Environmental Risk Assessment

Wurrumiyanga Waste Stabilisation Ponds
2023

PowerWater

Document History

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Glossary

Abbreviation	Explanation
ANZECC	Australian Water Quality Guidelines for Fresh and Marine Waters
ARMCANZ	Agriculture and Resources Management Council of Australia and New Zealand
Assessment end-points	The explicit expressions of the actual environmental value that is to be protected, operationally defined by an ecological entity and its attributes.
BOD	Biochemical oxygen demand
BUD	Beneficial Use Declaration – the uses of water specified in subsection 3 of the *Water Act* (1992)
BOM	Bureau of Meteorology
CSM	Conceptual site model
Cultural values	To provide water to meet aesthetic, recreational and cultural needs.
d	Day
DEPWS	Department of Environment, Parks and Water Security (NT)
DO	Dissolved oxygen
E. coli	*Escherichia coli*
Environmental Values	To provide water to maintain the health of aquatic ecosystems.
EPBC	Environment Protection and Biodiversity Conservation Act
ERA	Environmental risk assessment
ET	Equivalent Tenement – an average residential dwelling or house. Other developments are converted to an ET value by relating their average water demand (or sewage flow) to demand from one average house.
ICEGs	Indigenous Community Engineering Guidelines
kL	Kilolitre
Km	Kilometre
L	Litre
m	Metre
m^2	Square metre
Macrotidal estuary	Estuaries where the tidal range is in excess of 4 metres.
mg	Milligram
mL	Millilitre
N/A	Not applicable
N/C	Normally closed
NOx	Nitrogen oxides – the sum of nitrate and nitrite ionic species.
NT	Northern Territory
NTU	Nephelometric turbidity units
NT EPA	Northern Territory Environmental Protection Authority
PL	Primary lagoon
PWC	Power and Water Corporation previously Power and Water Authority (PAWA)

%	Per cent
Risk characterisation	The culmination of the planning, problem formulation and analysis of predicted or observed adverse ecological effects related to the assessment end-points.
Risk hypothesis	Assumptions made in order to evaluate logical or empirical consequences, or suppositions tentatively accepted to provide a basis for evaluation. They are used to test if an activity (e.g. contaminant discharges) has adverse effects on an assessment end-point.
s	Second
SL	Secondary lagoon
SOCs	Site of conservation significance
SPS(s)	Sewage pump station(s)
SS / TSS	Suspended solids / total suspended solids
TDS	Total dissolved solids – the portion of solids in wastewater that passes through a 2.0 micron filter.
TN	Total nitrogen
TP	Total phosphorous
TPWC	Territory Parks and Wildlife Conservation Act
WDL(s)	Waste discharge licence(s)
WSP(s)	Waste stabilisation pond(s)
WwTP(s)	**Wastewater treatment plant(s). All facilities that treat wastewater disposed of to the sewerage system consisting primarily of sewage as well as stormwater inflow and infiltration. These facilities may include a range of different types of treatment technologies e.g. waste stabilisation ponds.**

Note: Not all abbreviations may be used in this document

Executive Summary

This environmental risk assessment (ERA) provides an assessment of the risks associated with the discharge of secondary treated effluent from the Wurrumiyanga wastewater treatment plant (WwTP) to a nearby tidal creek.

Based on this ERA and water quality data, there is limited evidence to suggest deleterious impacts to the beneficial uses and environmental values identified for this receiving environment.

Risks to the assessment end-points, associated with the source, were assessed as having low to medium risk rankings. These rankings were associated with the very low discharge volumes into a macro-tidal estuary creek with minimal flushing constraints, while higher risk rankings were associated with impacts to cultural values including human health risks through aquatic food safety (pathogen accumulation in shellfish).

The risk rankings may change as uncertainties associated with current assessments are addressed. A range of recommendations have been made in this risk assessment to address knowledge gaps and identify opportunities for improvement.

Introduction

PWC operate the Wurrumiyanga (Nguiu) WwTP pursuant to Waste Discharge Licence (WDL) 223-01 issued on 09 July 2019. This WDL allows for continuous discharge of secondary treated sewage effluent from an authorised discharge point to a nearby tidal creek.

Wurrumiyanga is located on Bathurst Island, forming part of the Tiwi Islands located approximately 80 km north of Darwin across the Beagle Gulf (*Figure 1*). Wurrumiyanga has an estimated population of 1,668 in 2021 (BushTel 2023). The Wastewater Treatment Plant (WwTP) is located approximately 900m northwest of the Wurrumiyanga township (*Figure 2*).

Figure 1. Wurrumiyanga locality map (Google Earth 2017)

Figure 2. Wurrumiyanga site layout including WwTP and outfall location (NT ILIS 2017)

Background

Condition 34 of this WDL requires PWC to update the environmental risk assessment for the Licenced Activity.

Condition 34 of the WDLs specifies that the Environmental Risk Assessment must:

34.1 be conducted in reference to a conceptual site model;
34.2 characterise the impacts of discharge(s) on the relevant Environmental Values;
34.3 inform the development of the Performance Improvement Plan; and
34.4 be submitted to the Administrating Agency at least 60 business days prior to the end date of this licence, with the understanding that the Administrating Agency may require the licensee to revise, amend and/or resubmit the proposed assessment.

Purpose of the Desktop ERA

- identify assessment end-points;
- characterise environmental risks associated with the facility; and
- initiate an ongoing iterative environmental risk process associated with ongoing operation of the facility

Risk Assessment Methodology

The methodology employed has been adapted from ERAs completed by the PWC Water Quality team and the Victorian EPA *Guidelines for Risk Assessment of Wastewater Discharges to Waterways* ('the guidelines') (VIC EPA 2009). The guidelines utilise a framework (Figure 3) consistent with nationally and internationally accepted risk assessment frameworks by the Australian and New Zealand Environment and Conservation Council and Agriculture and Resources Management Council of Australia and New Zealand (2000).

