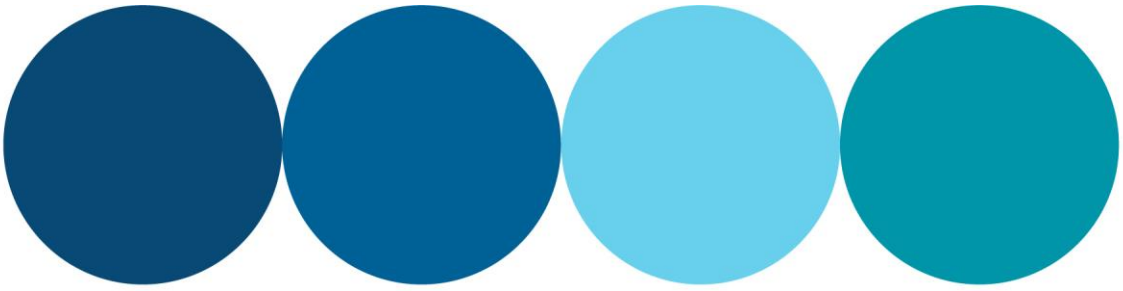
Bunbury Wastewater Treatment Plant Ocean Outlet Monitoring Program

Annual Report 2018/2019



WATER CORPORATION

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Acronyms

ANZECC/ARMCANZ	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
CFU	Colony forming unit
DoH	Western Australian Department of Health
EPA	Environmental Protection Authority
EQC	Environmental Quality Criteria
EQG	Environmental Quality Guideline
EQMF	Environmental Quality Management Framework
EQO	Environmental Quality Objective
EQS	Environmental Quality Standard
EV	Environmental Value
HEPA	High ecological protection area
MPN	Most probable number
NATA	National Association of Testing Authorities
SHEZ	Shellfish harvesting exclusion zone
TTC	Thermotolerant coliforms
TTM	Total toxicity of the mixture
TWW	Treated wastewater
WASQAP	Western Australian Shellfish Quality Assurance Program
WWTP	Wastewater treatment plant

Executive Summary

This report documents the results of the 2018–2019 marine environmental monitoring around the Bunbury ocean outlet. The monitoring has been carried out in accordance with the requirements of the Marine Impacts Monitoring and Management Plan (MIMMP; Water Corporation 2012). The monitoring program aims to determine the physical and chemical properties of the treated wastewater plume and establish its effect on the receiving marine environment. Results are reported in the context of the Environmental Quality Management Framework (EQMF) in accordance with the MIMMP (Water Corporation 2012). The results are summarised in Report Card format (Table ES 1). The report card contains-colour coded results, with the individual colours representing the extent to which the Environmental Quality Criteria (EQC) were met (Table ES 2–Table ES 4).

Table ES 1 Summary report card legend

Management response	Colour
Monitor: EQG met (continue monitoring)	
Investigate: EQG not met (investigate against the EQS)	
Action: EQS not met (management response required)	

Note:

1. The required response following an exceedance of either the Environmental Quality Guideline (EQG) or Environmental Quality Standard (EQS) is shown in parentheses.

Table ES 2 Summary report card for the Environmental Quality Objective 'Maintenance of Ecosystem Integrity'

Environmental quality indicator		EQC	Comments	Compliance
Toxicants in treated wastewater (TWW)	Bioaccumulating toxicants	EQG	Concentrations of cadmium and mercury in the undiluted TWW stream were below the ANZECC/ARMCANZ (2000) 80% species protection guideline	
	Non-bioaccumulating toxicants and initial dilution	EQG	Total ammonia, copper and zinc concentrations exceeded ANZECC/ARMCANZ (2000) guidelines in TWW prior to initial dilution. Initial dilution (of 1: 1:521 expected at the LEPA boundary) was sufficient to reduce contaminant concentrations to below the associated ANZECC/ARMCANZ (2000) 99% species protection guidelines.	
	Total toxicity of the mixture (TTM)	EQG	The TTM for the additive effect of ammonia, copper and zinc after initial dilution was 0.34 and below	

