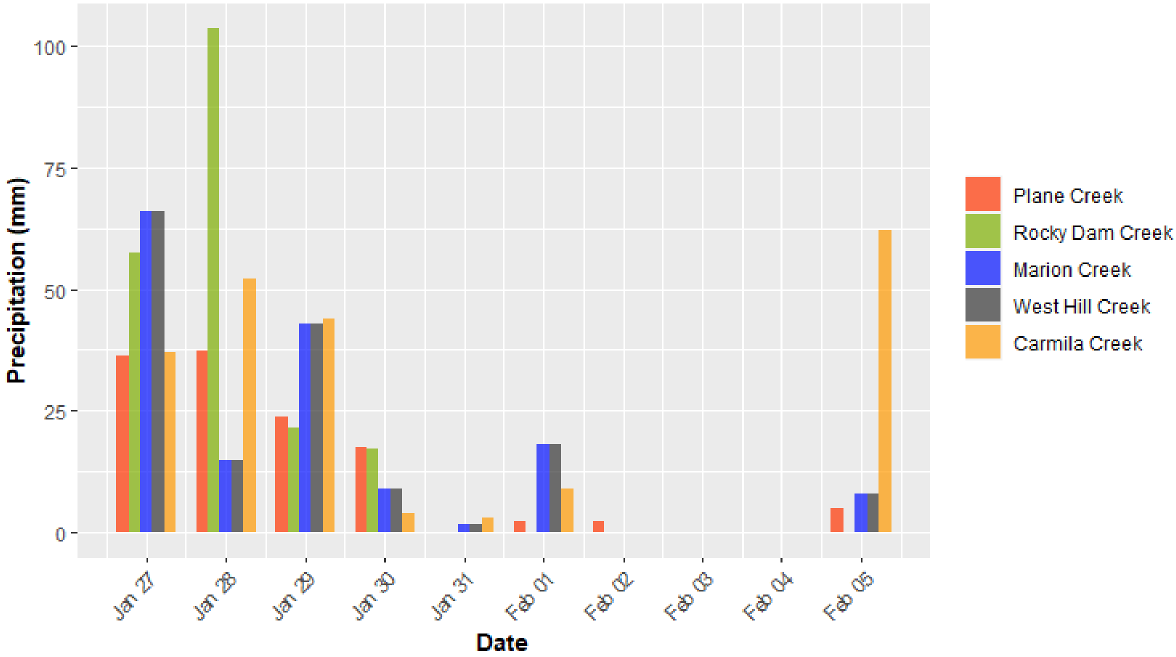

Figure 1: Daily rainfall records for each creek sampled during first sampling event 2020.

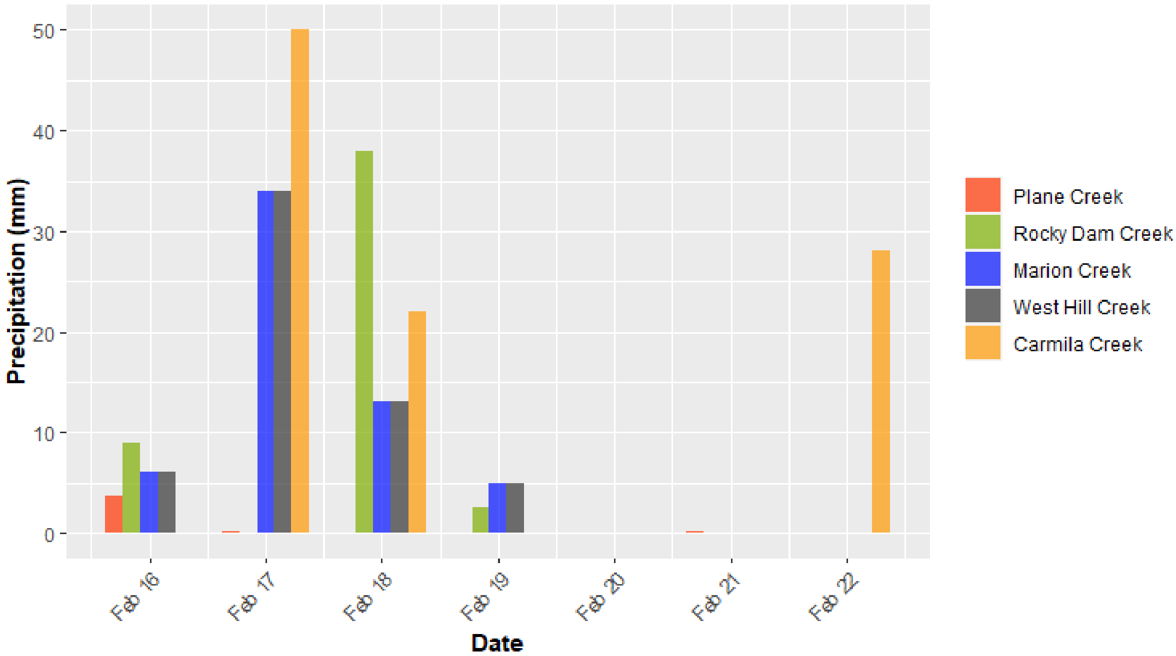

Figure 2: Daily rainfall records for each creek sampled during the second sampling event 2020.

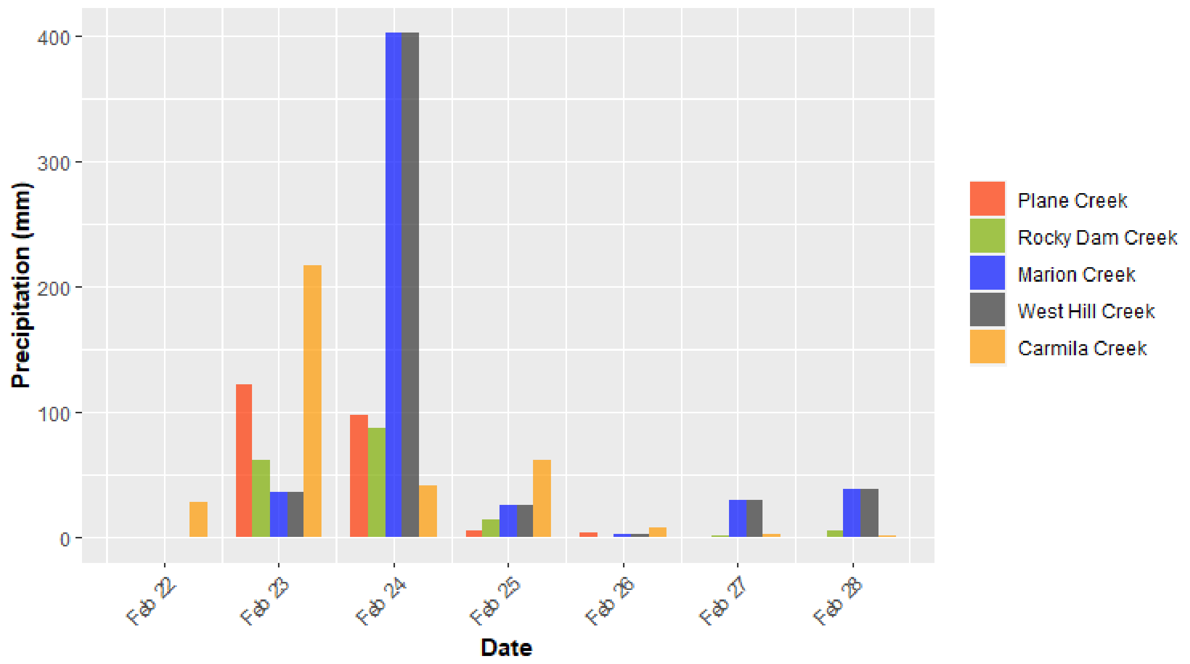

Figure 3: Daily rainfall records for each creek sampled during the third sampling event 2020.

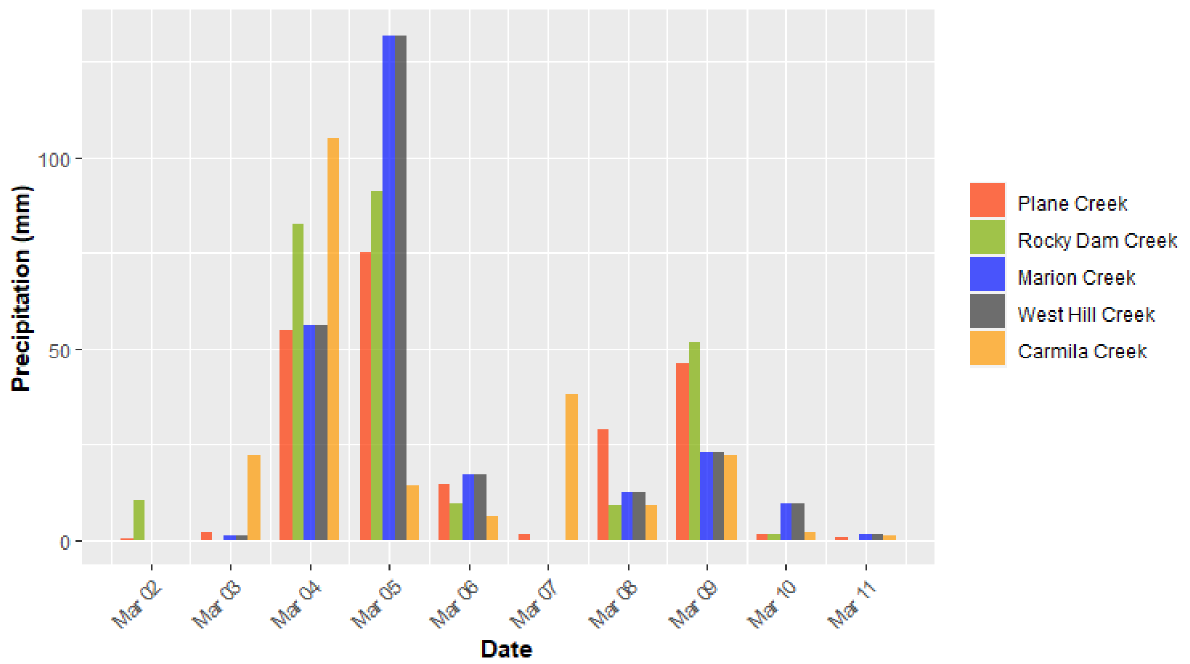

Figure 4: Daily rainfall records for each creek sampled during the third sampling event 2020.

3.1.1 Plane Creek

The most northerly site sampled in the Plane Basin was Plane Creek (approximately 37km's south of Mackay), where three events were sampled across the 2020 sampling period (Table 1).

During the three months following the commencement of the Plane Basin Grower Led Water Quality Monitoring program, rainfall over the Plane Creek catchment during the monitoring period reflected values lower than the average for each month (Figure 5). During the monitoring period the Plane Creek catchment received between 267mm and 348.2mm across each month (Australian Bureau of Meteorology Product Code: IDCJAC0009, Station 33059).