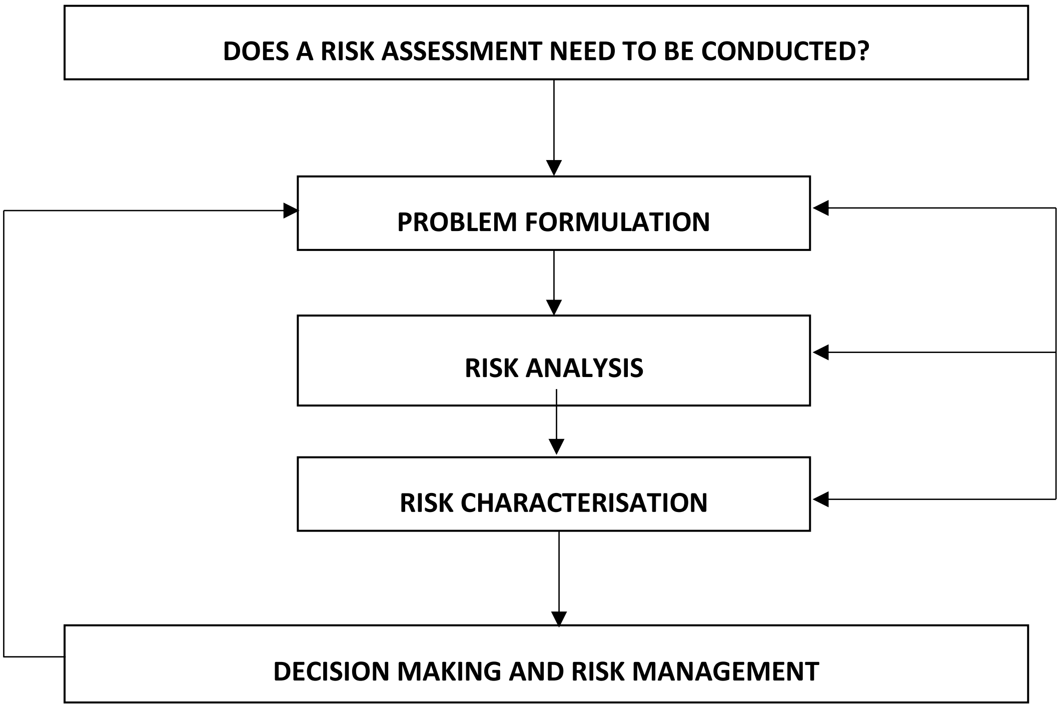

Figure 3. Risk assessment framework for wastewater discharges to waterways (Victoria EPA 2009)

Limitations

The following items have been identified as limitations associated with the preparation of this ERA:

- limited availability of inflow/outflow data;
- remoteness of communities impacting on the ability to understand systems due to costs, logistics and locally available expertise; and
- limited access to pond discharge points and surrounding environment due to climatic, safety and geographic factors.

Problem Formulation

The purpose of this ERA is to characterise potential impacts of effluent discharge on the relevant values and has been prepared with reference to section 1.1.

This problem is explored through the following:

- characterisation of the treated effluent discharged to the receiving environment;
- characterisation of the treated effluent discharge regime and subsequent dilution of treated effluent within receiving water; and
- identified values of receiving water and assessment end-points representative of those values.

Wurrumiyanga Wastewater Treatment Plant

The community utilises a pressure fed sewer reticulation system, which pumps raw sewage from the community to the WwTP (Figure 4). The Wurrumiyanga WwTP utilises waste stabilisation pond technology and ultraviolet disinfection to achieve secondary level treatment of sewage effluent. Based on current circumstances, the raw sewage is majority domestic in nature with no chemicals added during the treatment process. The WwTP was constructed in November 1977 (PWC 2021a), and consist of a primary facultative pond which gravity feeds into the secondary and tertiary maturation ponds before being discharged offsite.

There is no gross pollutant screening, grit removal, maceration or storm flow separation located on the inlet to the pond system. The majority of the removal process for gross pollutants and other entrained materials involves settling out to sludge layers or entrapment in concentrated surface scums that are physically removed. Desludging of the WSPs is conducted periodically to remove accumulated solids and increase hydraulic performance, which may result in improved treatment performance. Desludging was recently completed at Wurrumiyanga in 2016.

Prior to 2016, no regular wastewater monitoring was undertaken at the site. Regular wastewater monitoring commenced in March 2016, consistent with WDL 223. Samples of the secondary pond outlet are currently collected on a monthly basis. Monitoring results are included in the *PWC Annual Monitoring Report – Remote Community Waste Discharge Licences,* a summary is provided in Appendix E, Table 9.