			the ANZECC/ARMCANZ (2000) guideline value of 1.0	
Nutrient enrichment indicators of increased nutrients and algal growth potential	Chlorophyll-a	EQG	Median concentration of chlorophyll-a at compliance sites was equal to (and did not exceed) the 80th percentile of reference site data	■
	Phytoplankton biomass (measured as chlorophyll-a)	EQG	Chlorophyll-a biomass did not exceed 3 times the median of chlorophyll-a concentration of reference site data, on any occasion during summer monitoring	■
	Light attenuation coefficient (LAC)	EQG	Median light attenuation measured over the summer period at compliance sites did not exceed the 80th percentile of historical reference site data.	■
	Periphyton chlorophyll-a	EQG	Median concentration of periphyton biomass (measured as chlorophyll-a) at compliance sites exceeded the 80th percentile of reference site data. This triggered assessment against the seagrass health EQS.	■
	Seagrass health	EQS1	Median shoot density did not fall below the 20th percentile of reference sites, at any site, in two consecutive years (2018 and 2019).	■
		EQS2	Median shoot density, at all sites in 2019, was greater than the 5th percentile of the pooled reference site data	■
Physio-chemical stressor	Dissolved oxygen % saturation	EQG	Dissolved oxygen saturation in bottom waters remained above 90% saturation at all times.	■

Notes:

1. Green (■) symbols indicate the Environmental Quality Criteria (EQC) were met; amber (■) and red (■) symbols represent an exceedance of the Environmental Quality Guideline or Environmental Quality Standard (EQS), respectively.
2. TWW = treated wastewater, EQC = Environmental Quality Criteria, EQG = Environmental Quality Guidelines, EQS = Environmental Quality Standard, LEPA = Low Ecological Protection Area (100 m from diffuser).

Table ES 3 Summary report card for the Environmental Quality Objective 'Maintenance of Seafood for Human Consumption'

Environmental quality indicator		EQC	Comments	Compliance
Microbial contaminants	Thermotolerant coliforms (TTC)	EQG	Median TTC concentrations (<10 CFU/100 mL) did not exceed 14 CFU/100 mL and less than 10% of samples exceeded 21 CFU/100 mL	■
Algal biotoxins	Toxic phytoplankton species	EQG	No toxic phytoplankton species were recorded in numbers greater than WASQAP trigger values (DoF 2007)	■

Notes:

1. Green (■) symbols indicate the Environmental Quality Criteria (EQC) were met; amber (■) and red (■) symbols represent an exceedance of the Environmental Quality Guideline or Environmental Quality Standard (EQS), respectively.
2. WASQAP = Western Australia Shellfish Quality Assurance Program (DoF 2007)

Table ES 4 Summary report card for the Environmental Quality Objective 'Maintenance of Primary and Secondary Contact Recreation'

Environmental Quality Indicator		EQC	Comments	Compliance
Faecal pathogens	*Enterococci* spp.	EQG	All sites had *Enterococci* spp. concentrations <10 MPN/100 mL. Therefore, the 95th percentile of pooled *Enterococci* spp. concentrations was <40 MPN/100 mL	■
Algal biotoxins	Phytoplankton (cell concentration)	EQG	The toxic algal species of concern (*Karenia brevis, Lyngbya majuscula* and *Pfiesteria* spp.) were not recorded	■

Note:

1. Green (■) symbols indicate the Environmental Quality Criteria (EQC) were met; amber (■) and red (■) symbols represent an exceedance of the Environmental Quality Guideline or Environmental Quality Standard (EQS), respectively.

Introduction

Document purpose

Water Corporation is required to ensure that the discharge of treated wastewater (TWW) from the Bunbury wastewater treatment plant (WWTP) to the marine environment is environmentally sustainable and managed appropriately for the protection of ecosystem and social values. To meet this outcome, Water Corporation undertake their operations in accordance with environmental commitments and Licence Conditions that are outlined in Ministerial Statement (MS) 572.

