Waste Discharge Licence 147-08

Leanyer Sanderson Waste Stabilisation Ponds

2022 LICENCE REPORT

Water Services

Water Services

Period July 2019 to Feb 2022

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EXECUTIVE SUMMARY

This Licence Report is provided to satisfy the requirements to provide trend analysis and assessments for all monitoring data required to be collected under WDL 147-08. This WDL authorises the discharge of treated wastewater from Leanyer Sanderson Waste Stabilisation Ponds to Buffalo Creek in Shoal Bay, Darwin Harbour. Updates on progress against the 2017 Improvement Plan actions have also been detailed at the end of this Licence Report.

An assessment of annual load trends for nutrients and BOD found that recent loads were either, consistent with historical loads, or somewhat lower. Annual rainfall appears to be a significant driver of load variation at the ponds similar to catchment loads. Treatment performance in terms of *E.coli* log reductions between the inlet and outlet were similarly found to be improved since 2014. This was also reflected in improved pathogen indicator assessments in the receiving environment in recent years.

Assessments of physico-chemical parameters found that; pH continues to be within default criteria in all zones of the receiving environment; dissolved oxygen and total suspended solids had recent improvements in the transition and outer zones of Buffalo Creek. Water temperatures are higher in the wet season and decrease briefly in the dry season.

The 2016 and 2017 dry seasons had lower levels of exceedance of chlorophyll-a water quality criteria (factors of 1.5 and 1.5, respectively) in the transition zone compared to all previous dry seasons (factors of 2.0, 2.4, 18.1, 9.4 and 7.9) and in 2018 (factors of 10.5). Chlorophyll-a in sediment was found to be elevated in sediments in Buffalo Creek compared to reference creeks in the upper zone and most of the transition zone, but were likely to be detrital rather than actively photosynthesising. There are also indications of improvements in ammonia assessments in the transition zone (since the 2014 dry season). Total nitrogen continues to consistently exceed default water quality criteria in the transition zone while oxides of nitrogen have been mostly within default criteria in recent years. There were similar indications of improvements in assessment outcomes for filterable reactive phosphorous in the transition zone in 2017 and 2018 and these were consistent through to 2022 while total phosphorous continues to exceed default criteria. Total nitrogen, ammonia, total phosphorous and filterable reactive phosphorous in porewaters were more elevated at certain transition zone sites than at upper zone sites more proximal to the discharge.

There were improvements in filtered copper assessments in the upper zone from 2014 to 2022. Filtered zinc remains compliant in all zones of the receiving environment. Copper and zinc in sediments remain within Interim Sediment Quality Guideline Trigger values in all seasons. Filtered copper in porewaters in the upper zone exceeded ANZECC and ARMCANZ guidelines at sites in the upper zone in 2015, 2016 and 2018 and 2021.

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GLOSSARY

Abbreviation	Definition
Al	Aluminium
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
BOD	Biochemical oxygen demand
cfu	Colony forming units (expressed per unit of a specified volume of sample)
Chl-a	Chlorophyll-a, a photosynthetic pigment present in plants, algae and cyanobacteria that is used in oxygenic photosynthesis. It can be used as a measure of algal biomass and subsequently primary production
Cu	Copper
Cu-B	Bioavailable copper in sediment (estimated by dilute acid extraction)
Cu-F	Copper filtered (dissolved fraction)
Cu:Al	Total copper in sediment normalised to total aluminium content of the sediment
Cu-T	Total copper in sediment
DHWQO(s)	Darwin Harbour water quality objective(s)
DO	Dissolved oxygen
EC	Electrical conductivity
E. coli	*Escherichia coli*
EP	Equivalent population
FRP	Filterable reactive phosphorous (orthophosphate)
ERA	Environmental risk assessment
HCl	Hydrochloric acid
ISQG	Interim sediment quality guidelines
kg	Kilograms
kL	Kilolitres
L	Litres
LOP	Level of protection (species %)
LOR	Limit of reporting for chemical analysis
µg	Micrograms
mg	Milligrams
ML	Megalitres
N	Nitrogen
NH_3-N	Total ammonia as N (NH_3 and $NH4^+$ as N) as per ANZECC and ARMCANZ (2000)
NHMRC	National Health and Medical Research Council
NO_X-N	Oxidised nitrogen as N – the sum of nitrate and nitrite
NRETAS	Department of Natural Resources, Environment, The Arts and Sports, Northern Territory
NT	Northern Territory
NT DOH	Northern Territory Department of Health
NT EPA	Northern Territory Environment Protection Authority
NTU	National turbidity units
Pheo-a	Pheophytin-a, a degradation product of chlorophyll-a
PWC	Power and Water Corporation
SMD	A slightly-moderately disturbed aquatic ecosystem. This reflects both the management intent and subsequently the level of protection.
SMDZ	Slightly to moderately disturbed zone
SMP	Sediment monitoring program
SSTV(s)	Site specific trigger value(s)
TKN	Total Kjeldahl nitrogen
TN	Total nitrogen
TN:TOC	Total nitrogen to total organic carbon ratio in sediment

Abbreviation	Definition
TOC	Total organic carbon
TP	Total phosphorous
TSS	Total suspended solids
TV(s)	Trigger value(s)
WDL(s)	Waste discharge licence(s)
WQO(s)	Water quality objective(s)
WSP(s)	Waste stabilisation pond(s)
Zn	Zinc
Zn-B	Bioavailable zinc in sediment (estimated by dilute acid extraction)
Zn-F	Zinc filtered (dissolved fraction)
Zn:Al	Total zinc in sediment normalised to total aluminium content in sediment
Zn-T	Total zinc in sediment
ZOI	Zone of influence of the discharge

1. Monitoring Objective

The submission of this report fulfils Power and Water Corporation's (PWC's) requirement to provide a Monitoring Report pursuant to Condition 32 of WDL 147-08.

Additionally, Condition 33 of WDL 147-08 requires that the Monitoring Report:

33.1 is prepared in accordance with the requirements of the NT EPA 'Guideline for Reporting on Environmental Monitoring';
33.2 includes a tabulation of all monitoring data required as a condition of this licence;
33.3 includes long-term trend analysis of monitoring data to demonstrate any environmental impact associated with the activity over a minimum period of six years (where the data is available);
33.4 reports on progress relating to the Leanyer Sanderson WDL 147 Improvement Plan 2017 dated March 2017 and the Darwin Region Sewerage Strategy.

1.1 Prepared in accordance with the requirements of the NT EPA 'Guideline for Reporting on Environmental Monitoring' (Condition 33.1)

This Monitoring Report has been prepared in accordance with each section of NT EPA 'Guideline for Reporting on Environmental Monitoring' from May 2016 Version 1.0.

1.2 Tabulation of all monitoring data (Condition 33.2)

A summary of the monitoring data required under WDL 147-08 and how it has been provided within this Monitoring Report is provided in Table 1 below.

Table 1 Summary of all tabulated monitoring data required under the Leanyer Sanderson

Data Type	Data Provision WDL 147-08 Leanyer Sanderson
Surface water and discharge monitoring	Completed and provided as Attachment A– WDL 147 Summary Data and Plots Masterfile
Sediment monitoring	Completed and provided as Attachment B–WDL 147 Sediment Data Summary

1.3 Includes long-term trend analysis of monitoring data (Condition 33.3)

Plots with trend analysis and interpretation (assessment against RL's where applicable) are provided for all surface water and discharge monitoring parameters in Attachment A. In addition, summary baseline condition assessments have been undertaken on a seasonal basis for all parameters with pertinent water (Appendix 1) or sediment (Appendix 2) quality criteria. These historical data sets are comprised of 11 years (from February 2011 to February 2022) of water quality data and 9 annual dry seasons (2012, 2014 - 2022) of sediment data.

The assessments undertaken for the different parameter types in different matrices are summarised in Table 2.

Table 2 Baseline condition assessment tables against relevant water quality and sediment quality criteria

Parameter type	Matrix	WDL 147-08 Leanyer Sanderson
Physico-chemical	Water/effluent	Table 5
Nutrients and chlorophyll-a	Water/effluent	Table 6 Table 7 Table 8 Table 9 Table 10
	Sediment and sediment porewater	Table 14 Table 15 Table 16 Table 17
Pathogen indicators	Water/effluent	Table 12 Table 13
Metals	Water/effluent	Table 11
	Sediment	Table 18 Table 19
	Sediment porewater	Table 20

1.4 REPORTS ON PROGRESS RELATING TO THE LEANYER SANDERSON WDL 147 IMPROVEMENT PLAN 2017 DATED MARCH 2017 AND THE DARWIN REGION SEWERAGE STRATEGY (CONDITION 33.4)

The updated progress of actions identified in the 2017 Improvement Plan for WDL 147-08 is located in Improvement Plan – Progress at the end of this report.

Darwin Water supply and sewerage strategy have been developed separably. The provision of effective and efficient sewerage treatment and disposal is a key focus and it will be a component of the broader NT Sewerage Strategy.

1.5 SAMPLING SITES

Data considered within this Licence Report pertains to the sampling sites detailed in Figure 1.

1.6 DISCHARGE AND SURFACE WATERS

Surface water measurements and samples in Buffalo Creek are taken on neap ebb tides for consistency. This sampling is timed to capture as near to worst-case that can be measured (i.e. low tidal ranges, minimal dilution and flushing). The surface water data set considered covers the period January 2011 until Feb 2022. Data has been grouped seasonally into wet (October – April) and dry (May – September).

All data such as: nutrients, metals, bacteriological and so on have been collected at the frequencies defined in the Surface Water and Discharge Monitoring Plan, Appendix 1 of WDL 147-08.The sampling frequency is monthly for surface waters but can increase to daily (flow) to fortnightly (pH, EC, DO, Temp, Turbidity) for some physico-chemical parameters at the discharge monitoring point. Surface water samples are collected at a consistent depth of 0.2 m below the surface in the receiving environment. Duplicate samples are collected at one site on each run.

The assessment protocol for water quality Monitoring Report are specified in WDL 147-08 Appendix 5 and the trigger values for the surface water are located in Appendix 4 and in Appendix 2 for the sediments.

Figure 1 Sampling sites located at the discharge monitoring point and in the receiving environment

1.7 SEDIMENT

Sediment samples are collected in the dry season in accordance with the Sediment Monitoring Plan, Appendix 2 of WDL 147-08. Sediment sampling was undertaken during spring tides to facilitate sufficient temporal access to the sites. This program includes test sites in Buffalo Creek and control/reference sites in both Mickett and Kings Creek.

The sediment data set covers sampling undertaken in the 2012, 2014 – 2022 dry seasons. Data collected in 2012 was conducted under the Buffalo Creek Interim Sediment Monitoring Program (SKM 2013). Reference sites in Mickett and Kings Creek were included from 2014 based on recommendations arising from an independent review of the BCISMP (Alongi 2013). Sediment monitoring since 2014 has been conducted in accordance with a design originally detailed in the Stable Isotope Monitoring Plan that included sediment as a matrix (Munksgaard 2014). Sediment samples from each 'site' are a composite sample of multiple 10 cm depth cores collected from both sides of the channel. The pH of the composite sample is recorded in-situ (average of 3 in-situ readings utilised). Triplicate composite samples are taken at two sites in the test creek (Buffalo Creek) and at one site in each control creek (Mickett and Kings Creek). Triplicate samples are collected 10 m either side of the primary site.

1.8 ASSESSMENT PROTOCOLS

It is generally understood that the water quality criteria considered protective of beneficial uses may not be achieved and therefore that beneficial uses may not be protected in the mixing zones for discharges (ANZECC and ARMCANZ 2000a, EPAVIC 2009). Default criteria were not intended to be used as 'instruments to assess compliance' in these contexts. However, they can be useful in these zones for 'enhancing inference about the level of disturbance (enhance early detection and predictive capabilities)'(ANZECC and ARMCANZ 2000a).

All **surface water** quality assessments in this Licence Report have been undertaken based on valid protocols defined in relevant guidelines (ANZECC and ARMCANZ 2000a, b, NHMRC 2008, NRETAS 2010, DOH 2011). The sediment and sediment pore-water assessment protocols are performed in accordance with relevant guidelines (ANZECC and ARMCANZ 2000a)

Reference site based Darwin Harbour Water Quality Objectives (DHWQOs) for Upper and Mid Estuary water types apply to Buffalo Creek and Shoal Bay waters respectively (NRETAS 2010). While the condition of Buffalo Creek is generally considered highly disturbed, the management intent is slightly-moderately disturbed (SMD) for all Darwin Harbour waters. The assessment statistic for reference site based WQOs is the median of the test site data. Toxicity based trigger values (TVs) (ANZECC and ARMCANZ 2000a, b) are assessed using the 95th percentile of test site site data. Long-term microbial water quality assessment categories for recreational contact were similarly assessed using 95th percentiles (Hazen Method) (NHMRC 2008). Local alert level guidance (DOH 2011) based on these categories were assessed using the maximum test site value i.e. any exceedance.

For assessment purposes, it is useful to further group the receiving water sites for the discharge into various zones. These sub-zones have been identified based on long-term assessments of monitoring data, visual observations and physical conditions and constraints that exist within the tidal creek. These zones include:

- The **upper zone** inclusive of sites SLEBC01 and SLEBC03 that are situated closer to the discharge. The channel in this section is physically narrow, shaded by mangrove canopy and the water colour can have a characteristic 'pea green soup' appearance. Flushing/mixing within this zone is constrained by distance from the mouth of the creek and a rock bar between the upper and transition zone.
- The **transition zone** extends from below the rock bar of the upper zone to the Buffalo Creek boat ramp (SLEBC06). The channel is typically wider in this section, is not as shaded by mangrove canopy. Flushing is contained by the presence of a sand bar parallel to the coast

across the mouth of the creek and other physical features (rock bars). The water in this sub-zone can appear quite brown at times in response to elevated phytoplankton biomass.

- The **outer zone** inclusive of site SLEBC08 at the mouth of Buffalo Creek and SLESB02 in Shoal Bay, where the receiving waters become more consistent with the definition of a mixing zone. These two sites, while of different water type have water quality which begins to approach default criteria for these waters more consistently.

All sediment assessments have been undertaken in accordance with relevant guidelines (ANZECC and ARMCANZ 2000a). The assessment protocols have been summarised in Appendix 2 of WDL 147-07. In brief, sediment metals are assessed against Interim Sediment Quality Guideline (ISQG) TVs (ANZECC and ARMCANZ 2000a). Where no TVs are available (i.e. sediment nutrients), then a 2 x reference site TV is assumed to apply for assessment purposes (ANZECC and ARMCANZ 2000a).

1.9 Sampling Artefacts

All data assessments should be considered in the context of relevant operational history and other factors that may influence water quality temporally. A brief summary of these is included below:

- Leanyer Pond 3 desludging 2010 – dry season;
- Leanyer Pond 1 desludging from May 2011 – dry season;
- Leanyer Pond 2 desludging from May 2012 – dry season;
- Leanyer Pond 4 desludging from July 2013 – dry season;
- Leanyer Pond 3 and 4 offline temporarily June 2014 – dry season;
- Timed discharge trial July to September 2014 – dry season;
- Hydraulic study – Sanderson offline late April – early May 2016.
- Sanderson Pond 1 taken offline to desludged around inlet works – March 2016
- Sanderson Pond 1 taken offline for desludging (west side only) and jetty removal – August to October 2017
- Leanyer Pond 1 freeboard lowered by 0.5m to reduce the risk of an overflow into the inlet works construction site – January 2018
- Sanderson Pond 1 was taken offline to undertake desludging works for a period of approximately six months – from May 2018
- Biological Additive Dosing Trial added to the Malak Sewer Pump Station (SPS) upstream of the Sanderson Waste Stabilisation Pond treatment train; the duration of this trial and associated monitoring program was 8 months – from May 2018
- Sanderson Pond 1 inlet demolished and a new inlet installed as part of the inlet works program, duration of work approximately six months – from May 2018
- Leanyer Pond 1 taken offline for approximately four weeks to continue inlet works – April 2018
- Leanyer Pond 1 level is planned to be lowered 600mm to continue inlet works; duration of works 3 weeks – August 2018
- Alkali Dosing Trial; Magnesium Hydroxide Liquid (MHL) added to the Lakeside Drive and Tiwi Sewage Pump Stations upstream of the Leanyer Waste Stabilisation Pond Treatment train. The MHL dosing trial planned for 7 – 12 week period from August – October 2018
- Sanderson Pond 1 back online – December 2018
- Leanyer Sanderson Inlet works completed – December 2018

- Sanderson Pond 2 taken offline by redirecting inflows from Sanderson Pond 1 to Sanderson Pond 3 via a bypass line – March 2019
- Sanderson Pond 2 sewage pumped into Sanderson Pond 3 – March 2019
- Sanderson Pond 2 allowed to dry naturally prior to the removal of all sludge within the pond – March 2019
- Sanderson Pond 2 desludged completed – July 2019
- Re-filling of Sanderson Pond 2 and back online – July 2019
- Sanderson Pond 3 taken offline, allowed 2-3 weeks drying prior to removing the sludge around the edges – July 2019
- Sanderson Pond 5 was lowered to allow cleaning the discharge point up from any gross pollutants coming from the upstream ponds. It was cleaned out as best as possible without taking the pond completely of line – July 2019
- Sanderson Pond 3 is almost empty and will be allowed 2-3 weeks drying prior to removing the sludge around the edges – July 2019

It is apparent that in most years the DHSWMP that commenced in 2011 has been coincident with operational changes potentially influencing treatment outcomes in most years. Changes like desludging, which take ponds offline can reduce treatment efficacy. Similarly changes like opening penstocks which occurred frequently during the timed discharge trial can also reduce retention times and therefore treatment efficacy. PWC has recently begun trying to quantify the influence of these types of factors (i.e. opening penstocks) on effluent quality in response to apparent trends in effluent quality that appeared evident during the course of the trial in 2014.

In addition, PWC's sampling contractors reversed the sampling order in Buffalo Creek from November 2013 from outer zone through to upper zone sites to sampling of the upper zone sites first. This change was made due to persistent access issues (log jams) that either prevented access to the upper zone or presented a safety hazard to boat operation in this zone. This change has ensured that a higher part of the neap ebb tide has been sampled in the upper zone since this time.

2. MONITORING RESULTS

2.1 DISCHARGE VOLUMES AND LOAD TRENDS

2.1.1 Discharge volume trends

The total annual effluent flow volume discharged from Leanyer Sanderson in 2016-2017 (8,179 ML) and 2018-2019 (6,390 ML) have been slightly lower but higher than most previous years (Figure 2). In general, the variation in influent and effluent flow volumes appears consistent with total annual rainfall with the highest volume discharged across this period occurring in 2010-2011 with an annual rainfall of 2,381mm, the second highest discharge was in 2016-2017 with 2,551 mm of rain; compared with the lowest and most recent annual rainfall in 2018-2019 of 1,045 mm. Inferring trends in annual discharge are typically confounded by the influence of annual rainfall on inflows and subsequently outflows in each year. Dry season discharge may therefore be a more representative change indicator in response to increasing EP pressure at this site, due to less susceptibility to the influence of rainfall variability.

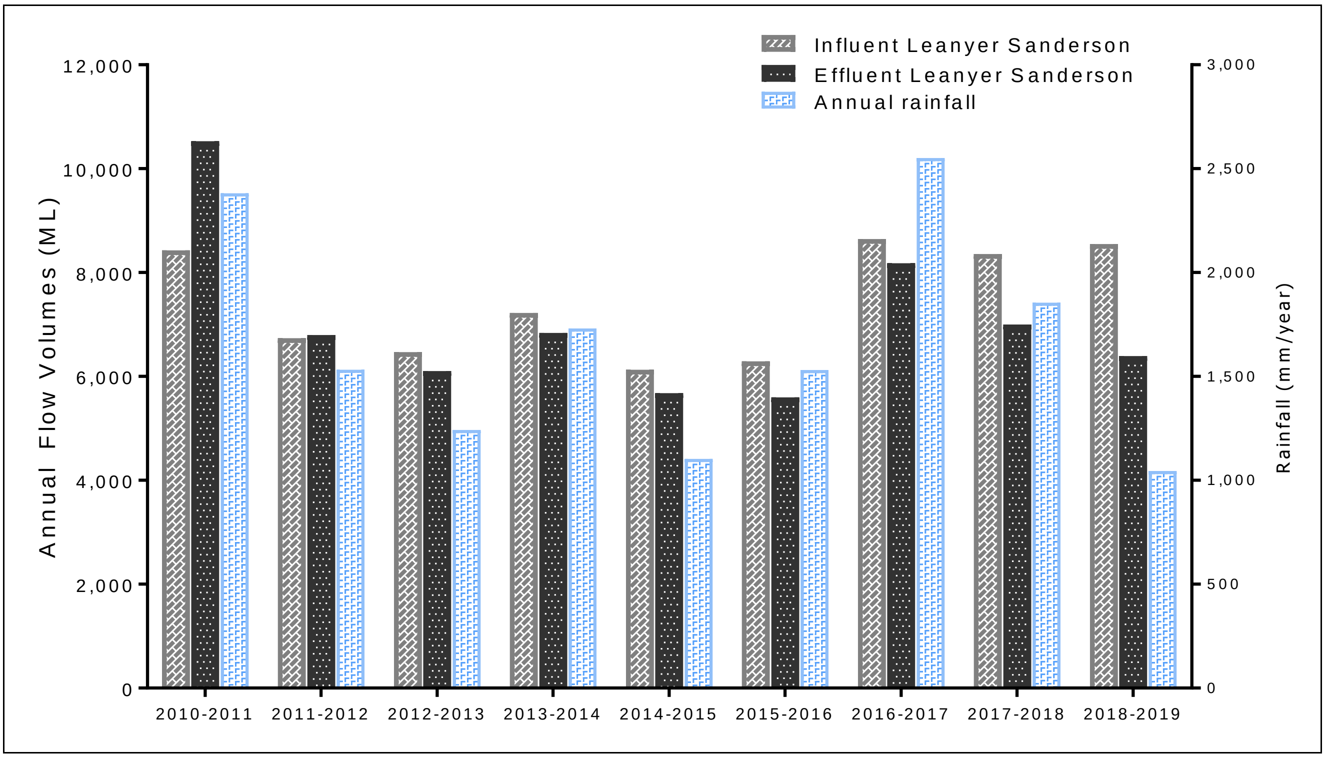

Figure 2 Annual flow volumes for influent and effluent at Leanyer Sanderson

2.1.1.1 Nutrient and BOD Load Trends

Total BOD discharge loads have decreased by 4.0% between 2011-2012 and 2018-2019 (Table 3). The decreasing load from Leanyer Sanderson occurred in spite of the discharge volume slightly increases across the same period and may also reflect improvements in removal efficiency, in combination with high flow volumes due to in-situ rainfall; low BOD indicates the level of organic matter left to be oxidised – generally in the receiving water.

TN loads have increased from Leanyer Sanderson between 2011-2012 and 2018-2019 (Table 3), this may reflect increases in discharge but the removal efficiency has improved; assessing nitrogen removal in WSPs is complicated, in facultative ponds, it is believed that the diurnal peak pH of some 9.5 helps ammonia to volatilise, it is possible in the lower anoxic pond conditions de-nitrification takes place to strip out nitrogen from the nitrates. Additionally, there is not sufficient knowledge on the nitrogen cycle in the Northern Territory WSPs, especially the high Top End temperatures.

Slight decreases in TP load have also been observed at Leanyer Sanderson WwTP across this same period, improvement in the efficiency for TP from 26% to 46%, Table 3.

Table 3 Parameters indicative of key discharge inputs to the receiving environment from the Leanyer Sanderson WwTP between 2010-2011 and 2020-2021

Parameter	WDL 147-08 Leanyer Sanderson annual discharge
Volume discharge	↑ **12%** from 6,796 ML/year in 2011-2012 to 7,798 ML/year in 2020-2021. The highest volume discharged across this period occurring in 2010-2011 with an annual rainfall of 2,381mm, the second highest discharge was in 2016-2017 with 2,551 mm of rain; this indicate how variable the indicator is making trend assessment across this period difficult. **Figure 2**
BOD load	↓ **18%** from 338.3 in 2011-2012 to 275.94 tonnes/year in 2020-2021. Removal efficiency ↑from 66 % to 72 % in this period **Figure 5**
TN load	↑ **13%** from 117.1 in 2011-2012 to 133.08 tonnes/year in 2020-2021. Removal efficiency for TN ↑ from 59 % to 62 % in this period **Figure 3**
TP load	↓ **0.02 %** from 27.8 in 2011-2012 to 27.35 tonnes/year in 2020-2021. Removal efficiency for TP has ↑ from 26 % to 37 % in this period **Figure 4**

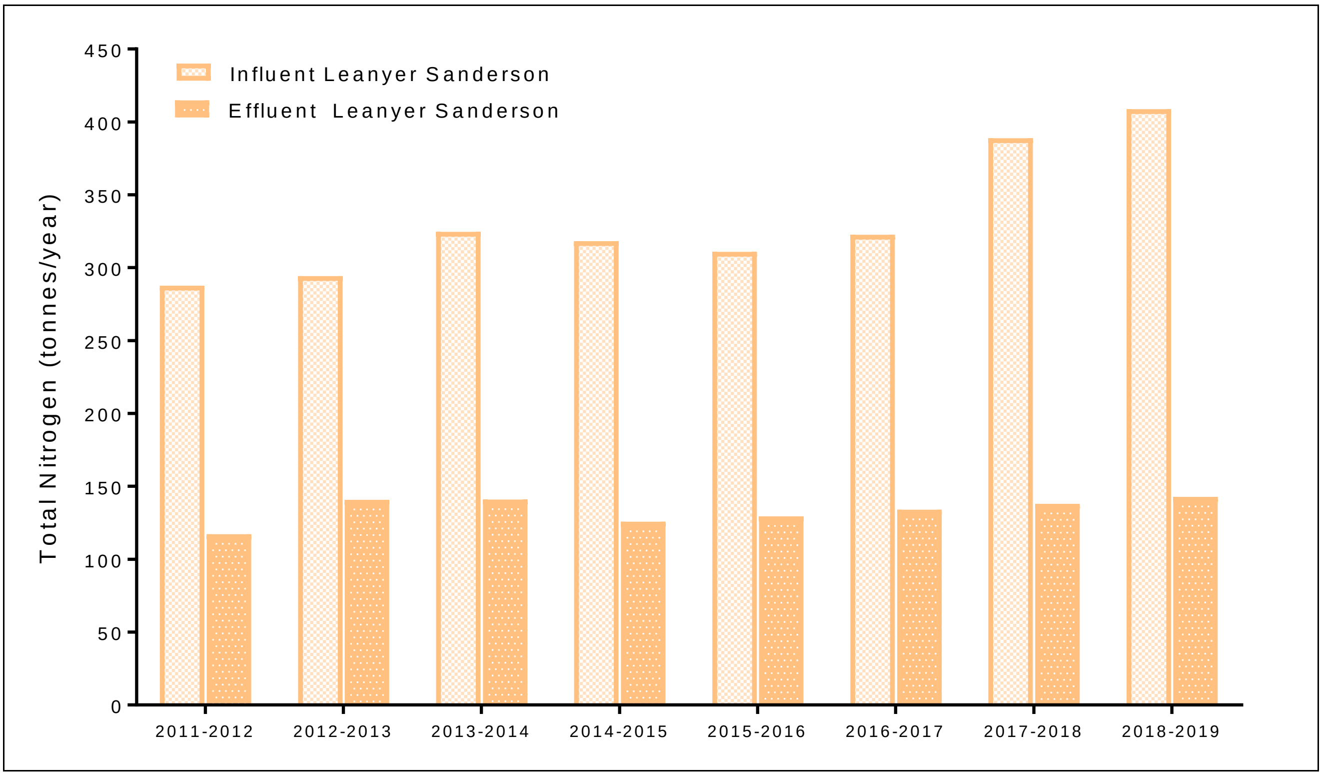

Figure 3 Annual total nitrogen loads in influent and effluent at Leanyer Sanderson

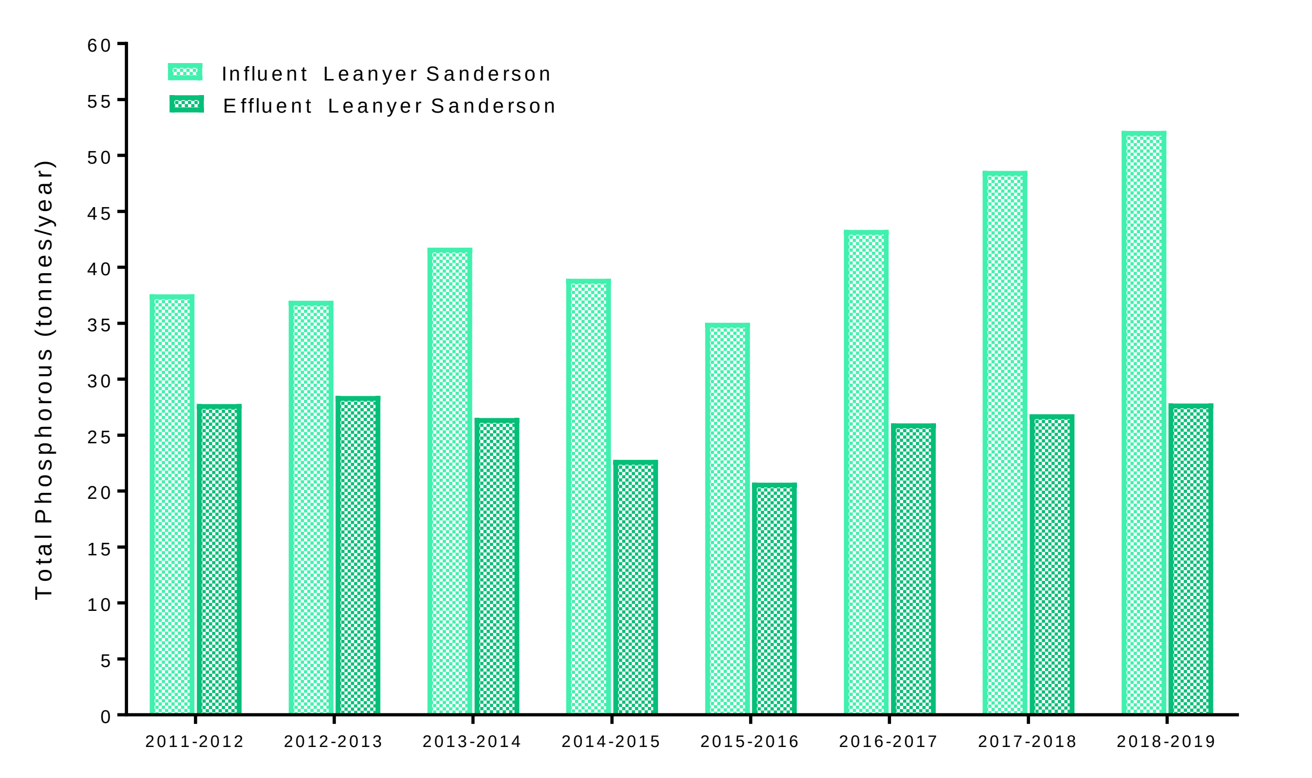

Figure 4 Annual total phosphorous loads in influent and effluent at Leanyer Sanderson

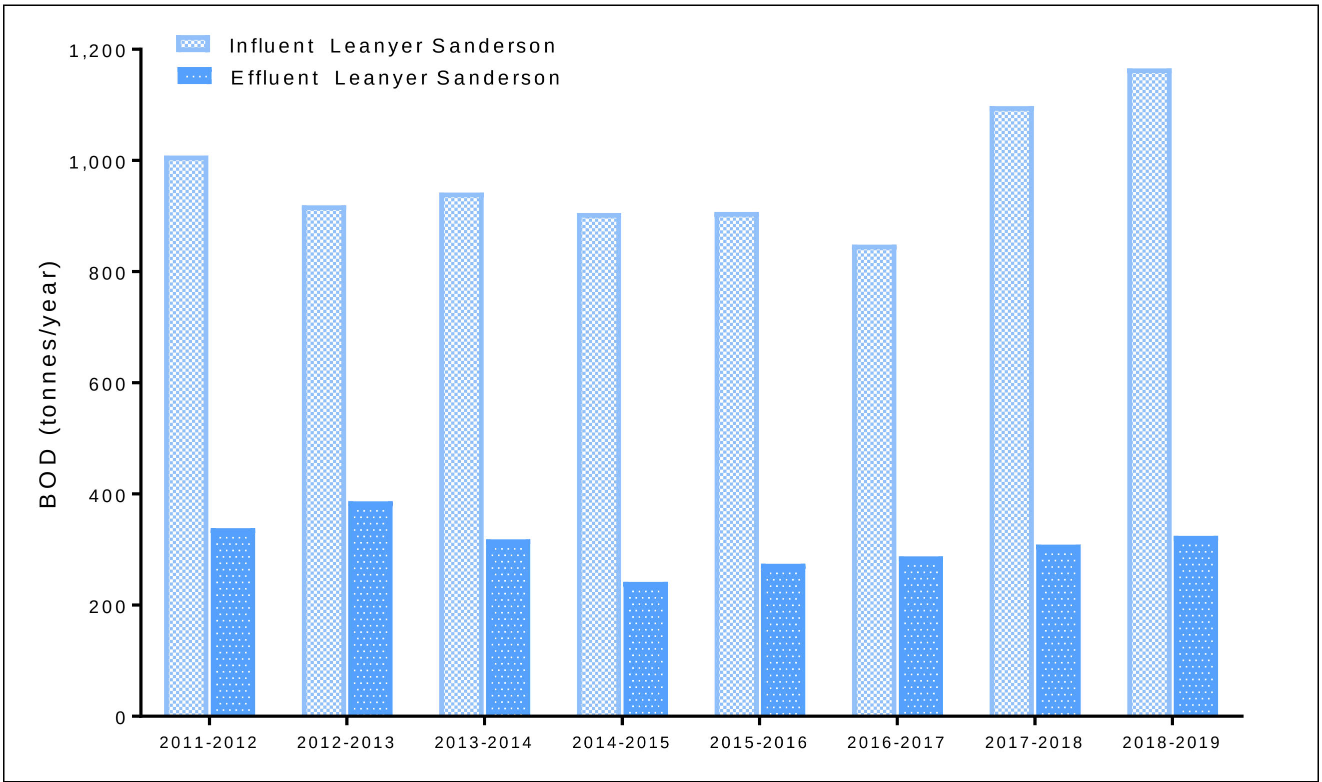

Figure 5 Annual BOD loads in influent and effluent at Leanyer Sanderson

2.2 TABULATION AND LONG-TERM TREND ANALYSIS OF MONITORING DATA

2.2.1 PHYSICO-CHEMICAL PARAMETERS

PWC monitors a suite of physico-chemical parameters in surface waters routinely. These include pH, electrical conductivity (EC), dissolved oxygen (DO), temperature, turbidity, biochemical oxygen demand (BOD) and total suspended solids (TSS). Of these, pH, DO and TSS have relevant water quality criteria that can be utilised for assessment purposes (Table 5). All DHWQO criteria are strictly only applicable in the dry season (NRETAS 2010) so it is not unexpected for wet season exceedances to occur.

