Remote Community Waste Discharge Licences
Waste Stabilisation Ponds

MONITORING REPORT 2022

Water Services

Remote Water Planning

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PowerWater

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Cover Image: Numbulwar Waste Stabilisation Ponds 2018 – Power and Water Corporation

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Table of Contents

List of Tables

List of Figures

Glossary

Abbreviation	Definition
ANZECC	Australian and New Zealand Environment and Conservation Council
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
DEPWS	Department of Environment, Parks and Water Security
DHWQO(s)	Darwin Harbour water quality objective(s)
DO	Dissolved oxygen
EC	Electrical conductivity
E. coli	*Escherichia coli*
EP	Equivalent population
ET	Equivalent tenement - calculation utilised in remote communities for an average residential dwelling or house (Indigenous Community Engineering Guidelines 2017)
ERA	Environmental risk assessment
FRP	Filterable reactive phosphorous (orthophosphate)
kL	Kilolitres
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)
NO_x-N	Oxidised nitrogen as N – the sum of nitrate and nitrite
NT	Northern Territory
NT EPA	Northern Territory Environment Protection Authority
NTU	National turbidity units
PWC	Power and Water Corporation
RL(s)	Reporting Limit(s)
RM	Rolling Median – of all years of available data; utilised in absence of adequate datasets.
TN	Total nitrogen
TP	Total phosphorous
TSS	Total suspended solids
WDL(s)	Waste discharge licence(s)
WSP(s)	Waste stabilisation pond(s)

Executive Summary

Power and Water Corporation have developed this Monitoring Report to satisfy the requirements under its remote Indigenous community Waste Discharge Licence conditions. A long-term trend analysis and comparative assessment of treated effluent monitoring results at all licensed remote communities has been provided where possible, to improve understanding of the potential environmental impacts occurring from the licensed activity. The report found that the monitoring conducted meets the needs specified within the licence conditions.

A review of calculated mean daily discharge volumes at all sites identified that Milingimbi and Maningrida potentially have the largest discharge volumes. All other remote community WSPs have relatively low discharge volumes in comparison to urban facilities such as Berrimah WSPs.

The assessment of water quality parameters across all remote sites found TSS, BOD, nutrients, and pathogens to be key indicators associated with environmental impacts from the operation of the remote WSPs. The key indicators are within the optimal ranges for WSPs, with elevations occurring considered to be the result of climatic fluctuations, particularly in 2019. Concentrations of Ammonia, *E. coli* and Enterococci in remote communities are the parameters that deviated most from the comparative values utilised (Berrimah - WSP), however there are a significant number of factors may influence varied treatment rates between the different systems, including pond configuration and design. Preliminary monitoring results at Woods Inlet surface water site suggest mixing and dilution/flushing are occurring within the zone of influence, with both increases and decreases identified in particular indicators.

Power and Water have previously conducted environmental risk assessments at all licensed sites. As more data is collected, the datasets will be utilised to inform level of risk in the future. Environmental risks are to be reviewed as more accurate information becomes available.

The discharge has a range of inputs/stressors that were identified as potentially deleterious to either the 'environment' or 'cultural' beneficial use that are typical for this source. Overall, the ecological health of the waterways where discharge occurs are considered largely intact with visual observations suggesting no indication of impacts to the receiving waters/environment.

Notably, the sites where 'High' risk rankings were identified within the ERA's were for cultural values within the area. 'High' risk rankings were determined for cultural use of areas at the discharge point for recreation and consumption of aquatic foods (pathogens). It is possible that these values may not be protected within the mixing zone. Further analysis of data will provide more confidence in the risks over time.

Power and Water have implemented additional monitoring at a number of sites, as well as progressively installing flow instrumentation at identified priority sites to ensure continued improvement.

1. Regulatory Requirements

Power and Water Corporation (Power and Water) operate 57 Waste Stabilisation Ponds (WSPs) across the Northern Territory (NT). Under the *Water Act 1992* (NT) it is an offence to cause, either directly or indirectly waste to come into contact with water; or water to be polluted, causing environmental harm unless authorised to do so. Waste Discharge Licences (WDLs) are a regulatory instrument granted under the provisions of Section 74 of the *Water Act 1992* (NT). These licences allow Power and Water to operate WSPs that have continuous discharge of secondary treated sewage effluent to a receiving waterway. Power and Water currently have 24 remote Indigenous communities that have WDLs issued.

The submission of this report fulfils Power and Water's requirement to provide a Monitoring Report under Condition 30 of the WDLs. A list of all current NT remote Indigenous community WDLs this report refers to is included within Appendix A. A single report is to be submitted annually for all of the remote WDLs.

Condition 30 of the WDLs specifies that the Monitoring Report:

30.1 Is prepared in accordance with the requirements of the Administrating Agency 'Guideline for Reporting on Environmental Monitoring'

30.2 Includes a tabulation of all monitoring data required as a condition of this Licence;

30.3 Includes long term trend analysis of monitoring data to demonstrate any environmental impact associated with the activity over a minimum period of three years (where the data is available);

30.4 Includes an assessment of environmental impact from the activity.

The main purpose of this report is to present the initial findings from treated effluent monitoring conducted at remote communities, which will be utilised to inform environmental risk assessments in the future.

1.1. Monitoring Report Requirements

Table 1 Monitoring Report Requirements

Condition No.	Provision
30.1	This Monitoring Report has been prepared in accordance with the NT EPA 'Guideline for Reporting on environmental Monitoring' (Version 1.0) where practicable and applicable. Some information has been omitted where data may not exist.
30.2	A tabulated summary of all monitoring data for remote community WDLs is completed and provided as Appendices B, C and D. Also Attachment A – Remote Community WDL Summary Data.
30.3	Trend analysis and interpretation of the results is provided in Section 4 - Monitoring Results. Monitoring data included in this report covers a period of 5 years of data where available.
30.4	An assessment of environmental impacts from the activity is included in Section 5. Further specific information is available in individual Environmental Risk Assessments for each community.
34	Review of surface water results and exceedances of trigger values at Belyuen WwTP is included in Section 4.7 - Surface Water
35	A record is to be kept of all exceedances of trigger values specified in Schedule 2 at the Belyuen WwTP is included in Section 3 – Trigger Value Exceedances

2. Background and Objective

The routine wastewater monitoring program for remote communities commenced initially in 2015 at selected sites and is currently completed at 24 remote facilities in line with WDL requirements.

The WSPs offer a low input, cost effective form of wastewater treatment that is particularly applicable in higher temperature environments with sufficient available land area. Being low maintenance and driven by solar energy, WSPs are a suitable option for remote Indigenous communities spread across the NT.

WDLs have been issued by Department of Environment, Parks and Water Security (DEPWS) at remote Indigenous communities based on sites that potentially discharge to a waterway utilising a risk ranked approach across all 24 communities:

- Round 1 licences – 8 highest risk sites due to higher discharge volumes (based on Equivalent Population (EP), continuous discharge and type of receiving environment.
- Round 2 licences – 10 medium risk sites, lower discharge volumes, continuous or intermittent discharge.
- Round 3 licences – 6 lower risk sites, lower discharge volumes, intermittent or seasonal discharge (some irrigation sites).
- All remaining remote community WSPs operate without a WDL in place as the majority of these do not discharge to waterways – irrigation to land or evaporation occurs. Fifteen communities rely on on-site wastewater treatment systems managed privately or as part of the public housing portfolio.

The frequency of wastewater monitoring at remote sites has been conducted based on licence issue dates and monitoring requirements. Details of the wastewater monitoring conducted at these communities is documented under Power and Water's internal Wastewater and Reclaimed Water Quality Monitoring Plan 2022-23. Monitoring of the Woods Inlet receiving environment at Belyuen is undertaken by an external contractor on neap ebb tides to capture near-to worst-case scenarios (i.e. low tidal range, minimal dilution and flushing).

The main objectives of the remote wastewater monitoring program are to:

- Ensure compliance with regulatory requirements;
- Minimise environmental and public health risks associated with sewage; and
- Understand operational performance to inform asset maintenance and improvements.

The datasets utilised for this report vary depending on the community and typically covers the period from January 2017 to June 2022. Frequency of wastewater monitoring at the discharge points vary between communities depending on specified licence conditions at the time and any investigative monitoring conducted. Monitoring at remote sites has progressively increased over time from 6-monthly to quarterly at most communities during the 2019-20 period, with monitoring increased to monthly at selected sites to increase datasets and meet changes to updated licences over time.

All samples were taken from the correct sampling locations and frequency required at the specified time. The location of the discharge points for each community are specified in the individual WDLs. As per Condition 28 (Belyuen WDL215), signage at all land based monitoring points is also installed and maintained so that the selected locations are identifiable at all times. Samples were collected and preserved in accordance with specified requirements for each water quality parameter, with analysis conducted at NATA accredited laboratories.

Rainfall recorded within the reporting period varies between regions, records from Darwin, Katherine and Maningrida weather stations have been utilised as a general reference in Table 2 below.

Table 2 Annual Average Rainfall Data (BOM, 2022)

Region	Weather Station Number	Average annual rainfall per year (mm)						Annual Average
		2017	2018	2019	2020	2021	2022	All years
Darwin	14163	2,364	1,654	957	1,795	1,658	1,181	1,600
Katherine	14902	N/A	787	659	849	1,008	487	632
Milingimbi	14405	1,329	1,323	743	1,391	1,558	695	1,173

2.1. Assessment Protocols and Limitations

Monitoring data collected and provided for the purposes of this report are collected at the final pond outlet (discharge point) at each site. These results provide a representation only of the effluent quality that is being discharged to the environment. It is generally understood that effluent quality results are not expected to achieve relevant water quality guideline values for environmental waters without the mixing and dilution that occurs within the receiving environment (zone of influence). Default criteria were not intended to be used as instruments to assess compliance, but rather to provide a tool to make inferences about the level of disturbance occurring (ANZECC, 2000). Therefore treated effluent monitoring conducted within the WSPs is not suitable to be specifically assessed against relevant water quality guidelines.

With no suitable guidelines available, for the purposes of this report default values in Appendix E have been utilised to provide a basis on which to make a valid comparison between communities and effluent values to understand the treated effluent quality and potential environmental risks:

- The Berrimah WDL WSPs 2021 Monitoring Report (data period of 2016-2021) has been utilised throughout the report for comparative purposes to review the wastewater quality data of remote facilities against those of an urban facility. This provides some context for consideration of possible environmental impacts where knowledge gaps exist at remote sites. Berrimah was selected due to the site being a smaller urban treatment plant.
- NSW Government Environmental Guidelines – Use of Effluent for Irrigation (2003) have also been utilised to assist with classification of effluent strength for comparative purposes in absence of NT guideline values.
- The Darwin Harbour Water Quality Objectives (DHWQO) where applicable have been utilised for surface water monitoring results in Section 2.1.
- Selected wastewater references which are widely acknowledged by wastewater specialists in Australia (Water Futures 2020).

There are a number of other limitations for data assessment that have been identified with association of the preparation of this report that affect statistical analysis and presentation of the results:

- Limited availability of flow data to determine discharge loads;
- Limited monitoring data availability at some sites, small sample sizes, and inconsistencies of monitoring frequencies between communities resulting in inconsistent results further reducing confidence in the data statistics (particularly long-term trends (ANZECC, 2000)).
- Transportation logistics may impact on collection of wastewater samples at remote Indigenous communities including bad weather/ access to site, aircraft break down, communications (phone) faults, community unrest, Essential Service Operator (ESO) and the available capacity to conduct sampling (prioritisation of provision of power and water; prioritisation of drinking water samples; human error). Where possible Power and Water endeavour to conduct samples as per the licence requirements and monitoring schedule, however some samples may be delayed due to the above issues. Power and Water endeavour to collect the required number of samples per annum.
- Monitoring results within this report have been presented as median values for long-term trends of all indicators as recommended in the ANZECC Guidelines. However due to limited datasets for some communities and or years, the Rolling Median (RM) of all years has been utilised for comparative purposes. This is required due to the inconsistencies associated with monitoring frequencies, some communities or years may only contain 1-4 sample results which does not provide a suitable dataset for analysis.
- Outliers and abnormalities – distortion of results have occurred due to the presence of outliers. These have not been removed for purpose of this report to ensure no bias has occurred. Datasets that are more rigorous are required to ethically remove these results. Elevated results are highlighted in bold within the monitoring results tables are considered outliers and may impact overall interpretation of results.
- Seasonal and geographic variations may be present, further monitoring is required to properly assess long-term seasonal trends. DHWQC criteria are only applicable in the Dry Season (NRETAS 2010) so it is not unexpected that Wet Season exceedances may occur. Seasonal assessments will be provided once more rigorous datasets become available.
- It is difficult to make comparisons between WSPs which have variations in design i.e. pond size, pond numbers, pond depths. Furthermore, the WSP’s have differences in inflow concentrations and volumes that will impact upon treatment performance and monitoring results.

3. Summary of Reporting Limit Trigger Value Exceedances

Site-specific trigger values are specified for only Belyuen WDL215-02 under the current WDLs. A summary of all the reporting limit trigger value exceedances in the receiving waters for Belyuen WwTP discharge are provided in Appendix D (Table 5).

4. Monitoring Results and Discussion

4.1. Discharge Volumes

The relatively low discharge volumes from licensed remote Indigenous community WSPs are consistent with the low equivalent populations (EP) (referred to as equivalent tenements in remote communities) in these sites. Maningrida is the largest Indigenous community with a WDL in place, with an ET of 2,773 and Acacia Larrakia is the smallest Indigenous community with an ET of 87 (DHCD, 2017). In comparison, the urban site of Berrimah has an EP of 1,362 (PWC, 2021). The EP/ET of each community is documented within the individual ERAs.

Figure 1 below illustrates the estimated mean annual discharge volumes for remote community WwTP's. Power and Water have implemented a risk-based approach for flow instrumentation to be progressively installed at the final discharge point at priority sites based on continuous flow to the environment, as per Action 4 in the Performance Improvement Plans. This is an ongoing program based on funding availability and approvals. The dataset for those communities with meters installed is currently being assessed for quality assurances and verification; the data sets contain inconsistencies, reducing confidence in the data.

For the purpose of this report, *in-situ* flow meter data is provided where available marked with an astricts in Figure 1 below. For communities where waste discharge flows are not metered an annual water balance is utilised to estimate a mean daily inflow and outflow volume based on forecast sewage Equivalent tenement (ET) flow, estimated total sewer ET, rainfall, evaporation and pond area. The calculation gives an estimated daily average flow.