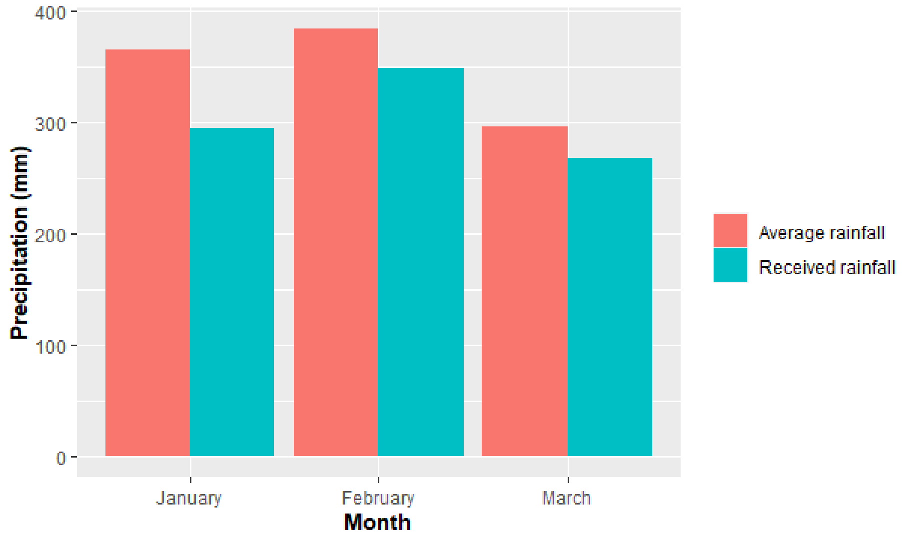

Figure 5: Monthly rainfall averages (1914-2020) versus actual rainfall received for months during the 2020 water quality monitoring period in the Plane Creek catchment.

3.1.2 Rocky Dam Creek

The second most northerly site sampled in the Plane Basin was Rocky Dam Creek (approximately 58km's south of Mackay), where four events were sampled across the 2020 sampling period (Table 1).

During the three months following the commencement of the Plane Basin Grower Led Water Quality Monitoring program, rainfall over the Rocky Dam Creek catchment during the monitoring period reflected values higher than the average for each month (Figure 6). During the monitoring period the Rocky Dam Creek catchment received between 305.5mm and 365mm across each month (Australian Bureau of Meteorology Product Code: IDCJAC0009, Station 33038).

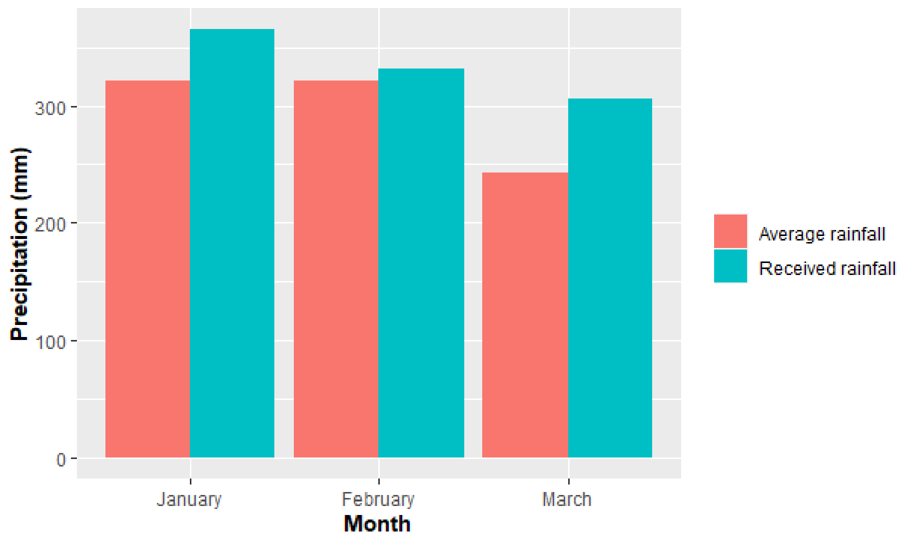

Figure 6: Monthly rainfall averages (1914-2020) versus actual rainfall received for months during the 2020 water quality monitoring period in the Rocky Dam Creek catchment.

3.1.3 Marion and West Hill Creek

The third and fourth most northerly sites sampled in the Plane Basin were Marion Creek (approximately 75km's south of Mackay), and West Hill Creek (approximately 87km's south of Mackay), respectively. A total of three events were sampled across the 2020 sampling period for

Marion Creek, and four events sampled for West Hill Creek (Table 1). These sites were combined for this section as the Orkabie West Hill weather station (33095) used for rainfall was the closest station for both creeks and therefore rainfall data were the same.

During the three months following the commencement of the Plane Basin Grower Led Water Quality Monitoring program, rainfall over the Marion Creek and West Hill Creek catchment during the monitoring period reflected values higher than the average for each month (Figure 7). During the monitoring period the catchment received between 289.2mm and 869.4mm across each month (Australian Bureau of Meteorology Product Code: IDCJAC0009, Station 33095).

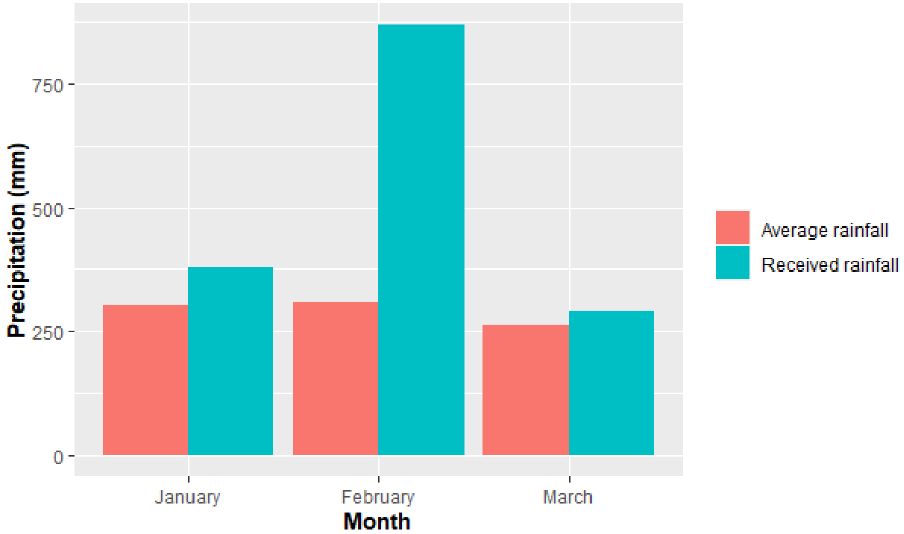

Figure 7: Monthly rainfall averages (1961-2020) versus actual rainfall received for months during the 2020 water quality monitoring period in the Marion Creek catchment.

3.1.4 Carmila Creek

The most southerly site sampled in the Plane Basin was Carmila Creek (approximately 124km's south of Mackay). A total of four events were sampled across the 2020 sampling period (Table 1) for Carmila Creek.

During the three months following the commencement of the Plane Basin Grower Led Water Quality Monitoring program, rainfall over the Carmila Creek catchment during the monitoring period reflected values higher than the average for each month (Figure 8). During the monitoring period the Carmila Creek catchment received between 132.3mm and 438mm across each month (Australian Bureau of Meteorology Product Code: IDCJAC0009, Station 33071).

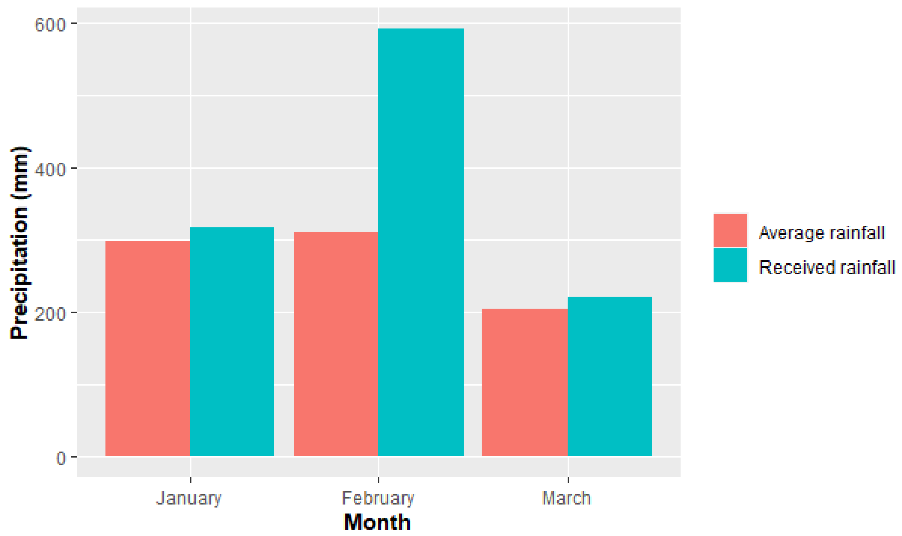

Figure 8: Monthly rainfall averages (1915-2019) versus actual rainfall received for months during the 2020 water quality monitoring period in the Marion Creek catchment.

3.2 Pesticides

The following sections provide an overview of the summary statistics of pesticide concentration data and exceedances of water quality guideline trigger values and objectives.

3.2.1 Overview of pesticide results

A total of **seven pesticides** were detected at concentrations greater than the analytical limit of reporting during the 2020 event sampling period between the five creek systems. The pesticides detected were: **hexazinone, diuron, diazinon, atrazine, imidacloprid, imazapic and metolachlor.** All other pesticides tested returned results below the limit of reporting.

3.2.2 Hexazinone

Hexazinone is a herbicide commonly used in a variety of commercial herbicide formulations. It is used extensively in agriculture as a control measure for annual, biennial, and perennial weeds (BCPC 2012; University of Hertfordshire 2013). Hexazinone typically enters aquatic environments because of vapour drift, surface and/or subsurface runoff following its application to the target area/plant. Hexazinone has been found to have low soil adsorption characteristics, indicating its high capacity to be transported in surface waters (Tu et al. 2001). These characteristics indicate hexazinone is persistent in the landscape, and highly mobile in surface, subsurface and ground waters (King et al. 2017).