The dry and wet season assessment in Table 5, pH complies with relevant criteria in all receiving environment zones. Median TSS rarely complies with relevant criteria in the upper zone; but has been only compliant particularly in the dry season in the transition zone in 2015, 2016 and 2017. TSS average is usually compliant in the outer zone at all sites; when exceedances do occur they are typically in the wet season as you would expect. Median DO in the upper zone is usually less than the lower limit DO criteria range and even hypoxic at times (< 30 %). Median DO increases in the transition and outer zone and exceeds the upper limit DO criteria relatively frequently. This is consistent with high levels of primary production in the receiving environment. DO in the outer zone has been compliant in the outer zone since the 2014 dry season; with the exception of 2018-2019 and 2016-2017 wet seasons at SLEBC08, when DHWQO criteria are not unexpected for wet season exceedances to occur.

2.2.1.1 pH and Dissolved Oxygen– Surface Waters Assessments vs Reporting Limit

The pH in the receiving water has consistently been in between the range of 6.00 and 8.50 pH unit, as per Figure 6. pH has exceeded the upper RL of 8.50 occasionally at site SLEBC06-boat ramp is likely to relate to the phytoplankton bloom (red tide) observed at this site. The bloom is the most likely cause of the exceedance of the pH reporting limit as during a bloom phytoplankton can use dissolved CO2 faster than it can be replaced from the atmosphere, causing the dominant CO2-HCO3- equilibrium to be displaced so that the pH is increased. The 2014 low pH below the reporting limit was around the same time when Leanyer Pond 3 and 4 were offline temporarily, in conjunction with timed discharge trial.

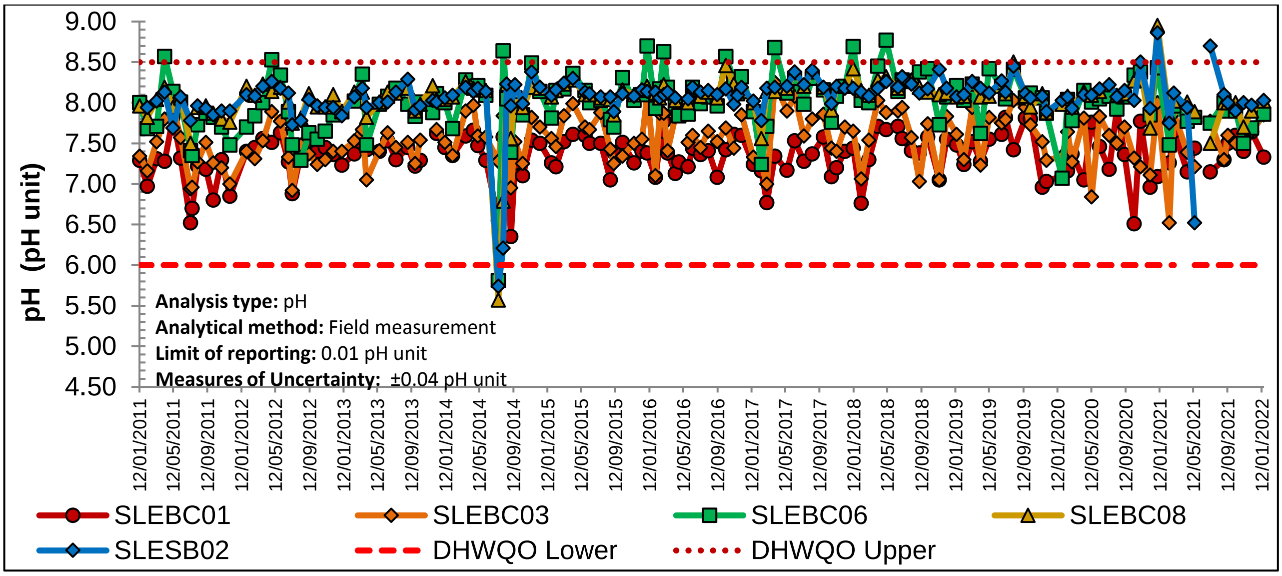

Figure 6 Long-term pH trend in surface waters in Buffalo Creek

The Dissolved Oxygen (% Sat.) at site SLEBC03 located closer to the discharge; the channel in this section is physically narrow and flushing/dilution is additionally constrained by a rock bar. At time in the wet season the DO saturation is below the toxic threshold trigger of 30% saturation by ANZECC as a trigger for water quality with the potential for toxic impacts on some fish species, Figure 7.

Depressed DO levels are often triggered by heavy rainfall or after the first rains of the wet season. As a result of stormwater run-off from the catchment into the creek, organic matter and pollutants are flushed downstream, in this case toward transition and upper zone at site SLEBC03, where natural biological activity decomposes the material resulting in reduction in DO, before it continues flowing toward the creek mouth. Immediately after a rainfall event the DO can increase because fresh water (stormwater) which is typically high in DO is flushed into the creek. However once biological activity commences the DO will decrease as a result of decomposition of organic matter.

Assessment Water Quality "median" for the last 24 months is greater than the assessment criteria of <30 %sat for ANZECC potential toxic impacts; ANZECC specifies that if the test values (median) is greater than the trigger values, there is low risk of adverse biological effects occurring and no further action is required.

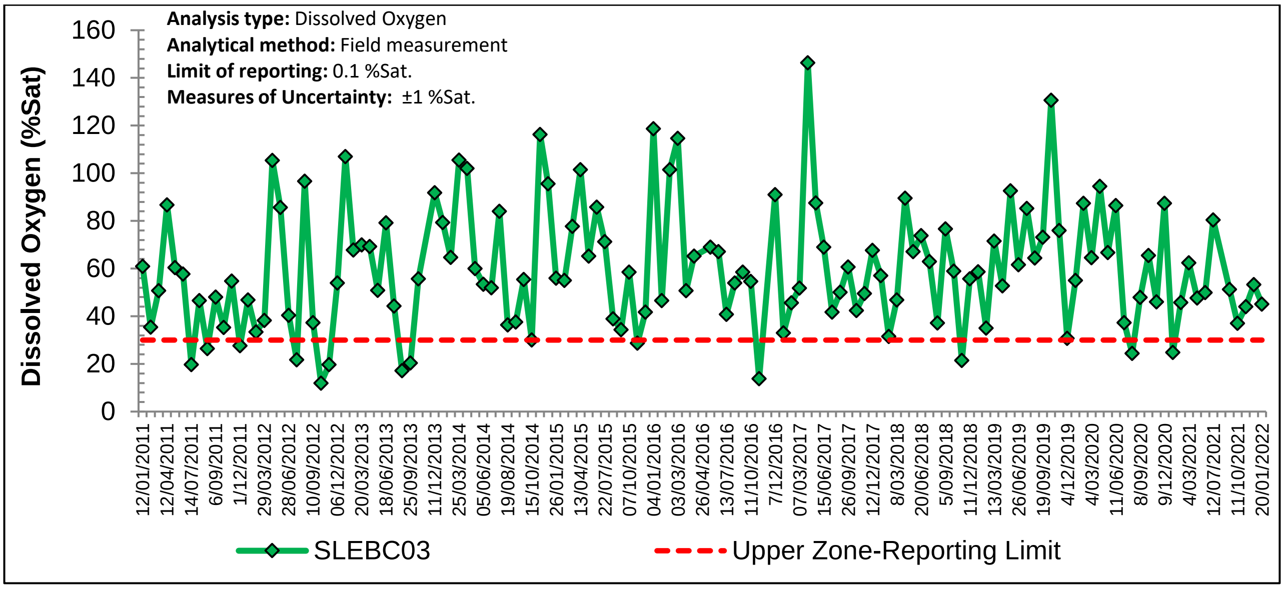

Figure 7 Long-term Dissolved Oxygen (% Sat.) trend in surface waters at upper zone in Buffalo Creek

In the transition zone default water quality criteria protective of beneficial uses is achieved due to mixing zone effects associated with discharges, Figure 8. At time the DO saturation can be above reporting limit for Darwin Harbour Water Quality Objective which is 100% saturation (and 120% saturation ANZECC), however, this is not part of Leanyer/Sanderson Licence reporting limit. When DO has high concentration are usually simultaneously with pH exceedance, the pH slightly above 8.5 reporting limit is likely to be related to observation of a phytoplankton bloom (red tide). During photosynthesis, algae remove carbon dioxide (CO2) from the water, which increases the hydroxide (OH−) levels, resulting in an increase in pH; they also produce large amounts of oxygen (O2), which may result in supersaturated levels of DO.

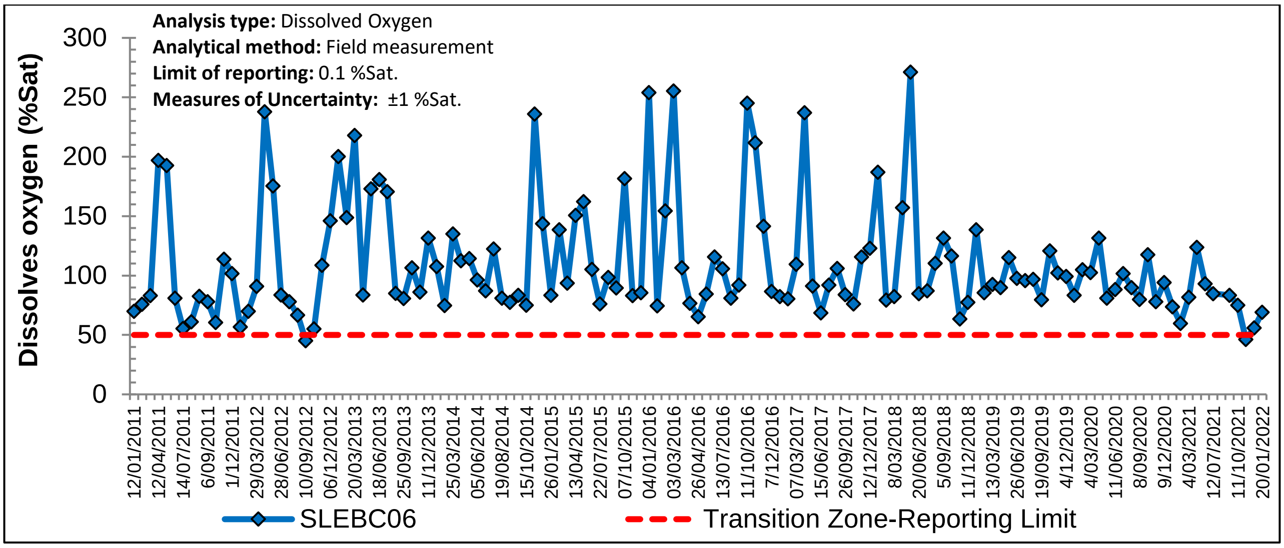

Figure 8 Long-term Dissolved Oxygen (% Sat.) trend in surface waters at transition zone in Buffalo Creek

In the outer zone the DO is continuously above the reporting limit of 75% Sat, Figure 9. However, at times during the wet season the DO % Sat decreases to near or below the lower limit of 75% Sat at SLEBC08, during this period all the DHWQO criteria should not be applied as they are strictly only applicable in the dry season (NRETAS 2010) so it is not unexpected for wet season exceedances to occur.

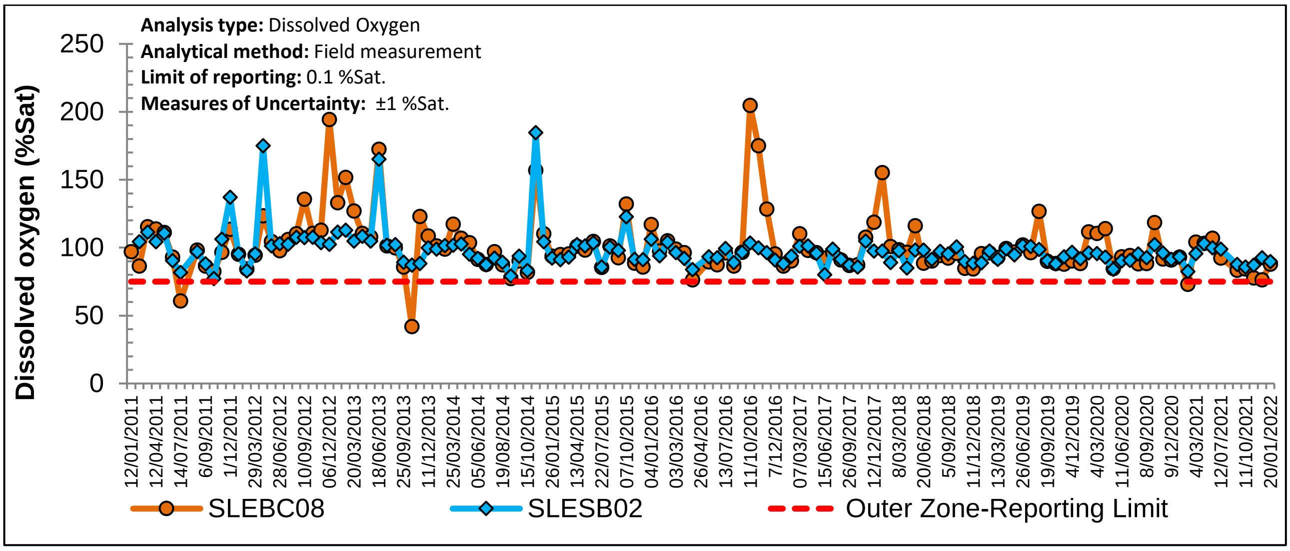

Figure 9 Long-term Dissolved Oxygen (% Sat.) trend in surface waters at outer zone in Buffalo Creek

Extremes of DO both low and high can be problematic for aquatic organisms. Some natural DO gradient between the poorly mixed and shaded upper zone and more oxygenated well flushed marine waters is anticipated.

2.2.1.2 TSS, EC, Temperature, Turbidity and BOD – Discharge and Surface Waters Assessments

The total suspended solids in the discharge have had a steady trend historically. In the upper zone has the higher TSS concentration of the surface water sites, but it is lower than previous years, Figure 10. In the transition zone the TSS has been decreasing over all. On the other hand, in the upper zone has been steady at SLESB02, while is has reduced at SLEBC08. There are spikes at time, which can be due to the large number of stormwater sources that influence this waterway in the wet season.

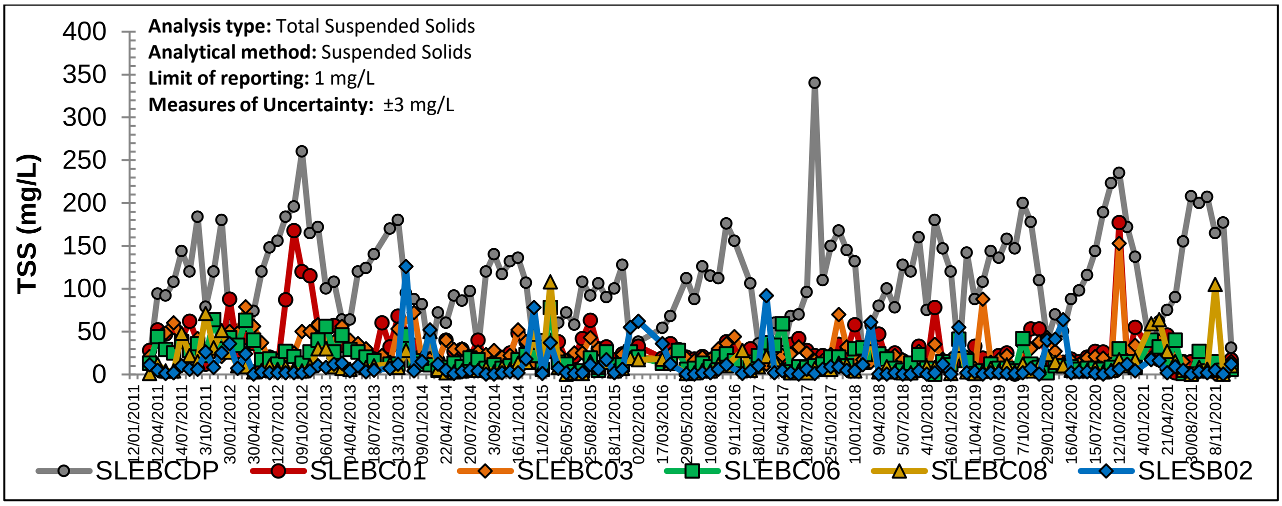

Figure 10 Long-term Totals suspended solids trend in surface waters in Buffalo Creek

The discharge is freshwater and therefore has low EC (< 600 µS/cm) while EC increases between the upper and outer zones within this tidal creek estuary (Figure 11). EC decreases markedly in the upper and transition zone during the wet season. Outer zone EC is more consistent with marine waters and has less pronounced decreases in the wet season. Both the discharge and catchment inputs would contribute to these seasonal decreases in EC.

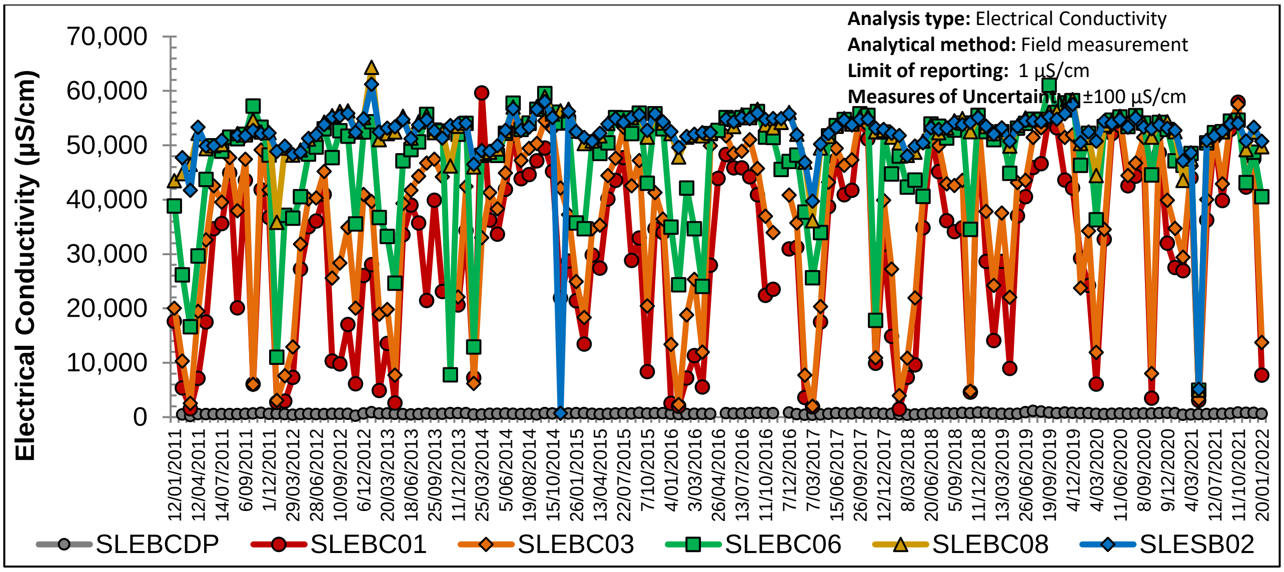

Figure 11 Long-term electrical conductivity trend in discharge and surface waters

Temperature trends at both the discharge point and in the receiving environment follow the same trend with lower temperatures in the more shaded upper zone (i.e. narrow channel with mangrove canopy) than in either the discharge or more marine outer zone sites (Figure 12). Water temperatures are higher in the wet season and decrease briefly in the dry season. Temperature can be an important driver of oxygen solubility and biomass growth for example. Increases in sea surface temperatures and low recent rainfall have been associated with several large scale events in northern Australian waters recently including the die-back of 1000 km of mangrove habitat in the Gulf of Carpentaria (Dias 2016).

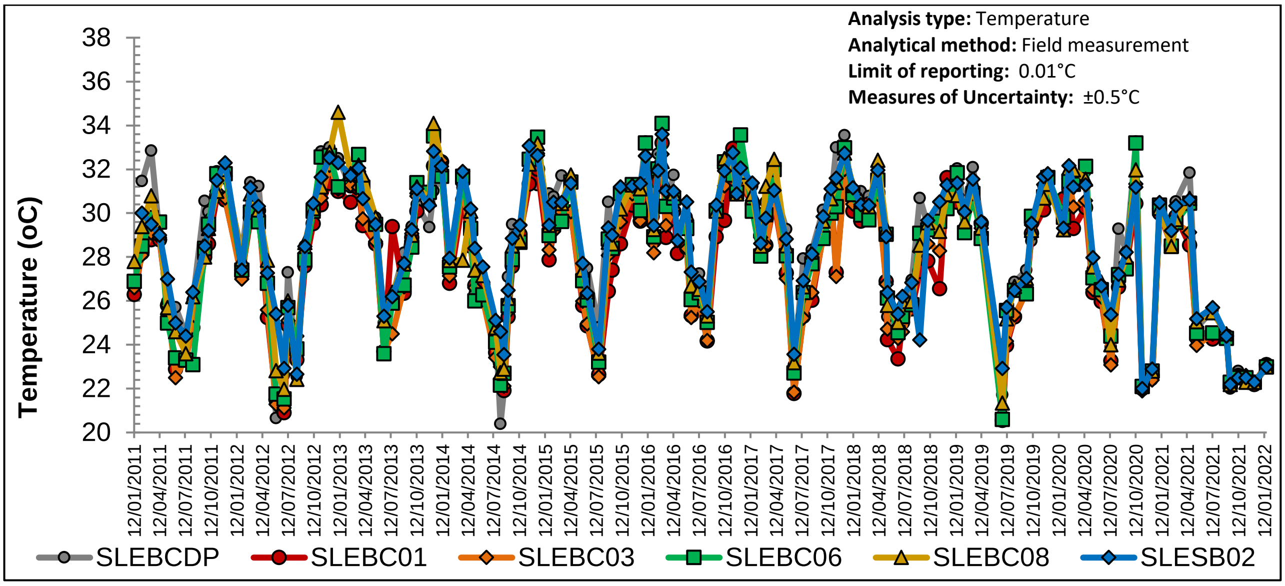

Figure 12 Long-term temperature trend in discharge and surface waters

BOD is typically detectable in the upper zone of Buffalo Creek and occasionally detectable through to the transition zone (SLEBC06) and the outer zone (SLEBC08) (Figure 13). It is rarely detected in the outer zone at SLESB02 in Shoal Bay. Increases in concentration in the upper zone can reflect increases in concentration in the discharge at times. Algal biomass can be a contributing factor to this type of profile (whether discharge derived or in-situ generated). Upper zone sites that are less directly interfaced with the marine environment may also have higher levels of trapped organic matter that may be contributing to this profile in this context.

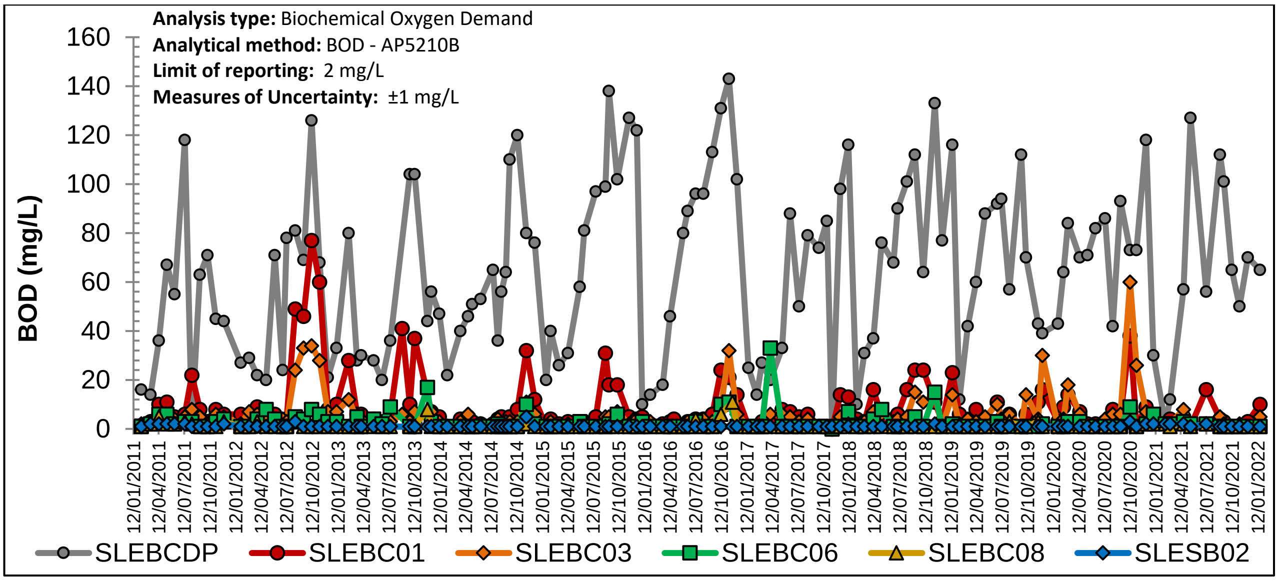

Figure 13 Long-term biochemical oxygen demand trend in discharge and surface waters

Similar to BOD, turbidity at sites in the upper zone can increase in response to increases in discharge (Figure 14). This probably reflects that turbidity can be a function of colour and the upper zone can still appear quite green due to algal biomass in the discharge. Transition and outer zone site turbidity appears to be less influenced by discharge concentrations.

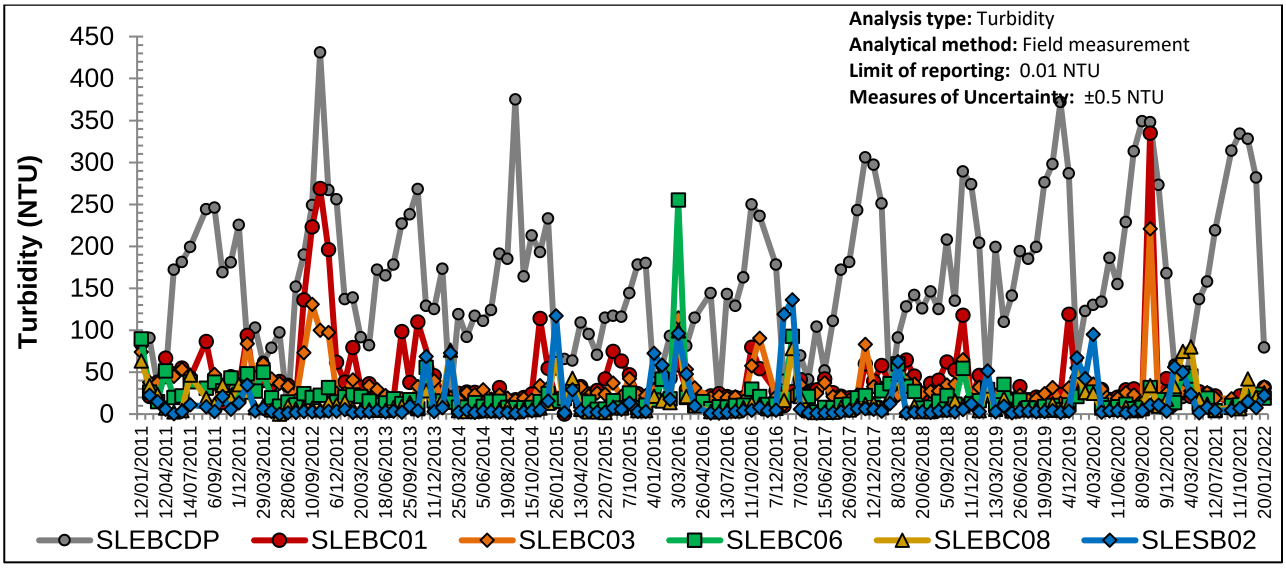

Figure 14 Long-term turbidity trend in discharge and surface waters

2.2.2 CHLOROPHYLL-A & NUTRIENTS

Chlorophyll-a is measured in the discharge, surface waters and in sediment. Nutrients are monitored in the discharge, surface waters, sediment and sediment pore-waters.