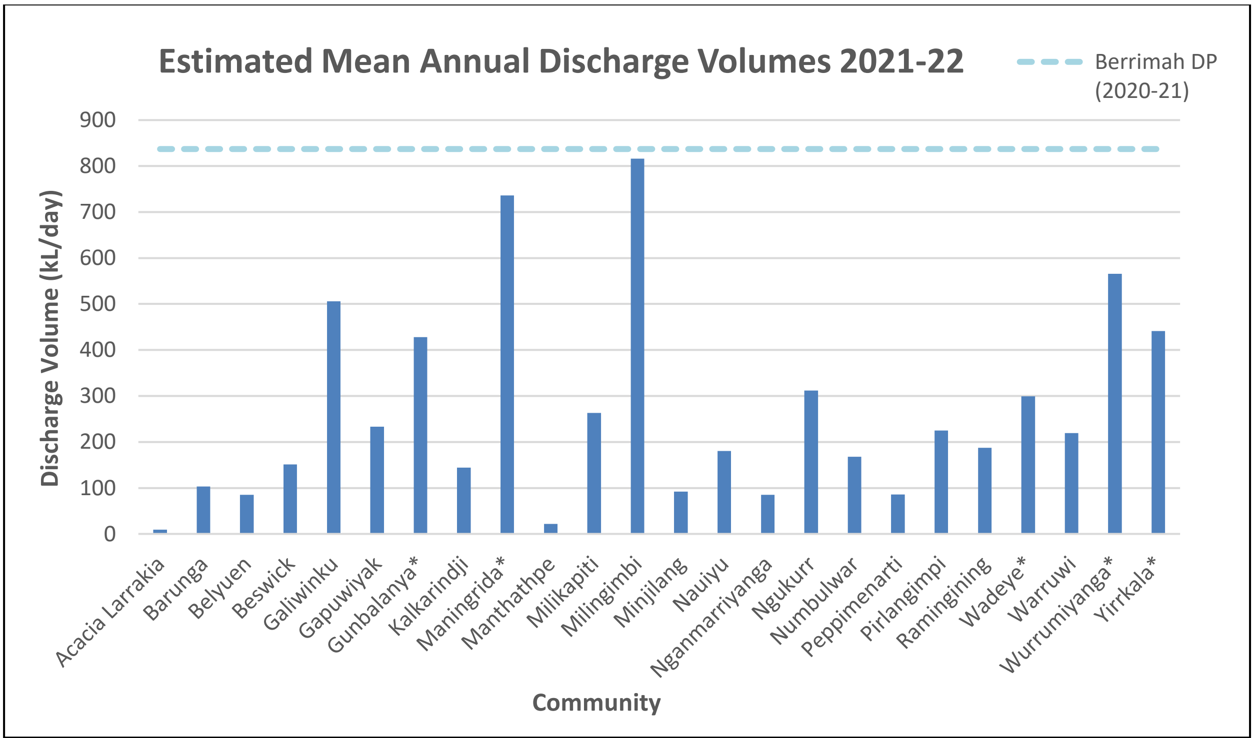

Figure 1 Estimated mean annual discharge volumes at remote sites in 2021-22
Note: **2020-21 is the most recent data available for Berrimah*

As a result of utilising estimated volumes, discharge volume trends over time are unable to be presented at this time. Rainfall recorded for the 2018-19 and 2019-20 Wet Seasons were below average in most areas, which has resulted in low water levels observed within some of the WSPs during these Dry Seasons, suggesting a possible decrease in flows for those past 2 years (BOM, 2022). In comparison, the 2020-21 and 2021-22 Wet Seasons brought rainfall above monthly averages; with pond discharge volumes assumed higher than in previous years (BOM, 2022).

Based on the estimations, Milingimbi, Maningrida and Wurrumiyanga are communities that have the highest estimated volume of continuous effluent being discharged to the environment on a daily basis. Whilst Acacia Larrakia, Manthathpe, Nganmarriyanga and Belyuen have the lowest estimated volume of discharge to the environment, discharging on a seasonal basis. These volume calculations of the remote communities may change over time as uncertainties associated with limited flow monitoring availability are addressed.

Due to the small community populations, the remote Indigenous communities have relatively low discharge volumes in comparison to other NT wastewater facilities in major centres. For example, urban sites such as Leanyer Sanderson and Berrimah WSPs discharged 17,000 and 590 kL/day in 2019-20 respectively.

4.2. Discharge Load Calculations

Discharge load calculations for remote Indigenous communities is unavailable or invalidated at this time. Further data collection is required. A recent study conducted at four remote community WSPs *'identified that these sites are receiving low loads in comparison to the typical influent domestic wastewater'* (Jacobs Engineering Group, 2021, pg. 79).

4.3. Physio-Chemical Parameters

Power and Water monitors a suite of physical-chemical parameters at remote WSP outlets routinely. These include pH, electrical conductivity (EC), dissolved oxygen (DO), turbidity and total suspended solids (TSS). Of these, pH and TSS are key water quality parameters that can be utilised for assessment purposes.

EC is an indicator of the concentration of salts within water, these levels can be impacted by source water, for example as indicated in Power and Water's Annual Drinking Water Report, communities such as Ngukurr have naturally occurring high TDS, Iron and Manganese concentrations in the source water which may elevate EC levels within the WSPs. Results for Turbidity can be highly variable dependent on pond water level, rainfall, and algal volumes within the pond at the time of sampling. EC and Turbidity are therefore not considered suitable key indicators associated with assessment of discharge impact on the receiving environment.

Effluent with low median DO concentrations discharged to the receiving environment may have an adverse effect on aquatic organisms, as it is necessary for photosynthesis (ANZECC, 2000). However, DO (% Sat.) levels are diurnal and are most accurately measured *in-situ* as the concentration levels vary considerably when the sample is cooled or stored. Once the samples are received in Darwin from remote communities these analytes may not be as accurate as field measurements as there are a number of factors that affect DO levels (algal load, bacterial load, temperature during transportation, time between sample collection and analysis in lab) (AWQC, 2020). The WSPs may also be producing more anaerobic conditions with low flows occurring within ponds (Patterson & Curtis, 2005). DO results from remote communities seen in Appendix B contain numerous abnormalities within the datasets further indicating that these results may not be representative of the actual DO levels at the pond outlets. DO directly correlates with BOD, and therefore BOD is considered a more suitable key indicator for the assessment of treated effluent results; BOD is generally utilised to assess oxygenation in waste stabilisation ponds.

4.3.1. pH and TSS

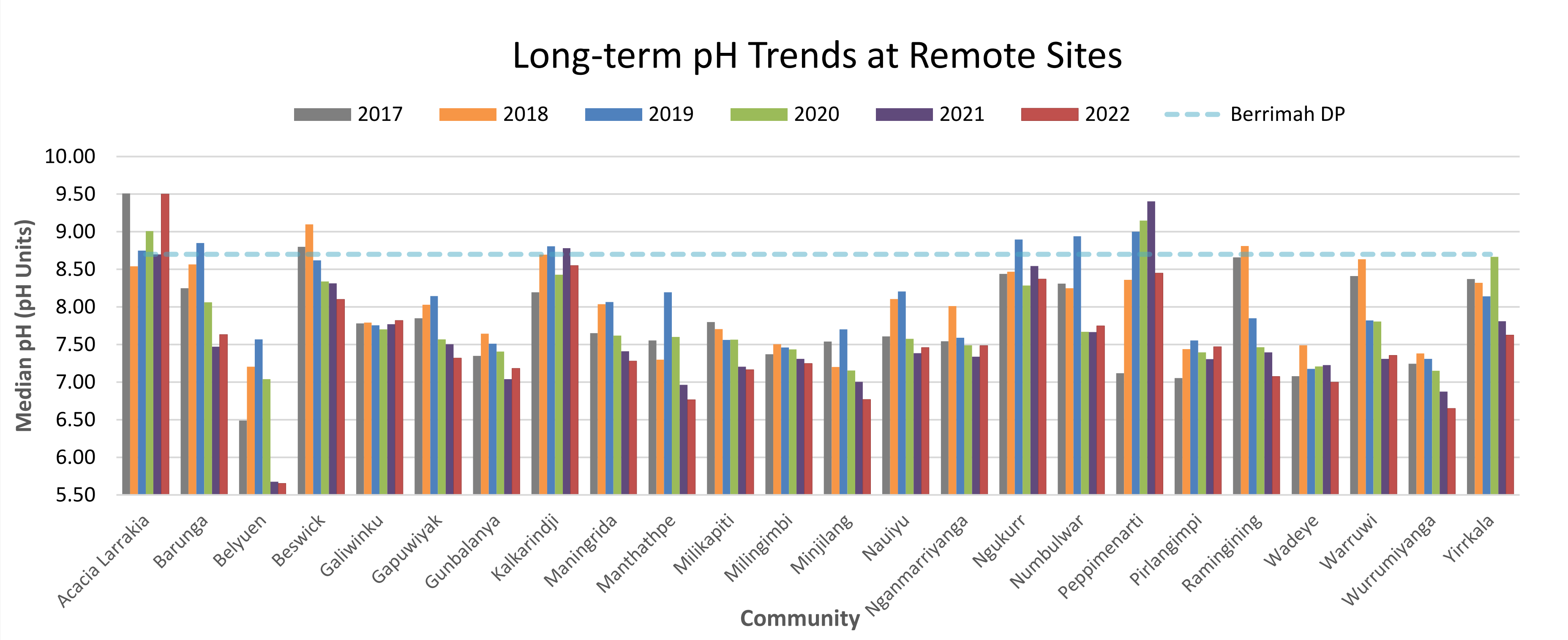

Figure 2 Long-term pH trends at remote sites

Discussion:
Changes in pH can affect metal solubility and toxicity, and an organism's ability to absorb minerals and nutrients (DENR, 2019) however as WSPs are designed to utilise biological processes, it has not been identified as a key indicator associated with environmental impacts of effluent discharge from WSPs.

Figure 2 demonstrates that pH values are slightly elevated in Acacia Larrakia, Beswick and Peppimenarti in comparison to other communities. This may be a result of higher source water pH values occurring within the inflow effluent. The pH levels observed at these communities in the Power and Water Annual Drinking Water Quality Report for 2019-20 are considered neutral (>7.2) however, these values are more alkaline than the source waters in other communities.

In general, maturation ponds are designed to have elevated pH levels, as seen at Berrimah discharge point (8.7). pH increases throughout the WSP system, this supports growth of microorganisms, the "killing process" of pathogens, nutrient removal and odour control. Elevated pH levels up to 9.5 within WSPs are seen as beneficial (Patterson and Curtis, 2005).

Historically pH results recorded at Belyuen are generally lower than those commonly reported in other communities, particularly in 2021 and 2022 (5.7), however the overall rolling median (RM) at Belyuen is 6.9, suggesting possible seasonal or biological fluctuations. Low pH is also observed in the Belyuen receiving environment (Table 4). pH results are diurnal and are most accurate when collected *in-situ* rather than lab tested, therefore long-term trends are difficult to accurately assess and validate (Patterson and Curtis, 2005).

Overall results in remote communities generally sit within the optimal water quality range for pH within environmental waters (6.0 – 8.5) (ANZECC, 2000).

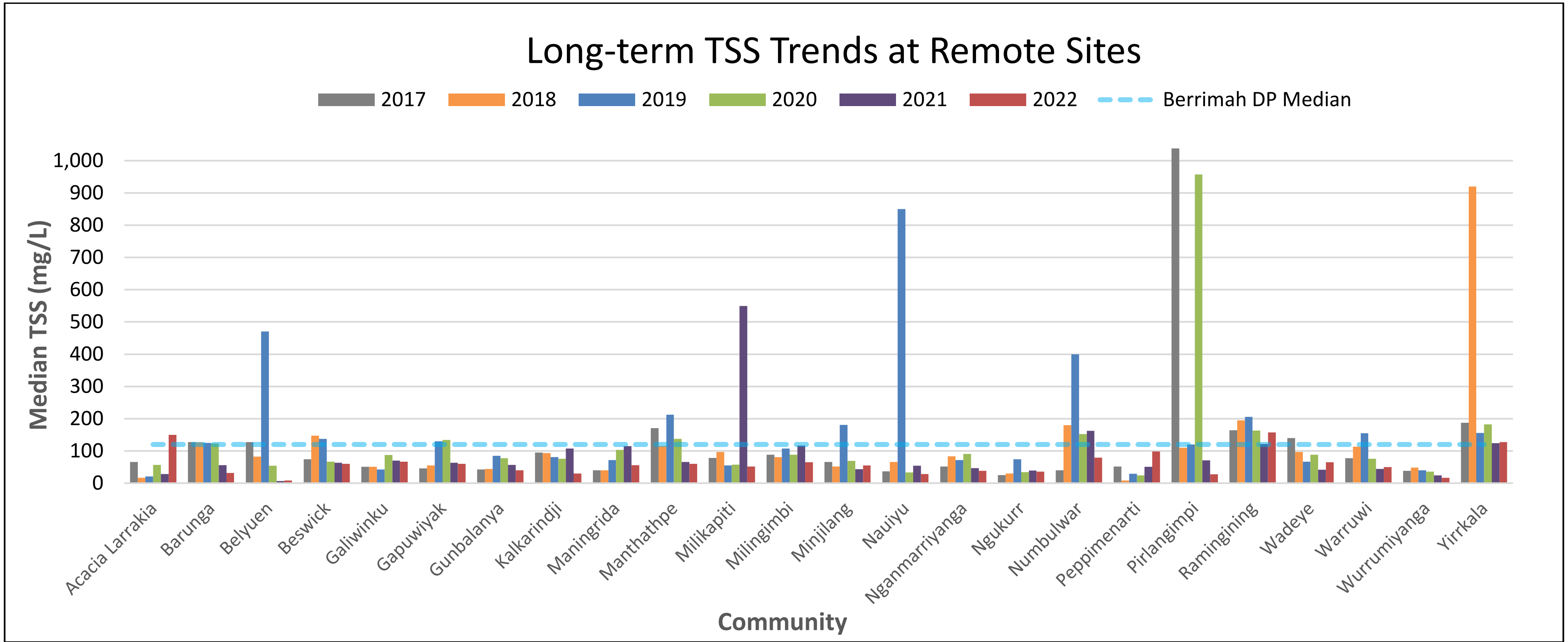

Figure 3 Long-term Total Suspended Solids trends at remote sites

Discussion:
TSS have the potential to reduce light penetration, which can reduce photosynthesis of aquatic plants/phytoplankton (ANZECC, 2000), TSS are key indicators associated with environmental impacts of effluent discharge from WSPs.

Figure 3 shows the concentration and reported levels of TSS can vary considerably between communities and between years. Yirrkala, Ramingining and Numbulwar have consistently higher TSS results over consecutive years in comparison to other communities, whilst Acacia Larrakia, Ngukurr and Peppimenarti have generally lower TSS concentrations over consecutive years.