Guideline values for hexazinone were extracted from the Proposed aquatic ecosystem protection guideline values for pesticides commonly used in the Great Barrier Reef catchment area: Part 1 (amended). The proposed aquatic ecosystem protection guideline values (µg/L) for hexazinone for the protection of 95% of species in freshwater ecosystems was **1.1µg/L** (King *et al.* 2017). **Results presented below (Figure 9) show no samples returned concentrations higher than the guideline values for any sample or event.**

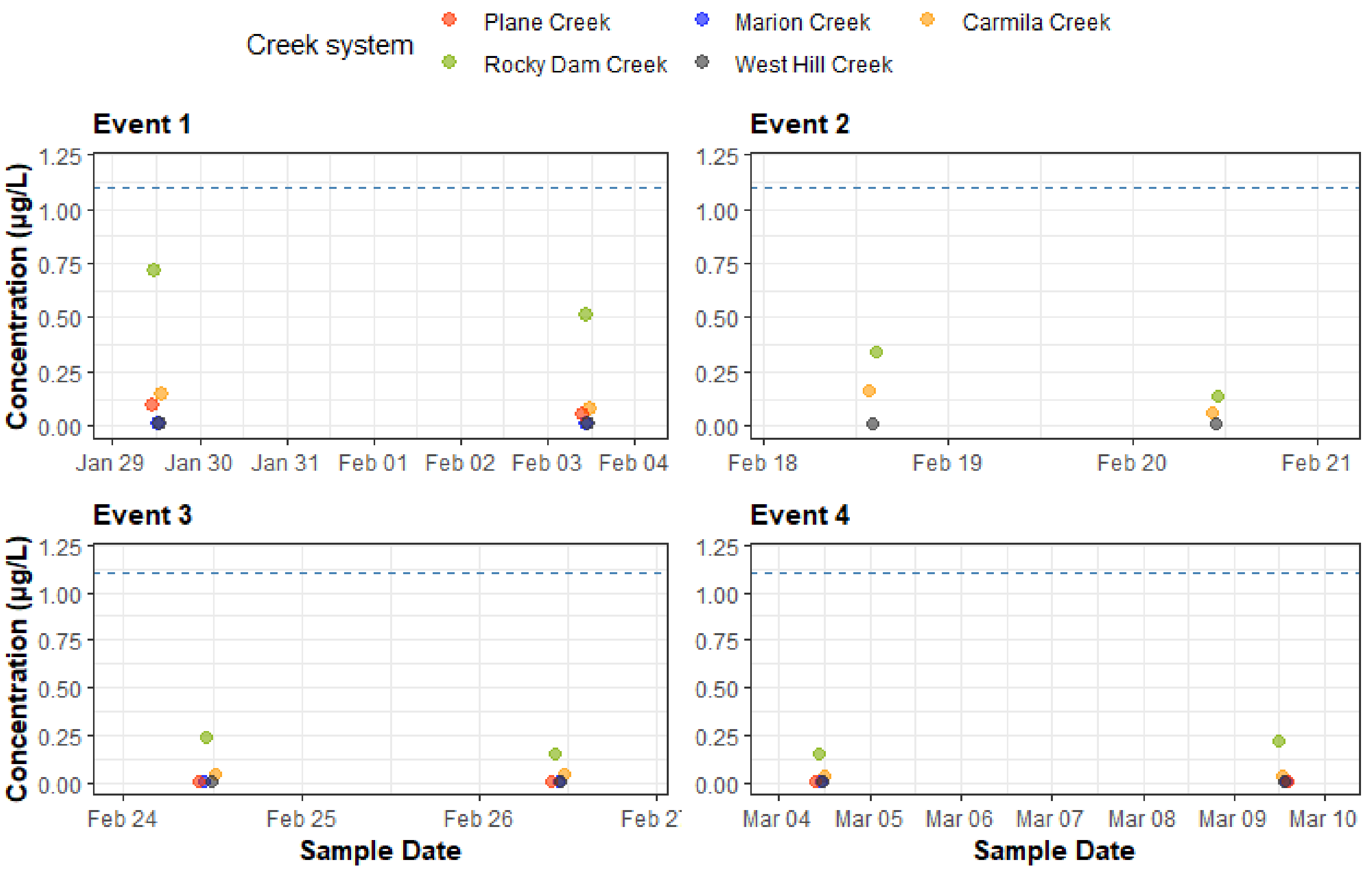

Figure 9: Hexazinone concentrations for all sampled creeks across all four events during 2020. Blue dashed lines represent the guideline value for hexazinone for the protection of 95% of species in freshwater ecosystems.

3.2.3 Diuron

Diuron is used widely used in the agriculture and forestry industry for the control of broad-spectrum weeds, the selective control of germinating grass and broad-leaved weeds in a variety of crops, including sugarcane, and weeds/algae within and/or around water bodies (BCPC 2012; King *et al*. 2017; University of Hertfordshire 2013). Within Australia, diuron was one of the most heavily used herbicides because of its use as both a pre-emergence, residual herbicide, and a post-emergence knockdown (AATSE 2002). Considered relatively mobile, surface and subsurface run-off from agricultural applications are the most common pathways for diuron ending up in aquatic environments, typically after heavy or persistent rainfall. However, it does exhibit low soil adsorption characteristics.

Guideline values for diuron were extracted from the Proposed aquatic ecosystem protection guideline values for pesticides commonly used in the Great Barrier Reef catchment area: Part 1 (amended). The proposed aquatic ecosystem protection guideline values (µg/L) for diuron for the protection of 95% of species in freshwater ecosystems was **0.23µg/L (King *et al.* 2017). Results presented below (Figure 10) show concentrations higher than the guideline values for five samples only in Rocky Dam Creek samples for Event 1, 2 and 3.**

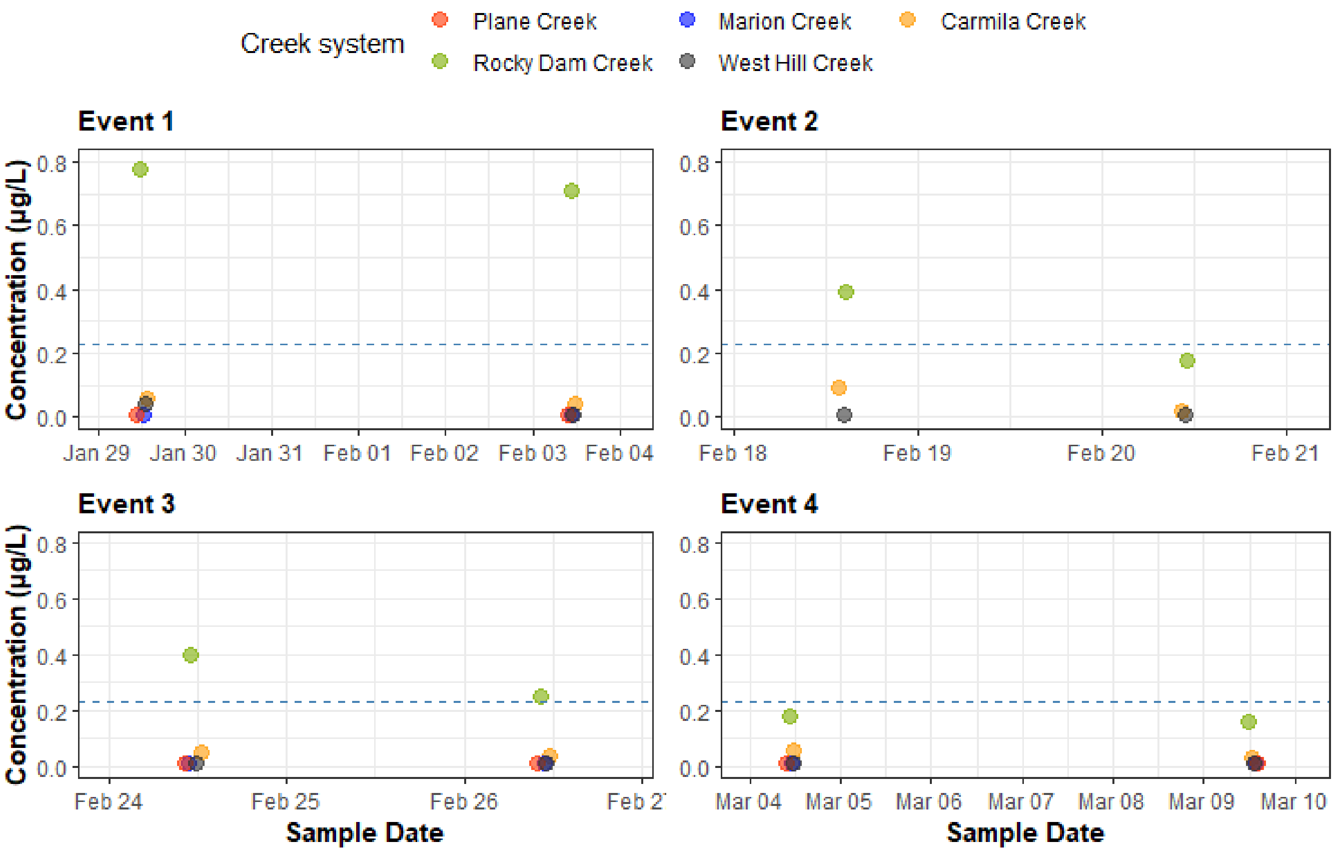

Figure 10: Diuron concentrations for all sampled creeks across all four events during 2020. Blue dashed lines represent the guideline value for diuron for the protection of 95% of species in freshwater ecosystems.

3.2.4 Diazinon

Diazinon is a contact insecticide commonly used in agriculture for the control of soil and foliage insects and pests on a variety of food crops. Diazinon has moderate water solubility and a medium to very high tendency to bind to soil (Harper 2009). It exhibits a half-life of 138 days in neutral water (pH 7), compared to only 12 days in acidic water (pH 5) eluding to its potential persistence in aquatic environments.

Guideline values for diazinon were extracted from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000). The proposed guideline trigger values for diazinon, for the protection of 95% of species in freshwater ecosystems was **0.01µg/L** (ANZECC & ARMCANZ 2000). **Results presented below (Figure 11) show concentrations higher than the guideline values for seven samples within Event 2, 3 and 4 across multiple creeks.**