2.2.2.1 Chlorophyll-a – Surface Waters Assessment

The dry and wet season assessment in Table 10, long-term seasonal chlorophyll-a assessments reveal the influence of the high biomass concentrations on upper zone sites which consistently exceed default criteria by > 1 order magnitude irrespective of season. Similar levels of exceedance in the transition zone typically occur in the wet season. Median chlorophyll-a concentrations in the transition and upper zone have never achieved default criteria in any season. Default criteria are typically achieved or are only slightly exceeded at outer zone sites in the wet season. Additionally, all the DHWQO criteria are strictly only applicable in the dry season (NRETAS 2010) so it is not unexpected for wet season exceedances to occur.

Chlorophyll-a can be both a source and a nutrient response indicator in these receiving waters. Aerobic zones of the waste stabilisation ponds are reliant on algal populations to produce oxygen to break down organic matter. Hence the discharge itself is typically very high in freshwater algal biomass.

Therefore, at sites in the upper zone more proximal to the discharge, chlorophyll-a is more likely to reflect source derived biomass profiles (Figure 15). The extent of freshwater biomass influence on chlorophyll-a further down the tidal creek is likely to be influenced by changes in salinity profiles between dry and wet seasons.

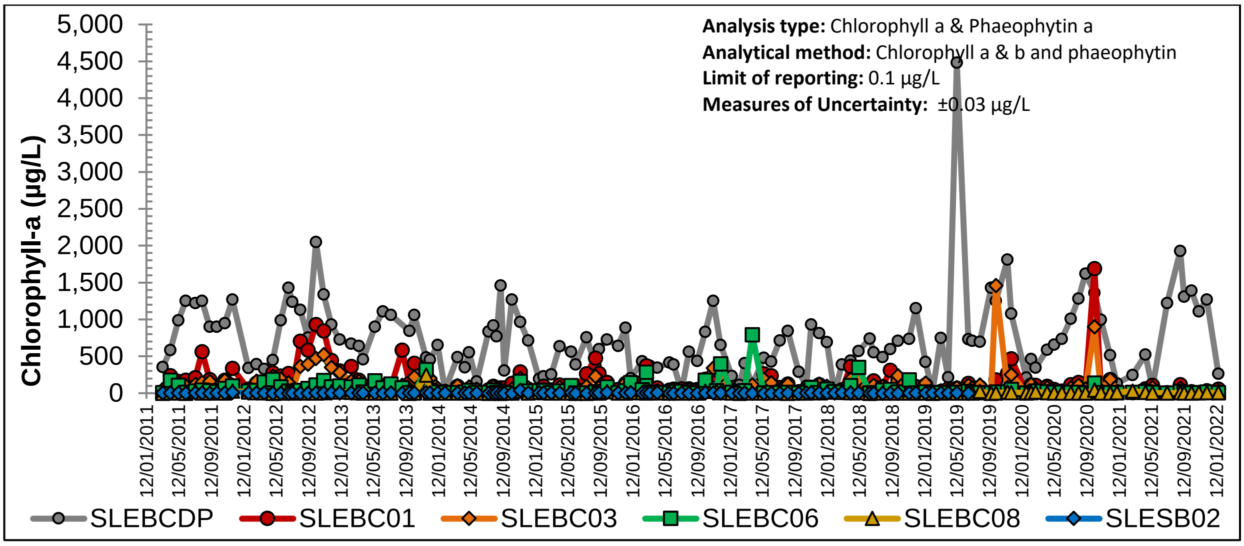

Figure 15 Long-term chlorophyll-a trend in discharge and surface waters

2.2.2.2 Chlorophyll-a – Sediment Assessment

Active chlorophyll-a in sediment may indicate the potential presence of benthic algal mats. Ratio of Chlorophyll-a to its detritus product pheophytin-a provides information about the relative levels of actively photosynthesizing organisms vs detritus/organic matter. These ratios indicate that the chlorophyll in sediment in Buffalo Creek is detrital rather than actively photosynthetic (Table 14). Chlorophyll-a in sediment is elevated in Buffalo Creek compared to control creeks, typically in the upper zone but also at sites in the transition zone.

2.2.2.3 Ammonia – Discharge and Surface Waters Assessment

The dry and wet season assessment in Table 8, the median NH3-N routinely exceeds default criteria in the upper zone; however median concentrations have been compliant by site SLEBC06 in the transition zone in recent years; with some exception in early 2018 dry season and also in 2017-2018, 2015-2016 wet seasons when exceedances of DHWQO criteria are not unexpected. On the other hand, in the outer zone has always been compliant in both the dry and wet seasons.

The 95th percentile from ANZECC and ARMCANZ (2000) pH adjusted for NH3-N concentrations have been well below the TVs in the outer zone in the receiving water (with an exception in 2013-2014 wet season), as per Table 9. While in the transition zone it has not exceed since 2013-2014. Though, in the upper zone usually exceed the NH3-N concentrations for pH adjusted. On the other hand, NH3-N acute toxicity concentration has never exceeded in the receiving water.

NH3-N concentrations in the discharge have been relatively consistent between mid-2012 and 2021, Figure 23. Concentrations appear lower prior to 2012 however this may represent an artefact due to the timing of sampling with diurnal variation evident for this parameter. Sampling has been more consistently conducted by the same contractor in recent years and stable (since 2013). In 2017 and 2018 dry season NH3-N concentrations in the discharge increased; in mid-2017 Sanderson Pond 1 taken offline for desludging (west side only) and jetty removal, then in mid-2018 Sanderson Pond 1 was taken offline to undertake desludging works for a period of approximately six months.

Ammonia removal in facultative ponds can occur through the following processes: gaseous ammonia stripping to the atmosphere, ammonia assimilation in algal biomass and biological nitrification. The low concentration of nitrates and nitrites in pond effluents indicates that nitrification generally does not account for a significant portion of ammonia removal. Ammonia assimilation in algal biomass depends on the biological activity in the system and is affected by temperature, organic load, detection time and wastewater characteristics.

During the period of time when Sanderson Pond 1 Facultative was taken offline for desludging works the retention time was reduce significantly; as a result, the biological oxidation of ammonia to nitrite followed by the oxidation of the nitrite to nitrate, known as the nitrification was also reduce, this can be seem in Figure 20, where the Total Oxidised Nitrogen (nitrite and nitrate) concentration decreased in the discharge, throughout the same period.

NH3-N remains relatively elevated at the upper zone sites with occasional increases in concentration in the transition and outer zone (Figure 23). These spikes in concentration have only been observed in the wet season since 2017.

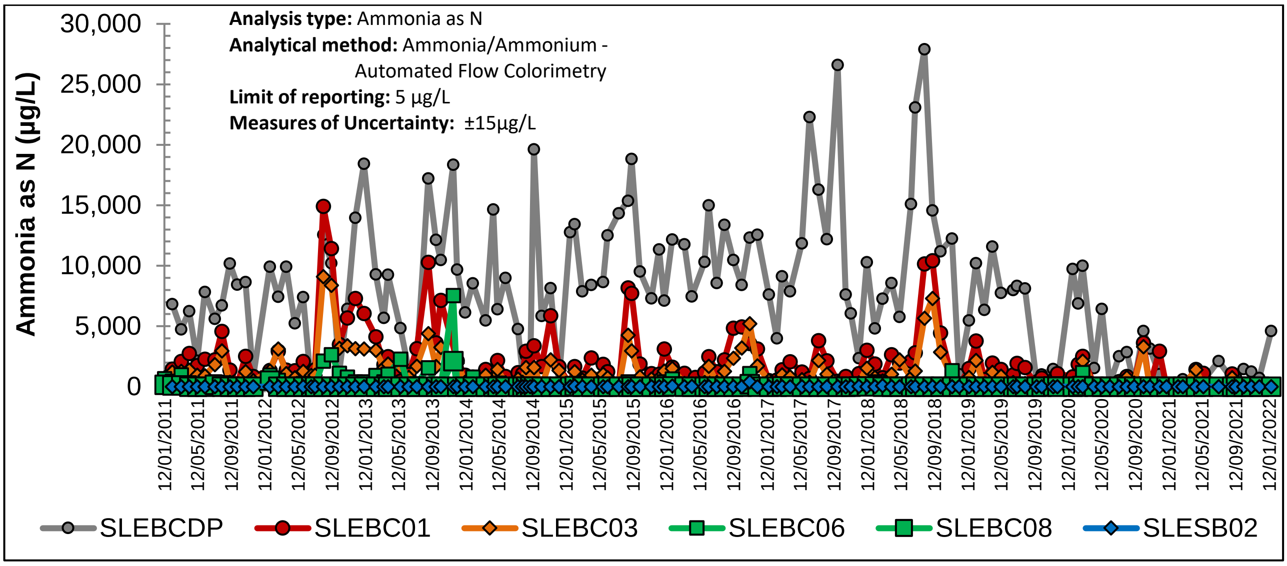

Figure 16 Long-term ammonia trend in discharge and surface waters

Surface Waters Assessments vs Reporting Limit, the trends in the receiving environment remain consistent with historical observations with no exceedances of pH adjusted chronic TVs at upper estuary SLEBC06 and SLEBC08 sites since 2013, Figure 17 and Figure 18.

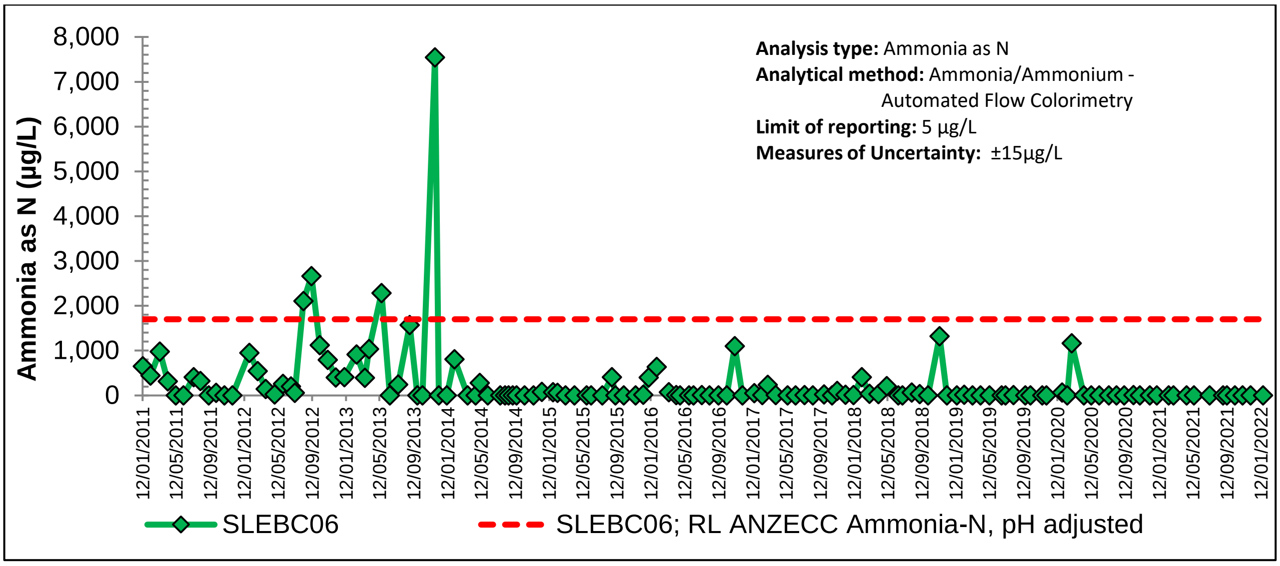

Figure 17 Long-term ammonia trend in surface waters at SLEBC06

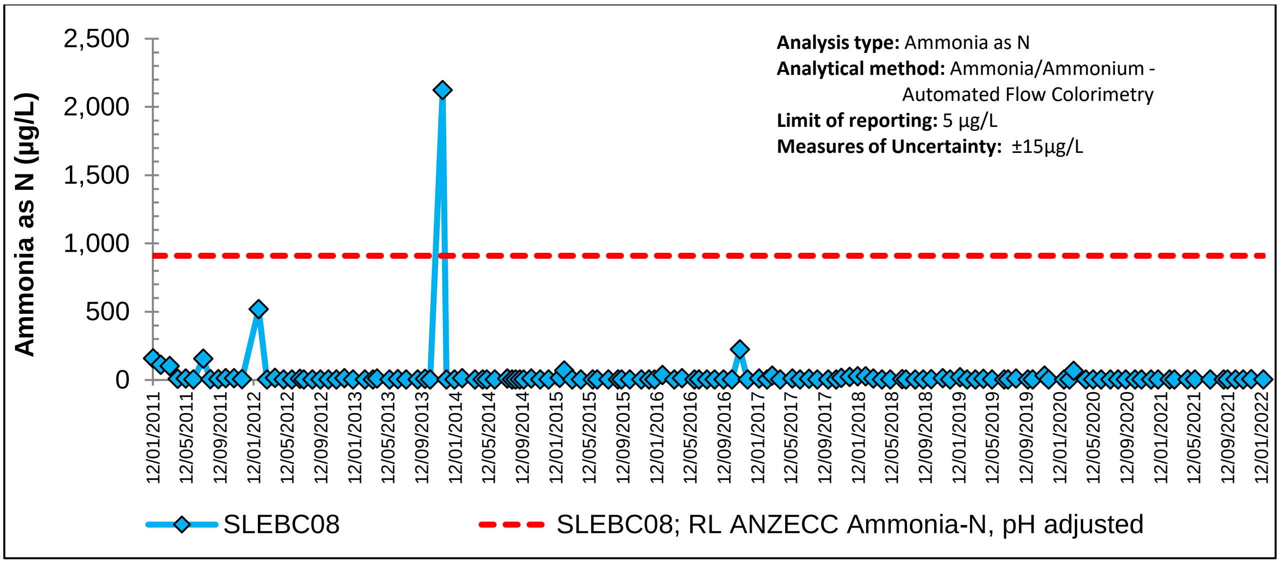

Figure 18 Long-term ammonia trend in surface waters at SLEBC08

On the other hand, the NH3-N has exceeded the reporting limit at SLESB02 in 2016-2017 and 2017-2018 wet seasons. The RL is based on the DHWQO for NH3-N which should only be applied to a dry season data set. A comparison of the NH3-N objectives/trigger values from DHWQO (20µg/L) and the ANZECC guidelines Table 8.3.7 trigger values as Total ammonia-N 910µg/L (ANZECC and ARMCANZ 2000a, b), which are suggested to be used, the NH3-N does not reach any of ANZECC toxic trigger values (either chronic or acute), see Figure 19.

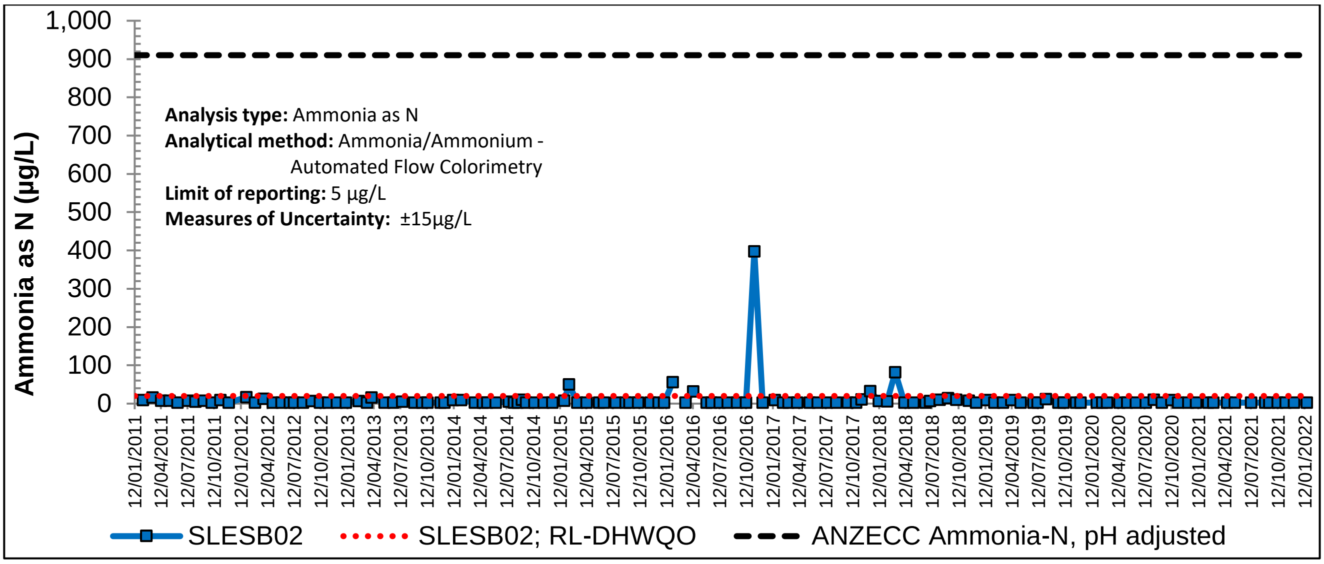

Figure 19 Long-term ammonia trend in surface waters at SLESB02

2.2.2.4 Ammonia – Sediment Assessment

Porewater concentrations of NH3-N are naturally elevated in tropical mangrove estuaries (Alongi et al. 1992, Alongi 1996). Concentrations observed in Buffalo Creek porewaters are within the range of concentrations observed in pristine mangrove deposits. However, local reference site based criteria are frequently exceeded at sites in the upper zone in all dry seasons and at times (2015, 2016 and 2017 dry seasons) at sites in the transition zone (Table 15).

2.2.2.5 Total Nitrogen and Oxides of Nitrogen – Discharge and Surface Waters Assessment

The dry and wet season assessment in Table 6, median TN exceeds default criteria in the upper zone significantly in all seasons (typically > 1 order of magnitude higher). Default criteria are also moderately exceeded consistently in the transition zone. Slight to moderate exceedances are still observed at outer zone sites. In contrast median NOX-N has more recently been compliant with default criteria in the transition zone and is mostly compliant in the outer zone in all seasons. Greater discrimination in water types in Darwin Harbour may demonstrate that the nutrient criteria are more correctly applicable to more open waters than to tidal creeks specifically.

Concentrations of total nitrogen (TN) (Figure 20) and oxides of nitrogen (NOX-N) (Figure 21) have been consistent with historical values.

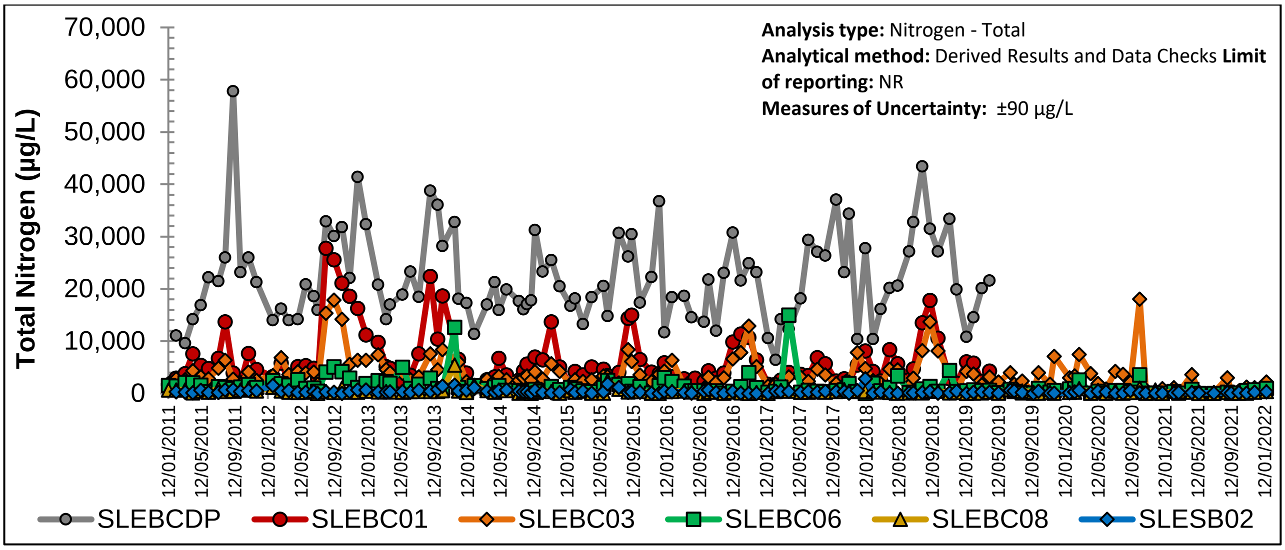

Figure 20 Long-term total nitrogen trends in discharge and surface waters

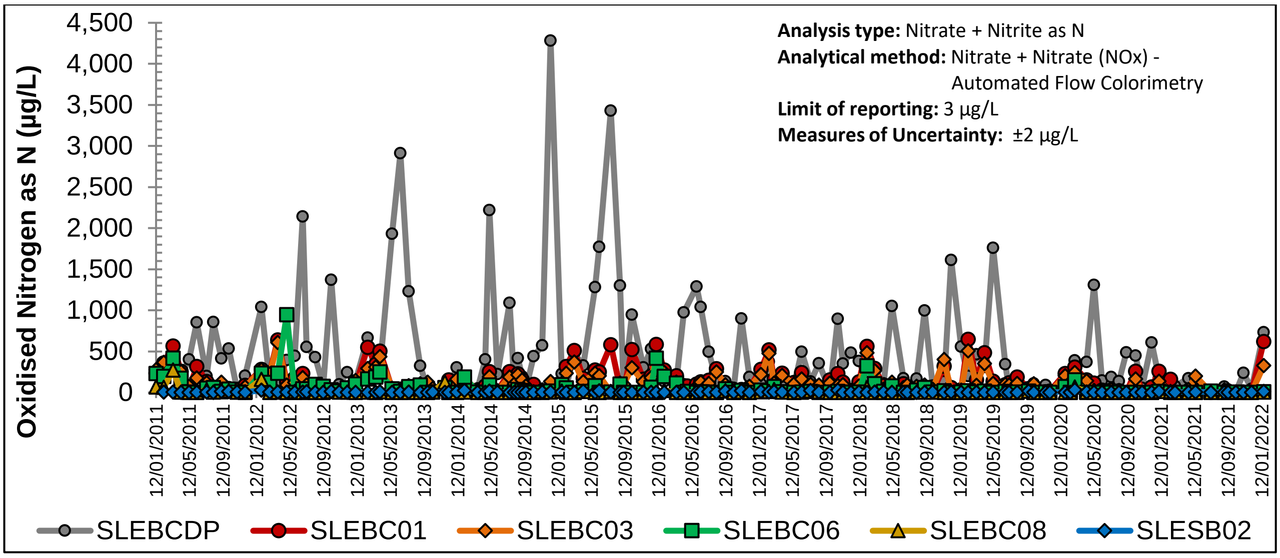

Figure 21 Long-term oxides of nitrogen in discharge and surface waters

2.2.2.6 Total nitrogen - Sediment and Porewaters Assessment

TN concentrations in sediment only exceed local reference site based criteria at upper zone sites, Table 16. Total nitrogen to total organic carbon ratios (TN:TOC) in sediment in Buffalo Creek are not significantly different to reference creeks in each season between 2014 and 2021.

TN in porewater concentrations seem more variable in that they don't follow an anticipated concentration gradient in all cases. In most years local reference site criteria are exceeded at SLEBC01 in the upper zone, Table 16. However, exceedances and even higher concentrations have been observed at transition zone sites. Whether this represents trapping type effects due to the multiple barriers to flushing present within this system is unclear.

2.2.2.7 Total phosphorous and filterable reactive phosphorous – Discharge and Surface Waters Assessment

The dry and wet season assessment in Table 7, median TP exceeds default criteria in all seasons in the upper (significant) and transition zones (moderate to significant) while outer zone sites are more typically within default criteria or moderately exceed. The level of exceedance in the outer zone in recent seasons is similar to historical exceedances between 2011 and 2012. Median FRP in the transition zone has either met or moderately exceeded default criteria in all seasons since the 2013-2014 wet season. It has been within default criteria in the outer zone in some dry and wet seasons.

Total phosphorous (TP) in the discharge has been consistent with historical values with somewhat lower peaks in recent years. In this most recent wet season, one of the highest TP concentrations at SLEBC06 in the transition zone was observed in October 2016, indicating that a first flush after several recent relatively dry years may have been captured during sampling, Figure 22.

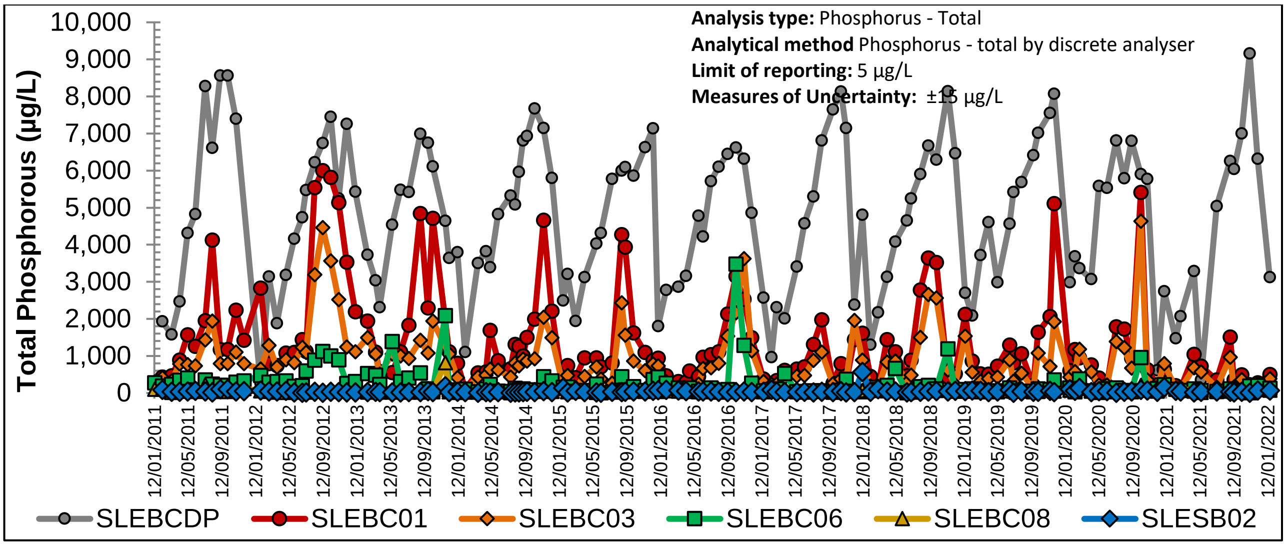

Figure 22 Long-term total phosphorous in discharge and surface waters

Filterable reactive phosphorous (FRP) in the discharge is also consistent with previous years with notable peaks between September and November in both 2014 and 2015, and October 2018, Figure 23.

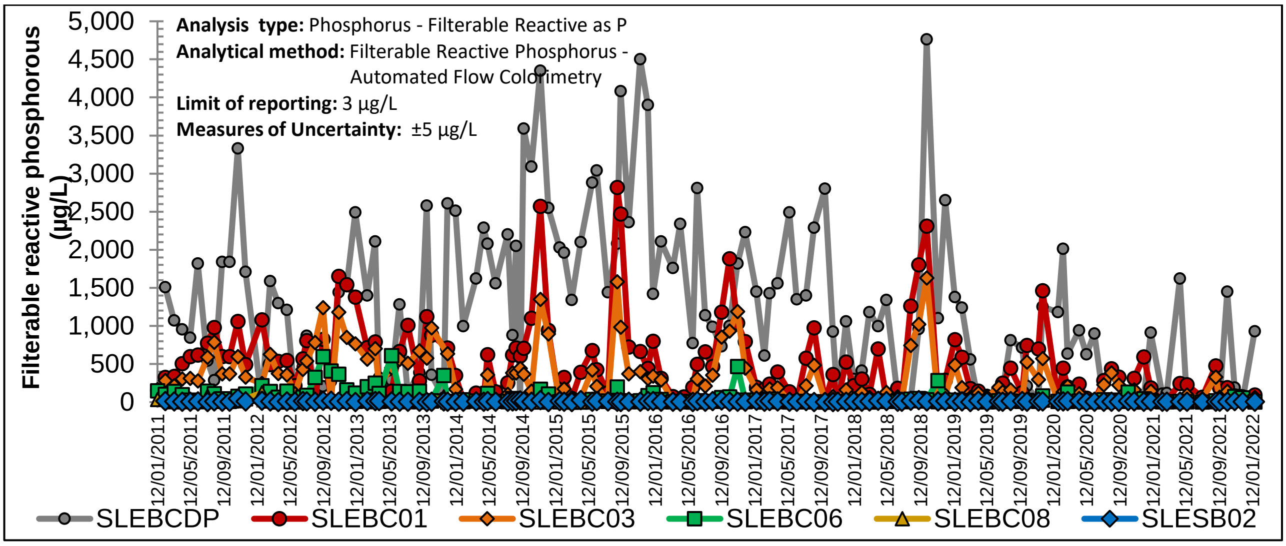

Figure 23 Long-term filterable reactive phosphorous in discharge and surface waters

2.2.2.8 Total phosphorous and filterable reactive phosphorous - Sediment and Porewaters Assessment

TP in sediment exceeds local reference site based criteria only in the upper zone, Table 17. The digestion method for TP in sediment analysis has changed from 2015. This change makes discussion of temporal trends somewhat difficult between 2012 and 2021 as it may be an artefact of the methodological change. Concentrations in the dry season in both Buffalo Creek and reference creeks appear relatively consistent.

TP and FRP in porewaters in the 2015 and 2016 dry season are actually more elevated at sites in the transition zone such as SLEBC04 than at sites in the upper zone more proximal to the discharge. These findings are interesting due to similar findings for NH3-N and TN in porewaters. It is unclear what may be influencing these findings. Possibilities include stormwater inputs from new developments below the upper zone, variable distribution of sediments following relatively low rainfall in preceding wet seasons or even changes in nutrient cycling within sediments further downstream. The TP and FRP concentration in porewaters decreased in 2018.

2.2.3 METALS

Metals with a source signal in the discharge are copper and zinc. Filtered copper and zinc are measured in discharge, surface and sediment porewaters. Total and bioavailable copper and zinc are measured in sediment. Total metals in sediment are also normalised using aluminium (Al) to account for the influence of sediment grain size on apparent distribution patterns (Munksgaards 2013).

2.2.3.1 Copper and Zinc – Discharge and Surface Waters Assessment

The dry and wet season assessment in Table 11, cases of suspected zinc contamination of receiving environment samples have been removed from seasonal assessments below (with outliers excluded). The assessments of metals in surface waters reveal that chronic toxicity due to copper is possible in the upper zone of Buffalo Creek with moderate level exceedances in multiple seasons (although less common in more recent seasons). Zinc does not appear to present any risk of chronic toxicity in either the source waters or in the receiving environment.

Filtered copper (Cu-F) is mostly not detected in the receiving environment (< 1 µg/L) but is detected more frequently in the upper zone, Figure 24. Relatively high occasional spikes in concentration in the transition zone appear to be in response to other sources.