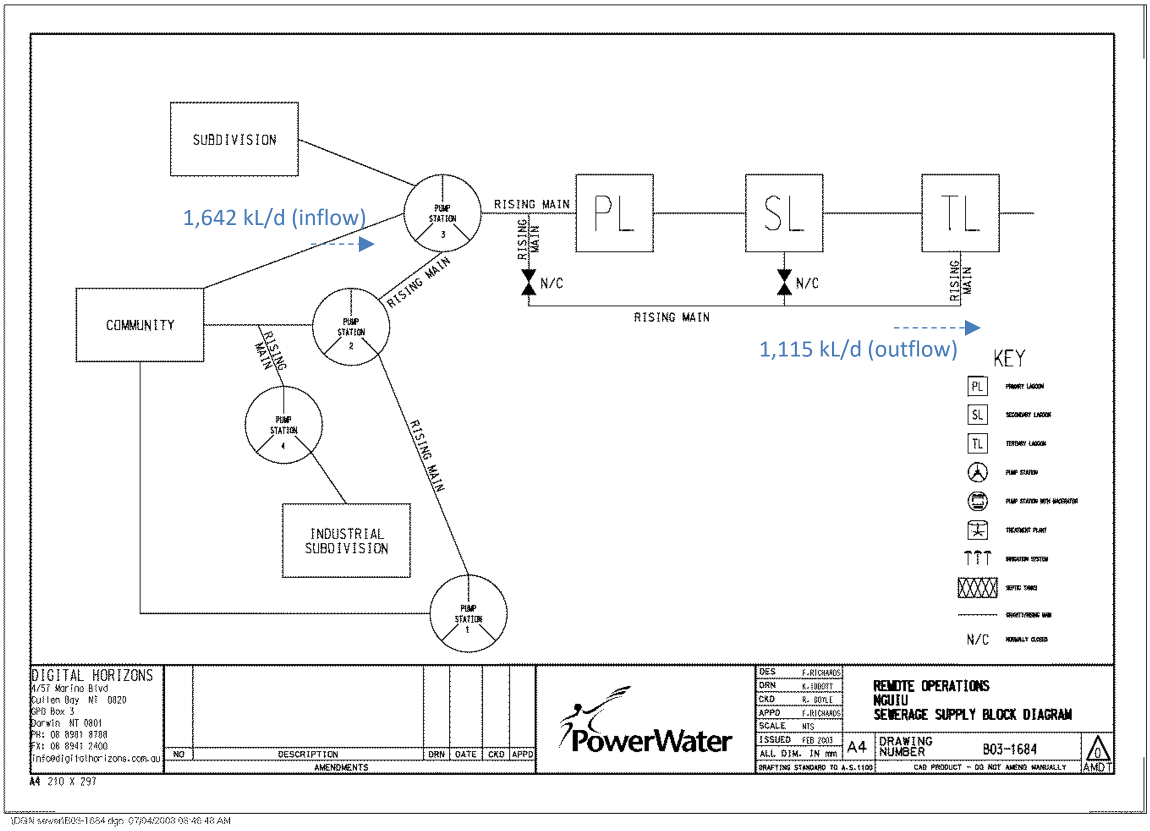

Figure 4. Wurrumiyanga wastewater collection and treatment configuration utilising flow meter data.

Discharge Regime

Discharge from the facility occurs from a gravity fed discharge pipe located in the final tertiary pond (Figure 4). Discharge is continuous on an as-required basis (discharge is all year round) and occurs daily into a tidal creek. The discharge outfall from the tertiary maturation pond is approximately 580m in length, and is located to the north-east of the ponds (*Figure 2*).

There is flow meter data available at the Wurrumiyanga WwTP inflow and outflow to determine actual inflow volumes from the community and discharge volumes to the receiving environment.

Based on flow meter data the mean daily inflow of untreated wastewater into the WwTP is approximately 1,642 kL/day. The mean measured outflow is approximately 1,115 kL/day (Appendix C, Table 7). Due to the small community population (1,972), Wurrumiyanga has relatively low discharge volume in comparison to other NT wastewater facilities in major centres (PWC 2015b).

Note that the volume of treated wastewater discharged to the environment varies seasonally with changes in rainfall. Data for the period of the previous 12 months has been included for the purposes of this assessment. Further data collation will verify current results for longer-term averages.

Pond Performance

WSPs offer a low input, cost effective form of wastewater treatment that is particularly applicable in higher temperature environments with sufficient available land area. While the inputs are low, because it is largely driven by solar energy, the processes are no less complex and are largely controlled by the appropriate design and maintenance of the pond system to achieve the treatment performance required.

Wastewater monitoring at the Wurrumiyanga primary pond inlet commenced in September 2018. This data will provide an accurate characterisation of the raw effluent entering the waste stabilisation pond system, and an indication of treatment performance.

Pond treatment performance can be measured at remote community sites utilising mean biochemical oxygen demand (BOD) removal performance and mean predicted *E.coli* disinfection performance. The results are a reduction in concentration levels from the primary pond inlet to the final pond outlet.

The average mean removal percentage at the Wurrumiyanga WSPs is currently:

- Biochemical Oxygen Demand (BOD): **65%**
- Free Ammonia (NH_3-N): **18%**
- Total Nitrogen (TN): **26%**
- Total Phosphorus (TP): **7%**

The average log reduction for the pathogens indicator is:

- *E. coli:* 1.5 log reduction

In previous years the Wurrumiyanga WwTP has seen removal rates of up to 39% for TP – further monitoring data, statistical analysis and investigation is required to verify these results.

The ponds ultimately provide a centralised treatment barrier that prevents direct contamination of the receiving environment and have an important role in the protection of both environmental and public health.

For the scope of this risk assessment, wastewater quality monitoring data collected at the final pond discharge point to the receiving environment are illustrated on the conceptual site model (CSM) (**Error! Reference source not found.**,Figure 12), and water quality table (**Error! Reference source not found.**, Table 9).

Receiving Environment

The unnamed creek that receives the Wurrumiyanga effluent discharge consists of tidal brackish water and extends approximately 1.25km north-west (Figure 5, Figure 6). Flow is directed towards the estuary separating Bathurst Island from Melville Island, which eventually flows into the Timor Sea via the Beagle Gulf.

The receiving environment is considered to have experienced minor disturbance due to easy access to the site with established vehicle tracks, and observed recreational use of both the creek and estuary areas (PWC 2017). The area consists of riparian vegetation, dominated by mangrove forest, particularly *Excoecaria ovalis* (Blind Your Eye mangrove) and *Rhizophora stylosa* (Stilt rooted mangrove) individuals that were identified at the discharge point, and healthy fish were also observed (Figure 7, Figure 8), (PWC 2017).

Figure 5. Wurrumiyanga WwTP discharge outlet (PWC 2017)

Figure 6. Receiving tidal creek (PWC 2017)

Figure 7. Mangrove habitat at outfall (PWC 2017)

Figure 8. Fish observed at discharge point during ERA site inspection, 19 June 2017 (PWC 2017)

Visual observations during a recent site visit in 2021 at the Wurrumiyanga WwTP discharge point indicate no significant changes to riparian vegetation (PWC 2021b) (Figure 9). Water clarity within the brackish creek was clear, with aquatic macroinvertebrates and fish species observed near the outlet (Figure 10).

Figure 9. Receiving tidal brackish creek – wet season 2021 (PWC 2021)

Figure 10. Mangroves at discharge point – wet season 2021 (PWC 2021)

The receiving environment is located within the Tiwi Islands Site of Conservation Significance number 9 (Appendix B, Figure 13), and is considered as having an International Significance rating. The area has high ecological values due to isolation from mainland Australia and unique environmental conditions. As a result, the island is home to many endemic species not recorded anywhere else in the NT (NT Gov 2017). The area contains 38 threatened flora and fauna species. The conservation status for these species listed under the Territory Parks and Wildlife Conservation Act 2000 (TPWC) and the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC) are summarised below in Table 1.