In general, the most elevated concentrations occurred during 2019 at a number of communities, particularly within the Dry Season indicating climate variations as seen in the monitoring results tables within Appendix B. Abnormal results were observed at the end of the Dry Season, indicating inconsistencies with RMs at Belyuen (470 mg/L, RM is 44 mg/L), Manthathpe (212.5 mg/L, RM is 115 mg/L) and Minjilang (181 mg/L, RM is 60 mg/L). The average annual rainfall for these areas in 2018 and 2019 was well below average (Table 2), with pond water levels during this period observed to be low. These results and visual observations indicate that increased evaporation rates and low rainfall may have impacted TSS results during this time.

Furthermore, abnormal results over the 5 year reporting period were observed at Milikapiti (550 mg/L, RM is 65 mg/L), Nauiyu (850 mg/L, RM is 48 mg/L), Numbulwar (400 mg/L, RM is 124 mg/L), Pirlangimpi (1,038; 957 mg/L, RM is 85 mg/L), and Yirrkala (920 mg/L, RM is 153 mg/L). These abnormalities occurred during the Wet Season, suggesting increased mixing from rainfall and wind within the pond waters during wet weather events affects water quality results.

Generally TSS concentrations are below the median concentration levels of 120 mg/L observed at Berrimah DP with the exception of the elevated outliers. As illustrated in the data TSS concentrations can often be impacted from weather events and seasonal changes, furthermore organic matter floating within the water column or water surface can also impact concentration levels resulting in sampling errors (Craggs, 2005). '*Singular grab samples, which may not be collected from the exact same location, or time of the day or in the same manner may also affect results'* (Jacobs Engineering Group, 2021, pg. 77).

4.4. Biological Parameters

Power and Water monitors Chlorophyll-a (Chl-a) and Biochemical Oxygen Demand (BOD) parameters at the pond outlets routinely.

4.4.1. Chl-a and BOD

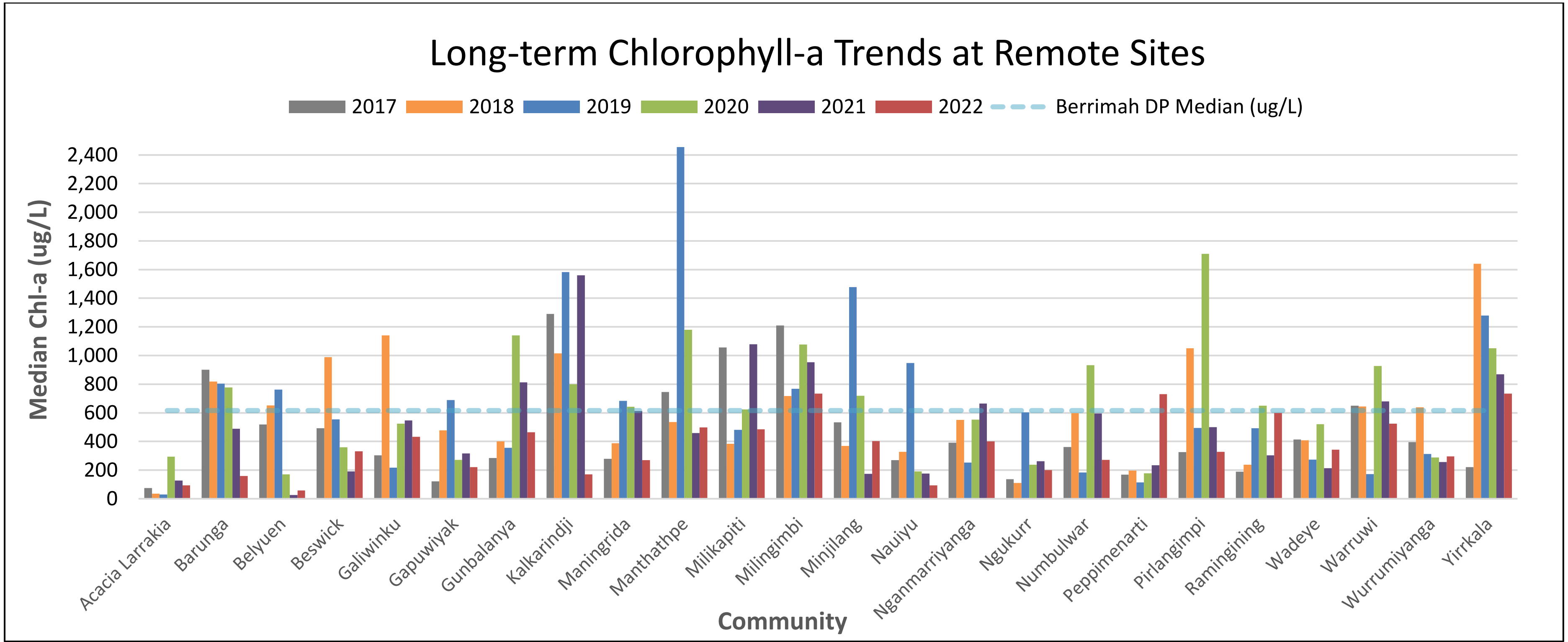

Figure 4 Long-term Chlorophyll-a trends at remote sites

Discussion:
Chl-a is considered a stressor response indicator in receiving waters (ANZECC, 2000). Aerobic zones of WSPs 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 (PWC, 2021). Therefore, Chl-a is not considered a suitable key indicator for assessment of environmental impacts of effluent discharge from the remote WSPs.

Figure 4 reveals longer term elevated Chl-a concentrations in Kalkarindji, Yirrkala and Milingimbi across consecutive years in comparison to other communities. Acacia, Peppimenarti and Ngukurr have relatively low levels of Chl-a over consecutive years. Increasing trends were observed in Pirlangimpi and Ramingining.

Similar to the TSS results, elevated concentrations in Chl-a are generally associated with the 2019 Dry Season samples as seen in Appendix B. The abnormal results recorded in this Dry Season were inconsistent with the RMs at Kalkarindji (1,583 ug/L, RM is 297 ug/L), Manthathpe (2,455 ug/L, RM is 681 ug/L) and Minjilang (1,478 ug/L, RM is 627 ug/L). Yirrkala results are also generally associated with Dry Season fluctuations (1,640 ug/L in 2018, RM is 822 ug/L). Elevated Chl-a results which are seen as outliers could be elevated in 2019 and 2020 due to low pond water levels and increases to algal growth from changes in seasonal temperatures.

Elevated concentrations can be seen at Kalkarindji and Milikapiti in 2021; the deviation between the sample results and median is minimal and not considered seasonal – the small dataset (2 samples) collected for this year to date may be influencing median values for the year. Further data will validate these results.

The discharge concentrations at the majority of communities excluding Kalkarindji and Milingimbi relatively consistent with the Berrimah discharge point median (616 ug/L) suggesting Chl-levels will fluctuate depending on time of the year, pond temperature and the biological processes occurring at the time, further seasonal assessment is required.

Preliminary surface water quality results seen in Table 4 suggest Chl-a concentrations decrease once within the receiving environment through dilution and mixing.

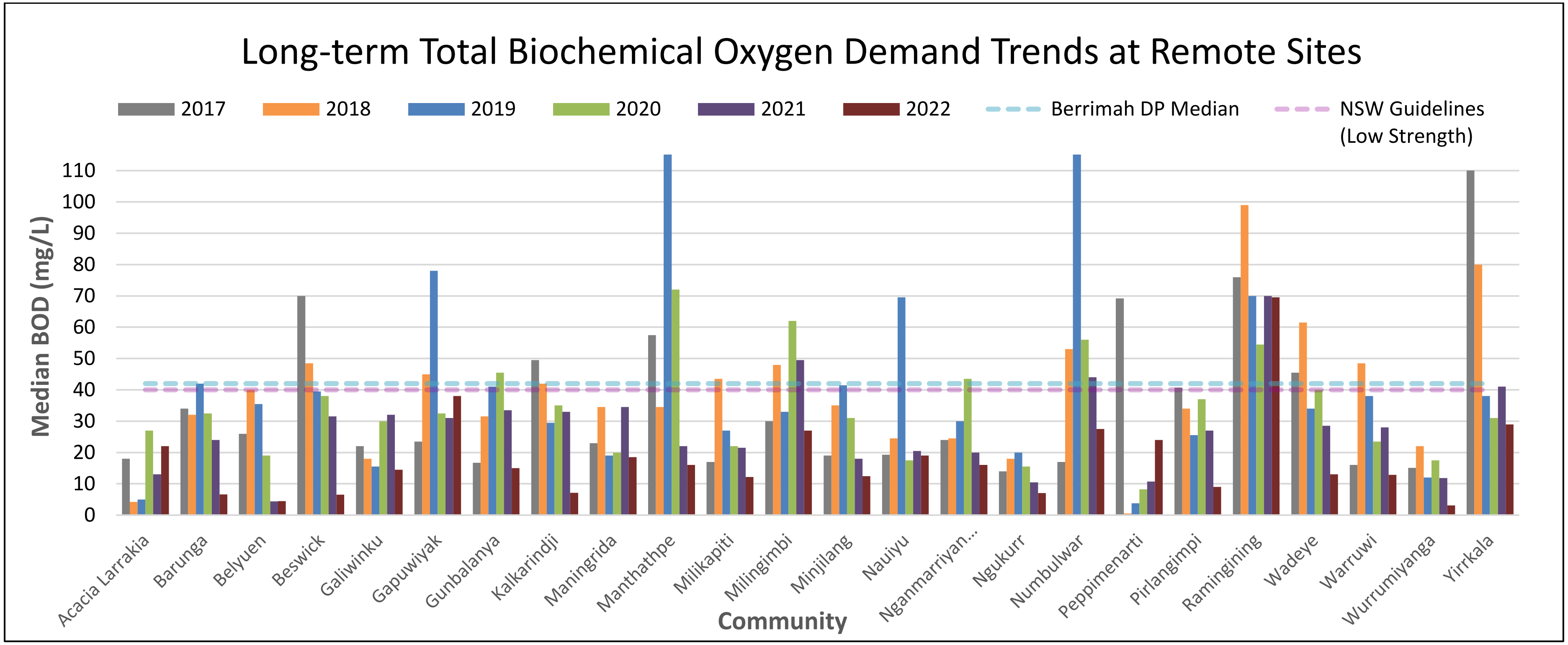

Figure 5 Long-term Biochemical Oxygen Demand trends at remote sites

Discussion:
BOD is a measure of the quantity of oxygen used by microorganisms and indicates the level of organic matter left to be oxidised within the WSPs (PWC, 2021). BOD is generally utilised as a pond performance indicator (Patterson and Curtis, 2005). Higher BOD levels may result in oxygen depletion within receiving waters, this can lead to fish kills and increased toxicity of other pollutants (PWC, 2021). Elevated BOD may also produce odours resulting in a reduction of amenity in the receiving environment (Patterson and Curtis, 2005). BOD is therefore a key indicator associated with the environmental and public health impacts of effluent discharge from WSPs.

Figure 5 illustrates Ramingining, Yirrkala and Manthathpe have higher concentrations of BOD across consecutive years in comparison to other communities. Gapuwiyak, Milingimbi and Peppimenarti have revealed slightly increasing trends across consecutive years. Acacia, Peppimenarti and Wurrumiyanga have relatively low levels of BOD over consecutive years in comparison to other communities.

As identified with other parameters, it is thought that recent elevated BOD concentrations in the WSPs may be attributed environmental conditions and seasonal fluctuations, mostly in 2019 due to low annual rainfall and low pond water levels. Results are elevated within the Dry Season samples at Manthathpe with a significantly elevated result in 2019 of 130 mg/L (RM is 41 mg/L). Other elevated results in 2019 were observed within the Wet Season at Gapuwiyak (190 mg/L, RM 35 mg/L), Nauiyu (69.5 mg/L, RM 24 mg/L) and Numbulwar (170 mg/L, RM 37 mg/L). BOD levels may also fluctuate depending on the time of the day the sample is collected (Jacobs Engineering Group, 2021).

For a majority of the remote community WSPs, BOD concentrations are lower than those at the Berrimah discharge point (42 mg/L), and the majority of sites are classed as having low strength concentrations for BOD with results of <40mg/L under the DEC Guideline value for effluent strength (DEC 2003). The exception of this is Ramingining.

Elevated BOD levels can also be an initial indicator for desludging. A number of aspects including sludge volumes, pond inflow loading and pond design can be considered to determine if treatment performance levels are adequate. Further investigations and data collection is required to accurately assess pond performance. Overall with low discharge volumes and low strength classification, this indicates that the impact of BOD on the receiving environment and public health may be lower than that of Berrimah WwTP.

4.5. Nutrient Parameters

Power and Water monitors Nutrient parameters at the pond outlets routinely.

4.5.1. Free Ammonia

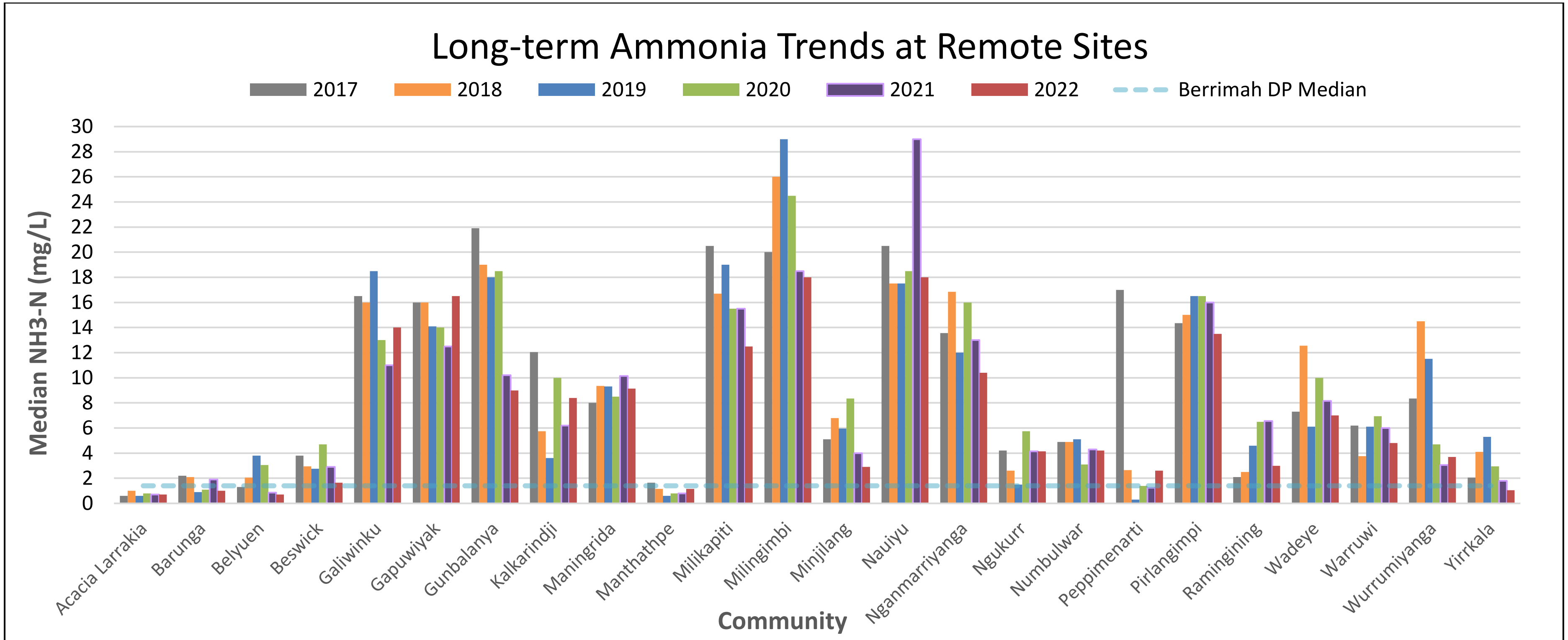

Figure 6 Long-term Ammonia trends at remote sites

Discussion:
Elevated levels of ammonia are considered toxic to fish and other aquatic organisms in water by inhibiting photosynthesis, causing damage to tissues and increasing susceptibility to disease and mortality (ANZECC, 2000). It is considered a toxicant under the ANZECC Guidelines and has been identified as a suitable key indicator for impacts of effluent discharge from the remote WSPs.