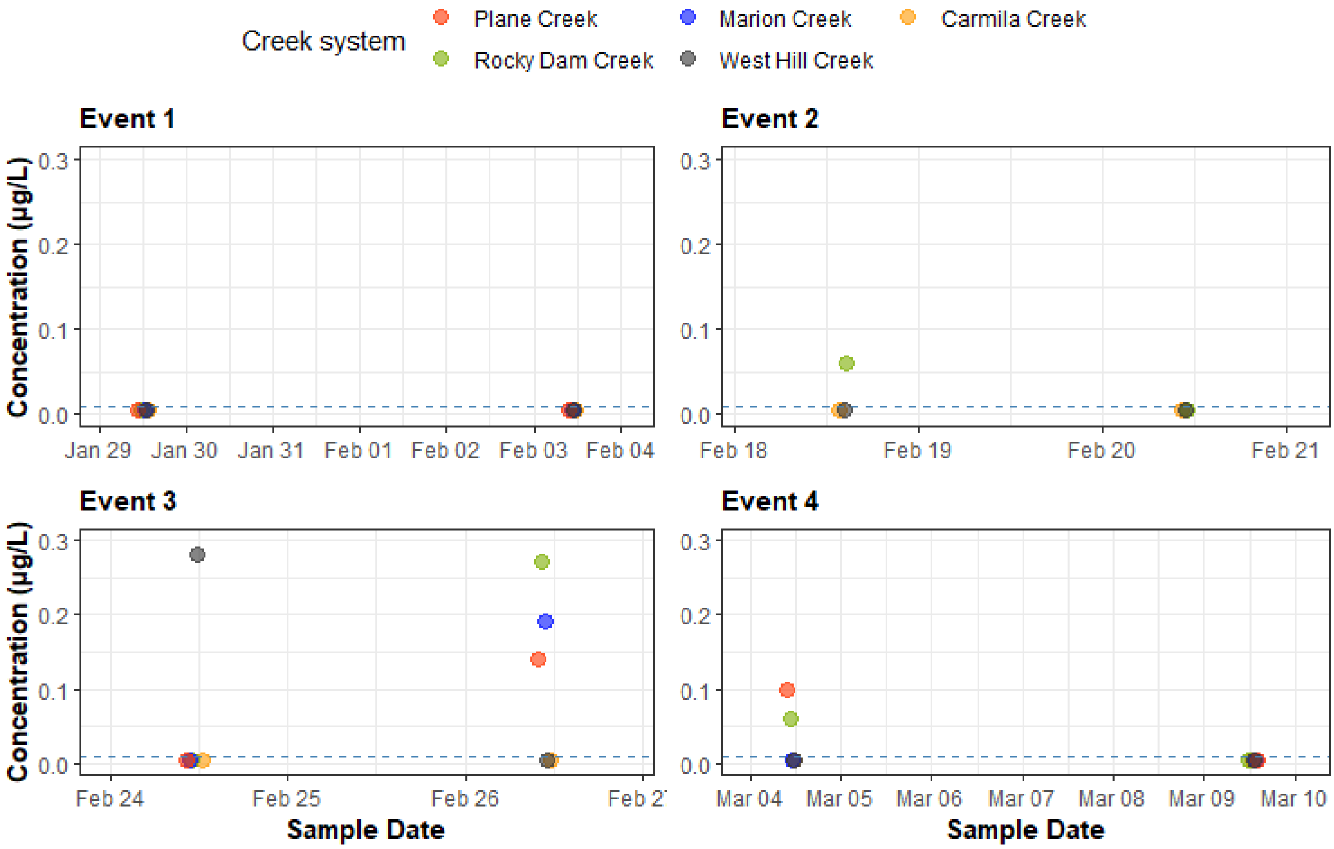

Figure 11: Diazinon concentrations for all sampled creeks across all four events during 2020. Blue dashed lines represent the guideline value for diazinon for the protection of 95% of species in freshwater ecosystems.

3.2.5 Atrazine

Atrazine is a herbicide used for controlling a variety of pre- and post-emergent grasses and broadleaved weeds in a variety of agricultural crops. Atrazine is one of the most widely used herbicide in Australian agriculture. It is known to be persistent in aquatic ecosystems (including groundwater) due to its slow break-down, and it exhibits a high to very-high mobility based on its soil adsorption coefficient. Typically, atrazine enters an aquatic ecosystem as a result of land-based run-off, although atrazine may also enter the air following application to the soil (ATSDR 2003).

Guideline values for atrazine were extracted from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000). The proposed guideline trigger values for atrazine, for the protection of 95% of species in freshwater ecosystems was **13µg/L** (ANZECC & ARMCANZ 2000). **Results presented below (Figure 12) show no concentrations higher than the guideline values for Event 1.**

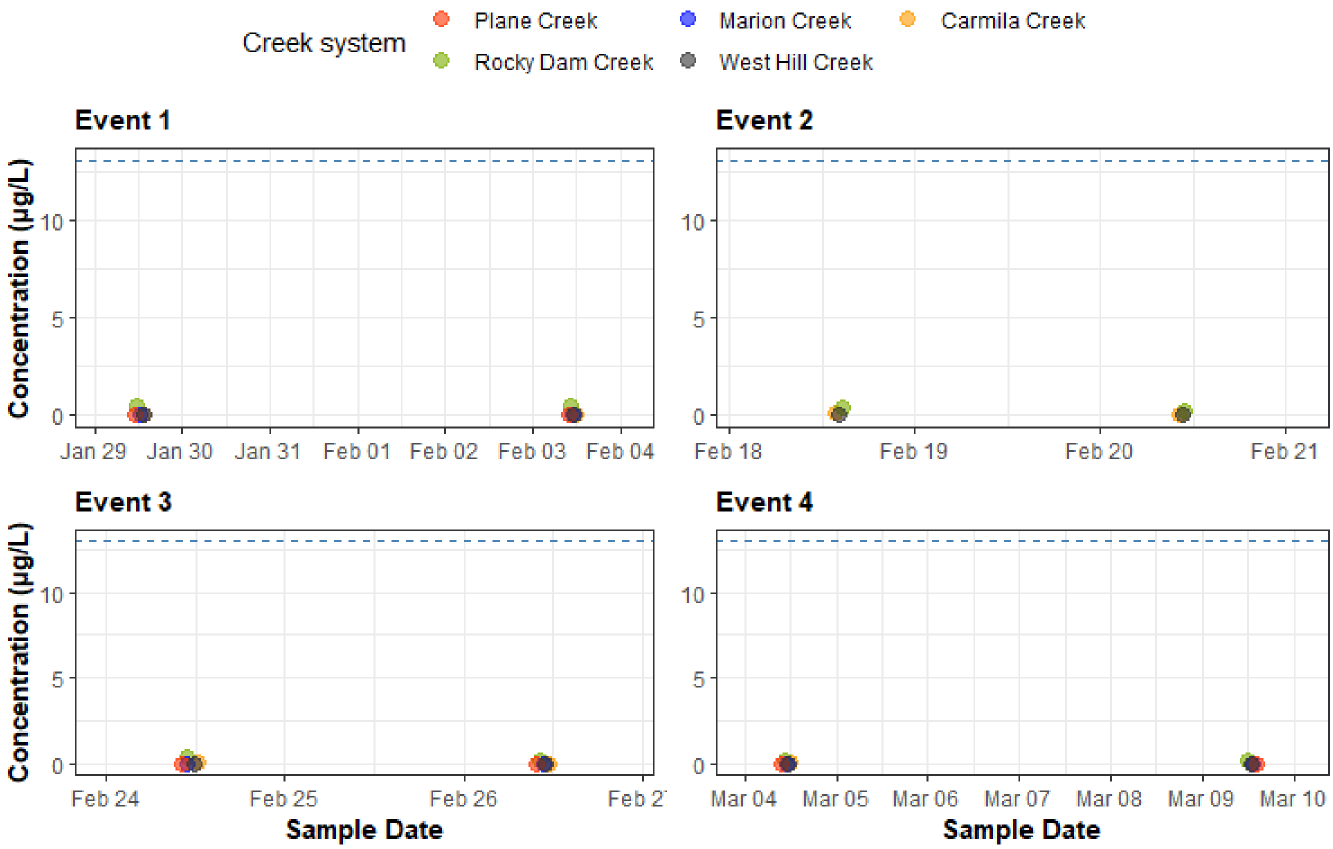

Figure 12: Atrazine concentrations for all sampled creeks across all four events during 2020. Blue dashed lines represent the guideline value for atrazine for the protection of 95% of species in freshwater ecosystems.

3.2.6 Imidacloprid

Imidacloprid is an insecticide used on lawns and in agricultural applications to control sucking, soil and some biting insects (BCPC 2012). Within the Great Barrier Reef Catchment area however, imidacloprid is the most commonly applied insecticide for canegrub control (APVMA 2014; Davis *et al.* 2008). Imidacloprid exhibits very high solubility in water and medium to high soil adsorption ability which suggests a moderate potential to leach in soil. Likewise, imidacloprid is highly persistent in soils. It is likely that imidacloprid exists in aquatic environments because of spray drift or run-off after application (King et al. 2017; Tišler *et al.* 2009).

Guideline values for imidacloprid were extracted from the Proposed aquatic ecosystem protection guideline values for pesticides commonly used in the Great Barrier Reef catchment area: Part 1 (amended). The proposed aquatic ecosystem protection guideline values (µg/L) for imidacloprid for the protection of 95% of species in freshwater ecosystems was **0.11µg/L** (King *et al.* 2017). **Results presented below (Figure 13) show nine samples returned concentrations higher than the guideline values for any sample.**

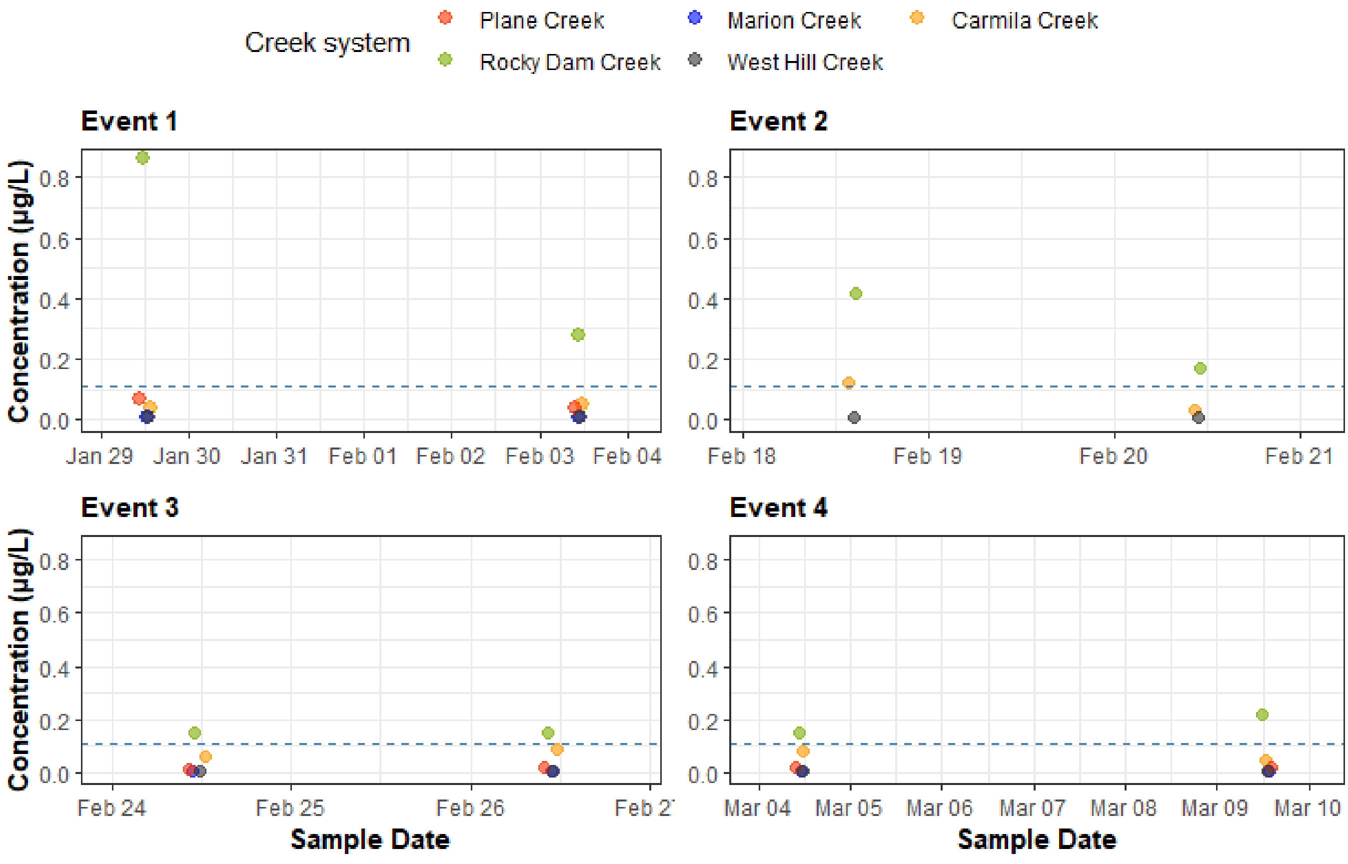

Figure 13: Imidacloprid concentrations for all sampled creeks across all four events during 2020. Blue dashed lines represent the guideline value for imidacloprid for the protection of 95% of species in freshwater ecosystems.