Table 1: Conservation status of species at risk from the Wurrumiyanga WwTP

Common name	Species name	National Status (EPBC)	NT Status (TPWC)
Plants			
Burmannia	*Burmannia sp.* Bathurst Island	EN	EN
Calochilus	*Calochilus caeruleus*	-	VU
N/A	*Cephalomanes obscurum*	-	EN
Zamia Palm	*Cycas armstrongi*	-	VU
Climbing Mistletoe	*Dendromyza reinwardtiana*	-	VU
Elaeocarpus	*Elaeocarpus miegei*	-	CR
Endiandra	*Endiandra limnophila*	-	VU
Giant Climbing Pandan	*Freycinetia excelsa*	-	VU
Climbing Pandan	*Freycinetia percostata*	-	VU
Native Mangosteen	*Garcinia warrenii*	-	EN
Waxflower	*Hoya australis subsp. oramicola*	VU	VU
N/A	*Luisia teretifolia*	-	VU
N/A	*Mapania macrocephala*	-	VU
N/A	*Mitrella tiwiensis*	VU	VU
N/A	*Tarennoidea wallichii*	-	EN
N/A	*Thrixspermum congestum*	-	VU
N/A	*Typhonium jonesii*	EN	EN
N/A	*Typhonium mirabile*	EN	EN
Xylopia	*Xylopia monosperma*	EN	EN
Vertebrates			
Australian Bustard	*Ardeotis australis*	-	VU
Partridge Pigeon	*Geophaps smithii*	VU	VU
Red Goshawk	*Erythrotriorchis radiatus*	VU	VU

Tiwi Hooded Robin	*Melanodryas cucullata melvillensis*	EN	EN
Tiwi Masked Owl	*Tyto novaehollandiae melvillensis*	EN	EN
Brush-tailed Rabbit-rat	*Conilurus penicillatus*	-	VU
Butler's Dunnart	*Sminthopsis butleri*	VU	VU
False Water-rat	*Xeromys myoides*	VU	DD
Northern Brush-tailed Phascogale	*Phascogale pirata*	-	VU
Merten's Water Monitor	*Varanus mertensi*	-	VU
Yellow-spotted Monitor	*Varanus panoptes*	-	VU
Flatback Turtle	*Natator depressus*	VU	DD
Green Turtle	*Chelonia mydas*	VU	LC
Hawksbill Turtle	*Eretmochelys imbricata*	VU	DD
Olive Ridley Turtle	*Lepidochelys olivacea*	EN	DD
Invertebrates			
Cognate Land Snail	*Amphidromus cognatus*	-	VU
Atlas Moth	*Attacus wardi*	-	EN
Dodd's Azure Butterfly	*Ogyris iphis*	-	EN
Land Snail	*Trochomorpha melvillensis*	-	VU
CR – Critically Endangered, EN – Endangered, VU – Vulnerable, LC – Least Concern, DD – Data Deficient			

Screening Level Risk Assessment

A screening level risk assessment is used to determine if a risk to the assessment end-point exists that should be further investigated. It is a method for prioritising risks and minimising effort in assessing low risks. **Error! Reference source not found.** provides a summary of the screening level risk assessment.

Risk hypotheses for the stressors identified in the conceptual site model (CSM) (Appendix A, **Error! Reference source not found.**) are defined with respect to their potential effects on the identified beneficial uses of the receiving environment.

The identified beneficial uses of the receiving environment are summarised below in

Table 2.

Table 2. Identified values of receiving environment at risk from the Wurrumiyanga WwTP

Values	Receptors	
Cultural **(Recreational Water Quality)**	Humans	Fishing (lines, nets spears) Shellfish harvesting (estuary) • Telescopium (longbums) • Periwinkles • Cockles/pipis • Mud crabs Swimming/wading/diving Food gathering and cooking Hunting
Cultural **(Aesthetics)**	Humans	Visible water quality Sacred sites
Environment **(Aquatic Ecosystem Protection)**	Aquatic	Fish Turtles Dugongs Dolphins Macro-invertebrates (mud crabs) Crocodiles
	Terrestrial	Wading birds Shorebirds Seabirds Invertebrates (water insects) Mammals Reptiles
	Plants	Native vegetation • Mangroves

Table 3: Screening level risk assessment for key indicators and stressors associated with Wurrumiyanga WwTP discharge

Indicator (water quality parameter)	Stressor (change to indicator)	Risk Hypothesis		Assessment end-points		Scope of this desktop ERA	Further investigation required?
		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.	The WwTP is considered a relatively effective barrier to gross pollutant entry to the receiving environment. This is due to the settling out to sludge layers and accumulation on pond surface where gross pollutants are physically removed as required. No evidence of gross pollutant accumulation during visual monitoring of discharge site (qualitative discharge criteria). No further investigation necessary at this stage.	No
Organic matter	Increase in BOD, decrease in DO	That release of high BOD effluent is leading to oxygen depletion in the environment resulting in toxicity to aquatic organisms and 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. Monitor potential anoxic conditions at sites with elevated BOD concentrations.	To maintain oxygen levels in the environment sufficient to prevent production of odours.	The median concentration of BOD in the discharge of Wurrumiyanga WwTP is 9.3 mg/L. As BOD is present in the discharge, it is determined at a screening level that a risk is present and further investigation is necessary.	Yes
Nutrients (nitrogen and phosphorus)	Increase in nutrient concentrations	That nutrients are leading to nuisance plant growth (e.g. phytoplankton blooms) resulting in oxygen depletion; displacement of endemic species; diminished light availability; release of toxins; and changes to ecosystem structure.	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. Monitor potential high nutrient conditions at sites with elevated TN and TP concentrations.	To maintain the amenity of the environment.	The median concentration of nutrients in the discharge of Wurrumiyanga WwTP is 13.45 mg/L total nitrogen (TN) and 2.05 mg/L total phosphorus (TP). As nutrients are present in the discharge, it is determined at a screening level that a risk is present and further investigation is necessary.	Yes
Toxicants	Increase in free ammonia concentration	That free ammonia is resulting in toxicity to aquatic organisms in water and sediments.		To maintain the presence of biota in the environment.		The median concentration of free ammonia in the discharge of Wurrumiyanga WwTP is 9.05 mg/L. At a screening level it is determined that a risk is present and further investigation is necessary.	Yes
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.	The median pathogen concentration in the discharge of Wurrumiyanga WwTP is 6,050/100mL. At a screening level it is determined that a risk is present and further investigation is necessary.	Yes

Risk Analysis and Characterisation

Power and Water Risk Management Framework

PWC has adopted a qualitative risk assessment methodology aligned to the Australia/New Zealand Standard *"AS/NZ 4360: Risk Management"* (PWC, 2009). This process is used to assess and manage activities that have potential to cause environmental harm.