Figure 6 illustrates ammonia concentrations in a number of communities are elevated over consecutive years with concentrations seen the highest at Milingimbi, Nauiyu, and Gunbalanya. Acacia, Barunga and Manthathpe have the lowest concentrations of Ammonia in consecutive years. Trends show a slight elevation of Ammonia concentrations at Minjilang, Pirlangimpi and Ramingining when in comparison against previous years.

Significant seasonal fluctuations in Ammonia concentrations haven't been apparent like other water quality parameters; an elevated result of 17 mg/L in Peppimenarti observed in the Dry Season of 2017 is inconsistent with the RM of 2.5 mg/L. Elevated results of multiple parameters have occurred on the same collection date including BOD, TN and TP, suggesting sampling error or an abnormal grab. Additional monitoring since has confirmed this exceedance is an abnormality. Elevated concentrations of 29 mg/L at Nauiyu may be the result of extreme wet weather (localised flooding causing increased stormwater intrusion into the sewage reticulation network).

Ammonia levels are considerably higher in comparison to the Berrimah DP median (1.4 mg/L). However, Craggs (2005) states removal of nutrients varies greatly between seasons and between pond systems of similar design. Nutrient concentrations depend on the degree of decomposition of wastewater before it reaches the WSPs, and varies depending on water pH, temperature and mixing rates. Ammonia is generally removed from effluent as part of a de-nitrification process where bacteria within a pond system break down ammonia levels and release nitrogen in the form of atmospheric gas. In order for nitrification to occur, a number of factors need to be considered including DO, BOD, pH, water temperature and mixing (Medcalf and Eddy, 2002). Further analysis and assessment of current data is required to determine impacts on the receiving environment. Ammonia concentrations would also only impact those receiving environments where the discharge flows directly into a waterway.

Preliminary surface water results suggest Ammonia concentrations substantially decrease once within the receiving environment through dilution and mixing (Table 3).

4.5.2. Oxidised Nitrogen and Total Nitrogen

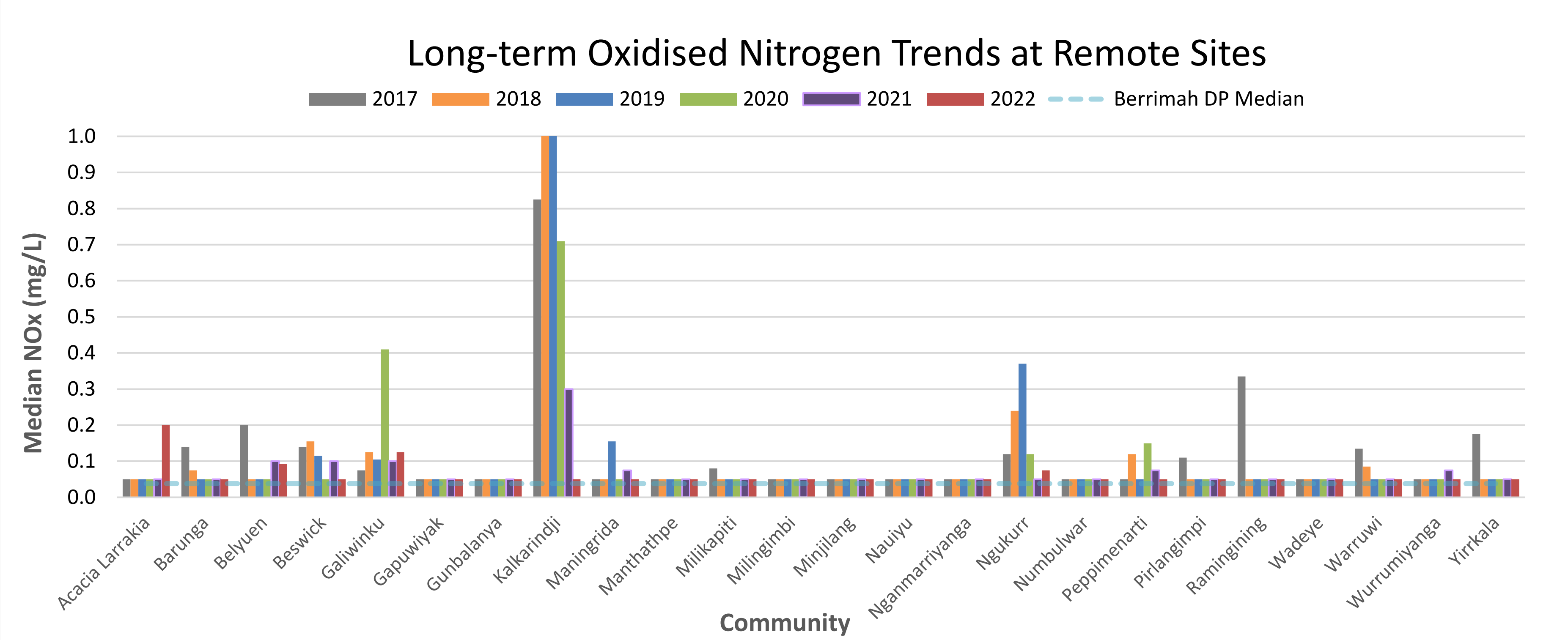

Figure 7 Long-term Oxidised Nitrogen trends at remote communities

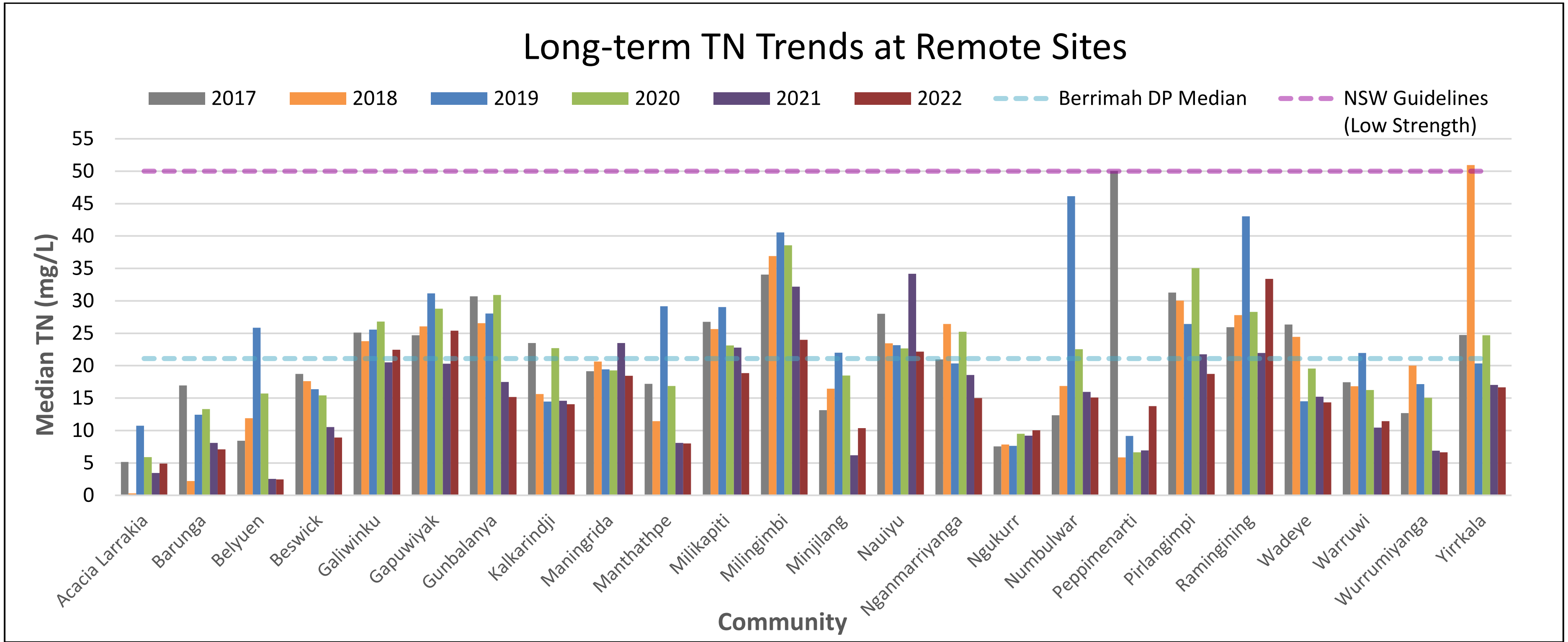

Figure 8 Long-term Total Nitrogen trends at remote sites

Discussion (Oxidised Nitrogen (NOx) and Total Nitrogen (TN)):
Elevated nitrogen in receiving waters may cause eutrophication and proliferation of nuisance aquatic plants, resulting in oxygen depletion; displacement of endemic species; diminished light availability; release of toxins; and changes to ecosystem structure (ANZECC, 2000). Elevated nutrients may also result in the reduction of amenity of the receiving environment through reduction in water clarity, objectionable discolouration and odours; with toxic blooms being a risk to public health. Therefore, NOx and TP are considered suitable key indicators associated with environmental impacts of effluent discharge from the remote WSPs.

Figure 7 above shows Kalkarindji and Ngukurr have substantially elevated NOx concentrations across consecutive years in comparison to other communities. Results at these communities are significantly higher than the median concentrations found at the Berrimah discharge point (0.04 mg/L). The results reported at Kalkarindji are unusually high in comparison to other communities with no obvious reasons apparent – the high NOx results at Kalkarindji may be the result of the denitrification processes within the pond system. Further investigation and monitoring is required to validate these results. A majority of the communities are slightly above the Berrimah WwTP value.

Figure 8 shows elevated concentrations of TN in a number of communities, with the concentrations highest reported at Milingimbi, Pirlangimpi, and Ramingining in consecutive years. Only a small number of communities have lower concentrations, with Acacia, Peppimenarti and Ngukurr having the lowest values in consecutive years. Peppimenarti had significantly higher reported concentrations during 2017. These abnormally high results recorded in the Dry Season are inconsistent with the RM (50.1 mg/L RM is 11.5 mg/L), as BOD and TP results were elevated this indicates potential sampling error or abnormal grab. Additional monitoring has confirmed these exceedances as sample abnormalities. Similarly Numbulwar and Yirrkala have inconsistent results for multiple parameters on the same day with results of 46.2 mg/L (RM is 16.2 mg/L), 102.8 mg/L (RM is 21.3 mg/L) respectively. Both samples were collected in January suggesting rainfall, increased levels of mixing and increased turbidity may be a factor for these abnormal results. Substantially lower concentrations of TN in 2021 suggest TN results have decreased from the above average rainfall that occurred over the 2020-21 Wet Season.

A majority of the TN results deviate only slightly over time, with some seasonal variations occurring at a few communities (increased periods of rainfall and prolonged dry season conditions).

Overall, the majority of communities have NOX and TN concentrations similar to that of the Berrimah discharge point (0.04 mg/L; 21 mg/L) and there are limited indications of increased nutrient trends. TN for all remote sites are assessed as having low strength concentrations of <50mg/L under the NSW effluent strength classification values (DEC, 2003).

The majority of remote communities have limited commercial, industrial and agricultural inputs, along with relatively low discharge volumes in comparison to urban sources within Darwin Harbour, therefore nutrient loads from the remote WSPs are considered potentially low (PWC, 2021).