3.2.7 Imazapic

Imazapic is a herbicide regularly mixed with a variety of other herbicides including glyphosate, to increase its efficacy. Typically, it is used for controlling annual and perennial broadleaf grasses and some broadleaf weeds in both pre and post emergent control (University of Hertfordshire 2013). Imazapic has high aqueous solubility, weak binding potential to soils and low adsorption to suspended soils which indicates a moderate mobility. However, although it has a weak potential to bind to soils, it is persistent in soil, with half-lives ranging from 31 – 410 days depending on soil types and climactic conditions (BCPC 2012; King *et al.* 2017; Tu *et al.* 2001).

Guideline values for imazapic were extracted from the Proposed aquatic ecosystem protection guideline values for pesticides commonly used in the Great Barrier Reef catchment area: Part 1 (amended). The proposed aquatic ecosystem protection guideline values (µg/L) for imazapic for the protection of 95% of species in freshwater ecosystems was **0.41µg/L** (King *et al.* 2017). **Results presented below (Figure 14) show two samples returned concentrations higher than the guideline values for Rocky Dam Creek samples in Event 1.**

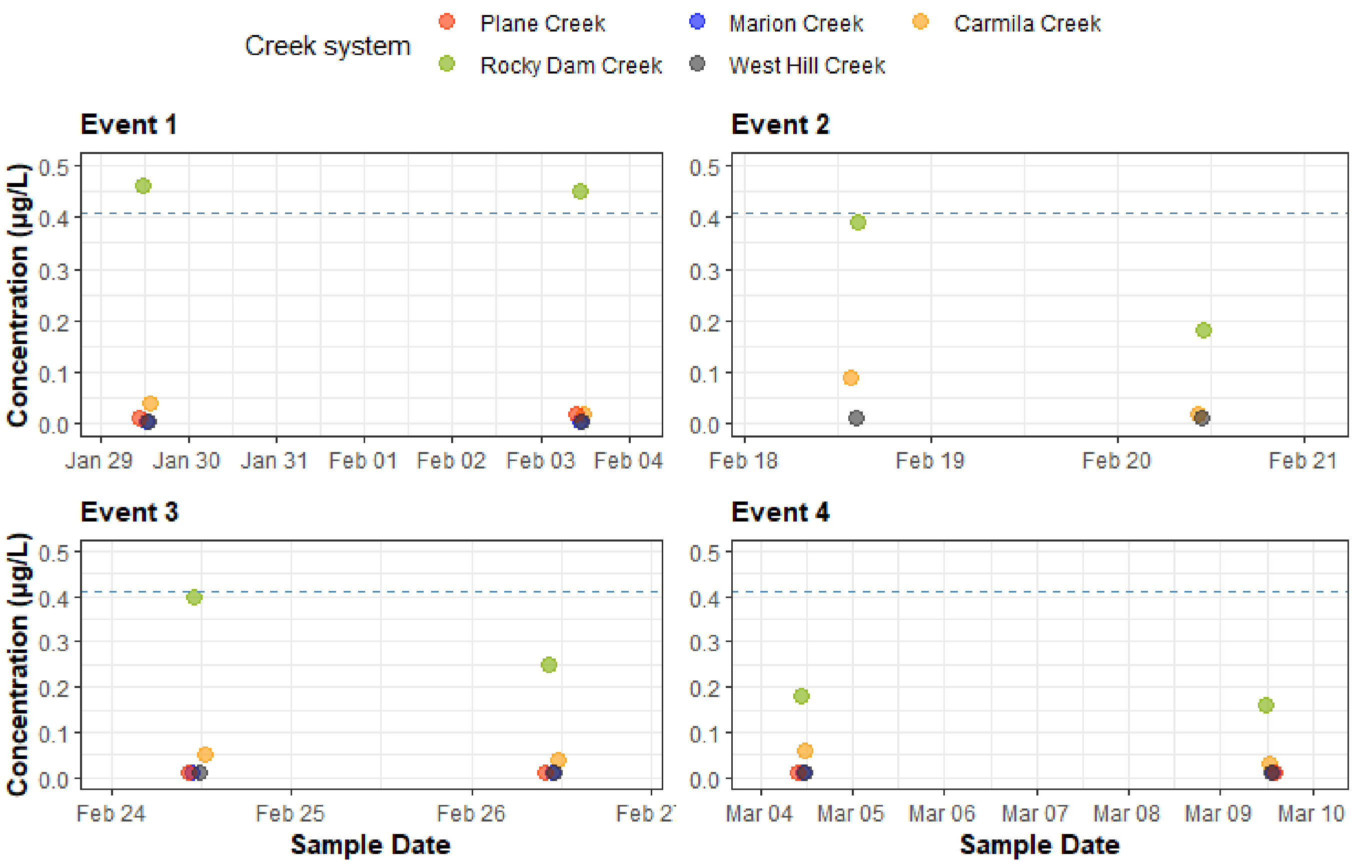

Figure 14: Imazapic concentrations for all sampled creeks across all four events during 2020. Blue dashed lines represent the guideline value for imazapic for the protection of 95% of species in freshwater ecosystems.

3.2.8 Metolachlor

Metolachlor is a herbicide used extensively in agriculture for the pre-emergent and early-post emergent control of annual and perennial broadleaf weeds, and does not affect established plants (Liu and Xiong 2009; CCME 1999; University of Hertfordshire 2013). Metolachlor exhibits low soil adsorption abilities, and therefore has high capacity to end up in surface waters via run-off (King *et al.* 2017).

Guideline values for metolachlor were extracted from the Proposed aquatic ecosystem protection guideline values for pesticides commonly used in the Great Barrier Reef catchment area: Part 1 (amended). The proposed aquatic ecosystem protection guideline values (µg/L) for metolachlor for the protection of 95% of species in freshwater ecosystems was **0.71µg/L (King *et al.* 2017). Results presented below (Figure 15) show no concentrations higher than the guideline values for one any sample or event.**

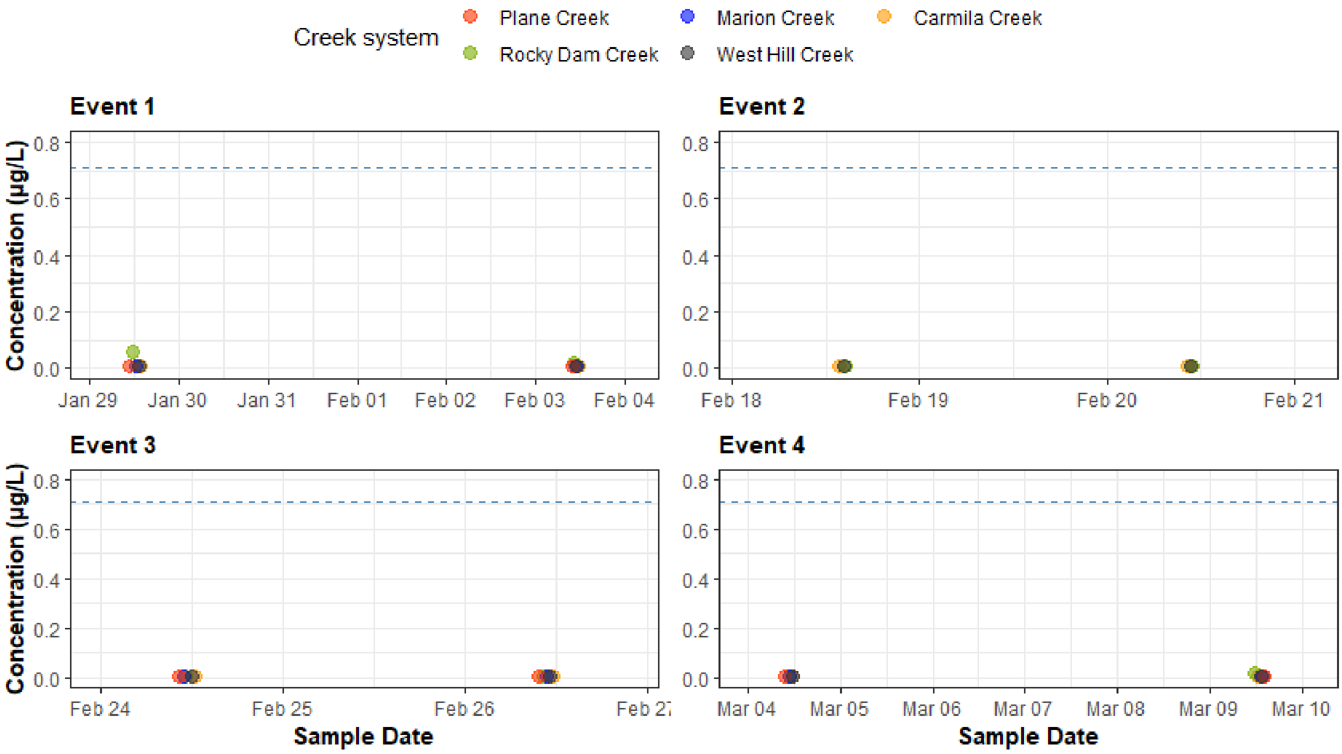

Figure 15: Metolachlor concentrations for all sampled creeks across all four events during 2020. Blue dashed lines represent the guideline value for metolachlor for the protection of 95% of species in freshwater ecosystems.

3.3 Nutrients

The following sections provide an overview of the summary statistics of nutrient concentration data and exceedances of water quality guideline trigger values and objectives.

3.3.1 Total suspended solids

Total suspended solids (TSS) is the dry weight of solids in water which can be caught in a filter (are not dissolved). Suspended solids can adversely affect aquatic ecosystems through a variety of pathways, however, typically suspended solids act to reduce light which would typically penetrate a waterway, in turn reducing primary production and potentially damaging phytoplankton, macrophytes, seagrasses, or benthic organisms and their habitats (ANZECC & ARMCANZ 2000).