The first step in the ERA process is to identify the aspects (problem formulation i.e. discharge of treated wastewater) (section 2.0) and corresponding potential impacts associated with each assessment end-point identified in the screening level risk assessment as seen in **Error! Reference source not found.**.

This methodology is based on knowledge of the existing environment and incorporates site-specific environmental factors into the analysis of the potential impacts. An assessment of each impact is analysed for likelihood and consequence.

The categories and associated rankings for environmental impact consequences are shown in Table 4 and the likelihood of an event occurring are shown in

Table 5. A risk score for each potential impact is determined by combining likelihood with consequence results as seen in Figure 11.

Low to medium risks can typically be managed by routine procedures and integration into management plans, while high to extreme risks require senior management attention, immediate action or more detailed research and management planning.

Table 4. PWC corporate risk ranking consequence table

	Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Severe (5)
Health & Safety	Minor event with or without injury; and/or No on-going impact to health.	Injuries requiring first aid treatment; and/or Minor short term inconvenience.	Medical Treated injury; and/or Short term reversible disabling effect to human health; and/or Lost Time Injury <1 week lost.	Hospitalisation; and/or Injuries resulting in Lost Time Injury > 1 week lost; and/or Long term (chronic) chemical health exceedance or short term chemical exceedance of chemical with acute health impacts; and/or Long term aesthetic exceedance with health impact on supply.	One or more fatalities; and/or One or more persons seriously injured (includes long term disabling effect); and/or Widespread release of untreated water (eg due to disinfection failure).
Financial **(impact on EBITDA)**	Loss less than $500K.	Impact between $500K and $2M.	Impact between $2m and $10m.	Impact between $10m and $40m.	Impact greater than $40m.
Legal/ Regulation	Legal issues managed by corporate procedures or practices; and/or Breach of internal policies or procedures without the need for formal investigation.	Matter requires legal advice to address issues; and/or Internal breach of policies or procedures requiring a formal investigation.	Required to operate under limited regulatory restrictions or orders; and/or Incident which requires legal representation resulting in court proceeding.	Required to operate under significant regulatory restrictions or orders; and/or Government inquiry/ intervention.	Criminal charges / civil litigation against the Corporation and/or Officers; and/or Operating licences revoked.
Environmental	Localised low level damage controlled but no remedial action required.	Localised low level damage controlled and remedied with minimal resources.	Widespread temporary damage with extended resources to remedy.	Long-term detrimental effect on environment and once controlled results in minor permanent damage.	Substantial permanent damage to widespread and sensitive areas.
Service Delivery (external customers only)	Category 1 loss of service (refer to Appendix C of this document)	Category 2 loss of service (refer to Appendix C of this document)	Category 3 loss of service (refer to Appendix C of this document)	Category 4 loss of service (refer to Appendix C of this document)	Category 5 loss of service (refer to Appendix C of this document)
Reputation	No media attention; and/or Isolated community or individual issue-based concern; and/or Localised dissatisfaction which is managed by normal business processes; and/or Short term aesthetic exceedance.	Occasional once-off negative media attention; and/or Localised community impacts and customer concerns; and/or Localised staff dissatisfaction which requires Human Resources in resolution; and/or Long term aesthetic exceedance.	Brief adverse media attention and/or community/customer condemnation (days); and/or Limited, localized loss of confidence by the community; and/or Localised staff dissatisfaction with localised impacts to service deliver and/or Short term chemical health exceedance.	Prolonged adverse media attention and/or community/ customer condemnation (weeks); and/or Prolonged, widespread community/ customer loss of confidence (weeks); and/or Widespread dissatisfaction and loss of confidence by staff resulting in temporary service delivery issues.	Sustained adverse media attention and/or community/customer condemnation (months); and/or Irreconcilable community/ customer loss of confidence; and/or Loss of stakeholder confidence in Board and/or Management; and/or Widespread dissatisfaction by staff resulting in sustained service delivery issues.

Table 5. PWC corporate risk ranking likelihood table

(E) Almost Certain	Event is expected to occur on a regular basis. One or more times per annum.	Not Applicable
(D) Likely	An event is expected to occur from time to time. Once every 1 – 3 years	Probability of occurring is greater than 33%
(C) Possible	An event should occur at some time. Once every 4 – 10 years.	Probability of occurring is greater than 10% and up to and including 33%
(B) Unlikely	An event could occur at some time. Once every 11 to 30 years	Probability of occurring is greater than 3% and up to and including 10%
(A) Rare	An event not expected but possible. Less than once in 30 years	Probability of occurring is up to and including 3%

		Consequence				
		Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Severe (5)
Likelihood	Almost Certain (E)	Medium	High	Very High	Extreme	Extreme
	Likely (D)	Low	Medium	High	Very High	Extreme
	Possible (C)	Low	Low	Medium	High	Very High
	Unlikely (B)	Low	Low	Medium	High	High
	Rare (A)	Low	Low	Low	Medium	Medium

Figure 11. Corporate risk matrix

Table 6: Risk assessment for key environmental and cultural assessment end-points associated with Wurrumiyanga WwTP discharge using corporate risk ranking methodology