The Bunbury Operations Environmental Management program and the Marine Impacts Monitoring and Management Plan (MIMMP; Water Corporation 2012) for the Bunbury Ocean Outlet were designed according to Schedule 2 (Proponent's Environmental Management Commitments) of MS 572. The monitoring for the 2018–2019 reporting period was carried out in accordance with the methods and criteria included in Water Corporation (2012).

This report describes the results and outcomes of the 2018–2019 Bunbury Ocean Outlet Monitoring (BOOM) program field surveys. The program aims to determine the chemical and physical properties of the TWW plume and to determine the effects of TWW discharge on the receiving marine environment.

Wastewater treatment plant infrastructure

Ocean disposal of TWW from the Bunbury WWTP commenced in July 2002. The Bunbury WWTP primarily services the City of Bunbury and had an annual average daily inflow of 11.14 ML over the 2018–2019 reporting period. Prior to disposal, the wastewater is treated using microbial processes to reduce concentrations of nitrogen via an intermittently decanting extended aeration plant. These processes produce secondary TWW and biosolids.

The ocean outlet is located ~7 km south of the Bunbury Central Business District, south-west Western Australia (Figure 1). TWW is discharge via a sub-sea diffuser 1.7 km due west of the shoreline (Water Corporation 2012). The freshwater TWW is less dense than seawater and forms a buoyant plume that rises through the water column and mixes as it ascends.

Figure 1 Location of the Bunbury wastewater treatment plant and ocean outlet

Conditions of operation

The Bunbury WWTP operates in accordance with Conditions outlined in MS 572. Conditions 6.1 and 6.2 of MS 572 include a requirement to ensure the ecological and social health objectives are met in their respective management areas.

Environmental Quality Management Framework

Monitoring was completed according to Western Australia's Environmental Quality Management Framework (EQMF; EPA 2016). The EQMF is based on:

- identifying **Environmental Values** (EVs) (Figure 2)
- establishing and spatially defining **Environmental Quality Objectives** (EQOs) that need to be maintained to ensure the associated EVs are protected (Figure 2)
- monitoring and managing to ensure the EQOs are achieved and/or maintained in the long-term in the areas they have been designated
- establishing Environmental Quality Criteria (EQC) which are quantitative benchmarks or 'trigger values' against which monitoring results can be compared.

There are two levels of EQC:

1. Environmental Quality Guidelines (EQGs) are quantitative, investigative triggers which, if met, indicate there is a high degree of certainty the associated EQO has been achieved. If the guideline is not met a more detailed assessment against the EQS is triggered.
2. Environmental Quality Standards (EQSs) are management triggers which, if exceeded, signify the EQO is at risk of not being met and that a management response may be required.