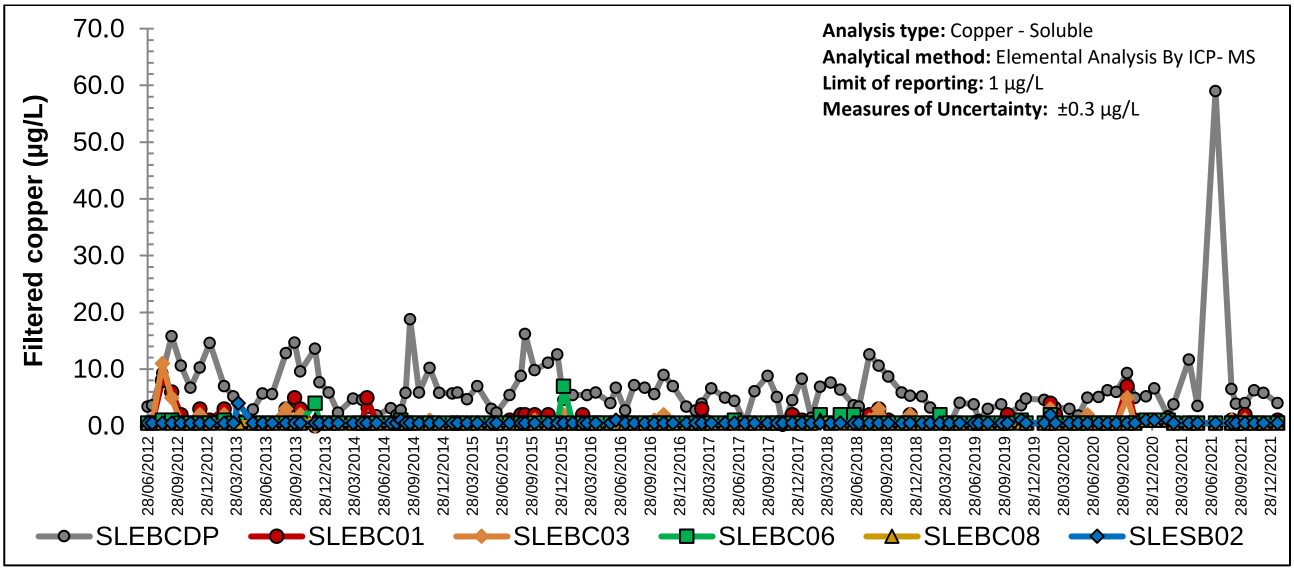

Figure 24 Long-term filtered copper in discharge and surface waters

The discharge is not the dominant source of zinc in this catchment (PWC 2017), as per Figure 25. Both filtered copper and filtered zinc concentrations in surface waters have been prone to suspected contamination issues at times, Figure 24 and Figure 26. These have been reported on an ongoing basis as they arise to the Administering Agency in monthly Exceedance Reports. Interlab comparison samples are being incorporated into monitoring runs at present in order to further investigate the source of these events when they do occur. These occurrences render an assessment of temporal trends in the receiving environment problematic. Seasonal assessments for both filtered copper and zinc were however provided with the recent updated environmental risk assessment (PWC 2021), Table 11.

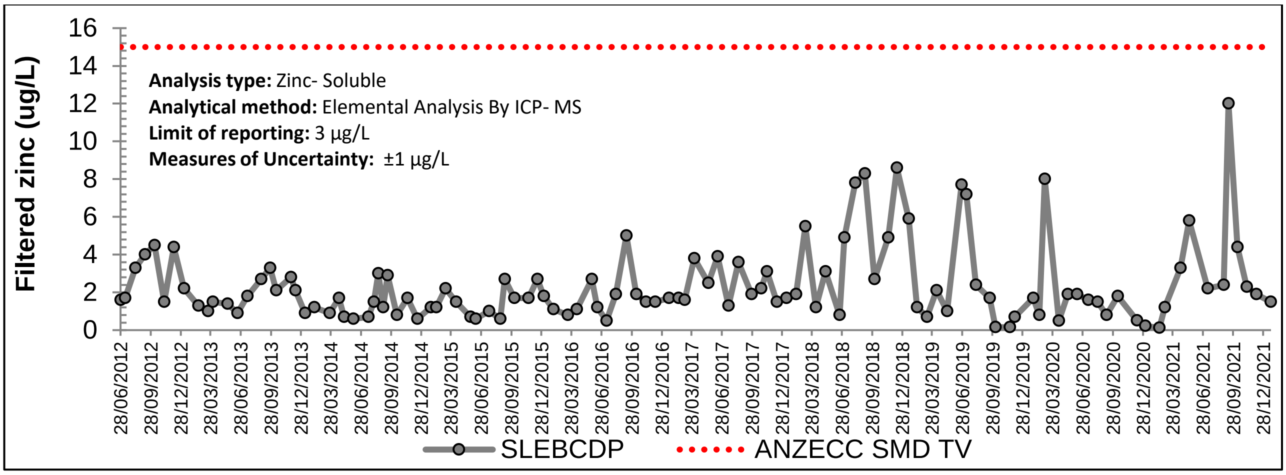

Figure 25 Long-term filtered zinc in the discharge

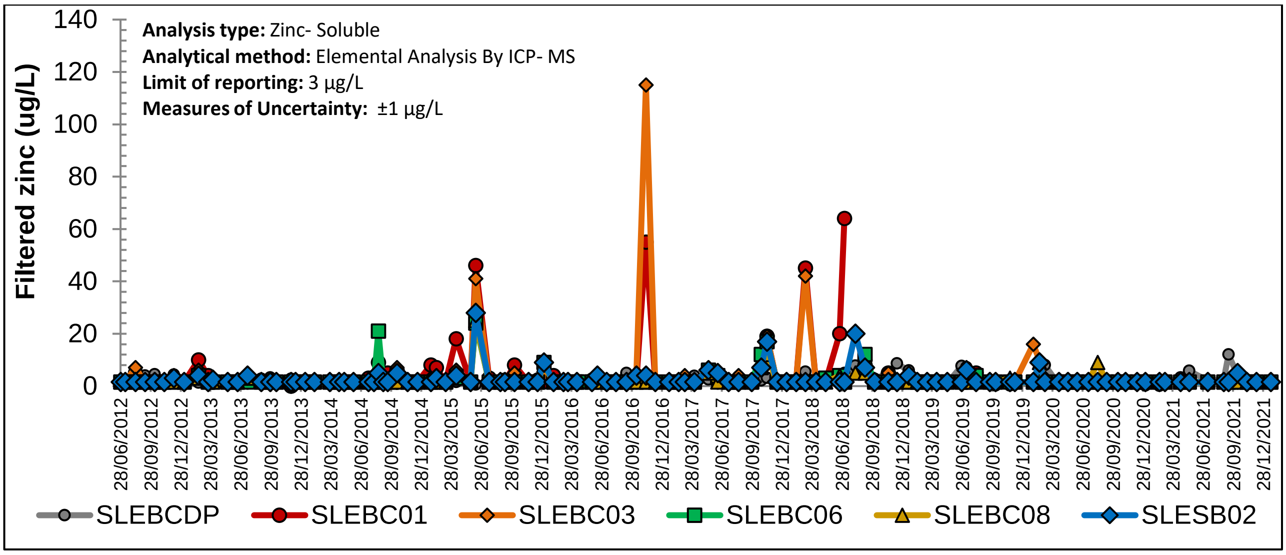

Figure 26 Long-term filtered zinc in surface waters

Surface Waters Assessments vs Reporting Limit, the trends in the receiving environment remain consistent with historical observations with no exceedances the filtered copper trigger values of ANZECC 95%LOP chronic and ANZECC 90%LOP from 2017 - 2021, with some spikes in 2013 and 2016, as per Figure 27 and Figure 28.

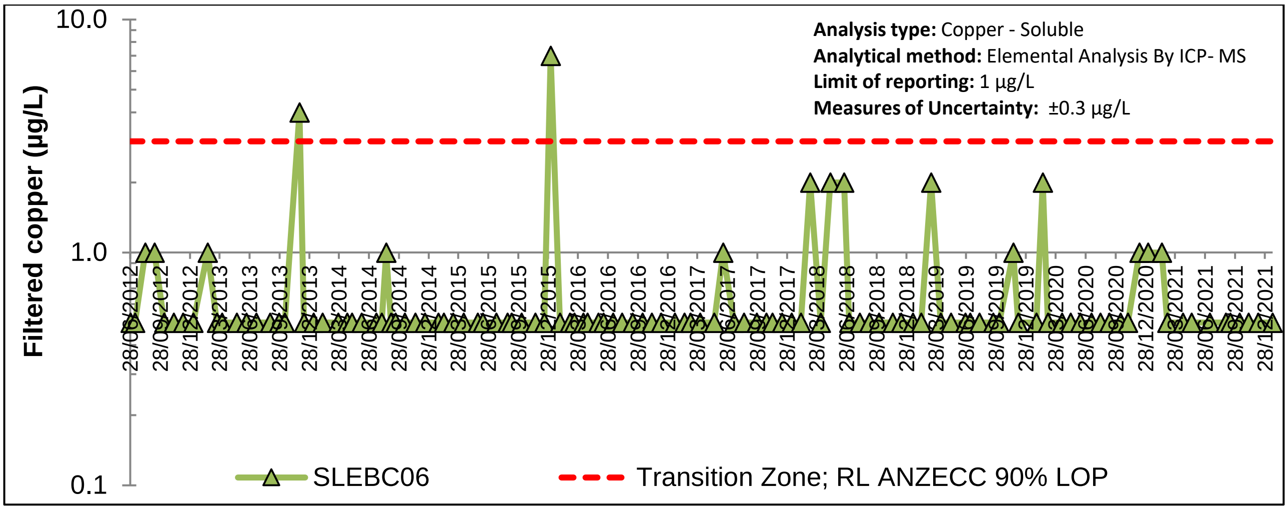

Figure 27 Long-term filtered copper trend in surface waters at SLEBC06

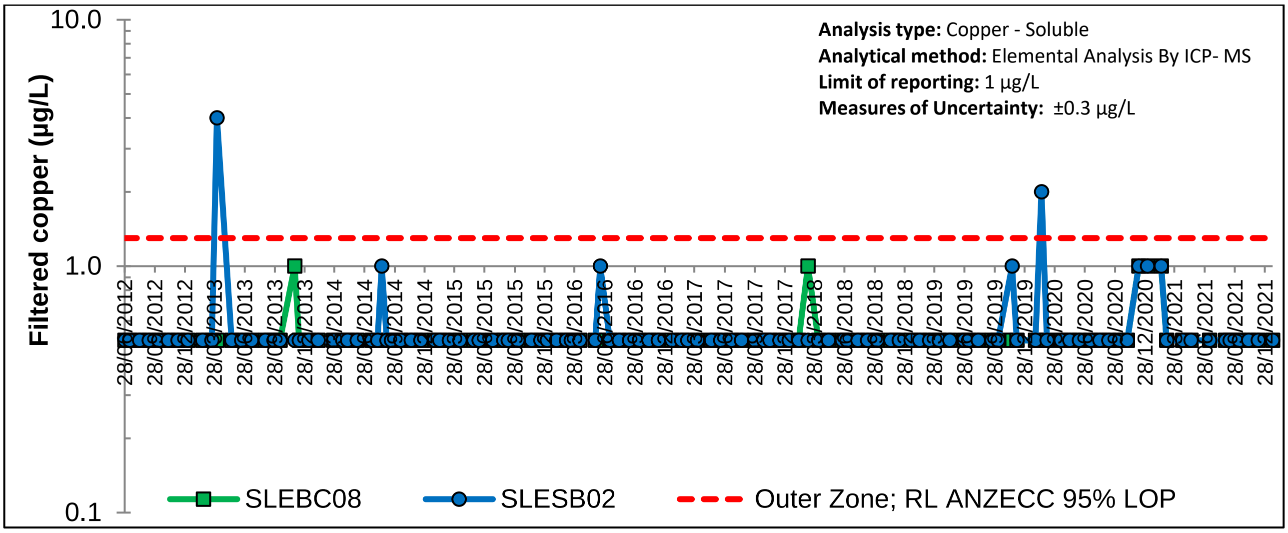

Figure 28 Long-term filtered copper trend in surface waters at SLEBC08 and SLESB02

2.2.3.2 Copper and Zinc – Sediment Assessment

Local reference site based criteria for copper total were exceeded in the upper zone in the dry season of 2016, 2017, 2018 and 2019 unlike in previous dry seasons, Table 18. Zinc total similarly exceeded local reference site based criteria at both sites in the upper zone in 2016 and has previously exceeded in this same zone in 2014, 2015 and recently in 2019.

The bioavailable Copper has only exceeded the reference site criteria either in Buffalo Creek upper zone in 2014, 2018 and 2019 dry season (Table 19), while the bioavailable Zinc has exceeded the reference site criteria in the upper zone of Buffalo Creek since 2014. However, total copper and zinc in sediments in Buffalo Creek do not exceed ANZECC and ARCANZ Interim Sediment Quality Low Trigger Values (ANZECC and ARMCANZ 2000a) in any season, as per Table 18, Figure 29 and Figure 30. *If total metals in sediment did exceed these TVs then the next tier of assessment would be to consider the bioavailable concentrations (ANZECC and ARMCANZ 2000a) but in this case further assessment is unnecessary.*

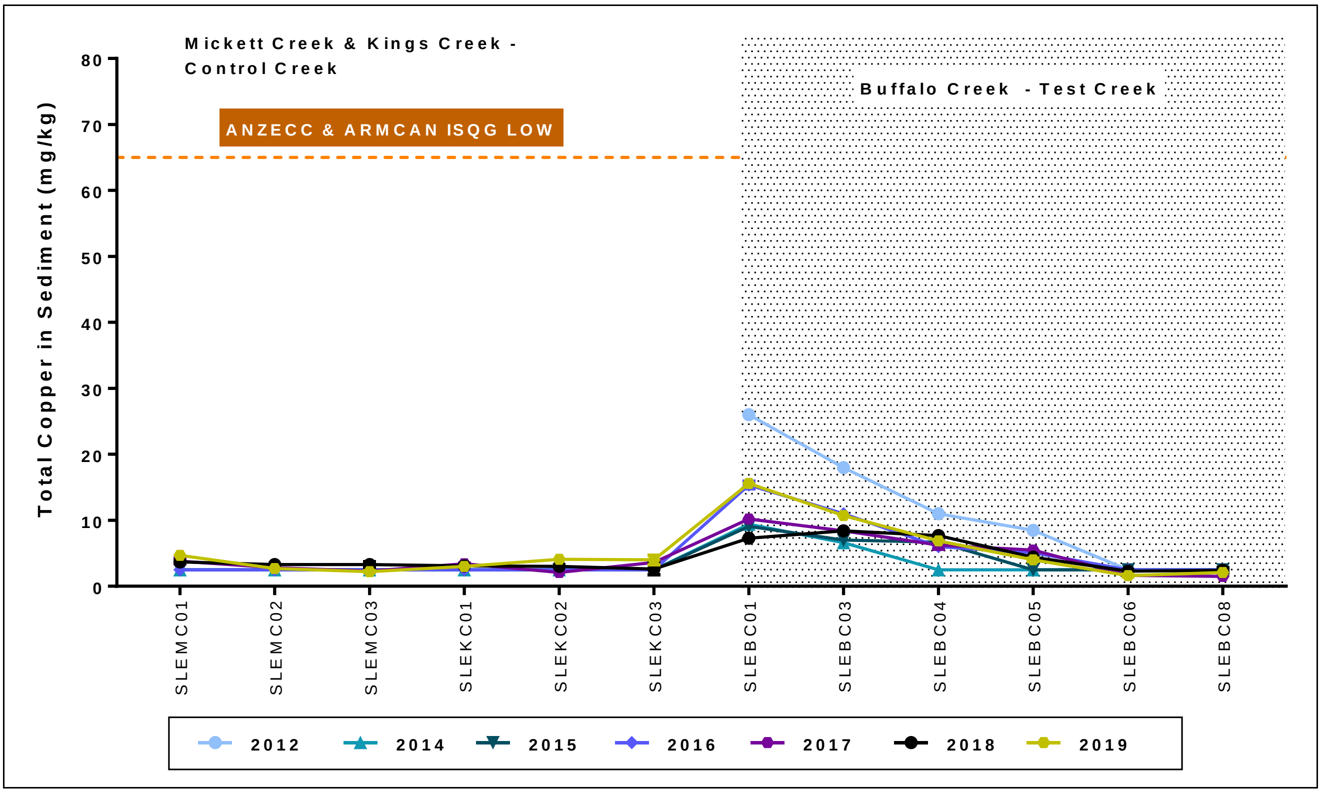

Figure 29 Total copper in sediments

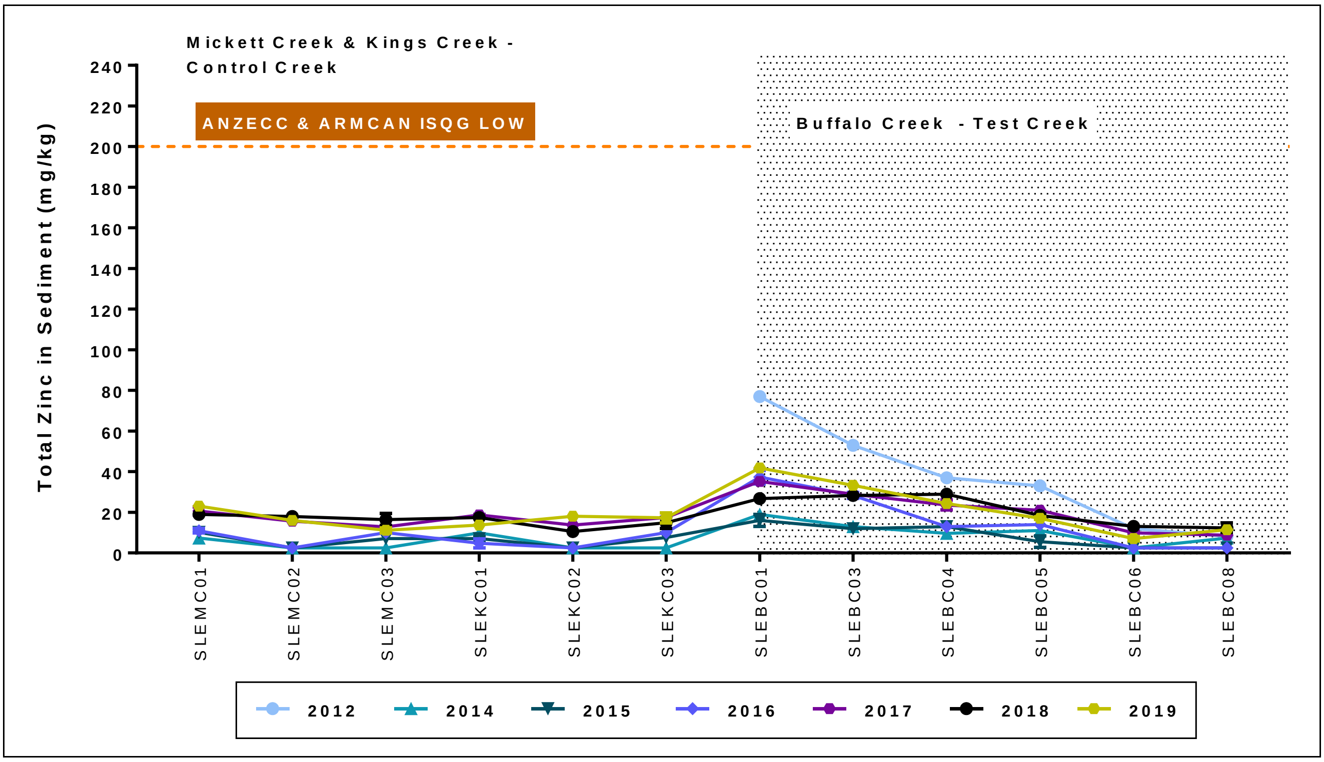

Figure 30 Total zinc in sediments

Al normalised total metal concentrations reveal that the concentrations of zinc in sediment in the upper zone of Buffalo Creek similarly exceed local reference site based criteria in 2016, as per Table 18, Figure 31 and Figure 32. Normalised copper concentrations were not significantly different to reference creeks in 2016 but normalised zinc concentrations were. This indicates that the spatial distribution and concentrations of zinc in Buffalo Creek sediments in the upper zone are unlikely to be due to differences in the distribution of finer grained sediments only. Given the relatively low concentrations of zinc in the discharge it appears unlikely that the discharge is responsible for these findings and it is more likely to be typical of urban catchments in this region with a large number of stormwater inputs as occurs in Buffalo Creek (PWC 2021).

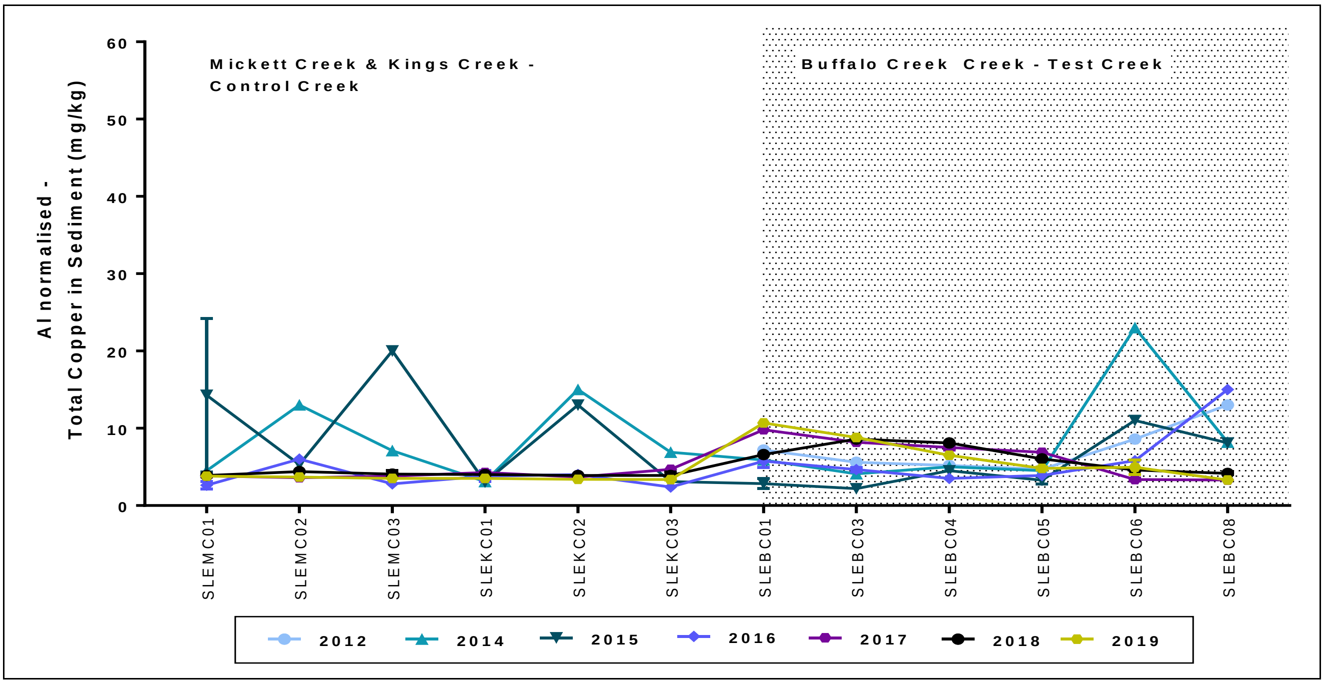

Figure 31 Al normalised copper in sediment

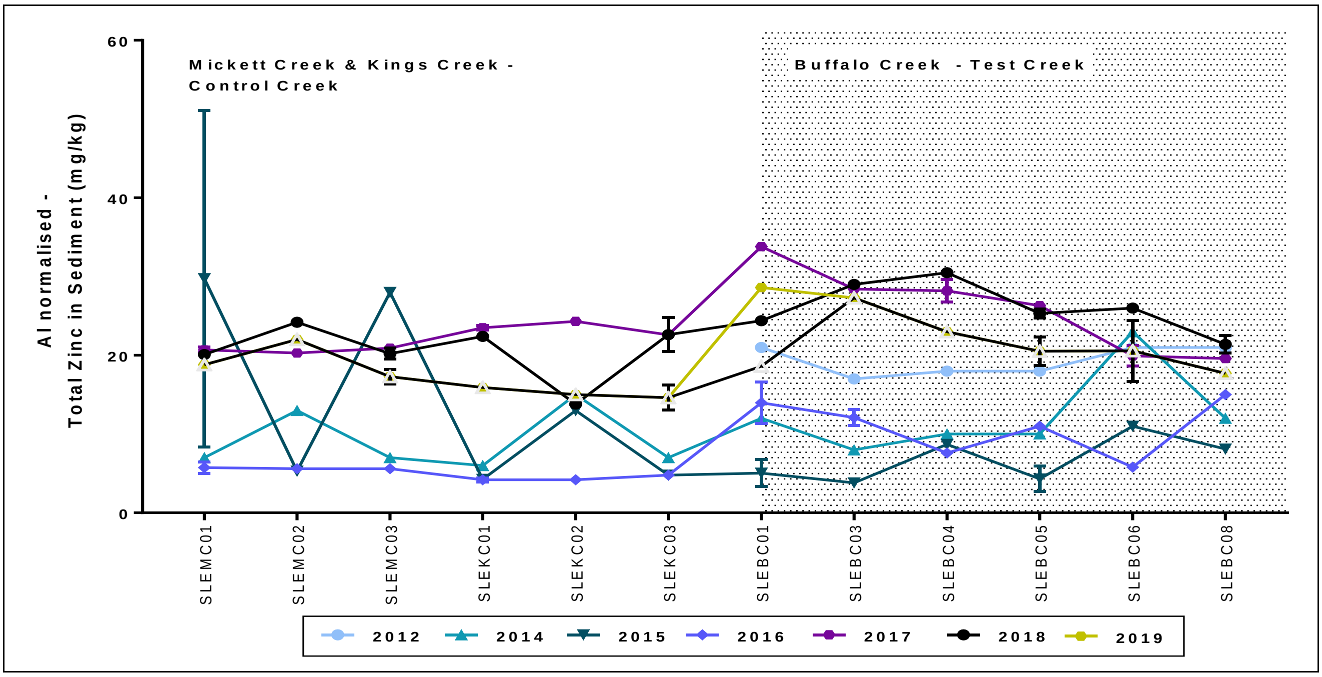

Figure 32 Al normalised zinc in sediment

2.2.3.3 Copper and Zinc – Porewaters Assessment

Cu-F in porewaters have exceeded ANZECC and ARMCANZ chronic toxicity trigger value in the upper zone of Buffalo Creek in 2015 and 2016 dry seasons, also in 2018 in the upper and transition zone, as per Table 20. Concentrations at SLEBC01 in the upper zone have also exceeded local reference site based criteria in the 2015 and 2016 dry season, also at SLEBC04 and SLEBC05 in 2018. Filtered copper is typically not detected in porewaters at the end of the transition and at the outer zones. In the same way, copper in porewater has exceeded the ANZECC and ARMCANZ chronic toxicity trigger value in the upper zone of Mickett Creek in 2019 and at Kings Creek in 2018 and 2019.

Zu-F in porewaters have not exceeded exceeded ANZECC and ARMCANZ chronic toxicity trigger value in any season. There has been some exceedance in the triplicate sample of local reference site based criteria at SLEBC01 in the 2016 dry season and at SLEBC05 in 2018 dry season.

2.2.4 PATHOGEN INDICATORS

The dry and wet season assessment in Table 12 Enterococci never comply with relevant criteria in the upper zone, with a few exceptions at SLEBC03 during the dry season; additionally it has been compliant particularly in the dry season in the transition. Maximum of Enterococci complies with relevant criteria in the outer zone in receiving environment, since 2014, with a minor exceedance in 20016-2017 wet season, possible due to a runoff. The assessment criteria from DHWQO are not unexpected for wet season exceedances to occur.

Enterococci concentrations in the discharge have been consistent with long-term concentrations (Figure 33), with some spike in the 2017 and 2018, these spikes are interesting due to similar findings for NH3-N, when Sanderson Pond 1 taken offline for desludging, which bring down the retention time; and consequently affected the pathogen reduction in the discharge. Receiving environment concentrations appear lower in recent years probably in response to less rainfall which can influence the concentrations of these indicators significantly.

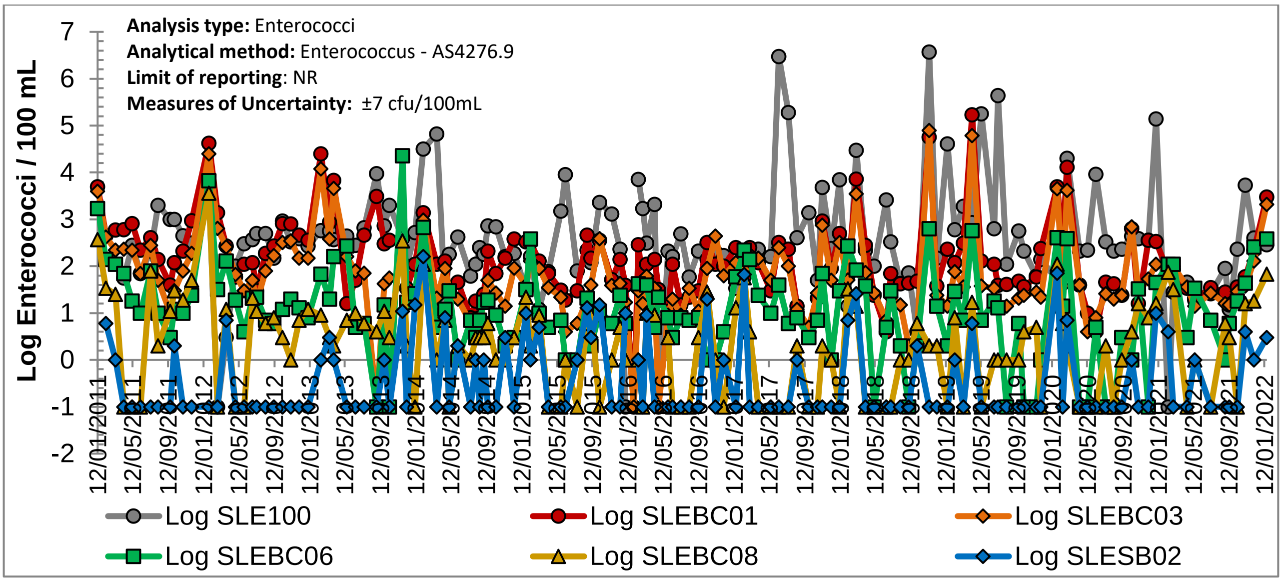

Figure 33 Long-term Enterococci in discharge and surface waters – log scale
log of '0' has been assigned a nominal value of '-1'

Surface Waters Assessments vs Reporting Limit, Enterococci concentrations in the receiving waters has been below the DHWQO target at SLEBC06 in the transition; exceedances are very much confined to the wet season. As previously mentioned DHWQO criteria are strictly only applicable in the dry season (NRETAS 2010) so it is not unexpected for wet season exceedances to occur; the trend for this site is illustrated in Figure 34. On the other hand, Enterococci at SLEBC08 and SLESB02 SLEBC06 in the outer zone have been below the reporting limit since 2014, as per Figure 35.