Hypothesis	Consequence		Likelihood		Risk Ranking
Environmental					
BOD is leading to oxygen depletion in the environment resulting in **loss of biota** and **changes to ecosystem structure**.	Discharge from Wurrumiyanga WwTP is to a tidal brackish creek, which receives daily flushing. The estimated dilution volume ratio between the effluent (1,346 kL/day) and receiving environment has been calculated at 1:12 within 300m of entering the estuarine environment (Appendix D), suggesting any observed oxygen demand would be absorbed by the environment.	Minor	Wurrumiyanga WwTP mean BOD discharge quality is 9.3 mg/L; concentrations are very low in comparison to other remote communities; these values are considered to be classified as low effluent strength (<40mg/L) (PWC 2022). Stressor not typically observed with such small discharge volumes and dilution experienced in receiving waters, and is unlikely to be sustained for long periods due to tidal fluctuations within the creek. Based on the sampling results to date, PWC considers that the likelihood of oxygen depletion in the receiving environment is unlikely.	Unlikely	Low
Free ammonia is resulting in **toxicity to aquatic organisms** in water and sediments.	One of the most visible means by which toxicity presents in an aquatic ecosystem is through the occurrence of fish kills. No fish kills have been observed or reported to date.	Minor	Wurrumiyanga WwTP free ammonia discharge quality is 9.05 mg/L. These ammonia concentrations are relatively consistent in comparison to concentrations at other remote communities (PWC 2022). Low pH may also be an indicator of increased ammonia toxicity (ANZECC 2000); a mean pH of 7.05 at Wurrumiyanga suggests the risk of ammonia toxicity to be low. Healthy fish have been observed at the immediate discharge point (PWC 2021b, PWC 2017). PWC considers that the likelihood of toxicity to aquatic organisms in the receiving environment is unlikely.	Unlikely	Low
Nutrients are leading to **nuisance plant growth** resulting in oxygen depletion; displacement of endemic species; diminished light availability; release of toxins; and changes to ecosystem structure.	Wurrumiyanga WwTP contributes very low levels of total nitrogen and phosphorus 6.61 and 1 tonnes/year respectively. The discharge area is densely vegetated with riparian mangroves suggesting increased levels of transpiration and uptake of nutrients from the discharge (PWC 2017).	Minor	Wurrumiyanga WwTP mean TN (13.45 mg/L) and TP (2.05 mg/L) discharge concentrations are generally low in comparison to other remote communities (PWC 2022). **No eutrophication/ algal blooms or scums have been observed within the creek, which is an indicator of excessive nutrient loads.** Stressor not typically observed with such small discharge volumes and dilution experienced in receiving waters. Based on the sampling results to date, PWC considers that the likelihood of nuisance plant growth in the creek is unlikely.	Unlikely	Low
Cultural					
BOD is leading to odours resulting in the **reduction of amenity** in the receiving environment.	Access to the creek is by boat, foot or vehicle. The creek and estuary do not have designated boat ramps however vehicle tracks and remnants of old fishing lines and nets and rubbish on the bank indicates the creek is readily accessed for land based fishing (PWC 2017).	Minor	Stressor not typically observed with such small discharge volumes. No evidence of odours during monitoring of discharge location at final pond (qualitative discharge criteria), however discharge outlet is next to cleared bank where recreational fishing may occur (PWC 2017). PWC considers that the likelihood of reduction in amenity from BOD is unlikely.	Unlikely	Low
Nutrients are resulting in the **reduction of amenity** of receiving environment through **reduction in water clarity**, objectionable **discolouration** and **odours**.	Access to the creek is by boat, foot or vehicle. The creek and estuary do not have designated boat ramps however vehicle tracks and remnants of old fishing lines and nets and rubbish on the bank indicates the creek is readily accessed for land based fishing (PWC 2017).	Minor	No evidence of reduction in water clarity, objectionable discolouration of receiving water or odours reported during inspection of discharge site (qualitative discharge criteria). PWC considers that the likelihood of reduction in amenity from nutrients is possible.	Unlikely	Low
Nutrients are resulting in **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.	The receiving creek may be used for fishing, however collection of shellfish may be limited due to the presence of dangerous aquatic animals (Campbell 2012). There is currently limited available data to indicate toxic blooms however ingestion of shellfish such as long bums is known to occur within the community (PWC 2017). Further information is required to understand how frequently the area is utilised for fishing and shellfish collection.	Moderate	No eutrophication/ algal blooms or scums have been observed within the creek, which is an indicator of excess nutrient loads. Stressor not typically observed with such small discharge volumes and dilution experienced in receiving waters. Based on the limited primary and secondary contact recreation and cultural uses of the creek, and the distance to the estuary from the community, PWC considers that the likelihood of toxicant exposure is unlikely.	Unlikely	Medium

Pathogens are leading to the **contamination of water** resulting in primary and secondary contact recreational a public health risk.	Contamination of water may present a risk to human health through exploratory activities and wading, which may result in medical treatment required. End points for assessment are risk of gastrointestinal illness and acute febrile respiratory illness, considered 'short term' incapacity i.e. of minor consequence. As the illness risk increases and more people would be likely to be affected if exposed, then the consequence would be elevated (NHMRC, 2008). Tidal creeks are not generally considered recreational water bodies in the NT due to the presence of dangerous aquatic animals (Campbell 2012). The receiving creek may be used for fishing.	Moderate	Based on the limited primary and secondary contact recreation and cultural uses of the creek, and the distance to the estuary, PWC considers that the likelihood of the illness from pathogen exposure from contact with the water is unlikely.	Unlikely	Medium
Pathogens are leading to **accumulation in shellfish** resulting in the consumption of shellfish a public health risk.	Collection and consumption of shellfish such as mud crabs is known to occur within the area, however only observed further away in the estuary area closer to the community (PWC 2017). Fishing nets and crabbing traps observed in area.	Moderate	*E. coli* concentrations in Wurrumiyanga discharge are 6,050/100mL, which is low in comparison to other remote communities (PWC 2022). Based on the evidence of fishing on the bank adjacent to the discharge, PWC considers that the likelihood of the illness from pathogen accumulation in shellfish is possible.	Possible	Medium

Summary and recommendations

The ERA found that the identified values of the nearby unnamed tidal creek subject to discharge from the Wurrumiyanga WwTP are environmental and cultural.

The key stressors that posed a risk to these values were the presence and accumulation of gross pollutants from influent carried through to effluent; increase in BOD; increase in nutrient concentrations; increase in free ammonia concentration and the presence of *E.coli*.

The ERA process has determined that the discharge from the Wurrumiyanga WwTP poses a low to medium risk to the identified values of the receiving waterway. The influence of the discharge on the receiving environment is considered sustainable given the very low discharge volumes and high dilution that occur further downstream in the creek before entering the estuary. Based on this ERA and modelled water quality data, there is limited evidence to suggest deleterious impacts to the receiving environment.

All risk rankings have considerable uncertainties attached to the assessments. The risk rankings may change as uncertainties associated with current assessments are addressed.

Based on the ERA process and outcomes, PWC make the following recommendations:

- continue monitoring quality of wastewater discharged to the environment;
- assess pond performance;
- incorporate recommendations into future Performance Improvements Plans;
- accurately quantify the volume of treated wastewater discharged to the environment; and
- update the ERA and CSM based on new information and additional wastewater quality data.