4.5.3. Filterable Reactive Phosphorous and Total Phosphorous

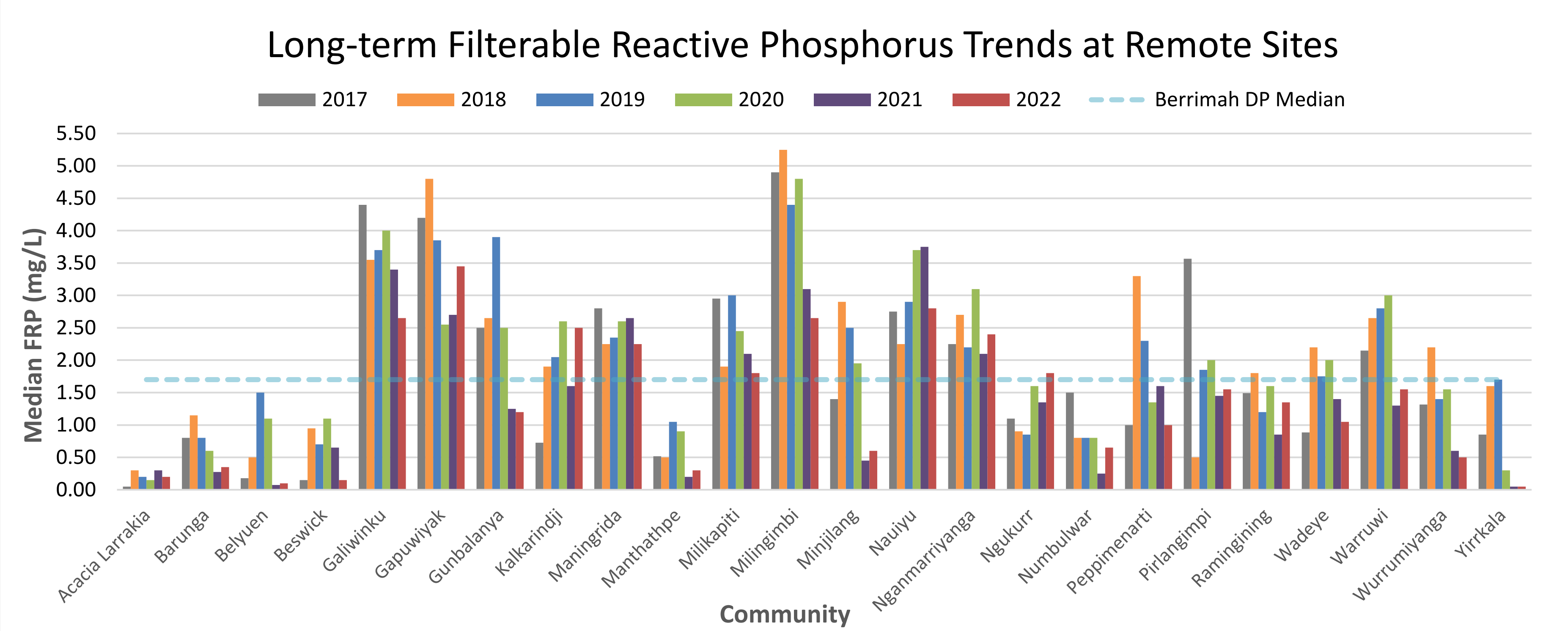

Figure 9 Long-term trends of Filterable Reactive Phosphorus at remote sites

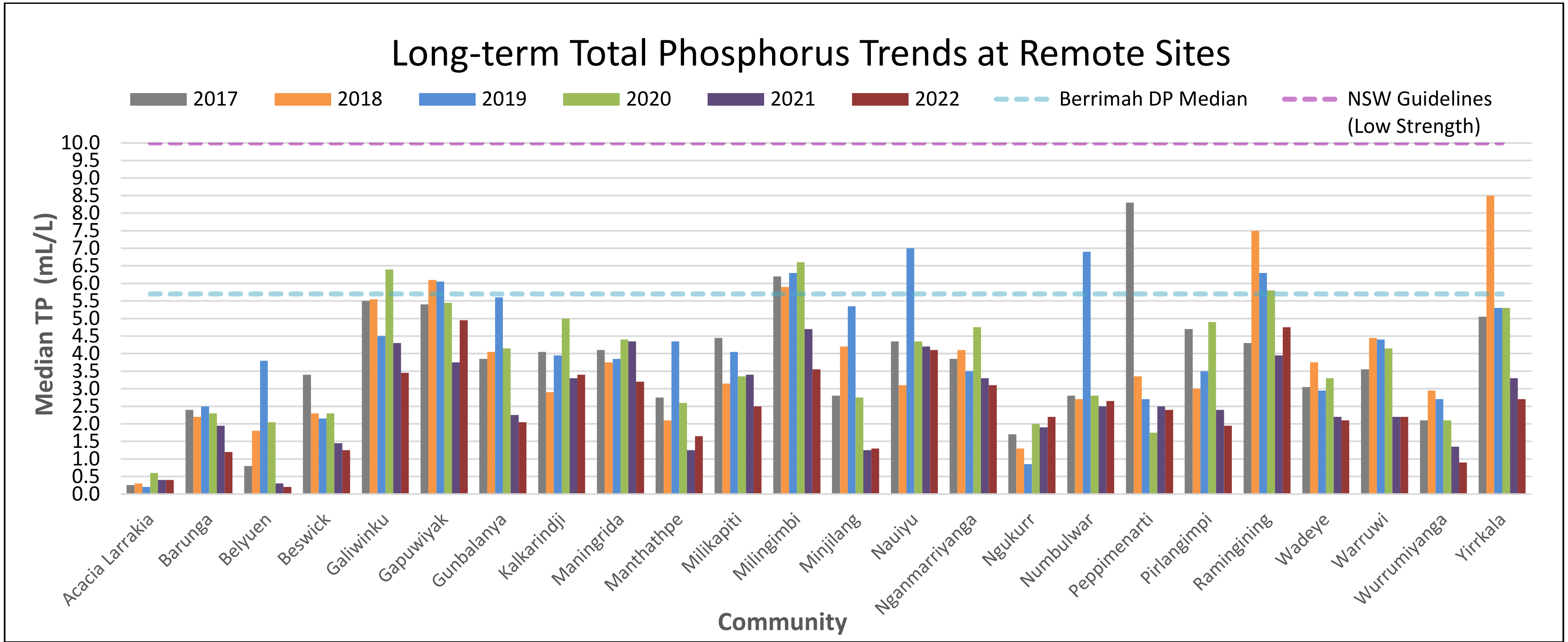

Figure 10 Long-term Total Phosphorus trends at remote site

Discussion:
Likewise with nitrogen, increased levels of FRP (available) and TP can cause increases in algae levels, resulting in algal blooms which affect the broader environment (DENR, 2019). Therefore, FRP and TP are considered key indicators associated with environmental impacts of effluent discharge from the remote WSPs.

Figure 9 indicates Milingimbi, Gapuwiyak and Galiwinku have elevated concentrations in FRP. These communities have consistently higher concentrations of FRP across the five years of monitoring in comparison to other communities. While similar to other parameters previously discussed, the communities that have lower FRP concentrations are Acacia Larrakia, Belyuen and Ngukurr having the lowest reported levels of FRP. Belyuen had elevated concentrations of 1.5 mg/L in 2019 inconsistent with other years (RM is 0.30 mg/L), these results are related to 3 samples collected during the Wet Season. Pirlangimpi has inconsistent elevated FRP concentrations in 2017 of 3.57 mg/L (RM is 1.90). As seen with these samples concentrations of multiple parameters such as BOD, TSS and nutrients may occur within the same sample. This suggests that there is a higher content of organic or soil matter, possibly from heavy rainfall, wind intensity (turbid waters) or the sampler has incorrectly grabbed a layer of sludge. About over half of the communities have FRP concentrations below that of the Berrimah discharge point (1.7 mg/L).

The results for TP moderately correspond with the FRP values, with a number of communities having similar concentrations including Milingimbi, Ramingining and Gapuwiyak. There have been no substantial differences within the years for TP, with the exception of possible climatic variations or abnormal sample grabs as previously mentioned. These communities include Yirrkala (8.50 mg/L, RM is 4.7 mg/L), Peppimenarti (8.30 mg/L, RM is 2.5 mg/L), Nauiyu (6.70 mg/L, RM is 4.35 mg/L) and Numbulwar (6.70 mg/L, RM is 2.70 mg/L). Mostly all of the remote communities have TP concentrations levels below Berrimah discharge point (5.7 mg/L).

TP for all remote sites are classed as having low strength concentrations of <10 mg/L under the NSW effluent strength classification values (DEC, 2003) with the majority of remote communities having limited commercial, industrial and agricultural inputs, further suggesting TP outputs are low. It is considered that WSPs are generally efficient at reducing phosphorus levels with phosphorus being removed through solid particles sinking to the pond floor (sludge accumulation) (Craggs, 2003).

4.6. Pathogen Indicators

Power and Water monitors Pathogen parameters at the pond outlets routinely.

4.6.1. *E. coli* and Enterococci

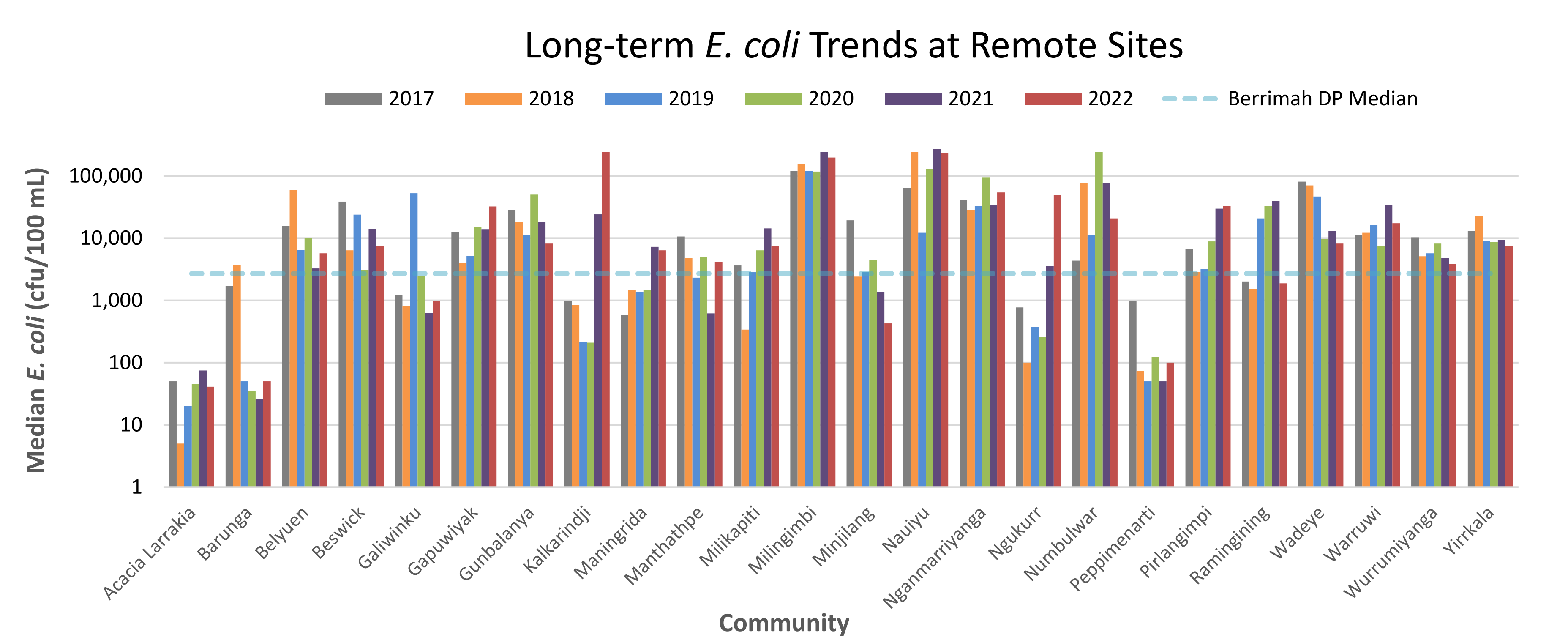

Figure 11 Long-term *E. coli* trends at remote sites – log10 scale

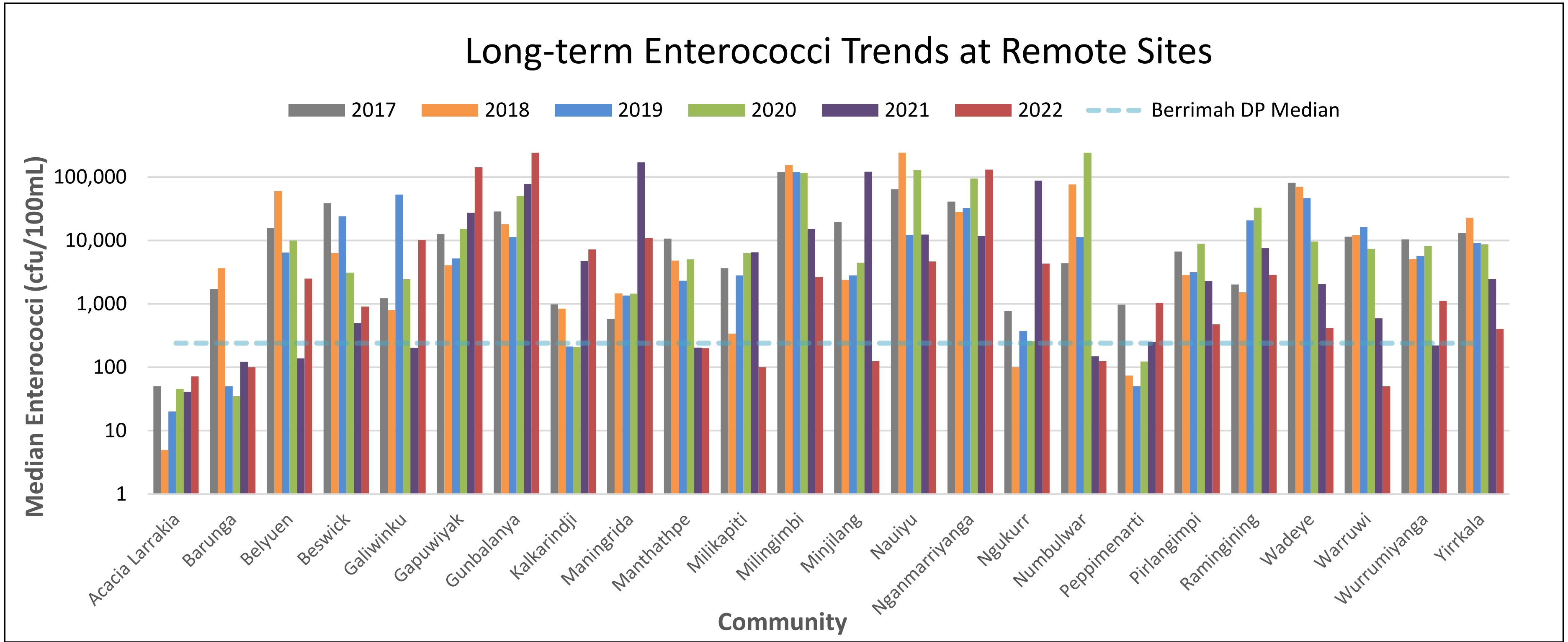

Figure 12 Long-term Enterococci trends at remote sites – log10 scale

Discussion:
E. coli and Enterococci are indicator species of bacterial pathogens that occur in treated effluent (Davies-Colley, 2005). The presence of increased pathogens in receiving waters may cause illness and lead to a public health risk, through recreation within contaminated waters and bacteria accumulation in shellfish that may be harvested for consumption (PWC, 2021). These parameters are considered key indicators associated with environmental and cultural impacts of effluent discharge from the remote WSPs.

Figure 11 and Figure 12 illustrate Milingimbi, Nauiyu, Numbulwar and Wurrumiyanga have higher concentrations of both *E. coli* and Enterococci in consecutive years in comparison to other communities. A number of communities have substantially lower levels of pathogen concentrations, the lowest observed at Acacia Larrakia, Barunga, Kalkarindji and Peppimenarti.

Substantial spikes in both parameters have generally occurred during the Wet Season, for example *E. coli* concentrations at: Belyuen (58,830 cfu/100 mL, RM is 6,685 cfu/100 mL) Galiwinku (52,915 cfu/100 mL, RM is 663 cfu/100 mL) Gunbalanya (82,965 cfu/100 mL, RM is 11,870 cfu/100 mL) and Numbulwar (77,010 cfu/100 mL, RM is 15,215 cfu/100 mL).

A majority of the remote communities have higher concentrations of *E. coli* and Enterococci in comparison to Berrimah discharge point (2,700 cfu/100mL; 240 cfu/ 100mL). However, WSPs are considered to be efficient at removal of pathogens (Davies-Colley, 2005). A large number of factors may influence varied disinfection rates between the different pond systems, including pond and regional temperatures, pH, algal production, pond configuration, depth and retention times (Davies-Colley, 2005).