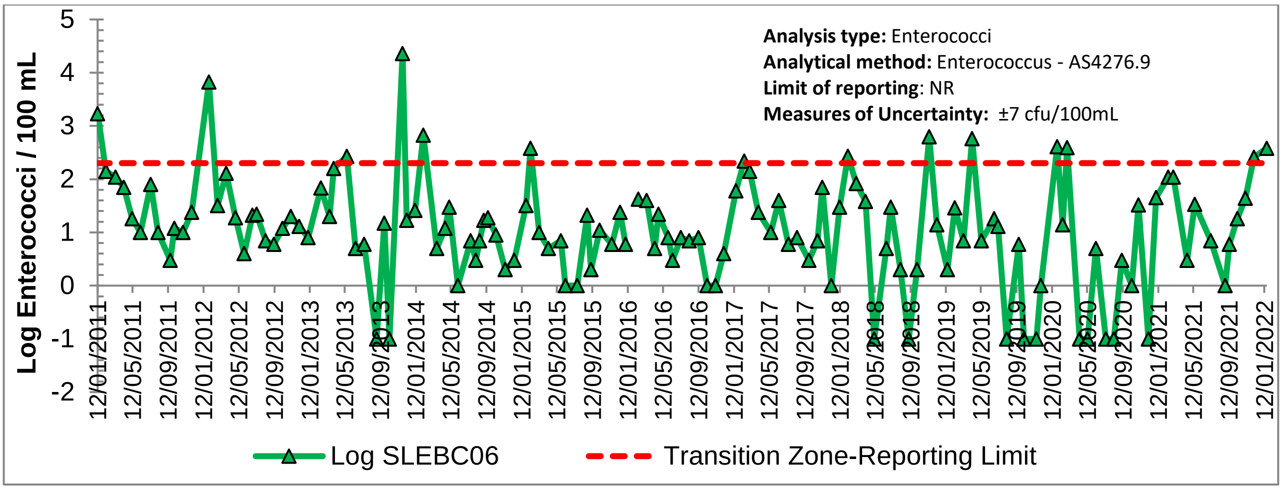

Figure 34 Long-term Enterococci at SLEBC06 in the transition zone – log scale

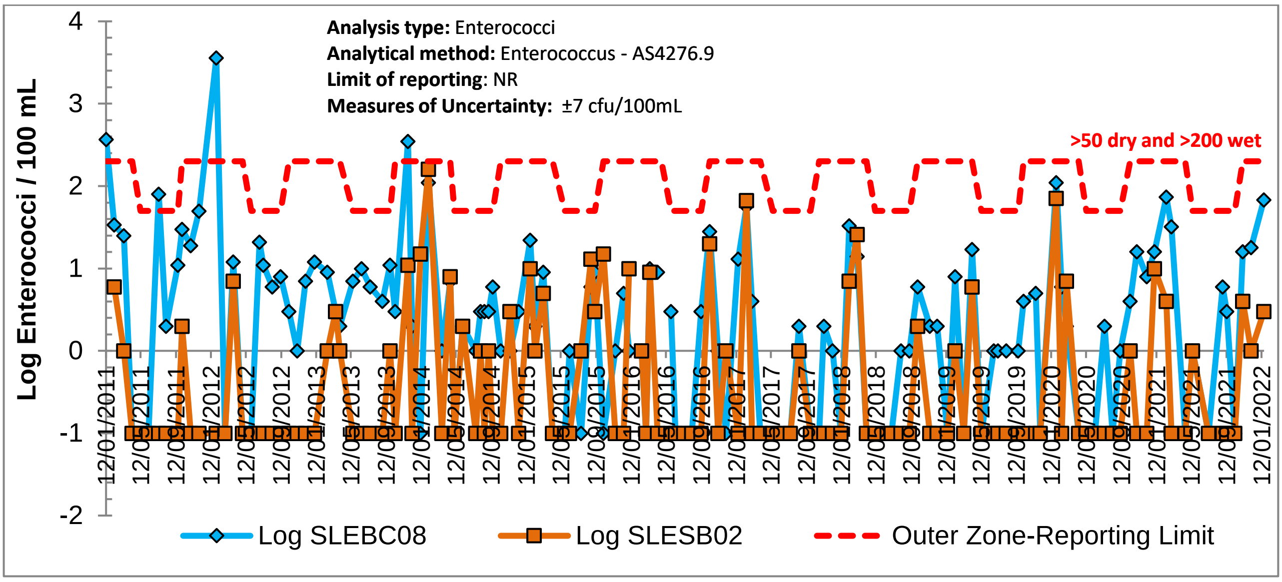

Figure 35 Long-term Enterococci at SLEBC08 and SLESB02 SLEBC06 in the outer zone – log scale

Enterococci long-term seasonal assessments against NHMRC protocols are also provided (Table 13). Tidal creeks in Darwin Harbour are not typically considered suitable for primary contact recreation. However any secondary contact recreation by children is assessed as primary contact recreation. For further details please refer to the recent risk assessment for the discharge (PWC 2021). Recent improvement is evident within the individual seasonal assessments while the negative influence of the wet season on suitability for primary contact is quite clear in the long-term seasonal assessment. 'Poor' suitability for recreational contact extends through to the outer zone in the wet season

The effect of rainfall on recreational water quality can be highly variable but characteristic for each recreational water area. *The flush from rainfall may increase pathogen loads in the recreational water, particularly in water bodies with continuous flow from large catchment areas*. PWC risk analysis and characterisation for pathogen exposure through secondary contact recreation by children at Transition zone (at boat ramp) found that the long-term classification for pathogen exposure is currently 'Very Poor'; consequence considered 'Moderate' due to gastrointestinal illness Risk of > 10% and Acute febrile respiratory illness Risk > 3.9 but short term incapacity end-point. **The 'Bather densities' is very low even at Darwin Harbour beaches due to crocodile and jellyfish presence.** Exposure of children through exploratory wading/splashing in terrestrially accessed shallower waters near sandbanks/boat ramp considered-Unlikely **(less likely to be permitted by parents in the wet season when marine stingers more likely)**.

However, this consequence is moderated by the likelihood that children would be exposed in the first place. The risk posed by exposure through recreational contact is subsequently mostly *'Low' for these end-points in the dry season* in areas where secondary contact recreation by children may possibly occur (the lower transition and outer zones). *In the wet season the risk increases to 'medium'* for these end-points in these zones. This would suggest that better public information/warning is required with respect to exploratory wading/splashing by children in this period so that informed decisions can be made. Apart from upgraded warning signs at the boat ramp, a comprehensive community education campaign was recommended by the Darwin Harbour Beach Water Quality Taskforce to effectively communicate the increased risk in the wet season in relation to rainfall events along with a range of other measures.

3. SUMMARY OF REPORTING LIMIT EXCEEDANCES

This Monitoring Report summarises Reporting Limit (RL) exceedances in the period from April 2017 to June 2021 in Table 21. Detailed reports identifying contributing factors for each exceedance have been provided previously.

4. IMPROVEMENT PLAN – PROGRESS

Reports on progress relating to the Leanyer Sanderson WDL 147 Improvement Plan 2017 dated March 2017 and the Darwin Region Sewerage Strategy (Condition 33.4)

Note: Some of these improvement plan actions have been reprioritised according to the most recent updated Leanyer Sanderson Improvement Plan 2021. This plan has been developed for the purposes of providing a focus for continuous improvement for the next licence application WDL 147-09.

Table 4 Progress against Improvement Plan Actions 2017

Item	Action Description	Timeframe	Status
1	Inlet Works – Construction and Commissioning	2017-2019	$16.2 million project **completed** in December 2018. Inlet works are inclusive of screening and grit removal process units. Odours are now concentrated and extracted for treatment using dual processes at this point (i.e. bio-trickling filter plus carbon polishing).
2	Pond Hydraulic Improvements and Pond Model Validation	2018-2020	**Pond model validation Ongoing.** $140K Design of hydraulic improvements on the Leanyer treatment train has been **completed**. A Preliminary Options Report (Hunter H2O 2019) has been provided and these options have been assessed using multi-criteria analysis. Preferred options have be evaluated using CFD model

Item	Action Description	Timeframe	Status
			evaluation under this design process. Options from this report are still being assessed among competing alternatives.
3	In-pond augmentation trials (e.g. aeration-mixing, AQUAMATS) to quantify performance in this context	2020-2021	Mixing-aeration options were identified and short-listed options evaluated using CFD modelling. Modelling revealed that full mixing and disturbance of sludge layers would occur even under the most conservative operating conditions for these options (AECOM 2019). Disturbance of sludge layers will drawdown available oxygen, reduce treatment efficacy and contribute to odours. PWC is proceeding with recommendations relating to reducing sludge volumes. Enhanced desludging has been implemented with desludging of Sanderson 1 in 2018 and now Sanderson 2 and 3 in 2019. In 2018 and now in 2019 PWC has been trialling the application of enhanced recirculation rates to supply additional oxygen to the primary ponds. This has been achieved by utilising temporary diesel pumps to increase capacity with promising findings. Therefore the focus of augmentation at present is on permanently increasing recirculation capacity at the site by upgrading on-site recirculation pump capacity. PWC is currently engaged on a CRC Project with multiple partners including Queensland Urban Utilities and the Advanced Water Management Centre at the University of Queensland. This project is titled Transforming Wastewater Treatment in Regional Australia with Robust Technology for Multiple Benefits. This project aims to develop and demonstrate a simple and low-cost technology to transform waste stabilisation ponds to environmental assets. An upscale trial of this technology is occurring at Leanyer Sanderson. The trial findings will be directly applicable to this site.

Item	Action Description	Timeframe	Status
4	a. Buffalo Creek Hydrodynamic Water Quality Model - validation	2019-2020	On-hold. PWC is currently reviewing the need for further model validation at this time. These changes would need to be reflected in an updated Improvement Plan once budgetary requirements for Action 2 & 3 have greater clarity.
	b. Application of Buffalo Creek Hydrodynamic to testing of alternative discharge strategies	2021-2022	Outside of this licence period
5	Draft Options Paper for Key Stakeholders	>2022	Outside of this licence period but has been provided by Hunter Water and improvement options are currently being assessed in the context of Master planning for Leanyer Sanderson catchment.

1. Appendix 1-SURFACE WATER BASELINE CONDITION ASSESSMENTS

Table 5 Surface water physio-chemical (Dissolved Oxygen, pH & Total Suspended Solids) baseline condition assessments – LeanyerSanderson

Indicator	Dissolved Oxygen	pH	TSS
Assessment Criteria	<75 and > 100 %sat [1]	6.0 - 8.5 pH unit	>10[1] mg/L (upper estuary) and >6[2] mg/L (mid estuary)
Source	Adjusted Water Quality Objectives, specific Assessment Criteria for the WDL 147-08 Appendix 5	DHWQO (2010)	Adjusted Water Quality Objectives, specific Assessment Criteria for the WDL 147-08 Appendix 5
BU	Environment - Aquatic Ecosystem (reference condition - ranges) and acute toxicity	Environment - Aquatic Ecosystem (background condition)	Environment - Aquatic Ecosystem (reference condition)
Assessment Statistic	Median	Median	Median
Analysis type	Dissolved Oxygen	pH	Suspended Solids
Analytical method	Field measurement	Field measurement	Suspended Solids 103C to 105C
LOR or Level of Precision	0.1 %Sat.	0.01 pH unit	1 mg/L
Measures of uncertainty	±1 %Sat.	±0.04 pH unit	±2 mg/L

Dissolved Oxygen

Season	2021-2022 Wet	2021 Dry	2020-2021 Wet	2020 Dry	2019-2020 Wet	2019 Dry	2018-2019 Wet	2018 Dry	2017-2018 Wet	2017 Dry	2016-2017 Wet	2016 Dry	2015-2016 Wet	2015 Dry	2014-2015 Wet	2014 Dry	2013-2014 Wet	2013 Dry	2012-2013 Wet	2012 Dry	2011-2012 Wet	2011 Dry	2011 Wet*
Discharge																							
SLE100	68	61	77	86	82	57	82	76	82	80	69	64	105	70	83	56	59	75	115	88	112	68	134
Upper ZOI																							
SLEBC01 *upper estuary*	43	31	30	42	40	38	30	32	36	51	36	36	55	58	52	35	59	14	52	29	31	26	30
SLEBC03 *upper estuary*	45	50	48	48	76	73	56	67	50	69	53	59	59	65	78	53	86	44	68	40	38	47	51
Transition ZOI																							
SLEBC06 *upper estuary*	56	84	82	88	103	97	90	111	116	91	142	92	107	99	139	87	108	171	146	78	91	80	83
Outer Zone																							
SLEBC08 *upper estuary*	78	92	93	88	90	97	96	92	101	96	110	89	97	98	95	90	107	101	127	106	95	93	114
SLESB02 *mid estuary*	90	93	96	91	93	99	91	97	98	96	100	93	94	100	93	92	100	102	108	103	95	91	104

pH

Season	2021-2022 Wet	2021 Dry	2020-2021 Wet	2020 Dry	2019 -2020 Wet	2019 Dry	2018-2019 Wet	2018 Dry	2017-2018 Wet	2017 Dry	2016-2017 Wet	2016 Dry	2015-2016 Wet	2015 Dry	2014-2015 Wet	2014 Dry	2013-2014 Wet	2013 Dry	2012-2013 Wet	2012 Dry	2011-2012 Wet	2011 Dry	2011 Wet*
Discharge	*Ambient assessment criteria are not directly applicable to discharge waters*																						
SLE100	7.51	7.30	7.71	7.54	7.97	7.50	7.68	7.77	7.86	7.72	7.65	7.66	8.23	7.89	8.26	7.67	7.95	7.49	8.15	7.92	8.26	7.66	8.21
Upper ZOI																							
SLEBC01 *upper estuary*	7.40	7.50	7.15	7.46	7.10	7.61	7.48	7.56	7.30	7.37	7.34	7.36	7.38	7.50	7.50	7.29	7.52	7.40	7.40	7.38	7.40	7.20	7.29
SLEBC03 *upper estuary*	7.65	7.60	7.32	7.60	7.52	7.82	7.61	7.88	7.54	7.86	7.44	7.52	7.55	7.67	7.70	7.53	7.61	7.45	7.40	7.37	7.31	7.39	7.43
Transition ZOI																							
SLEBC06 *upper estuary*	7.69	8.00	7.96	8.05	8.04	8.20	8.07	8.28	8.08	8.16	8.20	7.99	8.17	8.00	8.15	8.06	8.01	7.98	7.85	7.63	7.82	7.80	7.86
Outer Zone																							
SLEBC08 *upper estuary*	7.90	8.10	8.02	8.11	7.98	8.11	8.10	8.28	8.20	8.20	8.14	8.08	8.12	8.06	8.18	8.14	8.07	8.12	7.95	8.01	8.09	7.94	8.00
SLESB02 *mid estuary*	8.00	8.10	8.03	8.05	8.06	8.13	8.18	8.23	8.18	8.22	8.13	8.13	8.11	8.07	8.19	8.14	8.06	8.01	7.94	8.04	8.08	7.93	8.02

TSS

Season	2021-2022 Wet	2021Dry	2020-2021 Wet	2020 Dry	2019-2020 Wet	2019 Dry	2018-2019 Wet	2018 Dry	2017-2018 Wet	2017 Dry	2016-2017 Wet	2016 Dry	2015-2016 Wet	2015 Dry	2014-2015 Wet	2014 Dry	2013-2014 Wet	2013 Dry	2012-2013 Wet	2012 Dry	2011-2012 Wet	2011 Dry	2011 Wet*
Discharge																							
SLE100	165	178	75	144	88	144	120	120	132	96	60	112	68	92	60	97	82	132	108	156	74	120	57
Upper ZOI																							
SLEBC01 *upper estuary*	10	14	28	20	18	19	16	16	27	28	28	20	26	30	27	22	28	30	56	20	34	47	40
SLEBC03 *upper estuary*	1	13	19	19	30	17	18	21	21	24	22	19	23	25	28	26	29	22	50	20	48	42	30
Transition ZOI																							
SLEBC06 *upper estuary*	6	3	15	7	10	7	11	13	23	9	24	9	13	5	17	11	12	18	29	18	40	29	29
Outer Zone																							
SLEBC08 *upper estuary*	10	7	27	5	10	4	8	3	11	4	10	4	14	2	13	5	11	10	9	6	26	15	7
SLESB02 *mid estuary*	5	3	12	7	7	1	2	1	9	2	4	2	17	2	7	2	12	6	8	2	24	6	8

Hazard Ranking

Dissolved Oxygen: Hazard Ranges	pH: Hazard Quotient Ranges	TSS: Hazard Quotient Ranges
<30	< 6 Upper estuary	HQ < 1.5
≥ 30 but < 75	≥6 but ≤8.5 Upper estuary	1.5 ≤HQ < 10
≥75 and ≤100	> 8.5 Upper estuary	HQ ≥ 10
>100 and <110		
≥110		

Dissolved Oxygen (hazard ranking)

	2021-2022 Wet	2021 Dry	2020-2021 Wet	2020 Dry	2019-2020 Wet	2019 Dry	2018-2019 Wet	2018 Dry	2017-2018 Wet	2017 Dry	2016-2017 Wet	2016 Dry	2015-2016 Wet	2015 Dry	2014-2015 Wet	2014 Dry	2013-2014 Wet	2013 Dry	2012-2013 Wet	2012 Dry	2011-2012 Wet	2011 Dry	2011 Wet*
Discharge																							
SLE100	68	61	77	86	82	57	82	76	82	80	69	64	105	70	83	56	59	75	115	88	112	68	134
Upper ZOI																							
SLEBC01	43	31	30	42	40	38	30	32	36	51	36	36	55	58	52	35	59	14	52	29	31	26	30
SLEBC03	45	50	48	48	76	73	56	67	50	69	53	59	59	65	78	53	86	44	68	40	38	47	51
Transition ZOI																							
SLEBC06	56	84	82	88	103	97	90	111	116	91	142	92	107	99	139	87	108	171	146	78	91	80	83
Outer Zone																							
SLEBC08	78	92	93	88	90	97	96	92	101	96	110	89	97	98	95	90	107	101	127	106	95	93	114
SLESB02	90	93	96	91	93	99	91	97	98	96	100	93	94	100	93	92	100	102	108	103	95	91	104

pH (hazard ranking)

	2021-2022 Wet	2021 Dry	2020-2021 Wet	2020 Dry	2019 -2020 Wet	2019 Dry	2018-2019 Wet	2018 Dry	2017-2018 Wet	2017 Dry	2016-2017 Wet	2016 Dry	2015-2016 Wet	2015 Dry	2014-2015 Wet	2014 Dry	2013-2014 Wet	2013 Dry	2012-2013 Wet	2012 Dry	2011-2012 Wet	2011 Dry	2011 Wet*
Discharge	*Ambient criteria are not directly applicable to discharge waters*																						
SLE100	7.51	7.30	7.71	7.54	7.97	7.50	7.68	7.77	7.86	7.72	7.65	7.66	8.23	7.89	8.26	7.67	7.95	7.49	8.15	7.92	8.26	7.66	8.21
Upper ZOI																							
SLEBC01	7.40	7.50	7.15	7.46	7.10	7.61	7.48	7.56	7.30	7.37	7.34	7.36	7.38	7.50	7.50	7.29	7.52	7.40	7.40	7.38	7.40	7.20	7.29
SLEBC03	7.65	7.60	7.32	7.60	7.52	7.82	7.61	7.88	7.54	7.86	7.44	7.52	7.55	7.67	7.70	7.53	7.61	7.45	7.40	7.37	7.31	7.39	7.43
Transition ZOI																							
SLEBC06	7.69	8.00	7.96	8.05	8.04	8.20	8.07	8.28	8.08	8.16	8.20	7.99	8.17	8.00	8.15	8.06	8.01	7.98	7.85	7.63	7.82	7.80	7.86
Outer Zone																							
SLEBC08	7.90	8.10	8.02	8.11	7.98	8.11	8.10	8.28	8.20	8.20	8.14	8.08	8.12	8.06	8.18	8.14	8.07	8.12	7.95	8.01	8.09	7.94	8.00
SLESB02	8.00	8.10	8.03	8.05	8.06	8.13	8.18	8.23	8.18	8.22	8.13	8.13	8.11	8.07	8.19	8.14	8.06	8.01	7.94	8.04	8.08	7.93	8.02

TSS (hazard ranking)

	2021-2022 Wet	2021Dry	2020-2021 Wet	2020 Dry	2019-2020 Wet	2019 Dry	2018-2019 Wet	2018 Dry	2017-2018 Wet	2017 Dry	2016-2017 Wet	2016 Dry	2015-2016 Wet	2015 Dry	2014-2015 Wet	2014 Dry	2013-2014 Wet	2013 Dry	2012-2013 Wet	2012 Dry	2011-2012 Wet	2011 Dry	2011 Wet*
Discharge																							
SLE100	16.5	17.8	7.5	14.4	8.8	14.4	12.0	12.0	13.2	9.6	6.0	11.2	6.8	9.2	6.0	9.7	8.2	13.2	10.8	15.6	7.4	12.0	5.7
Upper ZOI																							
SLEBC01	1.0	1.4	2.8	2.0	1.8	1.9	1.6	1.6	2.7	2.8	2.8	2.0	2.6	3.0	2.7	2.2	2.8	3.0	5.6	2.0	3.4	4.7	4.0
SLEBC03	0.1	1.3	1.9	1.9	3.0	1.7	1.8	2.1	2.1	2.4	2.2	1.9	2.3	2.5	2.8	2.6	2.9	2.2	5.0	2.0	4.8	4.2	3.0
Transition ZOI																							
SLEBC06	0.6	0.3	1.5	0.7	1.0	0.7	1.1	1.3	2.3	0.9	2.4	0.9	1.3	0.5	1.7	1.1	1.2	1.8	2.9	1.8	4.0	2.9	2.9
Outer Zone																							
SLEBC08	1.0	0.7	2.7	0.5	1.0	0.4	0.8	0.3	1.1	0.4	1.0	0.4	1.4	0.2	1.3	0.5	1.1	1.0	0.9	0.6	2.6	1.5	0.7
SLESB02	0.8	0.4	2.0	1.2	1.2	0.2	0.3	0.1	1.5	0.3	0.7	0.3	2.8	0.3	1.2	0.3	2.0	1.0	1.3	0.3	4.0	1.0	1.3

Values in red text indicate the median value has exceeded a default assessment criteria for that water type; Excedances are subsequently ranked using a traffic light colour coding within the hazard ranking (from green to red). Hazard ranges indicate that the ranking is applied to the assessment statistic itself.

Hazard quotients indicate that the ranking is applied to the ratio of the assessment statistic to the assessment criteria (i.e. a hazard quotient). It should be noted that DHWQO are only applicable in the dry season (NRETAS 2010).

[1] Adjusted Water Quality Objectives for Upper Estuary, changed to more stringent Assessment Criteria for the WDL 147-08 (<75 - >100 rather than DHWQO <80- >100)

[2] Adjusted Water Quality Objectives for Mid Estuary

(2011 Wet*): this data includes less than 7 samples wet season during that period

Table 6 Surface water nutrients (Total Nitrogen & Oxidised Nitrogen as N) baseline condition assessments using Darwin Harbour Water Quality Objectives – LeanyerSanderson

Indicator	Total Nitrogen	Oxidised Nitrogen as N (NO_X)
Assessment Criteria	300[1] µg/L upper estuary and 270[2] µg/L mid estuary	20[1] µg/L upper estuary and 17[2] µg/L mid estuary
Source	*DHWQO (NRETAS 2010)*	*Adjusted Water Quality Objectives, specific Assessment Criteria for the WDL 147-08 Appendix 5*
Beneficial Use	Environment - Aquatic Ecosystem (background condition)	Environment - Aquatic Ecosystem (background condition)
Assessment Statistic	*Median*	*Median*
Analysis type	Nitrogen - Total	Nitrate + Nitrite as N
Analytical method	Derived Results and Data Checks	Nitrate + Nitrate (NOx) - Automated Flow Colorimetry
LOR or Level of Precision	NR	3 µg/L
Measures of uncertainty	±60 µg/L	±2 µg/L

Total Nitrogen

Season	2021-2022 Wet	2021 Dry	2020-2021 Wet	2020 Dry	2019 -2020 Wet	2019 Dry	2018-2019 Wet	2018 Dry	2017-2018 Wet	2017 Dry	2016-2017 Wet	2016 Dry	2015-2016 Wet	2015 Dry	2014-2015 Wet	2014 Dry	2013-2014 Wet	2013 Dry	2012-2013 Wet	2012 Dry	2011-2012 Wet	2011 Dry	2011 Wet*
Discharge																							
SLE100	*19,440*	*18,305*	*20,870*	*23,190*	*20,690*	*22,050*	*20,170*	*31,500*	*20,210*	*27,100*	*14,200*	*21,800*	*18,400*	*26,200*	*18,400*	*17,700*	*18,100*	*23,300*	*22,100*	*20,900*	*16,200*	*22,200*	*11,100*
Upper ZOI																							
SLEBC01 *upper estuary*	830	870	1,960	3,130	6,300	4,100	4,320	5,680	4,230	3,720	4,070	3,910	3,790	4,690	5,080	4,340	3,550	7,610	11,200	5,340	4,590	5,420	3,830
SLEBC03 upper estuary	1,250	390	930	2,170	3,830	2,230	3,750	4,530	2,470	3,160	3,220	3,030	3,560	3,400	2,670	3,010	2,570	3,890	6,380	4,100	3,600	3,200	2,850
Transition ZOI																							
SLEBC06 *upper estuary*	670	95	80	420	890	170	600	900	670	480	1,260	470	1,430	1,730	780	610	1,180	1,800	2,290	1,080	1,730	1,190	2,040
Outer Zone																							
SLEBC08 *upper estuary*	250	80	410	230	200	500	170	150	440	290	220	320	380	370	410	250	550	370	340	280	540	470	670
SLESB02 *mid estuary*	270	135	110	420	170	210	270	170	310	360	80	360	230	300	210	460	660	480	350	270	510	660	280
Hazard Ranking	**Hazard Quotient Ranges** HQ < 1.5 1.5 ≤HQ < 10 HQ ≥ 10																						
Discharge	**DHWQO are not applicable to source waters (i.e. discharge) but Hazard Quotients based on these criteria in discharge waters can provide an indication of potential for exceedance in receiving environment or vice-versa the level of dilution of the source that may be necessary to achieve criteria in receiving environment (this can also be influenced by background concentrations so it is an indicative measure only).**																						
SLE100	*65*	*61*	*70*	*77*	*69*	*74*	*67*	*105*	*67*	*90*	*47*	*73*	*61*	*87*	*61*	*59*	*60*	*78*	*74*	*70*	*54*	*74*	*37*
Upper ZOI																							
SLEBC01 *upper estuary*	3	3	7	10	21	14	14	19	14	12	14	13	13	16	17	14	12	25	37	18	15	18	13
SLEBC03 upper estuary	4	1	3	7	13	7	13	15	8	11	11	10	12	11	9	10	9	13	21	14	12	11	10
Transition ZOI																							
SLEBC06 *upper estuary*	2.2	0.3	0.3	**1.4**	3.0	0.6	2	3.0	2.2	1.6	4.2	1.6	4.8	5.8	2.6	2.0	3.9	6.0	7.6	3.6	5.8	4.0	6.8
Outer Zone																							
SLEBC08 *upper estuary*	0.8	0.3	**1.4**	0.8	0.7	1.7	0.6	0.5	**1.5**	1.0	0.7	**1.1**	**1.3**	**1.2**	**1.4**	0.8	1.8	**1.2**	**1.1**	0.9	1.8	1.6	2.2
SLESB02 *mid estuary*	**1.0**	0.5	0.4	1.6	0.6	0.8	**1.0**	0.6	**1.1**	**1.3**	0.3	**1.3**	0.9	**1.1**	0.8	1.7	2.4	1.8	**1.3**	**1.0**	1.9	2.4	**1.0**

Oxidised Nitrogen as N (NO_X)

Season	2021-2022 Wet	2021 Dry	2020-2021 Wet	2020 Dry	2019 -2020 Wet	2019 Dry	2018-2019 Wet	2018 Dry	2017-2018 Wet	2017 Dry	2016-2017 Wet	2016 Dry	2015-2016 Wet	2015 Dry	2014-2015 Wet	2014 Dry	2013-2014 Wet	2013 Dry	2012-2013 Wet	2012 Dry	2011-2012 Wet	2011 Dry	2011 Wet*
Discharge																							
SLE100	*239*	*93*	*173*	*187*	*214*	*60*	*308*	*170*	*352*	*133*	*104*	*493*	*377*	*1300*	*441*	*224*	*64*	*1230*	*245*	*443*	*204*	*411*	*270*
Upper ZOI																							
SLEBC01 *upper estuary*	4	4	68	26	154	116	152	40	127	122	159	127	203	251	98	157	97	40	94	88	123	99	307
SLEBC03 upper estuary	3	3	9	22	121	96	86	89	82	100	114	108	178	113	127	153	40	82	143	89	90	116	321
Transition ZOI																							
SLEBC06 *upper estuary*	2	3	2	2	2	6	4	29	12	3	21	5	64	6	13	5	3	42	102	44	119	11	212
Outer Zone																							
SLEBC08 *upper estuary*	4.0	3.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	5.0	8.0	1.5	1.5	1.5	4.0	1.5	1.5	1.5	4.0	1.5	6.0	3.0	65.0
SLESB02 *mid estuary*	1.5	3.0	1.5	1.5	1.5	1.5	1.5	1.5	3.0	4.0	5.0	7.0	1.5	1.5	4.0	1.5	1.5	1.5	1.5	1.5	6.0	1.5	3.0
Hazard Ranking	**Hazard Quotient Ranges** HQ < 1.5 1.5 ≤HQ < 10 HQ ≥ 10																						
Discharge																							
SLE100	*12*	*5*	*9*	*9*	*11*	*3*	*15*	*9*	*18*	*7*	*5*	*25*	*19*	*65*	*22*	*11*	*3*	*62*	*12*	*22*	*10*	*21*	*14*
Upper ZOI																							
SLEBC01 *upper estuary*	0	0	3	1	8	6	8	2	6	6	8	6	10	13	5	8	5	2	5	4	6	5	15
SLEBC03 upper estuary	0	0	0	1	6	5	4	4	4	5	6	5	9	6	6	8	2	4	7	4	5	6	16
Transition ZOI																							
SLEBC06 *upper estuary*	0.1	0.2	0.1	0.1	0.1	0.3	0.2	**1.5**	0.6	0.2	**1.1**	0.3	3.2	0.3	0.7	0.3	0.2	2.1	5.1	2.2	6.0	0.6	10.6
Outer Zone																							
SLEBC08 *upper estuary*	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.4	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	3.3
SLESB02 *mid estuary*	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.4	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.4	0.1	0.2

Values in red text have exceeded the assessment criteria; Hazard quotient ranges are then used to score these exceedances using a traffic light approach. Hazard quotients are the ratio of the assessment statistic for that site and the assessment criteria that applies to that parameter at that site.
It should be recognised that DHWQO are really only applicable to dry season assessments only (NRETAS 2010).
[1] Adjusted Water Quality Objectives, those values are the specific Assessment Criteria for the WDL 147
[2] Adjusted Water Quality Objectives for Mid Estuary
(2011 Wet*): this data includes less than 7 samples wet season during that period

Table 7 Surface water nutrients (Total Phosphorous & Filterable Reactive Phosphorous) baseline condition assessments using Darwin Harbour Water Quality Objectives – LeanyerSanderson