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Appendix A: Wurrumiyanga Conceptual Site Model

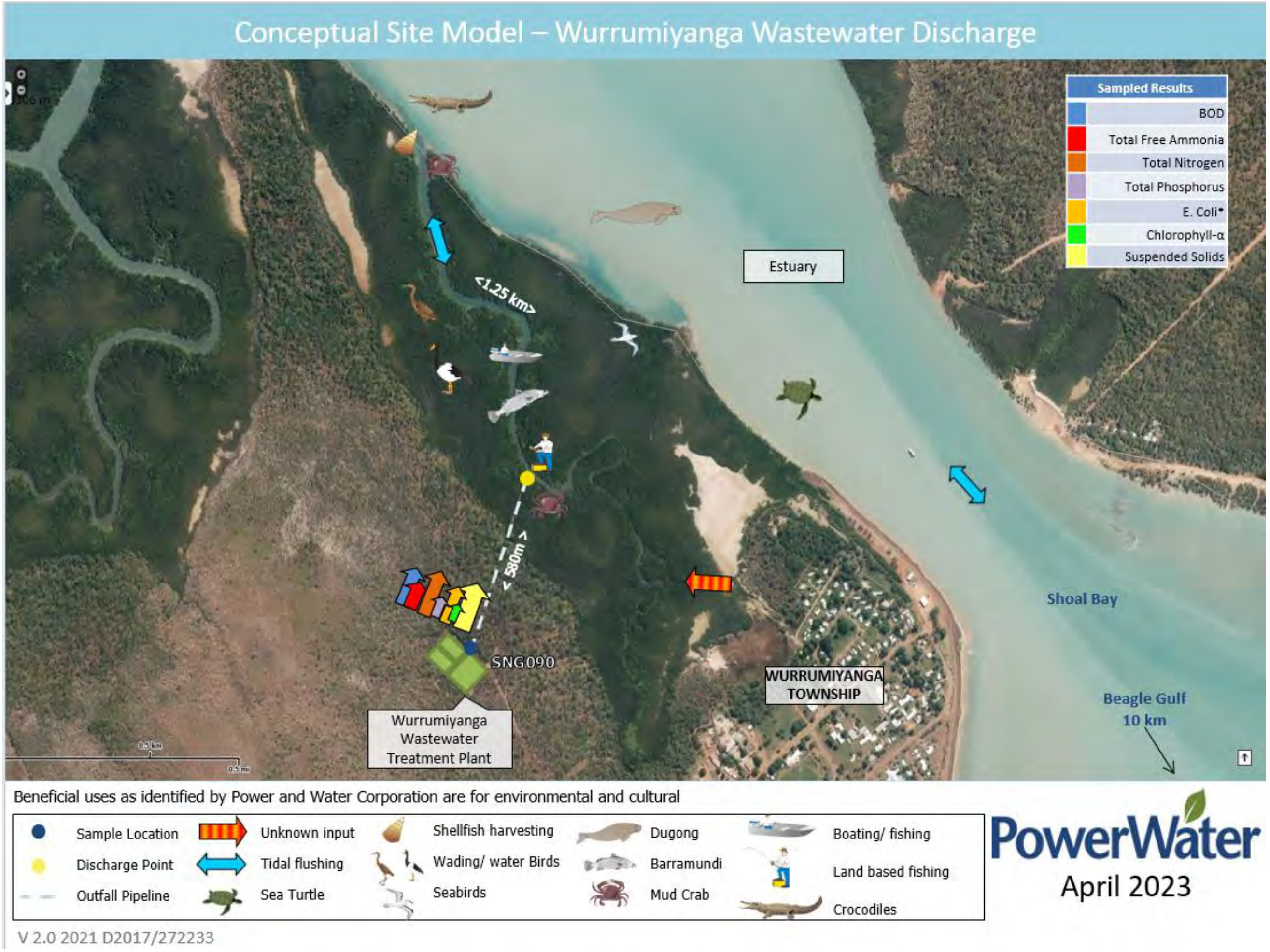

Figure 12: Conceptual site model for the key processes which may impact beneficial uses in the receiving environment of Wurrumiyanga WwTP