Additional monitoring is required to improve these datasets and provide more accurate long term trends. Furthermore, although the presence of *E.coli* in environmental waters is used as an indicator for faecal pollution, research suggests it is present naturally within the ecosystem, particularly within tropical climates where constantly high temperatures, high humidity and high nutrients occur. High *E.coli* concentrations have been found in numerous tropical locations in the absence of faecal sources (Winfield & Groisman, 2003).

The preliminary surface water results in Table 3 suggest *E. coli* concentrations decrease within the receiving environment, and are naturally present within receiving waters as observed when the Belyuen WSPs are not discharging during the Dry Season.

Studies suggest that birds and other wildlife account for a large proportion of *E. coli* concentrations found in environmental waters (Anastasi et. al, 2012). Migratory and shore bird species among others are regularly observed congregating at the WSPs across remote NT.

4.7. Surface Water

Surface water monitoring commenced at Woods Inlet in mid-2019, where discharge of the Belyuen WSPs occurs, as per WDL 215-1. Woods Inlet is a tidal brackish creek considered an upper estuary of the Darwin Harbour Region (DENR, 2019). A review of the surface water monitoring results against the *Water Quality Objectives for the Darwin Harbour Region* has been included to inform the development of site-specific trigger values for this site (Condition 34). These water quality objectives are applicable during the Dry Season months only from May through to October (DENR, 2019). For the purpose of this report, long term and seasonal trending is not suitable at this time as only preliminary results are available. Collection of additional data will continue to provide a more accurate assessment in the future.

As seen in Table 3 the results at the Belyuen discharge point (SBL090) are generally above the receiving waters DHWQO criterion (with the exception of pH, turbidity, TP and *E.coli*) as expected and discussed in Section 2.1. Similarly, the results at the Berrimah discharge point also generally exceed these parameters (PWC, 2021). In comparison to other remote communities, the Belyuen discharge has lower concentrations in BOD, ammonia, nitrogen and phosphorus, with the ponds observed to only discharge during the Wet Season when additional dilution would occur from increased rainfall and stormwater intrusion. This suggests the Belyuen discharge may pose a lower risk to the environment than other WSP systems.

Median results at Woods Inlet (SBLEP01) for pH, Chlorophyll-a, Ammonia, NOx, TN, FRP and Enterococci are within the limits of the DHWQO criteria, whilst median results for remaining indicators have exceeded the criteria. Elevated levels in Turbidity, TSS, TP and *E. coli* during the months of July through to December when ponds levels were low and discharge was not occurring (greyed section) suggests external input is occurring from the receiving environment. This is also the case for low levels of DO, also seen naturally occurring within the receiving environment. Exceedances of Ammonia, TN and TP concentrations in Woods Inlet have occurred – consistent with results observed at times at the Berrimah zone of influence – SBEBL02 (Blessers Creek) (PWC, 2021).

Results from the Berrimah receiving environment of Blessers Creek reveal that concentrations in all nutrient parameters may decrease further downstream of the WSPs within local brackish tidal creeks (PWC, 2021). Studies conducted in Darwin Harbour reveal there have been minimal increases in nitrogen annual loads within Woods Inlet over the last decade; with areas of intensive land use identified as a greater threat on macro tidal estuaries (Fortune, Butler and Gibb, 2020). Furthermore, data collected at the Ludmilla WSP receiving environment of East Point Outfall suggest high nutrient loads occur within the Darwin Harbour; high nutrient loads are often observed within tropical estuarine environments such as Woods Inlet.

Monthly discharge reports of Woods Inlet provided by external contractors note no odours, healthy mangrove vegetation and small fish observed at the monitoring point. Power and Water observed over the 2019, 2020 and 2021 Dry Seasons that pond water levels within the final ponds have been very low, with pond discharge to the receiving environment ceasing for a number of months across a number of communities. This may correspond with low rainfall patterns for the region over this period seen in

Table 2. In late July 2021 it was reported that the Belyuen ponds had ceased discharging, demonstrating that the discharge from the ponds is seasonal only. Further site inspections and an installation of a flow meter at the Belyuen discharge point have further validated these assumptions. Seasonal discharge to the Darwin Harbour only occurring within the wet season would subsequently reduce the risk to the receiving environment from the WwTP.

The Department of Environment, Parks and Water Security conduct water quality monitoring across the Darwin Harbour to *provide a snapshot of water quality and the health of aquatic ecosystems across the harbour and its catchments* (DEPWS, 2020). Located within the West Arm zone of Darwin Harbour, the waterways including and downstream of Woods Inlet maintains a Darwin Harbour Water Quality Report Card (2020) Grade of A: Excellent for a majority of the period from 2009 to 2022 (DENR, 2020). To date it is considered that there are no long-term trends of declining water quality within this area. West Arm area is considered undisturbed and is typically utilised as a reference condition in Darwin Harbour (DENR, 2020).

The continuation of a robust monitoring program will further determine the environmental impacts from the Belyuen WSPs discharge.

5. Environmental Impacts Summary

Environmental Risk Assessments (ERAs) have been conducted and issued for each of the remote community WDLs in accordance with licence conditions. The ERA's outline site-specific information, potential environmental risks, impacts and conceptual site models for each location.

Visual observations at each site confirm there has been no indication that the discharges are causing deleterious effects on the receiving environments, with no gross pollutants, fish kills or impacts on surrounding vegetation observed or reported. Visually, the waterways at each of the receiving sites look to contain healthy levels of fish and aquatic invertebrates.

The 'high' risk rankings determined within the most recent ERA's are associated with the risk to human health from pathogens from cultural uses of the area for primary and secondary recreation, for activities such as swimming, fishing, wading and consumption of shellfish; and a reduction of amenity within the area from nutrients. Signage has been installed at the discharge points to advise the public of the location of the effluent as seen in Figure 13.

The key water quality indicators associated with the environmental impacts from the remote community WSPs discussed in this report are outlined in Appendix F. Table 6 provides a summary of the assessment end-points whilst Table 7 provides a summary of the key indicators present at each of the communities. Conducting further monitoring and reviews will allow for improved environmental impact assessments in the future.

Figure 13 Effluent warning signage at Nauiyu DP (PWC, 2022)

6. Conclusion and Proposed Actions

This report presents a summary of effluent monitoring data collected at remote Indigenous community WSPs. Through the assessment of this data, the following conclusions have been made:

- Milingimbi and Ramingining have higher concentrations of key indicators for environmental impacts within the discharge
- Acacia, Peppimenarti and Ngukurr have the lowest concentrations of the key performance indicators within the discharge

The monitoring objectives for this program are considered accomplished, meeting the requirements of monitoring specified within the licence conditions. Assessment of treated effluent water quality results against environment water guideline values is not suitable at this point in time; however comparisons can be made against other local WSPs of similar EP where substantial environmental monitoring is conducted.

The results indicate that for a majority of the water quality parameters, concentration levels are somewhat consistent with Berrimah discharge point, suggesting no extreme concerns from water quality exceedances at these sites. Environmental impacts from remote community WSPs are considered to be lower risk than urban WSPs, taking into consideration the lower discharge volumes. Additional data collection and review of assessments will confirm whether these assumptions are correct.

There are a number of limitations of the data presented, including the variation in frequencies of monitoring at different WSPs which may distort the results and interpretation. Additionally, discharge flow monitoring and further seasonal assessment is required to assess climatic fluctuations and the level of risk.

Overall, the philosophy of ANZECC Guidelines is one of continued improvement against water quality objectives. Although it is difficult to assess treated effluent monitoring data against environmental and surface water guidelines, there has been great improvement over the past six years within the area of wastewater monitoring and analysis at remote WSPs, particularly with the initial WDLs only coming into effect in 2015. Additional monitoring and review of the ERAs will address knowledge gaps and identify opportunities for improvement. This will ensure that the environmental risks associated with these facilities are managed more effectively over time.

Power and Water have implemented monthly monitoring at a number of sites in the past two years to improve datasets and reduce abnormalities. Pond desludging and meter installation programs at specific sites are also being implemented where funding is available.

Appendix A – List of Remote Community WDLs

Community	WDL	Licence Expiry
Round 1		
Manthathpe	201-3	12/10/2022
Galiwinku	202-3	12/10/2022
Maningrida	203-3	12/10/2022
Yirrkala	204-3	12/10/2022
Wadeye East	205-3	12/10/2022
Ramingining	206-3	12/10/2022
Nauiyu	207-3	12/10/2022
Milingimbi	208-3	12/10/2022
Round 2		
Barunga	214-2	12/07/2023
Belyuen	215-2	12/07/2023
Gunbalunya	216-2	12/07/2023
Milikapiti	217-2	12/07/2023
Numbulwar	218-2	12/07/2023
Nganmarriyanga	219-2	12/07/2023
Peppimenarti	220-2	12/07/2023
Pirlangimpi	221-2	12/07/2023
Warruwi	222-2	12/07/2023
Wurrumiyanga	223-2	12/07/2023
Round 3		
Acacia Larrakia	225-2	11/12/2031
Beswick	228-2	11/12/2031
Gapuwiyak	230-2	11/12/2031
Kalkarindji	231-2	11/12/2031
Minjilang	233-2	11/12/2031
Ngukurr	234-2	11/12/2031

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Appendix B – Tabulation of Monitoring Results – Treated Effluent

PWC WDL Monitoring Report – Remote Community WDLs		
Remote Community WDL Summary Data Sheet	All samples collected are in accordance with Appendix 1 of the WDL's. Data is extracted from the PWC water quality database for assessment and filed on the PWC records management system. A tabulated summary of all years wastewater monitoring data and relevant statistics for remote community WDLs is completed and provided as Appendix B, attached as an Excel file format to the submission of this annual monitoring report.	Internal document number D2022/99942

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Appendix C – Tabulation of Monitoring Results – Surface Water

Table 3 Monitoring Results – Belyuen WSPs - WDL215-2

Alias	Asset Description	Collected Date	Physical-Chemical Parameters						Biological Parameters		Nutrient Parameters					Pathogen Indicators	
			pH (pH units)	EC (uS/cm)	DO (mg/L)	DO % Saturation	Turbidity (NTU)	TSS (mg/L)	BOD (mg/L)	Chlorophyll-a (ug/L)	NH3-N Free (mg/L)	NOX - N (mg/L)	Total N (mg/L)	FRP (mg/L)	TP (mg/L)	*E. coli* (mpn/100mL)	Enterococci (mpn/100ml)
Discharge Point - Waste Stabilisation Pond Outlet			Lab tested	Lab tested	Lab tested	Lab tested	Lab tested										
SBL090	Wq-Belyuen Pond 2 Outlet	04/12/2019 11:22:22	7.7	340	<0.1	69	150	190	11.0	326	15.0	<0.1	18.05	2.6	3.9	970	520
SBL090	Wq-Belyuen Pond 2 Outlet	08/01/2020 10:18:29	7.6	290	<0.1	<10	200	105	54.0	225	15.0	<0.1	20.45	1.1	2.9	17,329	826
SBL090	Wq-Belyuen Pond 2 Outlet	05/02/2020 10:07:12	7.1	140	4.23	49	18	22	6.7	216	3.40	<0.1	7.35	0.400	1.000	23,590	241,961
SBL090	Wq-Belyuen Pond 2 Outlet	04/03/2020 12:15:33	5.0	30	4.64	53	1	7	1.8	29	1.60	<0.1	2.35	0.100	0.200	86	160
SBL090	Wq-Belyuen Pond 2 Outlet	08/04/2020 10:30:35	5.8	32	6.71	79	9	14	<1	108	2.60	<0.1	3.45	0.100	0.200	1,145	63
SBL090	Wq-Belyuen Pond 2 Outlet	06/05/2020 09:26:37	5.8	26	4.75	57	5	6	1.2	123	2.40	<0.1	3.25	0.100	0.100	<100	<100
SBL090	Wq-Belyuen Pond 2 Outlet	03/06/2020 09:42:51	6.1	47	2.08	25	3	10	4.5	32	1.30	<0.1	2.45	0.100	0.300	5,200	<100
SBL090	Wq-Belyuen Pond 2 Outlet	08/07/2020 09:05:17	6.9	470	<0.1	<10	100	48	100.0	65	5.30	0.14	25.44	1.800	2.100	5,200	<100
SBL090	Wq-Belyuen Pond 2 Outlet	05/08/2020 09:14:33	7.4	530	0.10	<10	190	63	54.0	90	6.60	0.10	30.70	2.800	3.700	325,500	92,080
SBL090	Wq-Belyuen Pond 2 Outlet	02/09/2020 12:08:33	7.6	580	<0.1	<10	110	85	83.0	349	12.00	<0.1	36.05	3.800	4.700	8,500	387,300
SBL090	Wq-Belyuen Pond 2 Outlet	08/10/2020 08:22:00	7.6	330	4.69	56	220	145	12.0	2,880	17.00	0.29	20.49	2.700	4.700	248,900	12,360
SBL090	Wq-Belyuen Pond 2 Outlet	04/11/2020 08:22:29	7.0	350	<0.1	<10	**801**	**2,001**	38.0	1,090	25.00	0.14	28.04	1.300	4.100	12,997	24,196
SBL090	Wq-Belyuen Pond 2 Outlet	02/12/2020 08:45:21	7.2	230	0.41	<10	58	60	26.0	392	8.00	<0.1	10.95	1.100	2.000	4,800	241,961
SBL090	Wq-Belyuen Pond 2 Outlet	06/01/2021 09:15:49	6.1	56	1.37	16	73	118	13.0	47	3.90	0.10	6.00	0.300	0.700	<100	1,600
SBL090	Wq-Belyuen Pond 2 Outlet	10/02/2021 09:10:52	5.4	24	4.90	52	1	6	<1	2	0.70	0.10	1.60	<0.1	0.400	6,200	100
SBL090	Wq-Belyuen Pond 2 Outlet	03/03/2021 09:15:00	5.5	23	5.34	64	3	15	2.7	11	1.10	0.10	3.00	<0.1	0.100	9,320	50
SBL090	Wq-Belyuen Pond 2 Outlet	07/04/2021 08:30:00	5.5	27	3.34	41	3	17	3.4	7	0.90	0.10	2.10	<0.1	0.200	1,137	120
SBL090	Wq-Belyuen Pond 2 Outlet	05/05/2021 07:59:00	5.8	32	3.99	37	6	20	5.4	43	0.50	0.10	1.90	0.100	0.200	1,935	156
SBL090	Wq-Belyuen Pond 2 Outlet	02/06/2021 09:00:00	6.6	70	10.9	120	18	44	16.0	458	0.70	0.30	5.00	0.100	0.400	4,611	185
SBL090	Wq-Belyuen Pond 2 Outlet	07/07/2021 09:30:00	7.6	220.0	4.72	53	51	72	49.0	1,090	2.7	<0.1	98.05	0.3	1.6	262	573
SBL090	Wq-Belyuen Pond 2 Outlet	04/08/2021 11:45:45	7.1	310.0	0.78	<10	140	1850	48.0	2,090	4.7	<0.1	96.05	0.7	2.7	22,470	1,460
SBL090	Wq-Belyuen Pond 2 Outlet	08/09/2021 11:05:23	7.1	350.0	1.48	18	140	95	43.0	56	9.8	<0.1	86.05	1.0	2.3	34,480	1,210
			Field Tested	Field Tested	Field Tested	Field Testec	Field Tested	ield Teste									
SBL090	Wq-Belyuen Pond 2 Outlet	21/10/2021 11:01:00	7.4	0.331	2.8	38	64	193	40.0	823	8.291	0.02	14.42	1.92	3.57	1,187	2,613
SBL090	Wq-Belyuen Pond 2 Outlet	11/11/2021 10:35:00	6.7	0.247	1.66	23	38	22	754.0	754	5.45	0.01	14.01	1.47	2.53	4,352	24,196
SBL090	Wq-Belyuen Pond 2 Outlet	13/12/2021 12:22:00	8.2	0.216	8.2	111	0	640	48.0	1,250	3.66	0.01	22.11	1.02	3.36	1,414	84
SBL090	Wq-Belyuen Pond 2 Outlet	24/01/2022 13:03:00	6.7	0.156	4.48	58	16	19	8.0	102	1.982	0.05	5.13	0.203	0.607	34,480	104,620
SBL090	Wq-Belyuen Pond 2 Outlet	10/02/2022 12:15:00	6.0	0.045	3.91	54	3	6	5.0	53	0.713	0.09	1.99	0.018	0.219	12,810	5,910
SBL090	Wq-Belyuen Pond 2 Outlet	10/03/2022 11:07:00	5.8	0.043	6.93	96	5	9	3.0	63	0.019	0.04	1.61	0.007	0.167	6,020	50
SBL090	Wq-Belyuen Pond 2 Outlet	07/04/2022 10:41:00	6.5	0.031	6.62	88	6	7	4.0	49	0.195	0.11	1.0	0.009	0.066	310	50
SBL090	Wq-Belyuen Pond 2 Outlet	10/05/2022 11:02:00	6.1	0.038	6.34	81	8	12	6.0	134	0.086	0.08	1.61	0.004	0.168	2,460	50
SBL090	Wq-Belyuen Pond 2 Outlet	09/06/2022 12:14:00	6.7	0.085	6.65	86	29	34	10.0	352						19,863	4,352
		No. of Samples	**31**													**31**	
		Mean	**6.6**	**145**	**3.6**	**47**	**80**	**191**	**46.8**	**429**	**5.35**	**0.08**	**19.02**	**0.84**	**1.640**	**26,375**	**37,063**
		Median	**6.7**	**32**	**4.0**	**52**	**18**	**34**	**11.0**	**123**	**3.05**	**0.05**	**6.68**	**0.30**	**0.850**	**5,200**	**573**
		Dry Season Median	**7.0**	**145**	**3.4**	**38**	**57**	**56**	**28.0**	**242**	**4.70**	**0.05**	**20.49**	**0.70**	**2.100**	**5,200**	**892**
		Wet Season Median	**6.5**	**27**	**4.2**	**53**	**9**	**19**	**6.7**	**102**	**2.60**	**0.05**	**5.13**	**0.20**	**0.607**	**4,800**	**520**
		95th Percentile	**7.6**	**500**	**7.6**	**103**	**210**	**1245**	**91.5**	**1,670**	**16.10**	**0.22**	**91.55**	**2.76**	**4.430**	**141,690**	**241,961**