Indicator	Total Phosphorous																						
Assessment Criteria	30[1] µg/L upper estuary and 20[2] µg/L mid estuary																						
Source	*Adjusted Water Quality Objectives, specific Assessment Criteria for the WDL 147-08 Appendix 5*																						
Beneficial Use	Environment - Aquatic Ecosystem (background condition)																						
Assessment Statistic	***Median***																						
Analysis type	Phosphorus - Total																						
Analytical method	Phosphorus - total by discrete analyser																						
LOR or Level of Precision	5 µg/L																						
Measures of uncertainty	±18 µg/L																						
Season	2021-2022 Wet	2021 Dry	2020-2021 Wet	2020 Dry	2019- 2020 Wet	2019 Dry	2018-2019 Wet	2018 Dry	2017-2018 Wet	2017 Dry	2016-2017 Wet	2016 Dry	2015-2016 Wet	2015 Dry	2014-2015 Wet	2014 Dry	2013-2014 Wet	2013 Dry	2012-2013 Wet	2012 Dry	2011-2012 Wet	2011 Dry	2011 Wet*
Discharge																							
SLE100	*6,320*	*5,540*	*2,740*	*5,790*	*3,680*	*5,420*	*4,610*	*5,250*	*3,130*	*5,300*	*2,570*	*5,710*	*3,160*	*5,770*	*3,210*	*5,320*	*3,800*	*5,480*	*5,250*	*5,470*	*3,160*	*6,610*	*1,930*
Upper ZOI																							
SLEBC01 *upper estuary*	269	421	630	941	1,170	811	517	1,110	789	703	607	1,030	880	949	945	1,260	683	1,830	2,190	1,440	1,170	1,570	447
SLEBC03 *upper estuary*	258	260.5	350	671	715	430	554	864	376	475	411	678	604	704	472	734	454	1,050	1,240	1,230	793	790	367
Transition ZOI																							
SLEBC06 *upper estuary*	186	51	113	66	107	56	91	168	92	40	262	55	167	83	148	75	83	406	483	594	304	242	252
Outer Zone																							
SLEBC08 *upper estuary*	74	35.5	101	39	52	48	46	38	62	28	48	31	49	28	42	28	20	27	43	60	44	46	75
SLESB02 *mid estuary*	64	32	61	66	53	38	51	28	42	26	31	38	56	24	25	18	23	19	20	15	50	42	34
Hazard Ranking	Hazard Quotient Ranges HQ < 1.5 1.5 ≤HQ < 10 HQ ≥ 10																						
Discharge	***DHWQO are not applicable to source waters (i.e. discharge) but Hazard Quotients based on these criteria in discharge waters can provide an indication of potential for exceedance in receiving environment or vice-versa the level of dilution of the source that may be necessary to achieve criteria in receiving environment***																						
SLE100	*211*	*185*	*91*	*193*	*123*	*181*	*154*	*175*	*104*	*177*	*86*	*190*	*105*	*192*	*107*	*177*	*127*	*183*	*175*	*182*	*105*	*220*	*64*
Upper ZOI																							
SLEBC01 *upper estuary*	9	14	21	31	39	27	17	37	26	23	20	34	29	32	32	42	23	61	73	48	39	52	15
SLEBC03 *upper estuary*	9	9	12	22	24	14	18	29	13	16	14	23	20	23	16	24	15	35	41	41	26	26	12
Transition ZOI																							
SLEBC06 *upper estuary*	6.2	1.7	3.8	2.2	3.6	1.9	3.0	5.6	3.1	**1.3**	8.7	1.8	5.6	2.8	4.9	2.5	2.8	13.5	16.1	19.8	10.1	8.1	8.4
Outer Zone																							
SLEBC08 *upper estuary*	2.5	**1.2**	3.4	**1.3**	1.7	1.6	1.5	**1.3**	2.1	0.9	1.6	**1.0**	1.6	0.9	**1.4**	0.9	0.7	0.9	**1.4**	2.0	**1.5**	1.5	2.5
SLESB02 *mid estuary*	3.2	1.6	3.1	3.3	2.7	1.9	2.6	**1.4**	2.1	**1.3**	1.6	1.9	2.8	**1.2**	**1.3**	0.9	**1.2**	1.0	**1.0**	0.8	2.5	2.1	1.7

Indicator	Filterable Reactive Phosphorous																						
Assessment Criteria	9[1] µg/L upper estuary and 5[2] µg/L mid estuary																						
Source	*Adjusted Water Quality Objectives, specific Assessment Criteria for the WDL 147-08 Appendix 5*																						
Beneficial Use	Environment - Aquatic Ecosystem (background condition)																						
Assessment Statistic	***Median***																						
Analysis type	Phosphorus - Filterable Reactive as P																						
Analytical method	Filterable Reactive Phosphorus - Automated Flow Colorimetry																						
LOR or Level of Precision	3 µg/L																						
Measures of uncertainty	±3 µg/L																						
Season	2021-2022 Wet	2021 Dry	2020-2021 Wet	2020 Dry	2019- 2020 Wet	2019 Dry	2018-2019 Wet	2018 Dry	2017-2018 Wet	2017 Dry	2016-2017 Wet	2016 Dry	2015-2016 Wet	2015 Dry	2014-2015 Wet	2014 Dry	2013-2014 Wet	2013 Dry	2012-2013 Wet	2012 Dry	2011-2012 Wet	2011 Dry	2011 Wet*
Discharge																							
SLE100	*188*	*28*	*108*	*26*	*942*	*154*	*1,240*	*81*	*923*	*2,290*	*1,450*	*987*	*2,340*	*2,880*	*2,100*	*2,050*	*1,620*	*386*	*1,440*	*207*	*1,590*	*843*	*1,070*
Upper ZOI																							
SLEBC01 *upper estuary*	81	188	185	283	444	156	285	180	302	134	396	498	443	675	392	618	235	665	791	566	548	619	331
SLEBC03 *upper estuary*	70	80	23	222	205	130	118	126	58	33	190	302	306	422	145	367	99	559	700	538	372	372	249
Transition ZOI																							
SLEBC06 *upper estuary*	54	11	14	12	14	13	20	8	6	4	28	10	17	18	5	26	14	141	202	90	105	43	122
Outer Zone																							
SLEBC08 *upper estuary*	21	6	6	9	12	10	9	19	6	5	7	9	5	10	5	10	12	5	10	14	14	10	21
SLESB02 *mid estuary*	54	11	14	12	14	13	20	8	6	4	28	10	17	18	5	26	14	141	202	90	105	43	122
Hazard Ranking	Hazard Quotient Ranges HQ < 1.5 1.5 ≤HQ < 10 HQ ≥ 10																						
Discharge																							
SLE100	*21*	*3*	*12*	*3*	*105*	*17*	*138*	*9*	*103*	*254*	*161*	*110*	*260*	*320*	*233*	*228*	*180*	*43*	*160*	*23*	*177*	*94*	*119*
Upper ZOI																							
SLEBC01 *upper estuary*	9	21	21	31	49	17	32	20	34	15	44	55	49	75	44	69	26	74	88	63	61	69	37
SLEBC03 *upper estuary*	8	9	3	25	23	14	13	14	6	4	21	34	34	47	16	41	11	62	78	60	41	41	28
Transition ZOI																							
SLEBC06 *upper estuary*	6.0	**1.2**	1.6	**1.3**	1.6	**1.4**	2.2	0.9	0.7	0.4	3.1	**1.1**	1.9	2.0	0.6	2.9	1.6	15.7	22.4	10.0	11.7	4.8	13.6
Outer Zone																							
SLEBC08 *upper estuary*	2.3	0.6	0.7	**1.0**	**1.3**	**1.1**	**1.0**	2.1	0.7	0.6	0.8	**1.0**	0.6	**1.1**	0.6	**1.1**	**1.3**	0.6	**1.1**	**1.6**	**1.6**	**1.1**	2.3
SLESB02 *mid estuary*	10.8	2.1	2.8	2.4	2.8	2.6	4.0	1.6	**1.2**	0.8	**5.6**	2.0	**3.4**	3.6	**1.0**	5.2	**2.8**	**28.2**	40.4	18.0	21.0	**8.6**	24.4

Values in red text have exceeded the assessment criteria; Hazard quotient ranges are then used to score these exceedances using a traffic light approach. Hazard quotients are the ratio of the assessment statistic for that site and the assessment criteria that applies to that parameter at that site.

It should be recognised that DHWQO are really only applicable to dry season assessments only (NRETAS 2010)

[1] Adjusted Water Quality Objectives, those values are the specific Assessment Criteria for the WDL 147

[2] Adjusted Water Quality Objectives for Mid Estuary

(2011 Wet*): this data includes less than 7 samples wet season during that period

Table 8 Surface water nutrients (Ammonia-Total as N) baseline condition assessments using Darwin Harbour Water Quality Objectives – LeanyerSanderson

Indicator	Total Ammonia as N
Assessment Criteria	20[1] µg/L (upper and mid estuary)
Source	*DHWQO (NRETAS 2010)*
Beneficial Use	Environment - Aquatic Ecosystem (reference condition)
Assessment Statistic	***Median***
Analysis type	Ammonia as N
Analytical method	Ammonia/Ammonium - Automated Flow Colorimetry
LOR or Level of Precision	5 µg/L
Measures of uncertainty	±10 µg/L

Season	2021-2022 Wet	2021 Dry	2020-2021 Wet	2020 Dry	2019 - 2020 Wet	2019 Dry	2018-2019	2018 Dry	2017-2018 Wet	2017 Dry	2016-2017 Wet	2016 Dry	2015-2016 Wet	2015 Dry	2014-2015 Wet	2014 Dry	2013-2014 Wet	2013 Dry	2012-2013 Wet	2012 Dry	2011-2012 Wet	2011 Dry	2011 Wet*
Discharge																							
SLE100	*1,258*	*1,801*	*621*	*2,511*	*1,550*	*7,980*	*10,220*	*15,100*	*7,290*	*16,300*	*8,414*	*10,480*	*9,538*	*14,350*	*8,144*	*4,758*	*9,691*	*4,838*	*9,250*	*7,405*	*8,443*	*6,725*	*6,255*
Upper ZOI																							
SLEBC01 upper estuary	3	257	54	423	830	1,442	1,524	2,819	1,093	1,236	2,062	2,239	1,131	1,864	1,683	1,158	1,198	3,167	4,136	2,086	1,347	2,236	1,784
SLEBC03 upper estuary	6	5	3	265	129	282	771	2,220	475	590	987	1,289	723	1,050	969	633	763	1,677	3,139	1,288	1,091	962	1,242
Transition ZOI																							
SLEBC06 upper estuary	2.5	5.0	2.5	2.5	2.5	2.5	2.5	34.0	33.0	6.0	13.0	2.5	22.0	2.5	6.0	2.5	2.5	249.0	794.0	263.0	59.0	6.0	551.0
Outer Zone																							
SLEBC08 upper estuary	2.5	5.0	2.5	2.5	2.5	2.5	6.0	2.5	14.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	12.0	6.0	106.0
SLESB02 mid estuary	2.5	5.0	2.5	2.5	2.5	2.5	8.0	7.0	7.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	8.0	9.0

Hazard Ranking	Hazard Quotient Ranges
	HQ ≥ 10
	1.5 ≤HQ < 10
	HQ < 1.5

Discharge — ***DHWQO are not applicable to source waters (i.e. discharge) but Hazard Quotients based on these criteria in discharge waters can provide an indication of potential for exceedance in receiving environment or vice-versa the level of dilution of the source that may be necessary to achieve criteria in receiving environment***

Site	2021-2022 Wet	2021 Dry	2020-2021 Wet	2020 Dry	2019 - 2020 Wet	2019 Dry	2018-2019	2018 Dry	2017-2018 Wet	2017 Dry	2016-2017 Wet	2016 Dry	2015-2016 Wet	2015 Dry	2014-2015 Wet	2014 Dry	2013-2014 Wet	2013 Dry	2012-2013 Wet	2012 Dry	2011-2012 Wet	2011 Dry	2011 Wet*
SLE100	*62.9*	*90.025*	*31.05*	*125.55*	*77.5*	*399*	*511*	*755*	*365*	*815*	*421*	*524*	*477*	*718*	*407*	*238*	*485*	*242*	*463*	*370*	*422*	*336*	*313*
Upper ZOI																							
SLEBC01	0	13	3	21	42	72	76	141	55	62	103	112	57	93	84	58	60	158	207	104	67	112	89
SLEBC03	0	0	0	13	6	14	39	111	24	30	49	64	36	53	48	32	38	84	157	64	55	48	62
Transition ZOI																							
SLEBC06	0.1	0.3	0.1	0.1	0.1	0.1	0.1	1.7	1.7	0.3	0.7	0.1	1.1	0.1	0.3	0.1	0.1	12.5	39.7	13.2	3.0	0.3	27.6
Outer Zone																							
SLEBC08	0.1	0.3	0.1	0.1	0.1	0.1	0.3	0.1	0.7	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.6	0.3	5.3
SLESB02	0.1	0.3	0.1	0.1	0.1	0.1	0.4	0.4	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.4	0.5

Values in red text have exceeded the assessment criteria; Hazard quotient ranges are then used to score these exceedances using a traffic light approach. Hazard quotients are the ratio of the assessment statistic for that site and the assessment criteria that applies to that parameter at that site.
It should be recognised that DHWQO are really only applicable to dry season assessments only (NRETAS 2010).
[1] Adjusted Water Quality Objectives, those values are the specific Assessment Criteria for the WDL 147

Table 9 Surface water Ammonia baseline condition assessments using ANZECC & ARMCANZ trigger values – LeanyerSanderson

However, this is not part of the Assessment protocol for Water Quality

Indicator	Total Ammonia as N																						
Assessment Criteria	2490 µg/L upper zone and 1100 µg/L transition and outer zone																						
Source	*ANZECC and ARMCANZ (2000) pH adjusted SMD Trigger Values*																						
Beneficial Use	Environment - Aquatic Ecosystem (chronic toxicity)																						
Assessment Statistic	*95th percentile*																						
Analysis type	Ammonia as N																						
Analytical method	Ammonia/Ammonium - Automated Flow Colorimetry																						
LOR or Level of Precision	5 µg/L																						
Measures of uncertainty	±10 µg/L																						
Season	2021-2022 Wet	2021 Dry	2020-2021 Wet	2020 Dry	2019 -2020 wet	2019 Dry	2018-2019 Wet	2018 Dry	2017-2018 Wet	2017 Dry	2016-2017 Wet	2016 Dry	2015-2016 Wet	2015 Dry	2014-2015 Wet	2014 Dry	2013-2014 Wet	2013 Dry	2012-2013 Wet	2012 Dry	2011-2012 Wet	2011 Dry	2011 Wet*
Discharge																							
SLE100	*4,266*	*4,508*	*4,170*	*5,715*	*9,919*	*8,288*	*12,062*	*26,936*	*9,782*	*25,740*	*12,498*	*14,678*	*12,053*	*18,144*	*13,232*	*16,435*	*17,250*	*16,214*	*17,092*	*12,092*	*9,932*	*9,728*	*6,762*
Upper ZOI																							
SLEBC01 upper estuary	*76*	*1,112*	*3,419*	768	2,312	1,870	4,252	10,376	2,908	3,481	4,544	4,369	2,758	8,086	4,840	3,250	5,902	8,968	6,931	14,222	2,821	4,121	2,670
SLEBC03 upper estuary	*81*	*690*	*2,749*	683	1,650	769	2,664	6,976	1,394	1,945	4,612	2,236	1,455	4,012	1,967	1,596	2,942	3,849	3,320	8,959	2,588	2,732	1,377
Transition ZOI																							
SLEBC06 upper estuary	*3*	*7*	*7*	2.5	838.6	8.5	932.7	183.6	318.4	23.8	844.3	10.9	566.1	330.9	79.5	201.0	5,523.9	2,145.6	1,098.1	2,552.4	829.7	396.6	934.8
Outer Zone																							
SLEBC08 upper estuary	*6*	*7*	*3*	2.5	56.2	9.3	17.6	5.3	26.7	10.2	165.8	2.5	28.1	2.5	52.8	7.1	1,489.7	7.4	11.8	6.9	367.8	126.6	151.0
SLESB02 mid estuary	*3*	*5*	*3*	2.5	2.5	10.1	9.7	13.2	67.3	2.5	281.3	2.5	48.8	2.5	37.4	8.5	9.0	4.5	13.3	6.1	15.8	8.0	15.3
Hazard Ranking	Hazard Quotient Ranges																						
	HQ ≥ 10																						
	1.5 ≤HQ < 10																						
	HQ < 1.5																						
Discharge	*DHWQO are not applicable to source waters (i.e. discharge) but Hazard Quotients based on these criteria in discharge waters can provide an indication of potential for exceedance in receiving environment or vice-versa the level of dilution of the source that may be necessary to achieve criteria in receiving environment*																						
SLE100	*1.7*	*1.8*	*1.7*	*2.3*	*4.0*	*3.3*	*4.8*	*10.8*	*3.9*	*10.3*	*5.0*	*5.9*	*4.8*	*7.3*	*5.3*	*6.6*	*6.9*	*6.5*	*6.9*	*4.9*	*4.0*	*3.9*	*2.7*
Upper ZOI																							
SLEBC01	0.0	0.4	1.4	0.3	0.9	0.8	1.7	4.2	1.2	**1.4**	1.8	1.8	**1.1**	3.2	1.9	**1.3**	2.4	3.6	2.8	5.7	**1.1**	1.7	**1.1**
SLEBC03	0.0	0.3	1.1	0.3	0.7	0.3	1.1	2.8	0.6	0.8	1.9	0.9	0.6	1.6	0.8	0.6	**1.2**	1.5	1.3	3.6	1.0	**1.1**	0.6
Transition ZOI																							
SLEBC06	0.002	0.006	0.006	0.002	0.76	0.01	0.85	0.17	0.29	0.02	0.77	0.01	0.51	0.30	0.07	0.18	5.02	1.95	1.00	2.32	0.75	0.36	0.85
Outer Zone																							
SLEBC08	0.005	0.007	0.002	0.002	0.051	0.008	0.016	0.005	0.024	0.009	0.151	0.002	0.026	0.002	0.048	0.006	1.354	0.007	0.011	0.006	0.334	0.115	0.137
SLESB02	0.002	0.005	0.002	0.002	0.002	0.009	0.009	0.012	0.061	0.002	0.256	0.002	0.044	0.002	0.034	0.008	0.008	0.004	0.012	0.006	0.014	0.007	0.014

Indicator	Total Ammonia as N																						
Assessment Criteria	24, 900 µg/L upper zone and 11, 000 µg/L transition and outer zone																						
Source	*ANZECC and ARMCANZ (2000) pH adjusted SMD Trigger Values further adjusted using default acute to chronic ratio of 10 recommended by ANZECC and ARMCANZ (2000)*																						
Beneficial Use	Environment - Aquatic Ecosystem (acute toxicity)																						
Assessment Statistic	*95th percentile*																						
Analysis type	Ammonia as N																						
Analytical method	Ammonia/Ammonium - Automated Flow Colorimetry																						
LOR or Level of Precision	5 µg/L																						
Measures of uncertainty	±10 µg/L																						
Season	2021-2022 Wet	2021 Dry	2020-2021 Wet	2020 Dry	2019 -2020 wet	2019 Dry	2018-2019 Wet	2018 Dry	2017-2018 Wet	2017 Dry	2016-2017 Wet	2016 Dry	2015-2016 Wet	2015 Dry	2014-2015 Wet	2014 Dry	2013-2014 Wet	2013 Dry	2012-2013 Wet	2012 Dry	2011-2012 Wet	2011 Dry	2011 Wet*
Discharge																							
SLE100	*4,266*	*4,508*	*4,170*	*5,715*	*9,919*	*8,288*	*12,062*	*26,936*	*9,782*	*25,740*	*12,498*	*14,678*	*12,053*	*18,144*	*13,232*	*16,435*	*17,250*	*16,214*	*17,092*	*12,092*	*9,932*	*9,728*	*6,762*
Upper ZOI																							
SLEBC01 upper estuary	76	1,112	3,419	768	2,312	1,870	4,252	10,376	2,908	3,481	4,544	4,369	2,758	8,086	4,840	3,250	5,902	8,968	6,931	14,222	2,821	4,121	2,670
SLEBC03 upper estuary	81	690	2,749	683	1,650	769	2,664	6,976	1,394	1,945	4,612	2,236	1,455	4,012	1,967	1,596	2,942	3,849	3,320	8,959	2,588	2,732	1,377
Transition ZOI																							
SLEBC06 upper estuary	2.5	6.5	7.1	2.5	838.6	8.5	932.7	183.6	318.4	23.8	844.3	10.9	566.1	330.9	79.5	201.0	5,523.9	2,145.6	1,098.1	2,552.4	829.7	396.6	934.8
Outer Zone																							
SLEBC08 upper estuary	5.7	7.3	2.5	2.5	56.2	9.3	17.6	5.3	26.7	10.2	165.8	2.5	28.1	2.5	52.8	7.1	1,489.7	7.4	11.8	6.9	367.8	126.6	151.0
SLESB02 mid estuary	2.5	5.0	7.1	2.5	2.5	10.1	9.7	13.2	67.3	2.5	281.3	2.5	48.8	2.5	37.4	8.5	9.0	4.5	13.3	6.1	15.8	8.0	15.3
Hazard Ranking	Hazard Quotient Ranges																						
	HQ ≥ 1																						
	HQ < 1																						
Discharge																							
SLE100	*0.2*	*0.2*	*0.2*	*0.2*	*0.4*	*0.3*	*0.5*	*1.1*	*0.4*	*1.0*	*0.5*	*0.6*	*0.5*	*0.7*	*0.5*	*0.7*	*0.7*	*0.7*	*0.7*	*0.5*	*0.4*	*0.4*	*0.3*
Upper ZOI																							
SLEBC01	0.0	0.0	0.1	0.0	0.1	0.1	0.2	0.4	0.1	0.1	0.2	0.2	0.1	0.3	0.2	0.1	0.2	0.4	0.3	0.6	0.1	0.2	0.1
SLEBC03	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.3	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.4	0.1	0.1	0.1
Transition ZOI																							
SLEBC06	0.000	0.001	0.001	0.000	0.076	0.001	0.085	0.017	0.029	0.002	0.077	0.001	0.051	0.030	0.007	0.018	0.502	0.195	0.100	0.232	0.075	0.036	0.085
Outer Zone																							
SLEBC08	0.0005	0.0007	0.0002	0.0002	0.0051	0.0008	0.0016	0.0005	0.0024	0.0009	0.0151	0.0002	0.0026	0.0002	0.0048	0.0006	0.1354	0.0007	0.0011	0.0006	0.0334	0.0115	0.0137
SLESB02	0.0002	0.0005	0.0006	0.0002	0.0002	0.0009	0.0009	0.0012	0.0061	0.0002	0.0256	0.0002	0.0044	0.0002	0.0034	0.0008	0.0008	0.0004	0.0012	0.0006	0.0014	0.0007	0.0014

Values in red text have exceeded the assessment criteria; Hazard quotient ranges are then used to score these exceedances using a traffic light approach. Hazard quotients are the ratio of the assessment statistic for that site and the assessment criteria that applies to that parameter at that site.

It should be recognised that DHWQO are really only applicable to dry season assessments only (NRETAS 2010).

[1] Adjusted Water Quality Objectives, those values are the specific Assessment Criteria for the WDL 147

(2011 Wet*): this data includes less than 7 samples wet season during that period

Table 10 Surface water Biological Parameters (Chlorophyll-a) baseline condition assessments using Darwin Harbour Water Quality Objectives – LeanyerSanderson

Indicator	**Chlorophyll-a**																						
Assessment Criteria	**4[1] µg/L upper estuary and 2[2] µg/L mid estuary**																						
Source	*DHWQO (NRETAS 2010)*																						
Beneficial Use	Environment - Aquatic Ecosystem (background condition)																						
Assessment Statistic	***Median***																						
Analysis type	Chlorophyll a & Phaeophytin a																						
Analytical method	Chlorophyll a & b and phaeophytin																						
LOR or Level of Precision	0.1 µg/L																						
Measures of uncertainty	±0.3 µg/L																						
Season	2021-2022 Wet	2021 Dry	2020-2021 Wet	2020 Dry	2019- 2020 Wet	2019 Dry	2018-2019 Wet	2018 Dry	2017-2018 Wet	2017 Dry	2016-2017 Wet	2016 Dry	2015-2016 Wet	2015 Dry	2014-2015 Wet	2014 Dry	2013-2014 Wet	2013 Dry	2012-2013 Wet	2012 Dry	2011-2012 Wet	2011 Dry	2011 Wet*
Discharge																							
SLE100	*1110*	*1265*	*514*	*1010*	*589*	*730*	*709*	*570*	*442*	*480*	*404*	*415*	*431*	*562*	*635*	*771*	*486*	*981*	*728*	*1130*	*451*	*1220*	*469*
Upper ZOI																							
SLEBC01 *upper estuary*	32	13	58	80	110	66	60	133	67	126	48	55	113	262	92	60	57	100	364	268	146	186	125
SLEBC03 upper estuary	28	10	42	60	76	78	36	93	77	126	108	38	56	79	55	43	86	97	282	192	131	125	91
Transition ZOI																							
SLEBC06 *upper estuary*	6	3	7	11	18	9	9	42	22	6	32	6	41	8	29	9	15	73	98	37	64	32	93
Outer Zone																							
SLEBC08 *upper estuary*	6.2	1.9	9.3	1.4	6.8	1.5	3.4	2.2	11.1	0.7	5.2	1.0	6.2	1.9	4.2	1.6	4.1	1.1	8.6	4.6	5.5	1.5	2.6
SLESB02 *mid estuary*	2.4	0.8	3.7	0.6	1.9	0.5	2.0	0.5	1.0	0.4	1.2	0.4	4.2	1.6	3.0	0.7	1.9	0.8	1.2	0.5	1.6	0.9	1.9
Hazard Ranking	**Hazard Quotient Ranges**																						
	HQ < 1.5																						
	1.5 ≤HQ < 10																						
	HQ ≥ 10																						
Discharge	**DHWQO are not applicable to source waters (i.e. discharge) but Hazard Quotients based on these criteria in discharge waters can provide an indication of potential for exceedance in receiving environment or vice-versa the level of dilution of the source that may be necessary to achieve criteria in receiving environment (this can also be influenced by background concentrations so it is an indicative measure only).**																						
SLE100	*278*	*316*	*129*	*253*	*147*	*183*	*177*	*143*	*111*	*120*	*101*	*104*	*108*	*141*	*159*	*193*	*122*	*245*	*182*	*283*	*113*	*305*	*117*
Upper ZOI																							
SLEBC01 *upper estuary*	8	3	14	20	28	17	15	33	17	32	12	14	28	66	23	15	14	25	91	67	37	47	31
SLEBC03 upper estuary	7	3	11	15	19	20	9	23	19	32	27	10	14	20	14	11	22	24	71	48	33	31	23
Transition ZOI																							
SLEBC06 *upper estuary*	1.5	0.9	1.9	2.7	4.6	2.2	2.2	10.5	5.5	1.5	8.1	1.5	10.3	2.0	7.3	2.4	3.9	18.1	24.6	9.4	15.9	7.9	23.3
Outer Zone																							
SLEBC08 *upper estuary*	1.6	0.5	2.3	0.4	1.7	0.4	0.8	0.5	2.8	0.2	**1.3**	0.3	1.5	0.5	**1.1**	0.4	**1.0**	0.3	2.1	**1.2**	**1.4**	0.4	0.6
SLESB02 *mid estuary*	**1.2**	0.4	1.9	0.3	0.9	0.2	**1.0**	0.2	0.5	0.2	0.6	0.2	2.1	0.8	1.5	0.3	0.9	0.4	0.6	0.2	0.8	0.4	1.0

Values in red text have exceeded the assessment criteria; Hazard quotient ranges are then used to score these exceedances using a traffic light approach. Hazard quotients are the ratio of the assessment statistic for that site and the assessment criteria that applies to that parameter at that site.
It should be recognised that DHWQO are really only applicable to dry season assessments only (NRETAS 2010).
[1] Adjusted Water Quality Objectives, those values are the specific Assessment Criteria for the WDL 147
[2] Adjusted Water Quality Objectives for Mid Estuary
(2011 Wet*): this data includes less than 7 samples wet season during that period

Table 11 Surface water metals (Copper and Zinc filtered) assessments – LeanyerSanderson

Indicator	Copper Filtered																			
Assessment Criteria	**1.3 µg/L**																			
Level of Protection	*95% (SMD)*																			
Source	*ANZECC and ARMCANZ (2000)*																			
Beneficial Use	*Environment - Aquatic Ecosystem (chronic toxicity)*																			
Assessment Statistic	***95th Percenctile***																			
Analytical method	Elemental Analysis By ICP- MS																			
LOR or Level of Precision	1 µg/L																			
Measures of uncertainty	±0.1 µg/L																			
Season	2021-2022 Wet	2021 Dry	2020-2021 Wet	2020 Dry	2019-2020 Wet	2019 Dry	2018-2019 Wet	2018 Dry	2017-2018 Wet	2017 Dry	2016-2017 Wet	2016 Dry	2015-2016 Wet	2015 Dry	2014-2015 Wet	2014 Dry	2013-2014 Wet	2013 Dry	2012-2013 Wet	2012 Dry
Discharge																				
SLE100	*6.3*	*6.4*	*11.0*	*6.2*	*4.7*	*4.0*	*17.4*	*12.2*	*8.1*	*8.3*	*8.4*	*7.1*	*12.2*	*14.7*	*9.2*	*14.9*	*12.4*	*14.3*	*13.4*	*14.8*
Upper ZOI																				
SLEBC01	1.0	1.8	5.2	0.5	3.4	0.5	2.7	2.8	2.0	0.5	2.3	0.5	2.0	2.0	0.5	3.8	2.4	4.6	3.0	7.7
(with outlier excluded)								**0.5**	**0.9**											
SLEBC03	0.5	0.9	3.8	1.7	2.4	0.5	2.0	2.8	1.6	0.5	1.7	0.5	1.7	0.5	0.9	0.9	1.6	2.5	2.0	10.1
(with outlier excluded)								**1.0**	**0.5**											
Transition ZOI																				
SLEBC06	0.5	0.5	1.0	0.5	1.7	0.5	1.7	2.0	1.6	0.9	0.5	0.5	4.7	0.5	0.5	0.9	3.0	0.5	0.9	1.0
(with outlier excluded)								**0.5**	**0.5**											
Outer Zone																				
SLEBC08	0.5	0.5	1.0	0.5	0.5	0.5	0.5	0.5	0.9	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.9	0.5	0.5	0.5
(with outlier excluded)																				
SLESB02	0.5	0.5	1.0	0.5	1.7	0.5	3.7	0.5	0.5	0.5	0.5	0.9	0.5	0.5	0.5	0.9	0.5	0.5	3.0	0.5
(with outlier excluded)							**0.5**												**0.5**	
Hazard Ranking	**Hazard Quotient Ranges**																			
	HQ > 10																			
	1.5 ≤ HQ < 10																			
	HQ < 1.5																			
Discharge			***ANZECC and ARMCANZ Trigger Values are not directly applicable to source waters (i.e. discharge) however they can provide an indication of potential for exceedance in the receiving environment and/or level of dilution required***																	
SLE100	*4.8*	*4.9*	*8.4*	*4.8*	*3.6*	*3.1*	*13.4*	*9.4*	*6.3*	*6.4*	*6.5*	*5.5*	*9.3*	*11.3*	*7.1*	*11.5*	*9.5*	*11.0*	*10.3*	*11.4*
Upper ZOI																				
SLEBC01	0.7	1.3	4.0	0.4	2.6	0.4	2.1	2.2	1.5	0.4	1.7	0.4	1.5	1.5	0.4	2.9	1.8	3.5	2.3	5.9
(with outlier excluded)								**0.4**	**0.7**											
SLEBC03	0.4	0.7	2.9	1.3	1.8	0.4	1.5	2.2	1.2	0.4	**1.3**	0.4	1.3	0.4	0.7	0.7	1.3	1.9	1.5	7.8
(with outlier excluded)								**0.8**	**0.4**											
Transition ZOI																				
SLEBC06	0.4	0.4	0.8	0.4	1.3	0.4	1.3	1.5	1.2	0.7	0.4	0.4	3.6	0.4	0.4	0.7	2.3	0.4	0.7	0.8
(with outlier excluded)								**0.4**	**0.4**											
Outer Zone																				
SLEBC08	0.4	0.4	0.8	0.4	0.4	0.4	0.4	0.4	0.7	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.4	0.4	0.4
(with outlier excluded)																				
SLESB02	0.4	0.4	0.8	0.4	1.3	0.4	2.8	0.4	0.4	0.4	0.4	0.7	0.4	0.4	0.4	0.7	0.4	0.4	2.3	0.4
(with outlier excluded)							**0.4**												**0.4**	