Water quality objectives for TSS were extracted from the Mackay-Whitsunday Water Quality Improvement Plan (2014-2021). The target event-based water quality objectives for TSS in the catchment management area for the protection of 95% of species are shown in each graph in Figure 16 for the respective catchment management area. **Results presented below (Figure 16) show four samples collected from Rocky Dam Creek, Marion Creek and Carmila Creek returning concentrations higher than event-based objectives. However, no other samples showed concentrations above the respective event-based water quality objective for TSS.**

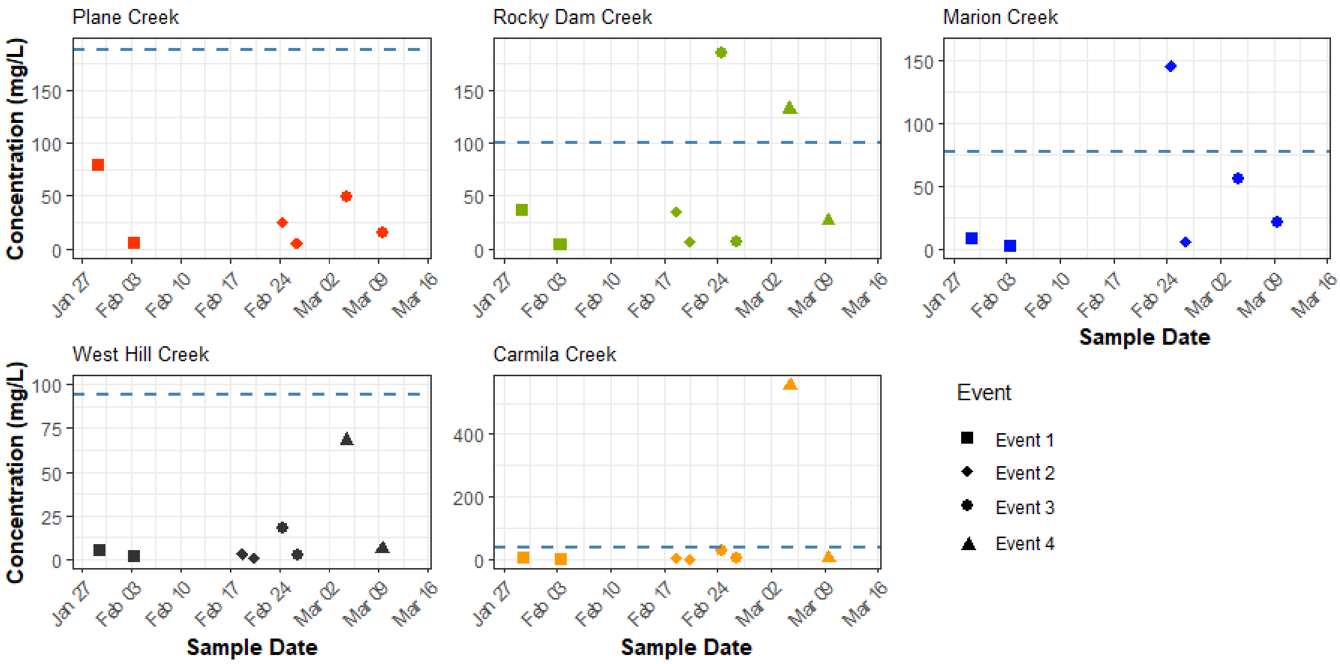

Figure 16: TSS concentrations (mg/L) for all sampled creeks across all four events during 2020. Blue dashed lines represent the relevant target event-based water quality objectives for TSS from the Mackay-Whitsunday Water Quality Improvement Plan (2014-2021) for that catchment management area.

3.3.2 Dissolved inorganic nitrogen

Dissolved inorganic nitrogen (DIN) refers to the concentrations of nitrate plus nitrite and ammonium, and commonly acts as a limitation for primary productivity. DIN has been recognised as a high-risk pollutant in the Mackay-Whitsunday region, with sugarcane contributing 78% of anthropogenic DIN load (Folkers et al. 2014). DIN also exhibits high solubility indicating its ability to be easily transported among ecosystems (Galloway et al. 2004). Typically, fertilisers containing nitrogen are the primary cause to increased levels of DIN in local waterways and the Reef. Increased levels of DIN in run-off to the GBR are understood to be responsible for extensive increases in algal blooms, crown-of-thorn starfish outbreaks, susceptibility to coral bleaching/coral diseases, and can lower coral diversity (Wallace et al. 2017).

Water quality objectives for DIN were extracted from the Mackay-Whitsunday Water Quality Improvement Plan (2014-2021). The target event-based water quality objectives for DIN in the catchment management area for the protection of 95% of species are shown below in Figure 17 for the respective catchment management area. **Results presented below (Figure 17) shows five sample returned concentrations higher than the guideline values across Rocky Dam Creek and Carmila Creek.**

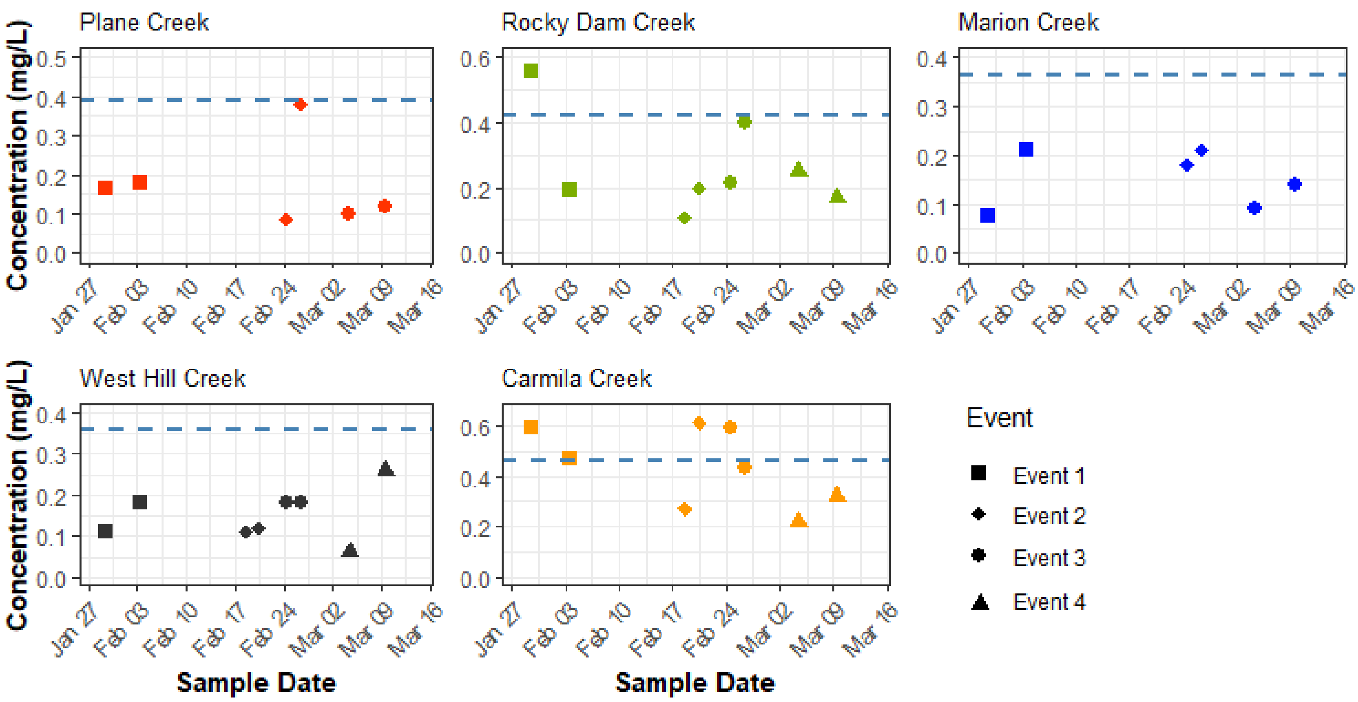

Figure 17: DIN concentrations (mg/L) for all sampled creeks across all four events during 2020. Blue dashed lines represent the target event-based water quality objectives for DIN from the Mackay-Whitsunday Water Quality Improvement Plan (2014-2021).

3.3.3 Filterable reactive phosphorus

Phosphorus (P) is required by all organisms for basic life processes. Phosphorus is a naturally occurring nutrient (found in rocks, soils, and organic material etc.) which binds readily with soil particles. Phosphorus is used extensively in fertilizers, which are one of the primary contributors to increased phosphorus levels in waterways. Increased level of P can result in excessive growth of aquatic plants which can lead to further problems such as toxic effects (especially due to cyanobacteria), reductions to dissolved oxygen concentrations, reduction in recreational amenity, blocking of waterways and changes to biodiversity.

Water quality objectives for filterable reactive phosphorus (FRP) were extracted from the Mackay-Whitsunday Water Quality Improvement Plan (2014-2021). The target event-based water quality objectives for FRP in the catchment management area for the protection of 95% of species is shown in Figure 18**. Results presented below (Figure 18) show concentrations higher than the guideline values for three samples taken.**

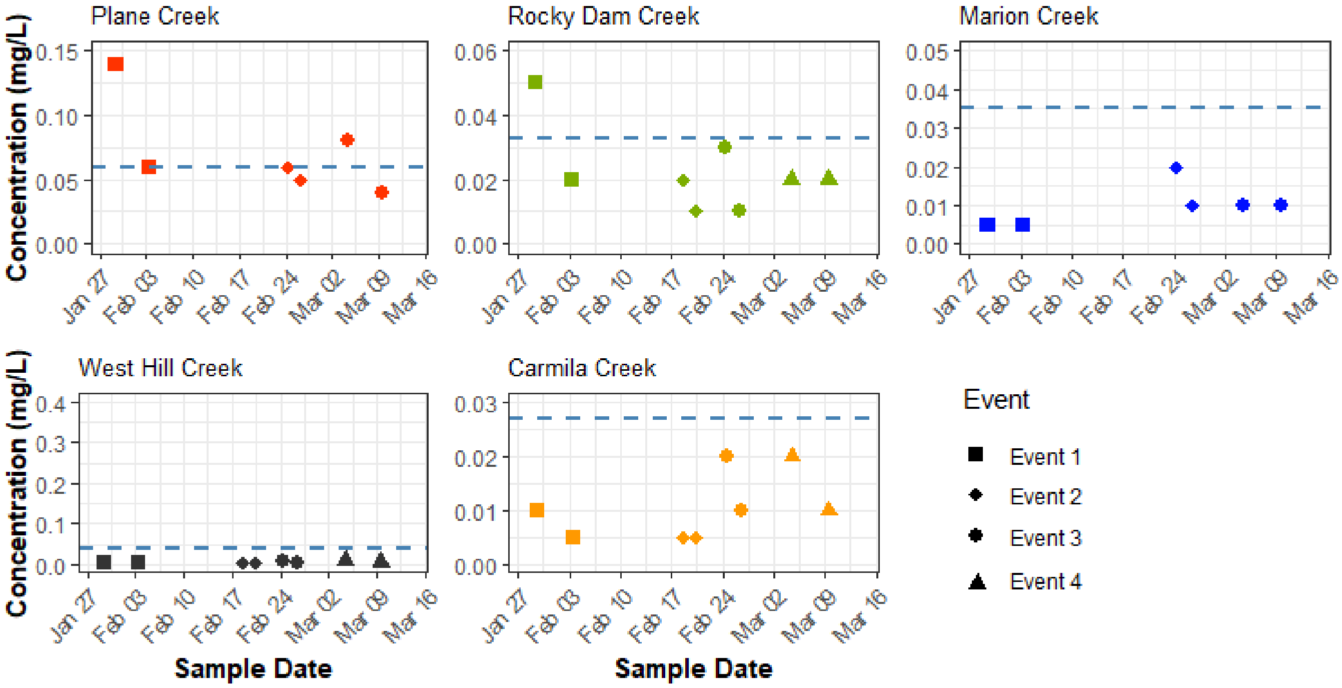

Figure 18: FRP concentrations (mg/L) for all sampled creeks across all four events during 2020. Blue dashed lines represent the target event-based water quality objectives for FRP from the Mackay-Whitsunday Water Quality Improvement Plan (2014-2021).