Appendix B: Tiwi Islands - Site of Conservation Significance

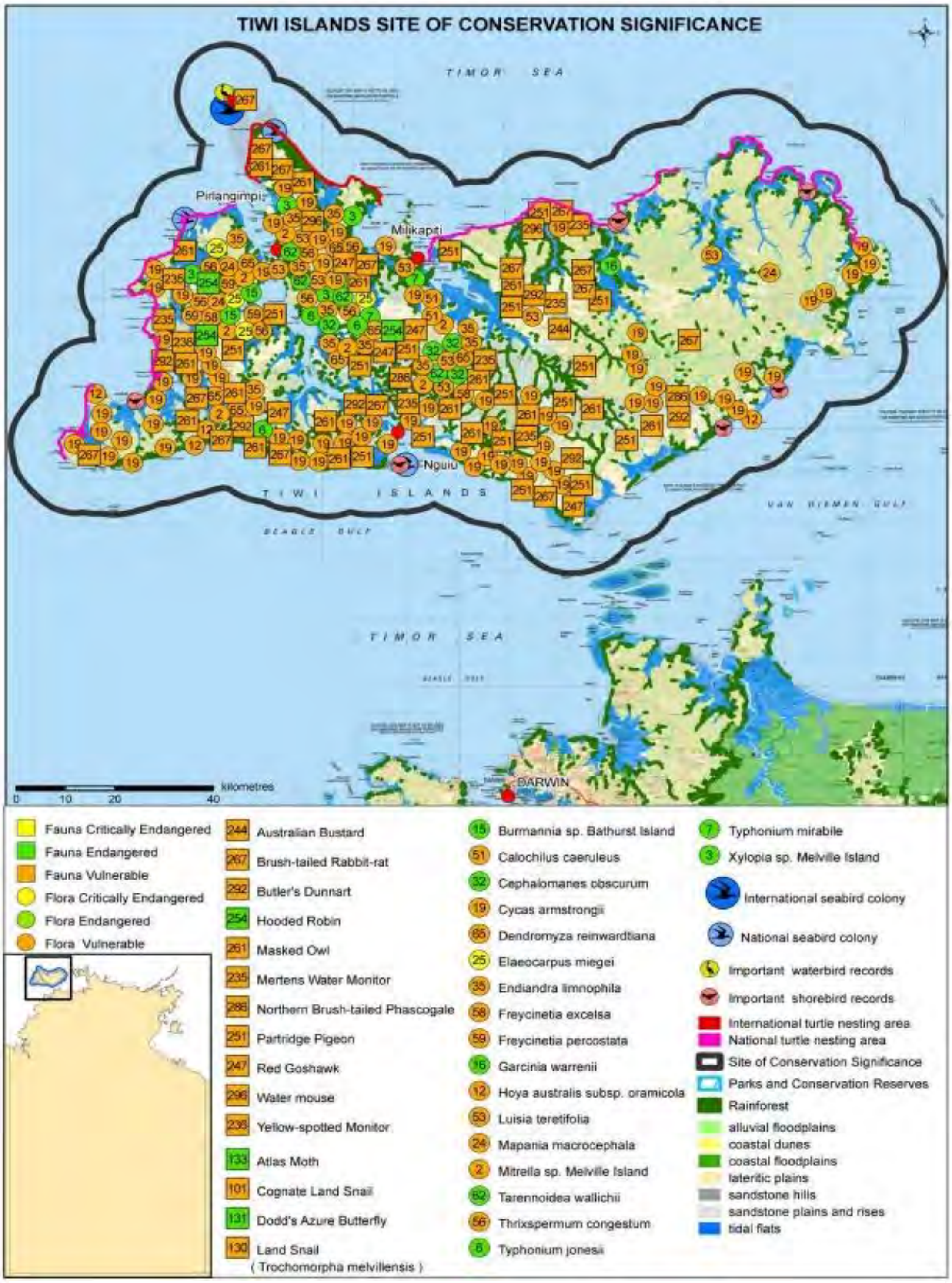

Figure 13. Tiwi Islands - Site of conservation significance map (NT Gov 2017)

Appendix C: Estimated flow rates for Wurrumiyanga WwTP

Wastewater flow rates based on remote flow meter telemetry. The flowrates have been taken from 5/25/21-5/25/22 due to a flowmeter failure resulting in unavailability of data from then onwards. This was considered more accurate than estimating based on ET figures.

Flow rates are summarised in the table below Flow rates are summarised in the table below (Table 7).

Table 7. Estimated average annual flows

Month	Average Inflow Rate L/s	Average Inflow kL/d	Average Outflow Rate L/s	Average Outflow kL/d
January	35.3	3,047	30.3	2,614
February	51.7	4,471	35.1	3,031
March	30.9	2,667	28	2,420
April	17.5	1,513	14.3	1,238
May	14.6	1,264	11.7	1,010
June	11.7	1,009	9.1	787
July	11.0	950	8.5	736
August	10.7	926	8.4	727
September	10.4	899	7.9	689
October	9.9	859	8.0	692
November	12.3	1,063	10.2	881
December	22.5	1,949	16.6	1,436
Mean	**19.7**	**1,702**	**15.6**	**1,346**

Appendix D: Dilution ratio for Wurrumiyanga WwTP

Treated wastewater (effluent) is discharged into an unnamed tidal creek, which then drains into an estuary. Prior to entering the estuary, limited dilution of treated wastewater occurs during the dry season. Dilution within the unnamed creek has been calculated using the method for estimating diffusion mixing in continuous discharge to a river outlined by Metcalf and Eddy (1991).

Due to the nature of the estuary (tidal), a time-averaged approximation has been calculated assuming that the net advective velocity in the estuary is equal to the volumetric flowrate of the treated wastewater entering the estuary. This would be the case in the conservative scenario when no other dilution is occurring from runoff in the catchment. A typical diffusion mixing decay constant of 0.3 d^{-1} has been assumed. The locations for which dilution ration have been calculated are shown in Figure 14. Calculated dilution ratios are tabulated in Table 8.

Figure 14. Wurrumiyanga wastewater discharge surface watercourse showing at 100, 200 and 400 m from discharge point (NT ILIS 2017)

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Table 8. Discharge volume and dilution ratio calculation

Distance from discharge point (m)	Point 1 (100)	Point 2 (200)	Point 3 (400)
Width of estuary channel (m)	14	15	25
Estimated mean depth of channel (m)	0.5	0.75	1.0
Maximum treated wastewater flow (kL/d)[1]	1,346		
Net advective velocity (m/s)	8.1×10^{-3}	1.4×10^{-4}	2.3×10^{-4}
Ratio[2]	1:1	1:1.4	1:12

[1] See appendix C for discharge volume calculations.

[5] Volume of receiving environment/volume of discharge = dilution ratio. Dilution ratio does not account for tidal influences.

Appendix E: Wastewater Quality Monitoring Results

Table 9: Summary of PWC wastewater quality results for Wurrumiyanga WwTP 2020-2023

Sample Location/Asset: SNG090 (Pond 3 Outlet)			
Indicator	**Reporting Value**		
	Median Wet Season	**Median Dry Season**	**Median**
Physio-chemical Parameters			
pH	6.87	7.2	7.05
Electrical Conductivity (uS/cm)	150	270	235
Dissolved Oxygen (% Saturation)	8	5	5
Turbidity (NTU)	13	30.5	20.5
Total Suspended Solids (mg/L)	25	39	30
Biological Parameters			
Biochemical Oxygen Demand (mg/L)	25	39	30
Chlorophyll-a (ug/L)	5.55	17.5	9.3
Nutrient Parameters			
Ammonia (Total[1] as N – NH3-N) (mg/L)	3.95	10	9.05
Total Nitrogen[2] (mg/L)	7.53	15.85	13.45
Oxidised Nitrogen (NOx)	0.05	0.05	0.05
Total Phosphorus (mg/L)	1.3	2.5	2.05
Pathogen Indicators			
Escherichia coli (E. coli/100mL)	6,050	6,437	6,050
Enterococci (Enterococci/100mL)	300	1755	310

[1]Calculated NH3-N Free

[2]Calculated NH3-N Organic + NH3-N Free + NOx

Appendix F: Additional Site Inspection Images

Figure 15. Wurrumiyanga WwTP Pond 1 (PWC 2017)

Figure 16. Wurrumiyanga WwTP Pond 2 and Pond 3 (foreground) (PWC 2017)


Figure 17. Wurrumiyanga Pond 3 Outfall (PWC 2017)


Figure 18: Effluent discharge to the receiving environment (PWC 2021)

Figure 19: Pond 3 outlet to receiving environment

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