Indicator	Zinc Filtered																			
Assessment Criteria	**15 µg/L**																			
Level of Protection	*95% (SMD)*																			
Source	*ANZECC and ARMCANZ (2000)*																			
Beneficial Use	*Environment - Aquatic Ecosystem (chronic toxicity)*																			
Assessment Statistic	***95th Percenctile***																			
Analytical method	Elemental Analysis By ICP- MS																			
LOR or Level of Precision	3 µg/L																			
Measures of uncertainty	±1 µg/L																			
Season	2021-2022 Wet	2021 Dry	2020-2021 Wet	2020 Dry	2019-2020 Wet	2019 Dry	2018-2019 Wet	2018 Dry	2017-2018 Wet	2017 Dry	2016-2017 Wet	2016 Dry	2015-2016 Wet	2015 Dry	2014-2015 Wet	2014 Dry	2013-2014 Wet	2013 Dry	2012-2013 Wet	2012 Dry
Discharge																				
SLE100	*2.3*	*10.5*	*4.6*	*1.9*	*6.1*	*7.6*	*7.8*	*8.2*	*4.8*	*3.8*	*3.2*	*4.5*	*2.4*	*2.4*	*2.1*	*3.0*	*2.6*	*3.2*	*4.5*	*3.9*
Upper ZOI																				
SLEBC01	1.5	1.5	1.5	1.5	1.5	4.3	4.4	57.4	37.2	5.1	39.0	1.5	6.6	37.4	15.0	7.8	1.5	1.5	8.2	4.5
(with outlier excluded)								**7.7**	**5.9**		**1.5**			**2.8**						
SLEBC03	1.5	1.5	1.5	1.5	14.2	1.5	4.0	9.1	35.1	5.6	81.7	3.5	4.7	33.1	6.7	3.3	1.5	1.5	5.1	6.2
(with outlier excluded)									**5.1**		**4.0**			**1.5**						
Transition ZOI																				
SLEBC06	1.5	1.5	1.5	1.5	1.5	3.5	1.5	10.8	15.5	5.6	1.5	1.5	6.4	19.5	3.7	15.2	1.5	1.5	3.3	1.5
(with outlier excluded)									**9.4**					**1.5**						
Outer Zone																				
SLEBC08	1.5	1.5	1.5	7.5	7.2	1.5	1.5	5.0	10.5	4.3	1.5	1.5	5.7	20.3	4.0	3.3	1.5	2.7	2.6	1.5
(with outlier excluded)														**1.5**						
SLESB02	1.5	4.1	1.5	1.5	6.7	5.1	3.3	17.4	14.0	5.8	4.0	3.5	6.4	22.7	4.7	4.0	1.5	3.5	3.7	1.5
(with outlier excluded)								**6.2**	**5.6**					**1.5**						
Hazard Ranking	**Hazard Quotient Ranges**																			
	HQ > 10																			
	1.5 ≤ HQ < 10																			
	HQ < 1.5																			
Discharge																				
SLE100	*0.2*	*0.7*	*0.3*	*0.1*	*0.4*	*0.5*	*0.5*	*0.5*	*0.3*	*0.3*	*0.2*	*0.3*	*0.2*	*0.2*	*0.1*	*0.2*	*0.2*	*0.2*	*0.3*	*0.3*
Upper ZOI																				
SLEBC01	0.1	0.1	0.1	0.1	0.1	0.3	0.3	3.8	2.5	0.3	2.6	0.1	0.4	2.5	1.0	0.5	0.1	0.1	0.5	0.3
(with outlier excluded)								**0.5**	**0.4**		**0.1**			**0.2**						
SLEBC03	0.1	0.1	0.1	0.1	0.9	0.1	0.3	0.6	2.3	0.4	5.4	0.2	0.3	2.2	0.4	0.2	0.1	0.1	0.3	0.4
(with outlier excluded)									**0.3**		**0.3**			**0.1**						
Transition ZOI																				
SLEBC06	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.7	1.0	0.4	0.1	0.1	0.4	1.3	0.2	1.0	0.1	0.1	0.2	0.1
(with outlier excluded)									**0.6**					**0.1**						
Outer Zone																				
SLEBC08	0.1	0.1	0.1	0.5	0.5	0.1	0.1	0.3	0.7	0.3	0.1	0.1	0.4	1.4	0.3	0.2	0.1	0.2	0.2	0.1
(with outlier excluded)														**0.1**						
SLESB02	0.1	0.3	0.1	0.1	0.5	0.3	0.2	1.2	0.9	0.4	0.3	0.2	0.4	1.5	0.3	0.3	0.1	0.2	0.2	0.1
(with outlier excluded)								**0.4**	**0.4**					**0.1**						

Values in red text have exceeded the assessment criteria; A hazard ranking is performed on all assessments using a traffic light system (green to red); Hazard quotients which are the ratio of the assessment statistic to the assessment criteria, are used for the hazard ranking . Due to frequent contamination issues associated with zinc in the marine sampling program results can be presented both with and without outliers excluded. High level zinc exceedances in the receiving environment appear unrelated to the discharge in any case (i.e. concentrations in discharge < ANZECC and ARMCANZ trigger values)

Table 12 Surface water pathogen (Enterococci) indicator assessments – LeanyerSanderson

Indicator	**Enterococci**
Assessment Criteria	**50 enterococci / 100 mL**
Source	*DHWQO (NRETAS 2010); Green Mode Open to Swimming LImit (DOH 2011)*
Beneficial Use	Secondary Contact Recreation has no WQO; Potential Secondary Contact by children assessed as 1^0 Contact
Assessment Statistic	***Maximum***
Analysis type	Enterococci
Analytical method	Enterococcus - AS4276.9
LOR or Level of Precision	NR
Measures of uncertainty	±4 cfu/100mL

Season	2021 Dry	2020-2021 Wet	2020 Dry	2019-2020 Wet	2019 Dry	2018-2019 Wet	2018 Dry	2017-2018 Wet	2017 Dry	2016-2017 Wet	2016 Dry	2015-2016 Wet	2015 Dry	2014-2015 Wet	2014 Dry	2013-2014 Wet	2013 Dry	2012-2013 Wet	2012 Dry	2011-2012 Wet	2011 Dry	2011 Wet*
Discharge																						
SLE100	*24,196*	*241,960*	*38,730*	*120,330*	*1,413,600*	*3,700,000*	*241,960*	*155,310*	*3,000,000*	*92,080*	*24,810*	*129,970*	*9,000*	*24,196*	*15,531*	*155,310*	*241,960*	*19,863*	*24,196*	*19,863*	*82,970*	*24,196*
Upper ZOI																						
SLEBC01	35	630	46	13,000	130	170,000	70	7,200	320	320	110	360	460	380	210	1,400	3,100	25,000	270	42,000	820	5,000
SLEBC03	27	700	26	4,500	38	79,000	27	3,500	250	440	34	390	40	130	50	970	160	12,000	170	25,000	280	4,000
Transition ZOI																						
SLEBC06	110	34	5	410	18	630	30	270	40	220	8	42	21	380	30	23,000	270	160	22	6,700	80	1,700
Outer Zone																						
SLEBC08	74	6	2	110	1	17	1	33	2	57	3	10	9	22	6	350	11	12	21	3,600	80	370
SLESB02	110	1	5	71	0	6	0	26	1	67	0	15	13	10	2	160	1	3	0	64	0	6

Hazard Ranking

Hazard Ranges (DOH 2011)

Red Mode - > 200 enterococci/ 100 mL (strictly 2 within 48 hours but samples collected monthly)

Amber Mode - All samples to be between 51 and 200

Green Mode - All samples ≤ 50 enterococci/ 100 mL

Discharge ***DHWQO and DOH alert ranges are not applicable to source waters (i.e. discharge) however these assessments can provide an indication of potential for exceedance in the receiving environment***

SLE100	*24,196*	*241,960*	*38,730*	*120,330*	*1,413,600*	*3,700,000*	*241,960*	*155,310*	*3,000,000*	*92,080*	*24,810*	*129,970*	*9,000*	*24,196*	*15,531*	*155,310*	*241,960*	*19,863*	*24,196*	*19,863*	*82,970*	*24,196*
Upper ZOI																						
SLEBC01	35	630	46	13000	130	170000	70	7,200	320	320	110	360	460	380	210	1,400	3,100	25,000	270	42,000	820	5,000
SLEBC03	27	700	26	4500	38	79000	27	3,500	250	440	34	390	40	130	50	970	160	12,000	170	25,000	280	4,000
Transition ZOI																						
SLEBC06	110	34	5	410	18	630	30	270	40	220	8	42	21	380	30	23,000	270	160	22	6,700	80	1,700
Outer Zone																						
SLEBC08	74	6	2	110	1	17	1	33	2	57	3	10	9	22	6	350	11	12	21	3,600	80	370
SLESB02	110	1	5	71	0	6	0	26	1	67	0	15	13	10	2	160	1	3	0	64	0	6

Assessment statistic value in red text have exceeded the Assessment Criteria; These exceedances are ranked using a traffic light hazard ranking based on hazard ranges; The hazard ranges are based on the NT Department of Health (2011) generic trigger levels for green, amber and red mode. In red mode precautionary advice against swimming would be issued by the relevant authority. The discharge point data is collected more frequently (weekly) than receiving environment data (monthly).

Table 13 Surface water NHMRC pathogen (Enterococci) indicator assessments – LeanyerSanderson

Season	Dry 2020					Wet 2020-2021					Dry 2021				
Statistics	n	95th percentile enterococci/100 mL (Hazen)	MW-QAC[a]	SIC[b]	Classification[c]	n	95th percentile enterococci/100 mL (Hazen)	MW-QAC[a]	SIC[b]	Classification[c]	n	95th percentile enterococci/100 mL (Hazen)	MW-QAC[a]	SIC[b]	Classification[c]
Discharge															
SLE100	376	38,730	D	High	**Very Poor**	387	41,000	D	High	**Very Poor**	394	24,810	D	High	**Very Poor**
Upper ZOI															
SLEBC01	52	460	C	High	**Poor**	76	25,000	D	High	**Very Poor**	57	460	C	High	**Poor**
SLEBC03	51	220	C	High	**Poor**	76	12,000	D	High	**Very Poor**	56	220	C	High	**Poor**
Transition ZOI															
SLEBC06	51	40	A	High	**Good (*)**	75	670	D	High	**Very Poor**	56	40	A	High	**Good (*)**
Outer Zone															
SLEBC08	52	11	A	Moderate	**Good (*)**	75	110	B	Moderate	**Good**	57	11	A	Moderate	**Good (*)**
SLESB02	52	2	A	Moderate	**Good (*)**	75	64	B	Moderate	**Good**	57	1	A	Moderate	**Good (*)**
Risk Assessment															

[a] MW-QAC (microbial water quality assessment categories) defined in Table 5.7 of NHMRC (2008) and Table 1.13;

[b] Sanitary Inspection Category is indicative of susceptibility to faecal influence as defined in Table 5.10 of NHMRC (2008) with a high SIC for discharge from lagoons with short outfalls extending into the upper zone and a moderate SIC assumed from the transition and outer zones in accordance with the Lee Point Sanitary Survey in the dry season (DOH 2010) i.e. due to distance from the outfall. In the wet season the high SIC is assumed to extend to the boat ramp (SLEBC06) due to environmental and other factors associated with rainfall/catchment sources that may influence susceptibility;

[c] Classification matrix for faecal pollution of recreational water environments as defined in Table 5.13 of NHMRC (2008);

[d] - **note that 'n' has increased substantially with the addition of the 2019 dry season data set that included autosampling in late August-early September - assessment value however remains the same.**

(*) Indicates possible discontinuos/sporadic contamination (often driven by results such as rainfall) - *Guidelines for Managing Risks in Recreational Water 2008*

2. Appendix 2 – SEDIMENT BASELINE CONDITION ASSESSMENTS

Table 14 Chlorophyll-a in sediment assessments

Chlorophyll-a IN SEDIMENT	CHL-A (mg/kg)								Chl-A:Pheo-A [a] (dimensionless)							
Analysis type	Chlorophyll a															
Analytical method	Spectrophotometric Analysis of Chlorophyll in Sediment															
LOR or Level of Precision	0.1 mg/kg															
Measures of uncertainty	± 0.3 mg/kg															
Dry Season	2014	2015	2016	2017	2018	2019	2020	2021	2014	2015	2016	2017	2018	2019	2020	2021
Alternative Assessment									Chl-A:Pheo-A ≤ 1 indicates not photosynthetically active (i.e. detrital); Chl-A:Pheo-A > 1 indicates photosynthetically active (i.e. not detrital)							
> 2 x Reference site 80th Percentile	3.02	3.98	1.56	1.92	2.70	2.54	4.02	1.71	0.48	0.52	0.58	0.72	0.58	0.70	2.38	0.77
Buffalo Creek sites downstream of discharge (site 01 is most upper estuary/closest to discharge in series)																
SLEBC01	**9.84**	**7.92 - 11.77**	**1.99 - 6.51**	**20.51**	**3.38**	**8.45**	**5.14**	**28.50**	0.29	0.17[b]	0.10[b]	0.36	0.16	0.29	0.14	0.39
SLEBC03	**15.56**	**6.38**	**2.29 - 3.10**	**2.81**	**2.61**	**14.10**	**6.71**	**4.60**	0.39	0.17	0.15[b]	0.16	0.16	0.31	0.20	0.20
SLEBC04	1.20	**20.77**	0.92	**4.25-8.30**	**15.00**	**6.10**	**0.45**	**6.37**	0.13	**0.59**	0.25	0.23[b]	0.48	0.29	0.07	0.22
SLEBC05	2.07	**5.51 - 7.81**	**2.38**	**2.90**	1.38-**2.80**	**2.55-6.78**	**2.89**	**6.28**	0.29	**0.56[b]**	0.23	0.16	0.12[b]	0.30[b]	0.20	0.28
SLEBC06	0.72	1.34	0.56	0.16-1.02	1.14	1.08-1.16	0.84	3.58	0.30	0.41	0.37	0.28[b]	0.21	0.30[b]	0.22	0.64
SLEBC08	0.95	0.63	0.40	0.55	0.48-1.00	0.54	1.19	1.31	0.28	0.25	0.29	0.10	0.19[b]	0.16	0.18	0.17
Mickett Creek & Kings Creek reference (sites where site 01 is most upper estuary in series)																
SLEMC01	1.75	1.90 - 2.46	0.32 - 0.78	1.43-**2.53**	0.57	1.56	1.50	0.72	0.24	0.26[b]	0.14[b]	0.22[b]	0.10	0.17	0.16	0.11
SLEMC02	1.51	0.69	0.23	0.55	0.32	0.76	0.23	0.63	0.49	0.23	0.55	0.26	0.14	0.35	0.22	0.39
SLEMC03	0.71	1.99	0.46	0.72	1.50-2.23	0.54-0.99	0.15	1.79	0.20	0.27	0.17	0.11	0.29[b]	0.26[b]	0.04	0.25
SLEKC01	1.27	1.66 - 1.81	0.87 - 1.35	0.79-0.96	1.35	1.27	5.37	0.86	0.22	0.04[b]	0.06[b]	0.15[b]	0.29	0.60	1.19	0.17
SLEKC02	0.20	1.34	0.38	0.63	< 0.10	0.23	2.01	0.46	0.09	0.09	0.29	0.36	0.21	0.29	1.18	0.21
SLEKC03	0.20	0.39	0.71	0.64	< 0.10-0.24	0.39-1.17	1.31	0.55	0.24	0.13	0.16	0.48	0.35[b]	0.35[b]	1.21	0.40

[a] Ratio of Chlorophyll a to its detritus product Pheophytin a provides information about the relative levels of actively photosynthesizing organisms vs detritus/organic matter. Although sites may vary, samples with values of 1.70 are considered to contain no Pheophytin a, while solutions with values of 1.0 are considered to be pure Pheophytin a;

[b] Average of triplicate ratios; Green shading indicates that benthic chlorophyll is not considered photosynthetically active based on ratio to pheophytin a wheras Orange shading indicates the opposite;

Red bold text indicates data values that were > 2 x reference site 80th percentiles in that season.

Ranges (minimum - maximum) indicate site has been sampled in triplicate.

CALCULATIONS: 2 x Reference site 80th Percentile

SLEMC01	1.75	2.46	0.78	2.53	0.57	1.56	1.50	0.72	0.24	0.26	0.14	0.22	0.10	0.17	0.16	0.11
SLEMC02	1.51	0.69	0.23	0.55	0.32	0.76	0.23	0.63	0.49	0.23	0.55	0.26	0.14	0.35	0.22	0.39
SLEMC03	0.71	1.99	0.46	0.72	2.23	0.99	0.15	1.79	0.20	0.27	0.17	0.11	0.29	0.26	0.04	0.25
SLEKC01	1.27	1.81	1.35	0.96	1.35	1.27	5.37	0.86	0.22	0.04	0.06	0.15	0.29	0.60	1.19	0.17
SLEKC02	0.20	1.34	0.38	0.63	<0.1	0.23	2.01	0.46	0.09	0.09	0.29	0.36	0.21	0.29	1.18	0.21
SLEKC03	0.20	0.39	0.71	0.64	0.24	1.17	1.31	0.55	0.24	0.13	0.16	0.48	0.35	0.35	1.21	0.40

Table 15 Ammonia in sediment porewater assessments

AMMONIA IN POREWATER	NH3-N (mg/L)								
Analysis type	Ammonia as N								
Analytical method	Ammonia as N by Discrete Analyser								
LOR or Level of Precision	0.01 mg/L								
Measures of uncertainty	± 0.7 mg/L								
Dry Season	2012	2014	2015	2016	2017	2018	2019	2020	2021
ANZECC & ARMCANZ pH Adjusted TVs[a] Buffalo Creek	0.62 - 2.84	1.85 - 2.49	2.84 - 5.07[b]	2.15- 4.83[b]	2.49 - 5.07[b]	3.56 - 5.07[b]	1.56-3.56[b]	3.2-4.5[b]	1.1-2.84[b]
2 x Reference site 80th Percentile	-	11.20	16.60	13.80	4.30	7.74	3.88	4.66	3.94
Buffalo Creek sites downstream of discharge (site 01 is most upper estuary/closest to discharge in series)									
SLEBC01	15	**28.00**	17-**18**	0.2 - **17**	**7.74**	3.70	**6.57**	**17.10**	**4.52**
SLEBC03	32	**17.00**	17.00	0.11 - **17**	2.18	4.78	**10.80**	**7.30**	**7.90**
SLEBC04	90	10.00	**43.00**	3.50	3.55-**4.81**	**7.78**	**8.13**	**7.00**	**7.49**
SLEBC05	85	4.90	8.80 - **26.00**	7.50	**4.88**	4.48-7.24	**8.58-9.35**	**12.20**	**4.70**
SLEBC06	-	3.50	5.90	1.30	1.62-2.38	3.60	2.96-3.53	5.38	6.13
SLEBC08	0.21	3.50	12.00	0.06	1.99	1.70-2.98	1.48	1.73	3.49
Dry Season	2012	2014	2015	2016	2017	2018			
ANZECC & ARMCANZ pH Adjusted TVs[b] Mickett and Kings Creek	-	1.85 - 3.2	2.49 - 5.29[b]	1.85 - 3.91[b]	3.56 - 5.07[b]	3.56 - 5.29[b]	2.15 - 3.56[b]	3.91 - 5.29[b]	2.49 - 3.2[b]
Mickett Creek & Kings Creek reference (sites where site 01 is most upper estuary in series)									
SLEMC01	-	4.10	7.0 - 8.3	5.3 - 6.9	1.31-2.15	3.16	1.97	3.16	1.97
SLEMC02	-	7.20	3.80	4.20	1.82	1.28	0.96	1.28	0.96
SLEMC03	-	5.60	6.30	6.80	0.42	2.33-6.32	1.16-1.94	2.33	1.16
SLEKC01	-	5.50	8.2 - 10	3.4 - 6.9	2.19-3.80	3.87	0.65	1.44	2.42
SLEKC02	-	2.20	0.73	0.55	1.14	0.68	0.10	1.10	0.94
SLEKC03	-	2.40	0.88	1.40	1.72	0.59-1.71	0.63-1.12	1.00	0.95

[a] Ammonia toxicant guidelines pH adjusted based on porewater pH as per Table 8.3.7 of ANZECC and ARMCANZ (2000);
[b] Field pH of composite sample used as it is more correct, in previous years laboratoy pH of composite sample had been applied to determine trigger value;
Orange shading indicates exceedance of ANZECC SMD guidelines;
Green shading indicates no exceedance of ANZECC SMD guideline;
Red bold text indicates data values that were > 2 x reference site 80th percentiles in that season
Ranges (minimum - maximum) indicate site has been sampled in triplicate.

Table 16 Total nitrogen and total organic carbon in sediment and total nitrogen in porewater

NUTRIENTS - TN IN SEDIMENT / NUTRIENTS - TN IN PORWATER	TN (mg/kg)								
Analysis type	Total Nitrogen as N								
Analytical method	Total Nitrogen as N (TKN + NOx)								
LOR or Level of Precision	20 mg/kg								
Measures of uncertainty	± 85 mg/kg								
Dry Season	2012	2014	2015	2016	2017	2018	2019	2020	2021
Alternative assessment									
2 x Reference site 80th Percentile	-	**1,580**	**3,200**	**1,880**	**1,860**	**2,220**	**2,020**	**1,940**	**1,500**
Buffalo Creek sites downstream of discharge (site 01 is most upper estuary/closest to discharge in series)									
SLEBC01	2,400	**1,700**	2,800 - 3,000	**2,500 - 3,100**	**2,140**	1,900	**2,740**	**2,710**	**2,390**
SLEBC03	2,500	**2,800**	1,100	1,700 - **2,500**	1,710	**2,230**	1,790	2,160	2,020
SLEBC04	3,000	1,500	2,100	1,200	1,430-1,820	1,720	1,570	1,030	1,860
SLEBC05	1,110	1,100	820 - 2,000	850	1,370	1,070-1,480	1,030-1,160	1,190	1,730
SLEBC06	460	10	780	400	340-440	660	180-200	600	690
SLEBC08	300	380	390	280	390	520-700	520	360	630
Mickett Creek & Kings Creek reference sites where site 01 is most upper estuary in series									
SLEMC01	-	790	1,200 - 2,500	680 - 950	960-1,150	1,110	1,220	1,090	770
SLEMC02	-	460	430	630	720	780	590	970	450
SLEMC03	-	520	1,600	770	660	990-1,140	540-710	780	750
SLEKC01	-	950	940 - 1,200	710 - 940	890-930	740	470	920	410
SLEKC02	-	10	220	330	570	390	320	700	420
SLEKC03	-	470	810	750	800	450-780	690-1,010	490	520
Symbol	-	-	-	-	-	-	-		
Alternative assessment									
> 2 x Reference site 80th Percentile	-	-	-	-	-	-			
Buffalo Creek sites downstream of discharge (site 01 is most upper estuary/closest to discharge in series)									
SLEBC01	-	-	-	-	-	-			
SLEBC03	-	-	-	-	-	-			
SLEBC04	-	-	-	-	-	-			
SLEBC05	-	-	-	-	-	-			
SLEBC06	-	-	-	-	-	-			
SLEBC08	-	-	-	-	-	-			
Mickett Creek & Kings Creek reference sites where site 01 is most upper estuary in series									
SLEMC01	-	-	-	-	-	-			
SLEMC02	-	-	-	-	-	-			
SLEMC03	-	-	-	-	-	-			
SLEKC01	-	-	-	-	-	-			
SLEKC02	-	-	-	-	-	-			
SLEKC03	-	-	-	-	-	-			

NUTRIENTS - TN IN SEDIMENT / NUTRIENTS - TN IN PORWATER	TOC (mg/kg)								
Analysis type	Total Organic Carbon								
Analytical method	Total Organic Carbon (TOC) in Soil								
LOR or Level of Precision	200 mg/kg								
Measures of uncertainty	± 700 mg/kg								
Dry Season	2012	2014	2015	2016	2017	2018	2019	2020	2021
Alternative assessment									
2 x Reference site 80th Percentile	-	**76,000**	**96,000**	**30,000**	**18,000**	**26,600**	**19,600**	**20,200**	**17,200**
Buffalo Creek sites downstream of discharge (site 01 is most upper estuary/closest to discharge in series)									
SLEBC01	27,000	26,000	46,000-65,000	**31,000-110,000**	17,000	24,500	14,200	24,700	29,400
SLEBC03	39,000	52,000	44,000	28,000-**54,000**	**32,000**	14,200	19,000	30,000	30,600
SLEBC04	25,000	17,000	45,000	14,000	13,200-14,700	12,300	10,500	13,000	31,200
SLEBC05	23,000	31,000	37,000-78,000	12,000	12,100	9,400-9,700	8,900-10,600	8,900	18,300
SLEBC06	16,000	28,000	32,000	2,000	5,900-7,300	5,300	1,700-2,100	5,600	10,400
SLEBC08	17,000	24,000	36,000	4,000	5,000	4,200-4,900	3,600	3,100	8,400
Mickett Creek & Kings Creek reference sites where site 01 is most upper estuary in series									
SLEMC01	-	26,000	32,000-41,000	1,000-8,000	7,900-9,800	7,400	8,600	10,100	9,500
SLEMC02	-	38,000	38,000	7,000	7,400	19,900	5,300	13,400	8,600
SLEMC03	-	78,000	30,000	15,000	6,700	7,000-7,800	4,600-8,700	7,000	8,000
SLEKC01	-	23,000	43,000-48,000	9,000-14,000	7,900-8,700	7,300	9,800	9,600	7,000
SLEKC02	-	28,000	81,000	< 1,000	6,100	1,900	5,400	8,200	5,500
SLEKC03	-	22,000	36,000	15,000	9,000	5,500-13,300	6,300-15,900	8,400	7,500
Symbol	TN:TOC (dimensionless)								
Alternative assessment	Significant difference to reference creek? (P< 0.05) - unpaired t-test								
	-	No, P = 0.1	No, P = 0.8	No, P = 0.3	No, P = 0.5	No, P = 0.8	No, P = 0.1	No, P = 0.3	No, P = 0.3
> 2 x Reference site 80th Percentile	-	**0.061**	**0.104**	**0.660**	**0.218**	**0.300**	**0.222**	**0.216**	**0.162**
Buffalo Creek sites downstream of discharge (site 01 is most upper estuary/closest to discharge in series)									
SLEBC01	0.089	**0.065**	0.053[a]	0.067[a]	0.126	0.078	0.193	0.110	0.265
SLEBC03	0.064	0.054	0.025	0.051[a]	0.053	0.157	0.094	0.072	0.265
SLEBC04	0.120	**0.088**	0.047	0.086	0.117[a]	0.140	0.150	0.079	0.265
SLEBC05	0.048	0.035	0.021[a]	0.071	0.113	0.138[a]	0.115[a]	0.134	0.265
SLEBC06	0.029	0.0004	0.024	0.200	0.058[a]	0.125	0.103[a]	0.107	0.265
SLEBC08	0.018	0.016	0.011	0.070	0.078	0.129[a]	0.144	0.116	0.265
Mickett Creek & Kings Creek reference sites where site 01 is most upper estuary in series									
SLEMC01	-	0.030	0.052[a]	0.395[a]	0.122[a]	0.150	0.142	0.108	0.081
SLEMC02	-	0.012	0.011	0.090	0.097	0.039	0.111	0.072	0.052
SLEMC03	-	0.007	0.053	0.051	0.099	0.149[a]	0.107[a]	0.111	0.094
SLEKC01	-	0.041	0.023[a]	0.078[a]	0.109[a]	0.101	0.048	0.096	0.059
SLEKC02	-	0.0004	0.003	0.330	0.093	0.205	0.059	0.085	0.076
SLEKC03	-	0.021	0.023	0.050	0.089	0.081[a]	0.083[a]	0.058	0.069

NUTRIENTS - TN IN SEDIMENT / NUTRIENTS - TN IN PORWATER	TN (mg/L)								
Analysis type	Total Nitrogen as N								
Analytical method	Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
LOR or Level of Precision	0.1 mg/L								
Measures of uncertainty	± 1 mg/L								
Dry Season	2012	2014	2015	2016	2017	2018	2019	2020	2021
Alternative assessment									
2 x Reference site 80th Percentile	-	**24.0**	**17.4**	**12.0**	**7.4**	**21.6**	**6.2**	**8.6**	**7.6**
Buffalo Creek sites downstream of discharge (site 01 is most upper estuary/closest to discharge in series)									
SLEBC01	23.0	**25.0**	17 - **18**	**16 - 21**	**11.4**	4.7	**11.3**	**25.5**	**8.4**
SLEBC03	40.0	17.0	17.0	0.4 - **21**	6.9	8.6	**13.2**	**15.6**	**13.8**
SLEBC04	190.0	8.9	**43.0**	10.5	**8.2-11.2**	13.0	**9.2**	**9.1**	**7.5**
SLEBC05	230.0	8.9	9.1 - **26**	**14.0**	**9.1**	9.4-19.6	**9.7-11.5**	**16.6**	**4.8**
SLEBC06	-	**26.0**	6.5	2.6	4.4-6.0	7.6	3.3-3.9	7.0	3.7
SLEBC08	12.0	5.8	12.0	8.1	6.0	4.7-6.3	2.4	3.3	8.1
Mickett Creek & Kings Creek reference sites where site 01 is most upper estuary in series									
SLEMC01	-	7.8	7.5 - 8.7	5.1 - 5.8	2.8-3.7	6.3	3.1	4.7	1.8
SLEMC02	-	12.0	3.9	4.7	2.8	4.3	1.9	2.4	<1.0
SLEMC03	-	6.0	6.3	8.6	1.2	5.4-10.8	1.9-4.0	3.7	5.1
SLEKC01	-	11.0	8.5 - 13	5.2 - 6.0	4.1-5.7	10.8	1.2	<0.05	3.5
SLEKC02	-	22.0	0.9	1.4	2.2	1.4	<0.5	<0.1	1.0
SLEKC03	-	4.0	3.5	1.9	3.2	1.6-3.7	<1.0-1.7	<0.1	1.2
Symbol	-	-	-	-	-	-	-		
Alternative assessment									
> 2 x Reference site 80th Percentile	-	-	-	-	-	-	-	-	-
Buffalo Creek sites downstream of discharge (site 01 is most upper estuary/closest to discharge in series)									
SLEBC01	-	-	-	-	-	-	-	-	-
SLEBC03	-	-	-	-	-	-	-	-	-
SLEBC04	-	-	-	-	-	-	-	-	-
SLEBC05	-	-	-	-	-	-	-	-	-
SLEBC06	-	-	-	-	-	-	-	-	-
SLEBC08	-	-	-	-	-	-	-	-	-
Mickett Creek & Kings Creek reference sites where site 01 is most upper estuary in series									
SLEMC01	-	-	-	-	-	-	-	-	-
SLEMC02	-	-	-	-	-	-	-	-	-
SLEMC03	-	-	-	-	-	-	-	-	-
SLEKC01	-	-	-	-	-	-	-	-	-
SLEKC02	-	-	-	-	-	-	-	-	-
SLEKC03	-	-	-	-	-	-	-	-	-

[a] Average of triplicate ratios; Green text indicates no significant difference to reference site TN:TOC ratios in that year;

b Ammonia toxicant guidelines pH adjusted based on porewater pH as per Table 8.3.7 of ANZECC and ARMCANZ (2000);

c Field pH of composite sample applied in 2015 whereas in previous years lab pH has been applied;

d Change in laboratory methodwhere the former method used K2SO4 and H2SO4 with a colorimetric finish and the latter method uses a HCl/HNO3 digestion with a ICP-OES finish;

Red bold text indicates data values that were > 2 x reference site 80th percentiles in that season

Ranges (minimum - maximum) indicate site has been sampled in triplicate.