3.3.4 Total Nitrogen

Nitrogen (N) is required by all organisms for basic life processes. However, high concentrations of nitrogen can have adverse effects on waterway health, such as overstimulation of aquatic plants which can clog waterways, deprive waterways of dissolved oxygen and block light penetrating to lower levels. Sources of nitrogen in waterways includes introduction via cropland, sewage, fertilisers, animal manure/storage areas among others. Total nitrogen (TN) is calculated by adding Total Kjedahl Nitrogen (TKN) and nitrite + nitrate as N (NOX) (i.e. TN = TKN + NOX).

No guideline values have been assigned for total nitrogen within any referenced literature used previously in this report and thus these results are presented without guideline values/objectives. **Plane Creek, Rocky Dam Creek and Carmila Creek returned the highest concentrations of TN across all sites and events (Figure 19).**

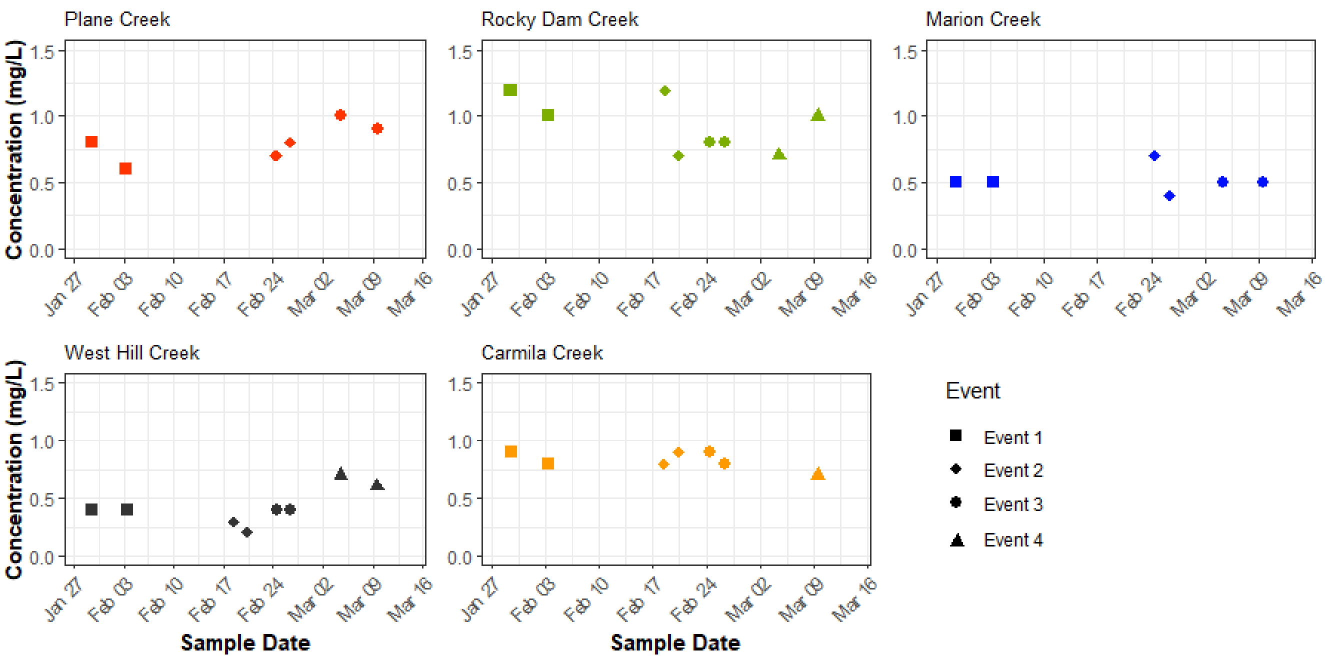

Figure 19: Total nitrogen concentrations (mg/L) for all sampled creeks across all four events during 2020.

3.3.5 Total Phosphorus

Total phosphorus (TP) unlike FRP includes all forms of phosphorus (including FRP) both dissolved, and particulate. This includes any plant and animal fragments suspended in a waterbody which can contribute to phosphorus concentrations.

No guideline values have been assigned for total nitrogen within any referenced literature used previously in this report and thus these results are presented without guideline values/objectives. **Carmila Creek returned the highest concentrations of TP in later events in the 2020 wet season (Figure 20).**

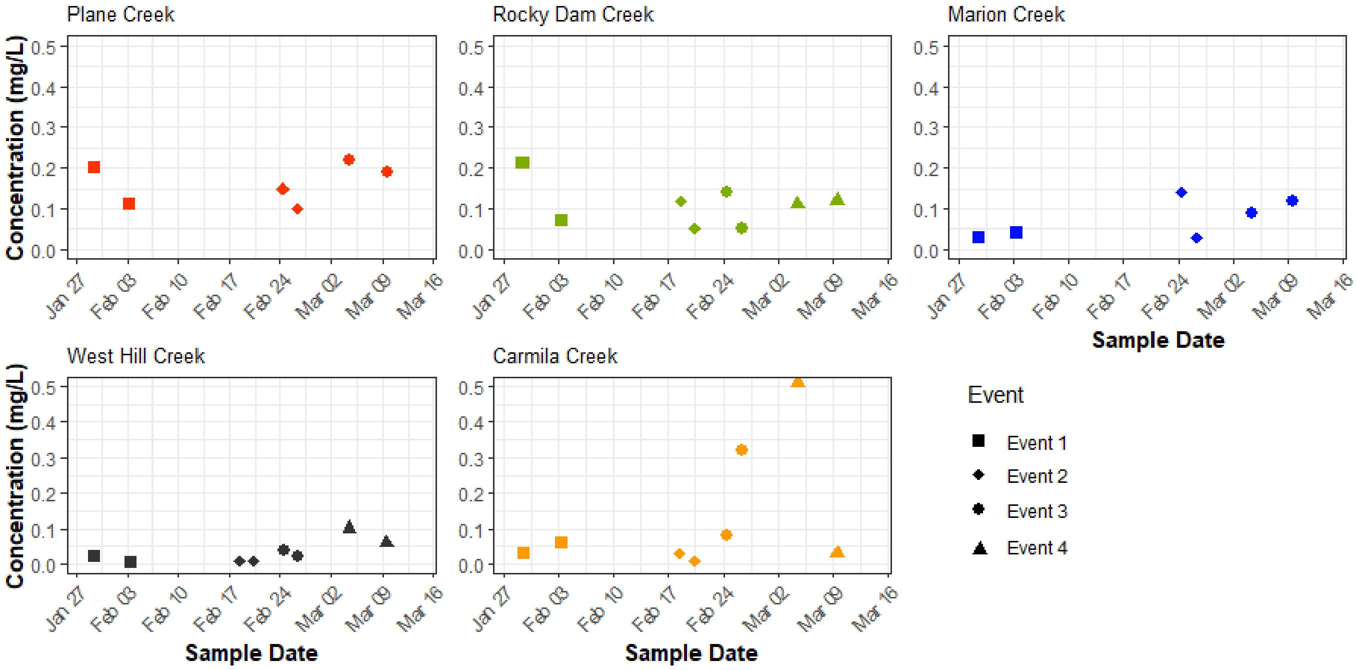

Figure 20: Total phosphorus concentrations (mg/L) for all sampled creeks across all four events during 2020.

4.0 Ambient water quality samples

Ambient water quality samples differ from event-based sampling, in that ambient sampling occurs when the flow of water is predominantly affected by groundwater discharge and the land-based flow element is small (i.e. no flow from rainfall run-off). An additional five creeks were sampled during this portion of the monitoring program to provide a broader understanding of surrounding creeks in ambient conditions.

Table 2: Sampling summary for ambient sampling periods.

Date	Creeks sampled	Ambient #
15/04/2020	Plane Creek, Rocky Dam Creek, Marion Creek, West Hill Creek, Carmila Creek	1
16/04/2020	Plum Tree Creek, Cherry Tree Creek, Basin Creek, Flaggy Rock Creek	1
13/05/2020	Plane Creek, Rocky Dam Creek, Marion Creek, West Hill Creek, Carmila Creek	2
14/05/2020	Plum Tree Creek, Cherry Tree Creek, Basin Creek, Flaggy Rock Creek, Station Creek	2

4.1 Ambient results

4.1.1 Pesticides

A total of **four pesticides** were detected at concentrations greater than the analytical limit of reporting across ambient water quality samples. The pesticides detected were **hexazinone, diuron,**

imidacloprid and imazapic. One or more of these pesticides were found in Rocky Dam Creek, Carmila Creek, Cherry Tree Creek, Station Creek and Plum Tree Creek.

Guideline values for pesticides were extracted from the Proposed aquatic ecosystem protection guideline values for pesticides commonly used in the Great Barrier Reef catchment area: Part 1 (amended) and Part 2. No pesticides during the ambient sampling component of the project returned concentrations higher than any guideline values.

Table 3: Rocky Dam Creek pesticide concentrations returned for ambient samples 2020 showing comparison to guideline value. If Result (µg/L) column, then the value is below the guideline value for projection of 95% of species in freshwater ecosystems.

Rocky Dam Creek pesticide concentrations				
Date	**Time**	**Sample number**	**Result (µg/L)**	**Guideline Value (µg/L)**
Hexazinone concentrations				
15/04/2020	10:25 AM	Ambient 1	0.12	1.1
13/05/2020	10:05 AM	Ambient 2	0.02	1.1
Diuron concentrations				
15/04/2020	10:25 AM	Ambient 1	0.11	0.23
13/05/2020	10:05 AM	Ambient 2	<0.02	0.23
Imidacloprid concentrations				
15/04/2020	10:25 AM	Ambient 1	0.04	0.11
13/05/2020	10:05 AM	Ambient 2	<0.01	0.11
Imazapic concentrations				
15/04/2020	10:25 AM	Ambient 1	0.02	0.41
13/05/2020	10:05 AM	Ambient 2	<0.01	0.41

Table 4: Carmila Creek hexazinone concentrations returned for ambient samples 2020 showing comparison to guideline value. If Result (µg/L) column is green, then the value is below the guideline value for projection of 95% of species in freshwater ecosystems, if red then the value is above the guideline value.

Carmila Creek - Hexazinone concentrations				
Date	**Time**	**Sample number**	**Result (µg/L)**	**Guideline Value (µg/L)**
15/04/2020	11:25 AM	Ambient 1	0.03	1.1
13/05/2020	11:15 AM	Ambient 2	<0.02	1.1

Table 5: Cherry Tree Creek hexazinone concentrations returned for ambient samples 2020 showing comparison to guideline value. If Result (µg/L) column is green, then the value is below the guideline value for projection of 95% of species in freshwater ecosystems, if red then the value is above the guideline value.