Table 4 Monitoring Results – Belyuen receiving environment - Woods Inlet – WDL215-02

Alias	Asset Description	Collected Date	Physical-Chemical Parameters: pH (pH units)	EC (uS/cm)	DO (mg/L)	DO % Saturation	Turbidity (NTU)	TSS (mg/L)	Biological Parameters: BOD (mg/L)	Chlorophyll-a (ug/L)	Nutrient Parameters: NH3-N Free (mg/L)	NOX - N (mg/L)	Total N (mg/L)	FRP (mg/L)	TP (mg/L)	Pathogen Indicators: *E. coli* (mpn/100mL)	Enterococci (mpn/100ml)
Belyuen Woods Inlet			Field Tested	Field Tested	Field Tested	Field Tested	Field Tested										
SBLEP01	WQ - Belyuen Outfall Woods Inlet	17/12/2019 13:11:07	7.5	53,900	2.68	37	17	79	*<1*	2	*<0.005*	*<0.003*	0.40	0.009	0.035	2,178	10
SBLEP01	WQ - Belyuen Outfall Woods Inlet	23/01/2020 13:36:03	6.6	1,423	3.87	55	90	104	2.8	2	0.30	0.14	0.55	0.010	0.084	145	52
SBLEP01	WQ - Belyuen Outfall Woods Inlet	13/02/2020 10:08:00	7.1	47,400	3.31	49	8	135	*<1*	2	*<0.005*	0.03	1.97	0.032	0.028	1,354	20
SBLEP01	WQ - Belyuen Outfall Woods Inlet	05/03/2020 10:50:00	6.8	3,050	4.15	53	30	3	*<2*	1	*<0.005*	0.01	0.10	0.007	0.028	175	*<10*
SBLEP01	WQ - Belyuen Outfall Woods Inlet	22/04/2020 04:59:00	6.7	3,170	4.17	56	38	50	*<2*	3	*<0.005*	0.01	0.22	0.010	0.011	281	86
SBLEP01	WQ - Belyuen Outfall Woods Inlet	28/05/2020 10:35:00	7.0	50,800	3.60	52	5	5	*<2*	2	0.013	0.004	1.83	0.012	0.028	933	20
SBLEP01	WQ - Belyuen Outfall Woods Inlet	25/06/2020 10:20:00	7.0	50,800	3.60	52	5	6	*<2*	1	0.005	0.004	1.29	0.016	0.039	627	*<10*
SBLEP01	WQ - Belyuen Outfall Woods Inlet	29/07/2020 11:51:00	7.8	41,600	4.48	61	9	16	*<2*	4	0.01	*<0.003*	1.84	0.004	0.046	850	*<100*
SBLEP01	WQ - Belyuen Outfall Woods Inlet	13/08/2020 10:57:00	7.1	45,400	3.03	44	11	12	*<2*	3	*<0.005*	0.01	1.62	0.020	0.038	1,281	*<10*
SBLEP01	WQ - Belyuen Outfall Woods Inlet	10/09/2020 09:59:00	6.8	57,000	3.10	49	5	6	*<2*	2	*<0.005*	*<0.003*	0.70	0.004	0.041	657	10
SBLEP01	WQ - Belyuen Outfall Woods Inlet	08/10/2020 09:45:00	7.0	26,500	5.78	80	314	28	*<2*	1	*<0.006*	*<0.003*	0.67	0.004	0.033	156	121
SBLEP01	WQ - Belyuen Outfall Woods Inlet	19/11/2020 09:50:00	7.4	55,900	3.08	50	9	13	*<2*	3	*<0.005*	0.02	0.75	*<0.003*	0.039	243	31
SBLEP01	WQ - Belyuen Outfall Woods Inlet	10/12/2020 11:30:00	7.1	49,900	3.20	53	12	17	*<2*	8	*<0.005*	*<0.003*	1.05	0.017	0.060	148	98
SBLEP01	WQ - Belyuen Outfall Woods Inlet	07/01/2021 11:34:00	7.2	6,180	4.17	57	26	21	*<2*	3	0.03	0.02	0.25	*<0.003*	0.036	98	31
SBLEP01	WQ - Belyuen Outfall Woods Inlet	18/02/2021 12:20:00	7.4	6,580	5.02	85	7	9	*<2*	2	0.01	0.01	0.15	0.006	0.012	300	246
SBLEP01	WQ - Belyuen Outfall Woods Inlet	16/03/2021 10:20:00	5.9	24,100	4.12	55	17	15	*<2*	3	0.008	*<0.005*	0.09	0.003	0.033	300	246
SBLEP01	WQ - Belyuen Outfall Woods Inlet	22/04/2021 13:58:00	7.8	3,780	4.33	61	11	10	4.0	5	*<0.005*	0.014	0.07	0.007	0.022	110	10
SBLEP01	WQ - Belyuen Outfall Woods Inlet	20/05/2021 10:41:00	7.3	9,810	4.78	62	11	4	*<2*	1	*<0.005*	*<0.005*	0.17	0.006	0.025	63	20
SBLEP01	WQ - Belyuen Outfall Woods Inlet	17/06/2021 12:13:00	7.4	44,300	3.73	57	5	*<2*	*<2*	5	*<0.005*	*<0.005*	0.5	0.009	0.028	241	10
SBLEP01	Q - SBLEP01 Belyuen Outfall Woods In	14/07/2021 14:37:00	7.6	37,100	4.13	59	12	1	0.5	5	0.039	0.006	0.034	0.006	0.034	168	52
SBLEP01	Q - SBLEP01 Belyuen Outfall Woods In	19/08/2021 11:40:00	7.3	32,500	5.01	70	6	1	0.5	2	0.027	0.006	0.037	0.005	0.037	436	*5*
SBLEP01	Q - SBLEP01 Belyuen Outfall Woods In	16/09/2021 11:00:00	6.9	53,200	3.26	54	16	16	16.0	3	*0.0025*	0.008	0.04	0.008	0.04	1,722	*5*
SBLEP01	Q - SBLEP01 Belyuen Outfall Woods In	21/10/2021 12:19:00	6.9	59,500	2.72	47	111	290	290.0	28	*0.0025*	0.005	0.327	0.017	0.327	*50*	100
SBLEP01	Q - SBLEP01 Belyuen Outfall Woods In	11/11/2021 10:02:00	6.6	51,600	3.09	52	6	1	0.5	2	*0.0025*	*0.0015*	0.026	0.004	0.026	1,178	30
SBLEP01	Q - SBLEP01 Belyuen Outfall Woods In	13/12/2021 12:55:00	8.2	216	2.41	40	0	1	0.5	3	0.025	*0.0015*	0.027	0.005	0.027	291	*5*
SBLEP01	Q - SBLEP01 Belyuen Outfall Woods In	24/01/2022 13:30:00	7.3	15,800	5.72	77	49	40	40.0	5	0.006	0.021	0.064	0.004	0.064	650	857
SBLEP01	Q - SBLEP01 Belyuen Outfall Woods In	10/02/2022 12:59:00	6.5	2,540	3.13	44	10	11	11.0	1	*0.0025*	*0.0015*	0.016	0.006	0.016	96	10
SBLEP01	Q - SBLEP01 Belyuen Outfall Woods In	10/03/2022 04:59:00	6.5	2,490	6.6	90	9	1	0.5	2	0.005	0.003	0.015	*0.0015*	0.015	41	20
SBLEP01	Q - SBLEP01 Belyuen Outfall Woods In	07/04/2022 11:06:00	5.7	15,300	7.59	103	12	1	0.5	3	*0.0025*	*0.0015*	0.036	0.006	0.036	245	63
SBLEP01	Q - SBLEP01 Belyuen Outfall Woods In	10/05/2022 11:33:00	6.4	5,930	7.71	102	13	4	4.0	1	0.022	0.003	0.034	0.004	0.034	31	20
SBLEP01	Q - SBLEP01 Belyuen Outfall Woods In	09/06/2022 12:41:00	7.8	2,870	4.7	62	9	24	24.0	2	0.05	0.003	0.022	0.004	0.022	10	10
		No. of Samples	**31**													**31**	
		Mean	**7.0**	**27,763**	**4.2**	**60**	**28**	**30**	**13.3**	**4**	**0.02**	**0.01**	**0.48**	**0.008**	**0.043**	**486**	**73**
		Median	**7.1**	**26,500**	**4.1**	**55**	**11**	**11**	**1.0**	**2**	**0.003**	**0.004**	**0.17**	**0.006**	**0.034**	**245**	**20**
		Dry Season Median	**7.0**	**44,850**	**3.7**	**56**	**10**	**6**	**1.0**	**3**	**0.003**	**0.004**	**0.59**	**0.007**	**0.038**	**532**	**15**
		Wet Season Median	**7.1**	**6,580**	**4.1**	**55**	**12**	**13**	**1.0**	**3**	**0.003**	**0.01**	**0.10**	**0.006**	**0.028**	**245**	**31**
		95th Percentile	**7.8**	**56,450**	**7.1**	**96**	**100**	**120**	**32.0**	**6**	**0.04**	**0.02**	**1.84**	**0.019**	**0.074**	**1,538**	**246**
Darwin Harbour Water Quality Objective (Upper Estuary)			**6.0-8.5**	**N/A**	**N/A**	**80-100**	**4**	**10**	**N/A**	**4**	**0.02**	**0.02**	**0.30**	**0.010**	**0.026**	**<200**	**<50**
ANZECC Guideline Value (Tropical Australia)			**7.0-8.5**	**N/A**	**N/A**	**80-120**	**20**	**N/A**	**N/A**	**2**	**N/A**	**0.03**	**0.25**	**0.005**	**0.020**	**1,000**	**230**

Notes:
Monitoring values highlighted in red have exceeded the Darwin Harbour Water Quality Objectives (DHWQC) criteria for upper estuary (DEPWS 2021; NRETAS 2010) criteria. Monitoring results highlighted in green have not exceeded the Darwin Harbour Water Quality Objective (NRETAS 2010) criteria. It should note that waste stabilisation pond and source-discharge waters are not expected to comply with these criteria and that these water quality water quality criteria are strictly only applicable to the dry season period. Median value should be utilised to compare with guideline values (ANZECC 2000).
In absence of DHWQO, ANZECC Guideline values for Tropical Australia page 3.3-12 have been utilised for comparison purposes (ANZECC & ARMCANZ 2000).
Monitoring values in italics red text are limit of reporting (LOR) laboratory values. Grey values indicate when the Belyuen WwTP was not discharging to the receiving environment.
ANZECC guidelines for pathogens are based on secondary contact in recreational waters; faecal coliforms value utilised in absence of *E. coli* value.
Further data collation is required to verify Dry and Wet Season statistical analysis. Pond outlet data highlighged in grey illustrates when pond system was not discharging to the receiving environment - values may not be valid.