Table 17 Total phosphorous in sediment and total phosphorous and filterable reactive phosphorous in porewater assessments

NUTRIENTS - TP IN SEDIMENT / NUTRIENTS - TP & FRP IN POREWATER	TP (mg/kg)									TP (mg/l)									FRP (mg/L)								
Analysis type	Total Phosphorus as P									Total Phosphorus as P									Dissolved Reactive Phosphorus as P								
Analytical method	Total Phosphorus as P by Discrete Analyser									Total Phosphorus as P by Discrete Analyser									Dissolved Reactive Phosphorus as P by DA								
LOR or Level of Precision	2 mg/kg									0.01 mg/L									0.01 mg/L								
Measures of uncertainty	± 35 mg/kg									± 0.03 mg/L									± 0.03 mg/L								
Dry Season	2012	2014	2015[a]	2016[a]	2017[a]	2018[a]	2019[a]	2020[a]	2021[a]	2012	2014	2015	2016	2017	2018	2019	2020	2021	2012	2014	2015	2016	2017	2018	2019	2020	2021
2 x Reference site 80th Percentile	-	680	980	1020	1178	1220	1022	1124	808	-	0.44	1.44	0.54	0.38	0.46	0.50	0.31	0.43	-	0.10	0.10	0.10	0.20	0.02	0.02	0.17	0.02
Buffalo Creek sites downstream of discharge (site 01 is most upper estuary/closest to discharge in series)																											
SLEBC01	710	450	**1200 - 1300**	**1200 - 1300**	891	602	924	1070	2360	1.50	**13.00**	0.33 - 0.55	**0.67**	**2.95**	<0.10	**4.31**	**10.70**	**0.69**	0.92	**15.00**	< 0.05	<0.05 - **0.09**	<0.10	0.01	**1.57**	**5.90**	**0.10**
SLEBC03	690	610	**1100**	740 - 1000	769	818	756	733	727	18.00	**1.40**	0.67	0.36 - **5.9**	**0.64**	**0.67**	**8.91**	**8.72**	**2.35**	18.00	**0.66**	< 0.05	<0.05 - **1.9**	<0.10	<0.01	**0.99**	**4.54**	**0.08**
SLEBC04	420	450	790	510	827-927	788	881	538	703	13.00	**6.80**	**18.00**	**4.00**	0.26-**0.52**	0.37	**5.88**	**3.15**	**0.59**	13.00	**6.40**	**20.00**	**7.30**	<0.10-<0.10	<0.01	**0.34**	**3.34**	**0.02**
SLEBC05	510	310	500 - 650	530	731	619-638	594-680	582	666	1.40	**2.50**	**4.7 - 7.7**	**1.90**	**0.70**	<0.10-<0.10	**4.17-7.41**	**6.49**	**0.40**	0.18	**2.40**	**0.36 - 6.1**	**2.00**	<0.10	<0.01-<0.01	**0.32-1.53**	**5.620**	**0.040**
SLEBC06	420	310	560	450	411-500	468	525-624	480	476	-	**1.00**	0.13	0.39	**0.48-0.88**	<0.10	<0.10-<0.10	0.19	0.08	-	0.05	< 0.05	< 0.05	**0.30-0.38**	<0.01	**0.03-0.03**	**<0.01**	**<0.01**
SLEBC08	400	200	470	380	423	363-485	491	44	429	0.06	0.31	0.54	0.15	0.22	<0.10-<0.10	<0.10	0.28	0.50	0.06	0.05	< 0.05	< 0.05	<0.10	<0.01-<0.01	0.020	<0.01	<0.01
Mickett Creek & Kings Creek reference (sites where site 01 is most upper estuary in series)																											
SLEMC01	-	340	540 - 560	470 -530	527-621	465	511	534	421	-	<0.05	0.64 - 1.5	0.16 - 0.33	<0.05-0.06	<0.10	<0.13	<0.14	<0.10	-	<0.05	<0.05 - 0.05	<0.05	<0.10-<0.10	<0.01	<0.01	<0.01	<0.01
SLEMC02	-	100	470	470	465	774	476	420	404	-	<0.05	0.19	0.15	<0.05	<0.10	<1.0	0.16	<0.10	-	<0.05	<0.05	<0.05	<0.10	0.01	<0.01	0.03	<0.01
SLEMC03	-	240	490	510	589	435-610	411-504	562	400	-	0.22	0.20	0.18	<0.10	<0.10-0.23	<0.10-0.21	<0.1	0.19	-	<0.05	<0.05	<0.05	<0.10	<0.01-0.01	<0.01-0.02	0.120	<0.01
SLEKC01	-	400	350 - 490	370 - 480	506-544	418	312	570	286	-	0.26	0.48 - 0.72	0.14 - 0.27	<0.10-0.19	4.56	0.25	<0.1	0.22	-	<0.05	<0.05 - <0.05	<0.05 - < 0.05	<0.10-<0.10	<0.01	<0.01	<0.01	<0.01
SLEKC02	-	200	420	360	502	421	295	523	372	-	<0.05	0.10	0.23	0.37	<0.05	0.31	<0.1	<0.10	-	<0.05	<0.05	<0.05	<0.10	<0.01	<0.01	0.020	<0.01
SLEKC03	-	270	390	310	450	330-465	401-511	323	325	-	<0.05	0.07	0.16	0.12	<0.05-<0.10	<0.05-0.22	<0.1	<0.10	-	<0.05	<0.05	<0.05	<0.10	<0.01-<0.01	<0.01-<0.01	<0.01	<0.01

Red bold text indicates data values that were > 2 x reference site 80th percentiles in that season.
a Method change from 2015 dry season - former method uses K2SO4 and H2SO4 with a colorimetric finish and the latter method uses a HCl/HNO3 digestion with a ICP-OES finish;
b Laboratory change in this year - digestion and finish similar to 2014 method (K2SO4 and H2SO4 with spectrophotometer).
Ranges (minimum - maximum) indicate site has been sampled in triplicate.

Table 18 Total copper and zinc in sediment assessments

Metals - Total IN SEDIMENT	Aluminium								
Analysis type	Aluminium								
Analytical method	Total Metals in Sediments by ICP-AES								
LOR or Level of Precision	50 mg/kg								
Measures of uncertainty	± 600 mg/kg								
Symbol	Al								
Dry Season	2012	2014	2015	2016	2017	2018	2019	2020	2021
AZECC & ARMCANZ (2000) ISQG Low Trigger Value	-								
2 x Reference site 80th Percentile	-								
Buffalo Creek sites downstream of discharge (site 01 is most upper estuary/closest to discharge in series)									
SLEBC01	36,000	16,000	24,000-39,000	24,000-30,000	10,400	11,000	14,600	18,000	19,900
SLEBC03	32,000	16,000	32,000	22,000-25,000	10,200	9,770	12,200	111,100	12,600
SLEBC04	21,000	10,000	15,000	17,000	7,480-8,890	9,460	10,600	14,100	16,100
SLEBC05	18,000	11,000	13,000-17,000	13,000	7,990	7,030-7,480	7,880-8,630	14,700	12,100
SLEBC06	5,800	2,200	4,600	8,600	4,880-4,990	5,040	3,430-4,120	4,270	7,640
SLEBC08	4,000	6,100	6,200	3,400	4,500	4,630-6,580	6,440	3,850	8,820
Mickett Creek & Kings Creek control sites where site 01 is most upper estuary in series									
SLEMC01	-	11,000	2,500-18,000	17,000-24,000	9,280-11,200	9,440	12,300	13,300	18,700
SLEMC02	-	3,800	9,500	9,000	7,720	7,430	7,260	7,400	15,100
SLEMC03	-	7,000	2,500	18,000	6,130	6,720-9,670	6,000-6,900	8,630	14,600
SLEKC01	-	16,000	15,000-20,000	11,000-16,000	7,900-8,010	7,780	8,660	7,000	11,000
SLEKC02	-	3,400	4,000	12,000	5,640	7,660	12,100	5,560	15,600
SLEKC03	-	7,200	16,000	21,000	7,710	5,100-8,210	10,300-14,300	9,740	13,300
Al[a] normalised total concentration in sediment (dimensionless) - x 10, 000 mg/kg									
Symbol									
2 x Reference site 80th Percentile	-								
Alternative assessment									
Buffalo Creek sites downstream of discharge (site 01 is most upper estuary/closest to discharge in series)									
SLEBC01	-	-	-	-	-	-	-		
SLEBC03	-	-	-	-	-	-	-		
SLEBC04	-	-	-	-	-	-	-		
SLEBC05	-	-	-	-	-	-	-		
SLEBC06	-	-	-	-	-	-	-		
SLEBC08	-	-	-	-	-	-	-		
Mickett Creek & Kings Creek control sites where site 01 is most upper estuary in series									
SLEMC01	-	-	-	-	-	-	-		
SLEMC02	-	-	-	-	-	-	-		
SLEMC03	-	-	-	-	-	-	-		
SLEKC01	-	-	-	-	-	-	-		
SLEKC02	-	-	-	-	-	-	-		
SLEKC03	-	-	-	-	-	-	-		

Metals - Total IN SEDIMENT	Copper								
Analysis type	Copper								
Analytical method	Total Metals in Sediments by ICPMS								
LOR or Level of Precision	1 mg/kg								
Measures of uncertainty	± 0.3 mg/kg								
Symbol	Cu								
Dry Season	2012	2014	2015	2016	2017	2018	2019	2020	2021
AZECC & ARMCANZ (2000) ISQG Low Trigger Value	65								
2 x Reference site 80th Percentile	-	10.0	10.0	10.0	7.2	7.4	9.4	7.8	7.0
Total concencentration in sediment (mg/kg)									
Buffalo Creek sites downstream of discharge (site 01 is most upper estuary/closest to discharge in series)									
SLEBC01	26	9.4	8.6-9.8	15-16	10.2	7.3	15.6	11.5	11.6
SLEBC03	18	6.6	7.0	11-11	8.4	8.4	10.7	9.5	9.6
SLEBC04	11	<5	6.7	6.0	5.6-6.9	7.7	6.9	5.4	8.9
SLEBC05	8.5	<5	<5-<5	5.1	5.5	4.3-4.5	3.8-4.2	5.0	6.5
SLEBC06	<5	<5	<5	<5	1.6-1.8	2.3	1.4-1.8	1.8	2.7
SLEBC08	<5	<5	<5	<5	1.5	2.0-2.7	2.1	1.1	2.8
Mickett Creek & Kings Creek control sites where site 01 is most upper estuary in series									
SLEMC01	-	<5	<5-<5	<5-<5	3.4-4.2	3.7	4.7	3.9	4.3
SLEMC02	-	<5	<5	<5	2.8	3.3	2.7	2.2	3.0
SLEMC03	-	<5	<5	<5	2.3	3.0-3.8	2.1-2.4	2.6	3.5
SLEKC01	-	<5	<5-<5	<5-<5	3.3-3.5	3.1	3.0	3.0	2.4
SLEKC02	-	<5	<5	<5	2.1	3.0	4.1	4.1	3.1
SLEKC03	-	<5	<5	<5	3.6	1.8-3.6	3.4-4.8	3.8	3.0
Al[a] normalised total concentration in sediment (dimensionless) - x 10, 000 mg/kg									
Symbol	Cu:Al								
2 x Reference site 80th Percentile	-	26.3	40.0	9.0	8.8	8.9	7.4	8.6	4.6
Alternative assessment	Significant difference to reference creek (P< 0.05) - unpaired t-test?								
		No, P=0.97	No, P=0.2	No, P=0.1	Yes, P=0.04	Yes, P=0.01	Yes, P=0.03		
Buffalo Creek sites downstream of discharge (site 01 is most upper estuary/closest to discharge in series)									
SLEBC01	7.2	5.9	2.3-3.6	5.0-6.7	9.8	6.6	10.7	6.4	5.8
SLEBC03	5.6	4.1	2.2	4.4-5.0	8.2	8.6	8.8	0.9	7.6
SLEBC04	5.2	5.0	4.5	3.5	7.2-7.8	8.1	6.5	3.8	5.5
SLEBC05	4.7	4.5	2.9-3.8	3.9	6.9	6.0-6.1	4.6-5.0	3.4	5.4
SLEBC06	8.6	23	11	5.8	3.2-3.6	4.6	4.1-6.0	4.2	3.5
SLEBC08	13	8.2	8.1	15	3.3	4.1-4.3	3.3	2.9	3.2
Mickett Creek & Kings Creek control sites where site 01 is most upper estuary in series									
SLEMC01	-	4.5	2.8-20	2.1-2.9	3.7-4.0	3.9	3.8	2.9	2.3
SLEMC02	-	13	5.3	6	3.6	4.4	3.7	3.0	2.0
SLEMC03	-	7.1	20	2.8	3.8	3.7-4.6	3.5-3.5	3.0	2.4
SLEKC01	-	3.1	2.5-3.3	3.1-4.5	4.2-4.4	4.0	3.5	4.3	2.2
SLEKC02	-	15	13	4	3.7	3.9	3.4	7.4	2.0
SLEKC03	-	6.9	3.1	2.4	4.7	3.5-4.4	3.3-3.4	3.9	2.3

Metals - Total IN SEDIMENT	Zinc								
Analysis type	Zinc								
Analytical method	Total Metals in Sediments by ICPMS								
LOR or Level of Precision	1 mg/kg								
Measures of uncertainty	±1 mg/kg								
Symbol	Zn								
Dry Season	2012	2014	2015	2016	2017	2018	2019	2020	2021
AZECC & ARMCANZ (2000) ISQG Low Trigger Value	200								
2 x Reference site 80th Percentile	-	14.8	16.8	20.0	38.0	38.0	38.0	28.2	38.0
Buffalo Creek sites downstream of discharge (site 01 is most upper estuary/closest to discharge in series)									
SLEBC01	77	19	13-19	35-41	35.2	26.8	41.8	40.3	35.8
SLEBC03	53	13	12	27-30	29.0	28.3	33.3	33.1	31.2
SLEBC04	37	9.7	13	13	21.4-26.1	28.9	24.4	24.8	33.4
SLEBC05	33	11	<5-7.9	14	21.0	17.5-19.1	16.6-17.8	23.5	25.9
SLEBC06	12	<5	<5	<5	9.2-10.5	13.1	6.1-8.2	9.7	13.5
SLEBC08	8.2	7.3	<5	<5	8.8	9.6-13.8	11.4	7.3	14.3
Mickett Creek & Kings Creek control sites where site 01 is most upper estuary in series									
SLEMC01	-	7.4	9.3-11	9.7-12	19.4-22.9	19.0	23.1	21.3	22.2
SLEMC02	-	<5	<5	<5	15.7	18.0	16.0	12.4	18.0
SLEMC03	-	<5	7.1	10	12.8	13.9-19.8	9.8-12.5	14.0	19.0
SLEKC01	-	9.9	6.4-8.4	<5-6.6	18.3-19.0	17.4	13.8	12.2	14.3
SLEKC02	-	<5	<5	<5	13.7	10.6	18.1	10.9	17.5
SLEKC03	-	<5	7.6	10	17.4	12.8-17.8	14.6-19.0	14.1	17.0
Al[a] normalised total concentration in sediment (dimensionless) - x 10, 000 mg/kg									
Symbol	Zn:Al								
2 x Reference site 80th Percentile	-	26.3	56.0	11.2	47.4	48.5	37.6	34.9	26.0
Alternative assessment	Significant difference to reference creek (P< 0.05) - unpaired t-test?								
		No, P=0.2	No, P = 0.2	Yes, P=0.00003	No, P = 0.1	Yes, P=0.02	Yes, P=0.03		
Buffalo Creek sites downstream of discharge (site 01 is most upper estuary/closest to discharge in series)									
SLEBC01	21	12	3.3-6.7	12-17	33.8	24.4	28.6	22.4	18.0
SLEBC03	17	8	3.8	11-13	28.4	29.0	27.3	3.0	24.8
SLEBC04	18	10	8.7	7.6	26.6-29.4	30.5	23.0	17.6	20.7
SLEBC05	18	10	2.9-6.1	11	26.3	25.0-26.0	19.2-22.6	16.0	21.4
SLEBC06	21	23	11	5.8	18.5-21.0	26.0	17.8-25.0	22.7	17.7
SLEBC08	21	12	8.1	15	19.6	20.7-22.7	17.7	19.0	16.2
Mickett Creek & Kings Creek control sites where site 01 is most upper estuary in series									
SLEMC01	-	7	5.2-44	5.0-6.5	20.4-21.1	20.1	18.8	16.0	11.9
SLEMC02	-	13	5.3	5.6	20.3	24.2	22.0	16.8	11.9
SLEMC03	-	7	28	5.6	20.9	19.4-20.7	16.3-18.1	16.2	13.0
SLEKC01	-	6	4.2-4.3	4.0-4.5	23.2-23.7	22.4	15.9	17.4	13.0
SLEKC02	-	15	13	4.2	24.3	13.8	5.0	19.6	11.2
SLEKC03	-	7	4.8	4.8	22.6	21.1-25.1	13.3-16.4	14.5	12.8

Data values with red text indicates > 2 x Reference site 80th percentile in that season;
Orange cell shading indicates data value exceeds ANZECC & ARMCANZ (2000) ISQG Low trigger value;
Green shading indicates data complies with ANZECC ISQG Low;
Grey shading indicates AL normalised data that is derived from < LOR values
Ranges (minimum - maximum) indicate site has been sampled in triplicate.

Table 19 Bioavailable copper and zinc in sediment assessments

Metals - Bioavailable IN SEDIMENT	Copper							Zinc						
Analysis type	Copper							Zinc						
Analytical method	HCl-Extractable Metals by ICPAES							HCl-Extractable Metals by ICPAES						
LOR or Level of Precision	1 mg/kg							1 mg/kg						
Measures of uncertainty	± 0.1 mg/kg							± 1 mg/kg						
Symbol	Cu							Zn						
Dry Season	2012	2014	2015	2016	2017	2018	2019	2012	2014	2015	2016	2017	2018	2019
AZECC & ARMCANZ (2000) ISQG Low Trigger Value	65							200						
2 x Reference site 80th Percentile	-	10	10	10	7.2	3.2	4.0	-	10	10	10	14.6	17.2	12.2
Bioavailable concencentration in sediment (mg/kg)														
Buffalo Creek sites downstream of discharge (site 01 is most upper estuary/closest to discharge in series)														
SLEBC01	1.98	*47 [a] (Cu T 9.4)*	< 5 - < 5	6.3 - 7.1	4.6	3.6	4.9	6.00	*130 [a] (Zn T 19)*	10 - 11	15 - 15	18.8	16.9	24.2
SLEBC03	1.30	*5*	< 5	< 5 - < 5	4.2	5.1	4.6	3.80	15	5.1	11 - 16	14.7	18.8	20.6
SLEBC04	0.52	*< 5*	< 5	< 5	3.4-4.2	5.2	3.1	3.40	< 5	7.5	< 5	10.7-12.9	17.3	12.9
SLEBC05	0.72	*< 5*	< 5 - < 5	< 5	2.4	2.7-2.8	1.2-1.9	2.60	6.8	< 5	5.3	10.1	9.1-9.9	8.8-8.9
SLEBC06	0.22	*< 5*	< 5	< 5	<1.0-<1.0	<1.0	<1.0-<1.0	1.40	< 5	< 5	< 5	3.3-4.4	6.0	2.7-7.8
SLEBC08	<0.02	*< 5*	< 5	< 5	<1.0	<1.0-<1.0	<1.0	0.86	< 5	< 5	< 5	3.9	4.0-7.0	4.0
Mickett Creek & Kings Creek control (sites where site 01 is most upper estuary in series)														
SLEMC01	-	< 5	< 5	< 5	1.2-2.0	1.7	2.0	-	< 5	< 5 - < 5	< 5 - 5.9	6.5-8.2	8.6	8.7
SLEMC02	-	< 5	< 5	< 5	1.1	1.2	<1.0	-	< 5	< 5	< 5	5.1	7.0	5.3
SLEMC03	-	< 5	< 5	< 5	1.3	<1.0-1.6	<1.0-1.1	-	< 5	< 5	< 5	5.1	5.8-8.8	4.5-5.2
SLEKC01	-	< 5	< 5	< 5	4.2-4.4	1.2	<1.0	-	7	< 5 - < 5	< 5 - < 5	5.8-7.3	7.6	4.5
SLEKC02	-	< 5	< 5	< 5	2.1	<1.0	2.0	-	<5	< 5	< 5	4.5	3.5	3.9
SLEKC03	-	< 5	< 5	< 5	3.6	<1.0-<1.0	<1.0-1.0	-	<5	< 5	< 5	5.8	4.1-6.7	5.2-6.1

Results with individual cells outlined would indicate that the ISQG Low on the total metal in sediment result was exceeded - none in 2012, 2014, 2015 and 2016 dry seasons;

[a] The total metal result at this site did not exceed the ISQG Low - in this case the second tier bioavailability assessment would not be required and this result similar to other 1 M HCl estimates at this site appear dubious;

Data values with red text indicates > 2 x Reference site 80th percentile in that season;

Orange cell shading indicates data value exceeds ANZECC & ARMCANZ (2000) ISQG Low trigger value;

Green shading indicates data complies with ANZECC ISQG Low

Table 20 Filtered copper and zinc in porewater assessments

Metals (Dissolved) IN PORE WATER	Cu-F (µg/L)							Zn-F (µg/L)						
Analysis type	Copper							Zinc						
Analytical method	Dissolved Metals in Saline Water by ORC-ICPMS							Dissolved Metals in Saline Water by ORC-ICPMS						
LOR or Level of Precision	1 µg/L							5 µg/L						
Measures of uncertainty	± 2 µg/L							± 1 µg/L						
Symbol	Cu							Zn						
Dry Season	2012	2014	2015	2016	2017	2018	2019	2012	2014	2015	2016	2017	2018	2019
ANZECC & ARMCANZ (2000) SMD Trigger	1.3							15						
2 x Reference site 80th Percentile	-	2	2	2	2	2	4	-	10	10	10	10	10	10
Buffalo Creek - Concentration in porewaters (µg/L) for sites downstream of the discharge on ebb tides														
SLEBC01	<1-<1	<1	2.0-**5.0**	<1-**3**	<1	<1	<1	3.2-3.6	3.1	<5- <5	<5-**11**	<5	<5	<5
SLEBC03	<1-<1	<1	<1	<1-2	<1	2.0	<1	2.8-3.0	<5	<5	<5-10	<5	10.0	<5
SLEBC04	<1-<1	<1-<1	<1	<1	<1-<1	**4.0**	<1	2.8-3.2	<5- <5	<5	<5	<5- <5	9.0	<5
SLEBC05	<1-<1	<1-<1	<1-<1	<1	<1	1.0-**7.0**	<1-<1	3.0-3.0	<5- <5	<5- <5	<5	<5	<5-**11.0**	<5- <5
SLEBC06	<1-<1	<1	<1	<1	<1-<1	<1	<1-<1	<0.02-<0.02	<5	<5	<5	<5- <5	<5	<5- <5
SLEBC08	<1-<1	<1	<1	<1	<1	<1-<1	<1	<0.02-<0.02	<5	<5	<5	<5	<5-<5	<5
Mickett Creek & Kings Creek - Concentration in porewaters (µg/L) for sites downstream of the discharge on ebb tides														
SLEMC01	-	<1	<1-<1	<1-<1	<1-<1	<1	2.0	-	<5	<5- <5	<5- <5	<5- <5	<5	<5
SLEMC02	-	<1	<1	<1	<1	<1	<1.0	-	<5	<5	<5	<5	<5	<5
SLEMC03	-	<1-<1	<1	<1	<1	<1-<1	<1.0-1.1	-	<5- <5	<5	<5	<5	<5- <5	<5- <5
SLEKC01	-	<1	<1-<1	<1-<1	<1-<1	<1	<1.0	-	<5	<5- <5	<5- <5	<5- <5	<5	<5
SLEKC02	-	<1	<1	<1	<1	**3.0**	2.0	-	<5	<5	<5	<5	<5	<5
SLEKC03	-	<1-<1	<1	<1	<1	<1-<1	<1.0-1.0	-	<5- <5	<5	<5	<5	<5-6	<5- <5

a Metals in porewaters have not previously been included in the Leanyer-Sanderson Sediment Monitoring Program so no data prior to 2015;
Green shading indicates compliance with ANZECC and ARMCANZ (2000) SMD guideline trigger values;
Orange shading indicates exceedance of ANZECC and ARMCANZ (2000) SMD guidelines.
Red bold text indicates exceedence of 2 x reference site 80th percentile in that season
Ranges (minimum - maximum) indicate site has been sampled in triplicate.

3. Appendix 3 - REPORTING LIMIT EXCEEDANCES

Table 21 Reporting Limit exceedances of WDL 147-08 from November 2017 to Feb 2021

Indicator	Site	Zone	Date	Reporting statistic	Reporting value	Reporting Limit	Significance
pH	SLEBC06	Transition Zone	10/01/2018	Individual value	8.69 pH	<6.00 and >8.50 pH	The pH reporting limit exceedance at SLEBC06 on the same day may relate to the Red tide bloom observed at this site on this day as phytoplankton uses dissolved CO2, causing the dominant CO2-HCO3- equilibrium to be displaced so that the pH is increased. The pH reporting limit is assessed against an individual value in this case for compliance purposes; however the pH was above the DHWQO pH range of 6 - 8.5 for the upper estuary water type. Overall the exceedance is considered slight and low risk. WDL 147-08 require any exceedance of the specified reporting limits to be reported.
	SLEBC06	Transition Zone	09/05/2018	Individual value	8.77 pH	<6.00 and >8.50 pH	During photosynthesis, algae remove carbon dioxide (CO2) from the water, which increases the hydroxide (OH−) levels, resulting in an increase in pH; they also produce large amounts of oxygen (O2), which may result in supersaturated levels of DO. The pH reporting limit is assessed against an individual value in this case for compliance purposes; however the pH was above the DHWQO pH range of 6 - 8.5 for the upper estuary water type. Overall the exceedance is considered slight and low risk. WDL 147-08 require any exceedance of the specified reporting limits to be reported.
	SLEBCO8 AND SLESB02	Outer zone	04/04/2021	Individual value	8.95 and 8.86 respectively	<6.00 and >8.50 pH	Both of these values are attributed to calibration drift of monitors
	SLESB02	Outer zone	12/07/2021	Individual value	8.7	<6.00 and >8.50 pH	Unusual. Isolated occurance, possibly attributable to monitor calibration drift. Minimal environmental risk
Dissolved oxygen	SLEBC03	Upper Zone	15/11/2018	Individual value	21.5 %sat.	<30 %sat.	At 21.5%sat the recorded DO% sat is below the low range DO %saturation specified for upper zone in WDL 147-08, which is the toxic threshold trigger of 30% sat specified by ANZECC as a trigger for water quality with the potential for toxic impacts on some fish species. Assessment Water Quality "median" for the last 24 months is 57.95% sat, which is greater than the assessment criteria of <30 %sat for ANZECC potential toxic impacts; ANZECC specifies that if the test values (median) is greater than the trigger values, there is low risk of adverse biological effects occurring and no further action is required.
	SLEBC08	Outer zone	15/02/2021	Individual value	73%sat	<80%sat	Below the outer zone DO minimum. Isolated incident. Not reoccurring at this site and not reflective of long term trend. Minimal environmental risk, no action required.
	SLEBC06	Transition zone	08/11/2021	Individual value	46.3%sat	<50%sat	Below the 50% SSTV value for the Transition zone but an isolated occurance, not reflective of long term trend. Minimal environmental risk, no action required.
Enterococci	SLEBC06	Transition Zone	08/02/2018	Individual value	270/100mL	>200/100mL	The Enterococci reporting limit exceedance at SLEBC06 is likely to be related to stormwater. All cases Enterococci exceedances appear to occur at this transition zone site following rainfall, possibly resulting in the animal wastes and other matter are washed from sealed road access and car park areas in from the Buffalo creek catchment.
	SLEBC06	Transition Zone	15/11/2018	Individual value	630/100mL	>200/100mL	The Enterococci reporting limit exceedance at SLEBC06 is likely to be related to stormwater that has runoff from sealed road access and car park areas from the Buffalo creek catchment into the creek, as a result organic matter and pollutants are flushed downstream, in this case toward site SLEBC06, before it continues flowing toward the creek mouth. This site is adjacent to the boat ramp at Buffalo Creek, a recreational site in the transition zone. At the site SLEBC06 the Enterococci measured 630/100mL exceeding the > 200RL. Additionally, there was 52.4 mm of rainfall accumulated over the 5 previous days, the water was observed to have high stormwater influence by the field personnel.
	SLEBC06	Transition Zone	11/04/2019	Individual value	580/100mL	>200/100mL	The reportable exceedance is for Enterococci in Buffalo Creek, site SLEBC06. Notation on field sheets indicate that buffalo creek samples presented as muddy in colour, due to the presence the impacts of stormwater and high tidal variation (1.2m at 3:33AM to 6.35m at 9:52AM). Contamination via stormwater runoff downstream of the discharge point and upstream of SLEBC06 is considered to be the cause for exceedance in the transition zone. Previous exceedances recorded at this location have also been observed to follow season rainfall trends.

Indicator	Site	Zone	Date	Reporting statistic	Reporting value	Reporting Limit	Significance
Total Ammonia as N	SLESB02	Outer Zone Shoal Bay	12/12/2017	Individual value	33 µg/L	>20 µg/L	This slight exceedance is not significant - no risk. The RL is based on the DHWQO for NH3-N which should only be applied to a dry season data set. The NH3-N concentrations in Buffalo Creek transition and the other outer zone site is low (these concentrations do not anywhere near approach any possible toxicity thresholds (either chronic or acute).
	SLESB02	Outer Zone Shoal Bay	08/03/2018	Individual value	82 µg/L	>20 µg/L	The NH3-N reporting limit exceedance at SLESB02 is not significant, a risk analysis for NH3-N exposures in the outer zone at SLESB02 in Shoal Bay surface waters indicates a 'Low' risk ranking. All cases NH3-N exceedances appear to occur at outer zone SLESB02 in Shoal Bay. The RL is based on the DHWQO for NH3-N which should only be applied to a dry season data set. The Ammonia does not reach the lowest toxic trigger value (99% level of protection) from ANZECC which is 500µg/L since 2014.

4. ATTACHMENT A - WDL 147 LEANYER SANDERSON SUMMARY DATA AND PLOTS MASTERFILE

WDL 147 Leanyer Sanderson Summary Data and Plots Masterfile		
Summary Data and Plots Masterfile	All samples collected consistent with Appendix 1 – no reports of missed sampling in Field Sheets or Site Notes stored in F2011/6237 in this period Summary data and plots Masterfile – D2015/229226 Data is extracted from the PWC data water quality database for assessment against criteria specified in Appendix 1. The summary data and plots of water quality data collected in accordance with Appendix 1 are contained in RM8 D2015/229226 are assessed against the reporting criteria specified in Appendix 5.	F2011/6237 D2015/229226

5. ATTACHMENT B - WDL 147 SEDIMENT DATA SUMMARY

WDL 147 Sediment Data Summary		
Sediment Data Summary	Sediment monitoring is conducted in accordance with Appendix 2 of the Licence and data is summarized in file D2014/390684, and WDL 147 Sediment Assessment D2015/374189	D2014/390684 D2015/374189

6. ATTACHMENT C – PARAMETERS ASSOCIATED WITH THE WASTEWATER DISCHARGE DATA SUMMARY

Parameters associated with the Wastewater discharge Data Summary		
Parameters associated with the Wastewater discharge Data Summary	The summary of the Parameters associated with the Wastewater discharge such as Flow, BOD, TP and TN data is summarized in file D2017/74917, and the most recent calculations are in folder F2018/479 where Mass Loads Estimates 2018-2019 are located in D2018/534397	D2017/74917 F2018/479 D2018/534397

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