Cherry Tree Creek - Hexazinone concentrations				
Date	**Time**	**Sample number**	**Result (µg/L)**	**Guideline Value (µg/L)**
16/04/2020	10:40 AM	Ambient 1	0.04	1.1
14/05/2020	10:05 AM	Ambient 2	<0.02	1.1

Table 6: Station Creek pesticide concentrations returned for ambient samples 2020 showing comparison to guideline value. If Result (µg/L) column is green, then the value is below the guideline value for projection of 95% of species in freshwater ecosystems, if red then the value is above the guideline value.

Station Creek - Hexazinone concentrations				
Date	**Time**	**Sample number**	**Result (µg/L)**	**Guideline Value (µg/L)**
14/05/2020	10:20 AM	Ambient 1	0.06	1.1
Diuron concentrations				

14/05/2020	10:20 AM	Ambient 1	0.02	0.23

Table 7: Plum Tree Creek hexazinone concentrations returned for ambient samples 2020 showing comparison to guideline value. If Result (µg/L) column is green, then the value is below the guideline value for projection of 95% of species in freshwater ecosystems, if red then the value is above the guideline value.

Plum Tree Creek - Hexazinone concentrations				
Date	**Time**	**Sample number**	**Result (µg/L)**	**Guideline Value (µg/L)**
16/04/2020	10:20 AM	Ambient 1	0.02	1.1
14/05/2020	09:55 AM	Ambient 2	<0.02	1.1

4.1.2 Nutrients

Water quality objectives for nutrients were extracted from the Mackay-Whitsunday Water Quality Improvement Plan (2014-2021). The target ambient-based water quality objectives for nutrients in the catchment management are shown in Table 8. **Results presented below (Table 8) show eight samples returned concentrations higher than the guideline values during the ambient water quality monitoring period for 2020.**

Table 8: Creek nutrient concentrations returned for ambient samples 2020 showing comparison to guideline value (when possible, if not then n/a). If Result column is green, then the value is below the target ambient-based water quality objective (WQO) for projection of 95% of species in freshwater ecosystems, if red then the value is above the guideline value, if orange then the same value as the WQO.

Site name	Date	Ambient sample	TSS (mg/L)		DIN (mg/L)		FRP (mg/L)		TN (mg/L)	TP (mg/L)
			Result	WQO	Result	WQO	Result	WQO	Result	Result
Plane Creek	16/04/2020	1	5	3	0.09	0.08	0.01	8	0.6	0.05
Plane Creek	14/05/2020	2	3	3	0.02	0.08	0.01	8	0.4	0.06
Rocky Dam Creek	16/04/2020	1	6	4	0.16	0.01	<0.01	6	0.5	0.03
Rocky Dam Creek	14/05/2020	2	3	4	0.1	0.01	<0.01	6	0.3	0.02
Marion Creek	16/04/2020	1	<1	3	0.18	0.08	<0.01	5	0.2	0.01
Marion Creek	14/05/2020	2	<1	3	0.02	0.08	<0.01	5	0.1	0.01
West Hill Creek	16/04/2020	1	<1	2	0.05	0.09	<0.01	2	0.2	0.02
West Hill Creek	14/05/2020	2	1	2	0.02	0.09	<0.01	2	0.2	0.01
Carmila Creek	16/04/2020	1	1	3	0.3	0.08	<0.01	5	0.5	0.01
Carmila Creek	14/05/2020	2	<1	3	0.17	0.08	<0.01	5	0.3	<0.01
Cherry Tree Creek	16/04/2020	1	<1	n/a	0.23	n/a	<0.01	n/a	0.4	0.02
Cherry Tree Creek	14/05/2020	2	<1	n/a	0.13	n/a	<0.01	n/a	0.3	<0.01
Plum Tree Creek	16/04/2020	1	<1	n/a	1.34	n/a	<0.01	n/a	0.7	0.03
Plum Tree Creek	14/05/2020	2	<1	n/a	0.24	n/a	<0.01	n/a	0.4	<0.01
Basin Creek	16/04/2020	1	<1	n/a	<0.01	n/a	<0.01	n/a	<0.01	<0.01
Basin Creek	14/05/2020	2	3	n/a	0.02	n/a	<0.01	n/a	0.2	<0.01
Flaggy Rock Creek	16/04/2020	1	<1	3	<0.01	0.08	<0.01	5	<0.01	<0.01
Flaggy Rock Creek	14/05/2020	2	<1	3	0.03	0.08	<0.01	5	0.01	<0.01
Station Creek	14/05/2020	1	<1	n/a	0.28		<0.01	n/a	0.5	0.02

5.0 Limitations

Across any monitoring program, limitations in the data must also be considered before any definitive decisions or courses of action are concluded. The following considerations should be recognized within the objectives of the project and any future water quality monitoring programs or application of these data.

Firstly, the number of samples collected along with the number of events were not consistent across all catchments. Differences in sample numbers and events must therefore be considered when interpreting results.

Concentrations of pesticides and nutrients represent discrete points in time, and therefore should be considered in the context of rainfall or river height data.

The first sampling event does not represent the first rainfall event of the 2019/2020 wet season, and therefore the sampling regime might have missed the initial periods of increased concentrations. Likewise, events later in the wet season are likely to show decreased concentrations. For future water quality monitoring programs, ensuring collection of the initial wet season flush (first large event) would allow a more thorough understanding of the concentrations and mobility of pesticides and nutrients.

Lastly, data relating to the application and usage of fertiliser from landholders in the region would benefit in contextualising the differences in monitored concentration data presented in this report. This would provide further understanding of the connection between application rates and loss pathways (Wallace et al.2017).

6.0 Conclusions and recommendations

The results in this report demonstrate the clear influence of weather on pollutant concentrations from land-based runoff. Event-based monitoring returned more detections of pollutants, in higher concentrations when compared with the ambient-based water quality monitoring results. Consistently high nutrient concentrations suggest the need for a focus on protecting, restoring, and managing riparian vegetation around agricultural land which will help to absorb/filter runoff, slow rainfall and reduce bare soil, in turn reducing surface run-off. High pesticide concentrations are also a concern, in Rocky Dam Creek in particular, which returned a large number of results higher than guideline values for the protection of 95% of freshwater species. Through the completion of this program, we have helped to highlight priority areas for water quality improvement in the future. Water quality monitoring should continue in all of these catchments into the future to ensure a greater understanding of water quality, to identify any high-risk catchments, to recognise the best-practice management techniques and to highlight any short or long-term water quality trends. Providing a greater understanding of our local waterways will allow for a more strategic and effective means of managing and mitigating pollutant concentrations in the hopes of improving water quality before it enters the Great Barrier Reef lagoon.

6.1 Recommendations

To reduce the risk posed by nutrients and pesticides to the health and resilience of the reef, four key recommendations can be made:

- Use pesticides and fertilisers which have low (or reduced) environmental toxicity.
- Adopt application techniques which require lower rates of application.

- Use pesticides and fertilisers which are less mobile (and thus less susceptible to run-off), have a shorter half-life and/or have a high soil sorption coefficient (i.e. bind to the soil easier and are therefore less likely to be dispersed via run-off).
- Implementing farm management practices which help to minimise off-farm losses.

Additional support programs and support tools can be found at the following website which aim to support sugarcane farmers adopt improved farming practices: https://www.qld.gov.au/environment/agriculture/sustainable-farming/reef/reef-regulations/producers/sugarcane/support-programs

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8.0 Appendix

8.1 Definitions

Analyte: A substance whose chemical constituents are being identified and measured.

Adsorption: The process by which a solid holds molecule of gas or liquid or solute as a thin film.

Absorption: The process by which one thing absorbs or is absorbed by another.

Solubility: The ability to be dissolved, especially in water.

Mobility: The ability to move or be moved freely and easily.

Annual plant: A plant whose lifecycle only lasts on year (from seed to flower to seed).

Perennial plant: A plant which lives for more than two years and can live for many growing seasons.

Benthic: of, or relating to, or occurring at the bottom of a body of water.

Cyanobacteria: A division of microorganisms that are related to the bacteria but are capable of photosynthesis.

Phytoplankton: Plankton consisting of microscopic plants.

Macrophytes: An aquatic plant large enough to be seen by the naked eye.

Organism: An individual animal, plant, or single-celled life form.

8.2 SLCMA sampling locations

Table 9: SLCMA event-based sampling locations with GPS coordinates.

Site Name	Latitude	Longitude	Sample type
Plane Creek	-21.42772	149.2195	Event sample
Rocky Dam Creek	-21.66117	149.3117	Event sample
Marion Creek	-21.7091	149.3591	Event sample
West Hill Creek	-21.80881	149.3712	Event sample
Carmila Creek	-21.92594	149.3704	Event sample

Table 10: SLCMA ambient-based sampling locations with GPS coordinates.

Site Name	Latitude	Longitude	Sample type
Plum Tree Creek	-21.51536	149.2311	Ambient sample
Cherry Tree Creek	-21.59273	149.2306	Ambient sample
Basin Creek	-21.75084	149.3689	Ambient sample
Flaggy Rock Creek	-21.96792	149.4339	Ambient sample
Station Creek	-21.60051	149.2393	Ambient sample

8.3 Pesticide testing list

Table 11: Pesticides included in ALS analytical suites (87 total).

Azinphos-methyl	Pirimiphos-methyl	Hexaconazole
Azinphos-ethyl	Profenofos	Paclobutrazole
Bromophos-ethyl	Prothiofos	Penconazole
Carbofenothion	Sulfotep	Propiconazole
Chlorfenvinphos	Sulprofos	Tebuconazole
Chlorpyrifos	Temephos	Cyprodinil
Chlorpyrifos-methyl	Terbufos	Pyrimethanil
Coumaphos	Tetrachlorvinphos	Diuron
Demeton-O & Demeton-S	Triazophos	Fluometuron
Demeton-S-methyl	Trichlorfon	Tebuthiuron
Diazinon	Trichloronate	Bromacil
Dichlorvos	Aldicarb	Chlorsulfuron

Dimethoate	Bendiocarb	Ametryn
Disulfoton	Benomyl	Atrazine
EPN	Carbaryl	Cyanazine
Ethion	Carbofuran	Cyromazine
Ethoprophos	3-Hydroxy Carbofuran	Prometryn
Fenamiphos	Methiocarb	Propazine
Fenchlorphos (Ronnel)	Methomyl	Simazine
Fenitrothion	Molinate	Terbuthylazine
Fensulfothion	Oxamyl	Terbutryn
Fenthion	Thiobencarb	Diclofop-methyl
Malathion	Thiodicarb	Fenarimol
Mevinphos	Pendimethalin	Irgarol
Monocrotophos	Trifluralin	Oxyfluorfen
Omethoate	Hexazinone	Thiamethoxam
Parathion	Metribuzin	Imidacloprid
Parathion-methyl	Cyproconazole	Imazapic
Phorate	Difenoconazole	Diketonitrile (DKN)
Pirimiphos-ethyl	Flusilazole	Isoxaflutole