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Appendix D – Tabulation of Reporting Limit Trigger Values

Table 5 Monitoring Results – Trigger Value Exceedances – Woods Inlet – WDL215-2

Belyuen Woods Inlet (SBLEP01) - WDL Surface Water Monitoring Exceedances - WDL215-02						
Sampling month	**Analyte**	**Units**	**Trigger Value**	**Current Result**	**Discharge occuring preceeding 10 days**	**Comments**
Dec-21	DO	%	75-100	40.4	Y	Mean value is 56% - DO levels are generally outside the trigger value range in both the dry and wet seasons.
Dec-21	TN	ug/L	300	3,050	Y	Mean value is 0.9mg/L - observed outlier.
Jan-22	*E. coli*	/100mL	<200	650	Y	Mean value is 962/100mL - *E.coli* concentrations >600/100mL are reported during the Dry Season when ponds are not discharging - elevations are therefore naturally occurring in Woods Inlet.
Jan-22	Enteroccocci	/100mL	<50	857	Y	Mean value is 787/100mL - Enteroccocci concentrations >50/100mL are reported during the Dry Season when ponds are not discharging - elevations are therefore naturally occurring in Woods Inlet.
Jan-22	TSS	mg/L	10	40.0	Y	Mean value is 31.9 mg/L - TSS > 10mg/L are reported during the Dry Season when ponds are not discharging - fluctuations in TSS during grab sampling is common depending on weather and tidal conditions.
Feb-22	DO	%	75-100	43.7	Y	Mean value is 59% - DO levels are generally outside the trigger value range in both the dry and wet seasons.
Apr-22	Enteroccocci	/100mL	<50	63	Y	Mean value is 712/100mL, median value of 20/100mL. Result is generally consistent with previous data.
Apr-22	DO	%	75-100	103.3	Y	95th Percentile value is 88% - observed outlier
Apr-22	pH	pH Unit	6.0-8.5	5.74	Y	Mean value is 7.1 pH - possibly observed outlier along with DO % at time of sampling.
May-22	DO	%	75-100	102.1	Y	95th Percentile value is 98% - observed outlier
Jun-22	DO	%	75-100	62.2	Y	95th Percentile value is 97% - observed outlier
Monitoring Exceedance Criteria:						
Exceedance of a trigger value on three consecutive sampling occasions for parameters specified in Schedule 2 of this licence.						
Exceedance of three times or more a trigger value for parameters specified in Schedule 2 of this licence.						
Trigger values only apply if discharges from SBE090 have occurred in the preceeding 10 days.						
Monitoring Exceedance Criteria:						
Exceedance of a trigger value on three consecutive sampling occasions for parameters specified in Schedule 2 of this licence.						
Exceedance of three times or more a trigger value for parameters specified in Schedule 2 of this licence.						
Trigger values only apply if discharges from SBE090 have occurred in the preceeding 10 days.						

Appendix E - Tabulation of Comparative Guideline Values

Table 3.1: Classification of effluent for environmental management

Constituent	Strength (average concentration mg/L)[1]		
	Low[2]	Medium	High
Total nitrogen	<50	50–100	>100
Total phosphorus	<10	10–20	>20
BOD_5	<40	40–1,500	>1,500
TDS[3]	<600	600–1,000	>1,000–2,500
Other pollutants (e.g. metals, pesticides)	Effluent with more than five times[4] the ANZECC and ARMCANZ (2000) long-term water quality trigger values for irrigation waters must be considered high strength for the purpose of establishing a strength class for runoff and discharge controls and will require close examination to ensure soil is not contaminated.		
Grease and oil	Effluent with more than 1,500 mg/L of grease and oil must be considered high strength and irrigation rates and practices must be managed to ensure soil and vegetation is not damaged.		

Notes:

1. Average concentrations established from a minimum of 12 representative samples, collected at regular intervals over a year.
2. Effluent generated by municipal sewage treatment plants with secondary treatment will generally be considered to be low strength.
3. Refer to Section 3.7 for relationship of TDS to EC.
4. Criteria of five times the ANZECC and ARMCANZ (2000) long-term irrigation criteria have been selected as nominal criteria at which the level of those contaminants warrants a higher level of management of the reuse system for the following reasons. This criteria when applied to 1 ML/d of effluent irrigated over 100 hectares would take approximately 10 years for soil contaminant levels in the top 15 cm of soil to rise to near the soil contaminant criteria for Cadmium, Chromium and Zinc, which are the most sensitive heavy metal pollutants in this scenario. This criteria is also approximately half the value for Nickel, Mercury, Beryllium and Arsenic at which the effluent would be considered a liquid waste and would need to be managed and disposed of according to the DEC's *Environmental Guidelines for the Assessment, Classification and Management of Liquid and Non-Liquid Waste* (EPA 1999a).

Figure 14 Environmental Guidelines for Classification of Effluent Strength (DEC 2003)

Indicator for Environmental Use: Aquatic Ecosystem Protection	Marine and Estuarine Systems					Freshwater Systems			
	Offshore Marine	Inshore marine	Outer Estuary	Mid Estuary	Upper Estuary	Freshwater Rivers & streams[b]	Aquifer Fed Springs	Lagoons	Groundwater
To maintain and protect the ecological condition of marine, estuarine and freshwater ecosystems of the Darwin Harbour Region.									
DO% saturation	Refer ANZECC (2000)	Refer ANZECC (2000)					To be determined		-
Upper			100	100	100	100		100	
Lower			80	80	75	54		37	
Water Quality Objective	-	-	Maintain DO between 80-100% saturation	Maintain DO between 80-100% saturation	Maintain DO between 80-100% saturation	Maintain DO between 50-100% saturation	-	Maintain DO between 35-100% saturation	-
pH	Refer ANZECC (2000)	Refer ANZECC (2000)							
Upper			8.5	8.5	8.5	7.5	8.0	6.0	8.0
Lower			7.0	7.0	6.0	6.0	7.0	5.0	7.0
Water Quality Objective	-	-	Maintain pH between 7.0-8.5	Maintain pH between 7.0-8.5	Maintain pH between 6-8.5	Maintain pH between 6.0-7.5	Maintain pH between 7.0-8.0	Maintain pH between 5.0-6.0	Maintain pH between 7.0-8.5
Turbidity (NTU)	Refer ANZECC (2000)	Refer ANZECC (2000)	-	-	-	1-20	To be determined	1-2.5	-
Water Quality Objective	-	-	-	-	-	Maintain Turbidity <20 NTU	-	Maintain Turbidity <3 NTU	-
Conductivity (µS/cm)	Refer ANZECC (2000)	Refer ANZECC (2000)	-	-	-	20-200	320-390	13-22	350
Water Quality Objective	-	-	-	-	-	Maintain Conductivity <200 µS/cm	Maintain Natural Conductivity range	Maintain Conductivity <25 µS/cm -	Maintain conductivity to < 400 µS/cm
Nutrients (µg/L)	Refer ANZECC (2000)	Refer ANZECC (2000)					To be determined		-
Total N (µg N/L)			440[a]	270	300	80-225		550	
Water Quality Objective	-	-	Maintain TN<440µg/L	Maintain TN <270 µg/L	Maintain TN <300µg/L	Maintain TN <230 µg/L	-	Maintain TN <550µg/L	-
NOx (µg N/L)			10	17	20	8	nd	8	nd
Water Quality Objective	-	-	Maintain NOx <10 µg/L	Maintain NOx <20µg/L	Maintain NOx <20 µg/L	Maintain NOx <8 µg/L	-	Maintain NOx <8 µg/L	-
NH_3-N (µg/L)			20	20	20			nd	
Water Quality Objective	-	-	Maintain Ammonia <20 µg/L	Maintain Ammonia <20 µg/L	Maintain Ammonia <20 µg/L	-	-	-	-
Total P (µg P/L)			16	20	26	10		18	
Water Quality Objective	-	-	Maintain TP <20 µg/L	Maintain TP <20 µg/L	Maintain TP <30µg/L	Maintain TP <10µg/L	-	Maintain TP <20 µg/L	-
FRP (µg P/L)			8[a]	5	9	5	To be determined	1	
Water Quality Objective	-	-	Maintain FRP <10µg/L	Maintain FRP <5µg/L	Maintain FRP <10µg/L	Maintain FRP <5 µg/L	-	Maintain FRP <5 µg/L	-
Chlorophyll a (µg/L)	Refer ANZECC (2000)	Refer ANZECC (2000)	1	2	4	2	-	6	-
Water Quality Objective	-	-	Maintain Chl *a* <1 µg/L	Maintain Chl *a* <2 µg/L	Maintain Chl *a* <4 µg/L	Maintain Chl *a* <2 µg/L	-	Maintain Chl *a* <6 µg/L	-
TSS (mg/L)	-	-	6[a]	6[a]	10[a]	5[a]	-	-	-
Water Quality Objective	-	-	Maintain TSS <10mg//L	Maintain TSS <10mg//L	Maintain TSS <10mg//L	Maintain TSS <5mg//L	-	-	-

Figure 15 Darwin Harbour Water Quality Objectives Table (NRETAS 2010)

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Appendix F - Key Indicators associated with the environmental impacts of WSPs

Table 6 Assessment end-points for key indicators associated with the discharge from remote community WSPs

Indicator (water quality parameter)	**Stressor (change to indicator)**	**Risk Hypothesis**		**Assessment end-points**	
		ENVIRONMENTAL	**CULTURAL**	**ENVIRONMENTAL**	**CULTURAL**
Gross pollutants	Presence and accumulation of gross pollutants from influent carried through to effluent	That gross and micro-scale pollutants are ingested by biota resulting in death of animals and environmental degradation.	That gross pollutants are resulting in the reduction of visual amenity in the receiving environment.	To maintain the presence of biota in the environment.	To maintain the visual amenity of the environment.
Suspended Solids	Increase in TSS	That a reduction in light penetration is reducing photosynthesis of aquatic plants/phytoplankton and smothering benthic fauna.	That suspended solids are resulting in the reduction of amenity of receiving environment through reduction in water clarity.	To maintain the physical processes and presence of biota in the environment.	To maintain the visual amenity of the environment.
Organic matter	Increase in BOD, decrease in DO	That BOD is leading to oxygen depletion in the environment resulting in loss of biota (e.g. fish kills) and changes to ecosystem structure.	That BOD is leading to odours resulting in the reduction of amenity in the receiving environment.	To maintain the presence of biota in the environment.	To maintain oxygen levels in the environment sufficient to prevent production of odours.
Nutrients (nitrogen and phosphorus)	Increase in nutrient concentrations	That nutrients are leading to nuisance plant growth (e.g. phytoplankton blooms/ eutrophication) resulting in oxygen depletion; displacement of endemic species; diminished light availability; release of toxins; and changes to ecosystem structure. Different in marine, estuary and freshwater systems.	That nutrients are resulting in the reduction of amenity of receiving environment through reduction in water clarity, objectionable discolouration and odours; toxic blooms that are a public health risk; and blooms of toxin producing species whereby the toxins bio-accumulate in shellfish and fish ingested by humans.	To maintain nutrient levels so that the levels of primary production do not have an adverse impact on ecosystem structure.	To maintain the amenity of the environment.
Toxicants	Increase in free ammonia concentrations	That free ammonia is resulting in toxicity to aquatic organisms in water and sediments.		To maintain the presence of biota in the environment.	
Pathogens	Presence of *E. coli*		That pathogens are leading to the contamination of water resulting in primary and secondary contact recreation a public health risk; and accumulation in shellfish resulting in the consumption of shellfish a public health risk.		To maintain that pathogens from municipal wastewater are not increasing the risk of illness via primary and secondary contact recreation and consumption of shellfish.

Table 7 Community assessment of where key indicators are high or low in concentration

Summary of communities with high or low concentrations of key parameters																								
Indicator (water quality parameter)	**Community**																							
	Acacia Larrakia	Barunga	Belyuen	Beswick	Galiwinku	Gapuwiyak	Gunbalanya	Kalkarindji	Maningrida	Manthathpe	Milikapiti	Milingimbi	Minjilang	Nauiyu	Nganmarriyanga	Ngukurr	Numbulwar	Peppimenarti	Pirlangimpi	Ramingining	Wadeye	Warruwi	Wurrumiyanga	Yirrkala
Gross pollutants																								
Suspended solids	↓															↓	↑	↓	↑	↑			↓	↑
Organic matter (BOD)	↓									↑						↓	↑	↓		↑			↓	↑
Nutrients (nitrogen)	↓							↑				↑				↑		↓	↑	↑				
Nutrients (phosphorus)	↓		↓		↑	↑						↑				↓				↑			↓	
Toxicants (Ammonia)	↓	↓					↑			↓		↑		↑										
Pathogens	↓											↑		↑		↓	↑	↓			↑			
Flow Volume (kL/day)	9	103	85	151	506	233	428	144	736	22	263	816	92	180	85	312	168	86	225	187	299	219	566	441
Population (ICEG)	92	381	212	627	2,527	1,042	1,437	385	2,811	N/A	547	1,290	377	559	466	1,296	845	232	455	995	2,678	516	1,865	1,003
Indigenous Community Engineering Guidelines (2017) - Appendix A: Population and water data for NT remote communities																								

References

Anastasi, E., Matthews, B., Stratton, H., & Katouli, M. (2012). Pathogenic *Escherichia coli* found in sewage treatment plants and environmental waters. *Applied and Environmental Microbiology.* 78 (16): 5536-5541.

ANZECC and ARMCANZ (2000) Australian and New Zealand guidelines for fresh and marine water quality. National Water Quality Management Strategy. Australian and New Zealand Environment and Conservation Council and Agriculture Resource Management Council of Australia and New Zealand, Chapters 1 and 2.

AWQC (2020) Australian Water Quality Centre, information provided by Laboratory Manager Scott Kraft, 13/02/2020.

BOM (2022) Bureau of Meteorology. Climate Data Online. Australian Government. Accessed 16 June 2022. http://www.bom.gov.au/climate/data/

Craggs, R. (2005) Nutrients. Pond Treatment Technology. IWA Publishing, London, UK.

Davies-Colley, R. (2005) Pond disinfection. Pond Treatment Technology. IWA Publishing, London, UK.

DENR (2020) Darwin Harbour Report Cards 2020: West Arm. Department of Environment and Natural Resources, Northern Territory Government.

Fortune, J., Butler, E. & Gibb K. (2020) A decade of nitrogen inputs to a tropical macrotidal estuary of Northern Australia, Darwin Harbour. Regional Studies in Marine Science, 36 (2020), pg. 101275.

Jacobs Engineering Group (2021) Jacobs Engineering Group. Waste Stabilisation Ponds; Assessment Report; Power and Water Corporation.

Medcalf & Eddy, Inc (2002). Wastewater Engineering: Treatment and Reuse. McGraw Hill Publishing. Boston.

Patterson, C. & Curtis, T. (2005) Physical and chemical environments. Pond Treatment Technology. IWA Publishing, London, UK.

PWC (2021) Power and Water Corporation. Berrimah Waste Discharge Licence 146-08 Monitoring Report, Northern Territory Government.

NRETAS (2010) Water quality objectives for the Darwin Harbour region – Background documentation. Aquatic Health Unit, Department of Natural Resources, Environment, The Arts and Sport, Northern Territory Government.
Water Futures (2020) Water Futures Pty Ltd, Conversations on site with Dr. Daniel Deere, Technical Wastewater Specialist, at remote community waste stabilisation ponds conducted during fieldwork in 2020.