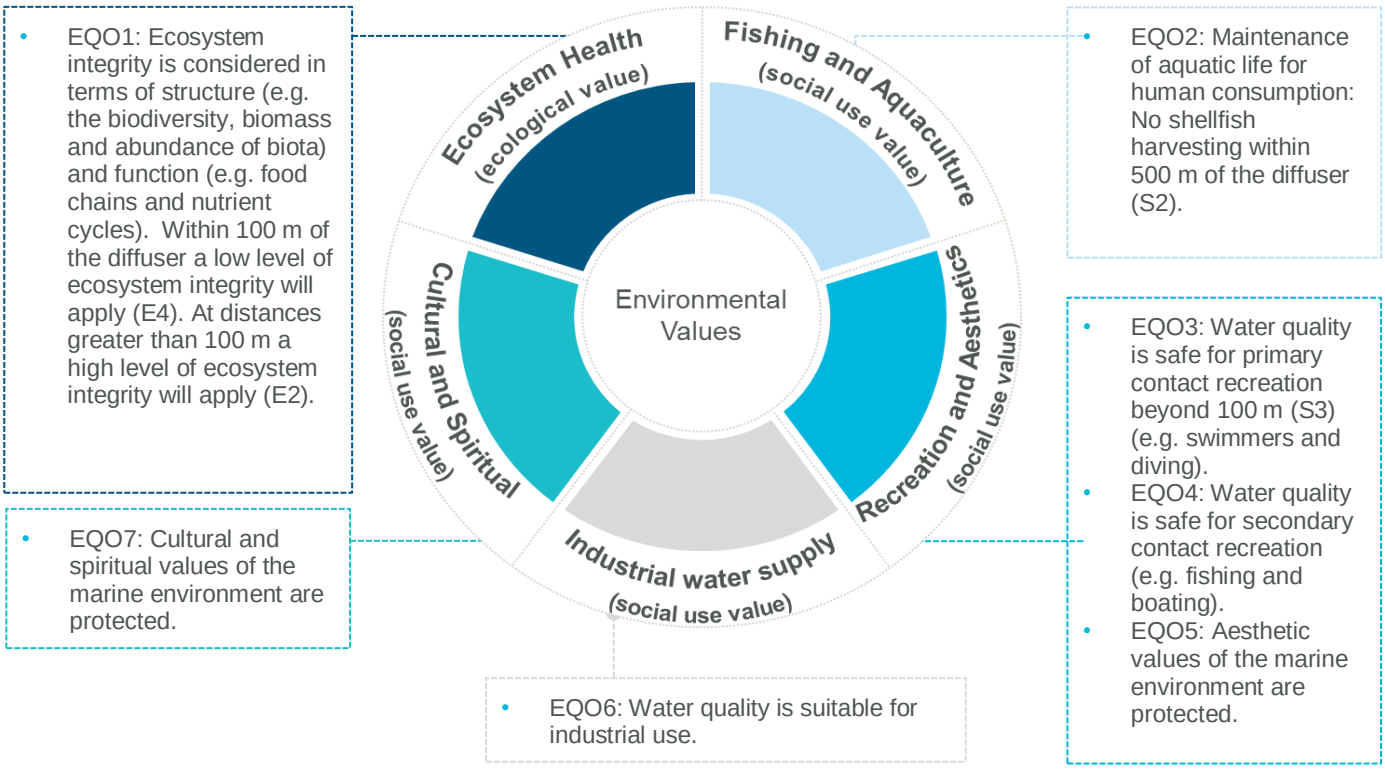


Figure 2 Environmental Values and Environmental Quality Objectives (EQO) for the marine waters of Western Australia

BOOM program framework

MS 572 requires that the EVs Ecosystem Health and Recreation and Aesthetics are maintained and the associated EQOs (EQO1, EQO3, EQO4 and EQO5; Figure 2) are met within 100 m of the Bunbury TWW ocean outlet (Figure 3). MS 572 requires that the EV Fishing and Aquaculture is maintained and the associated EQOs (EQO2 Figure 2) are met within 500 m of the Bunbury TWW ocean outlet (Figure 3).

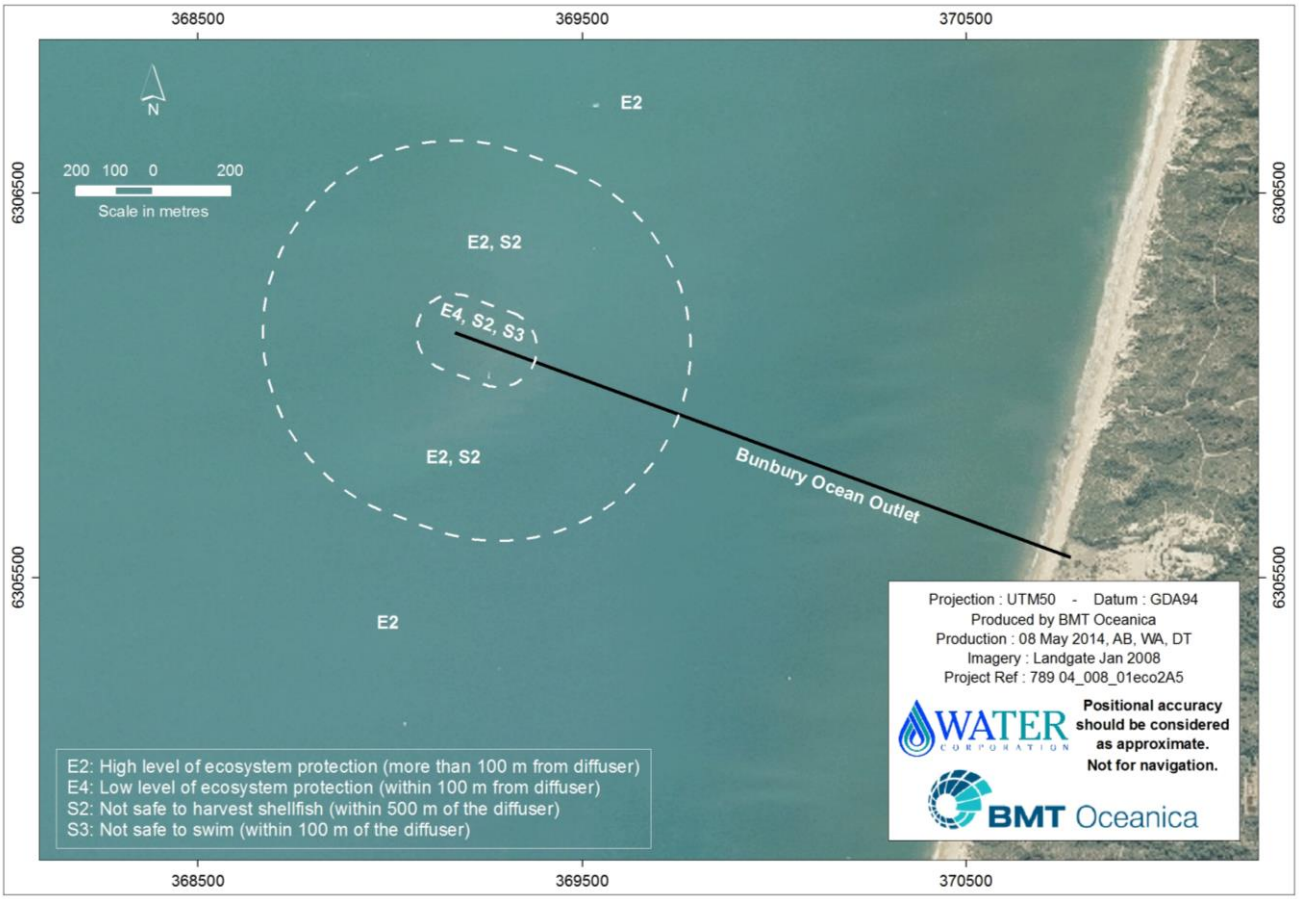


Figure 3 Environmental management areas as defined in Schedule 1 of Ministerial Statement 572

'Maintenance of ecosystem integrity' EQO

The intent of this EQO is to maintain a healthy and diverse ecosystem. The EQO is applies a designated level of ecological protection: low, moderate, high or maximum (Figure 4). A low level of ecological protection applies in the low ecological protection area (LEPA) occupying the area within a 100 m radius of the diffuser at the Bunbury outfall. Waters outside the LEPA are designated as a high ecological protection area (HEPA) and maintained to a high level of ecological protection.

The extent to which the EQO for the Maintenance of Ecosystem Integrity was met during the 2018–2019 reporting period is assessed against the EQC for waste stream characterisation (i.e. toxicants in TWW) and the EQC for receiving waters (i.e. water quality and seagrass health).

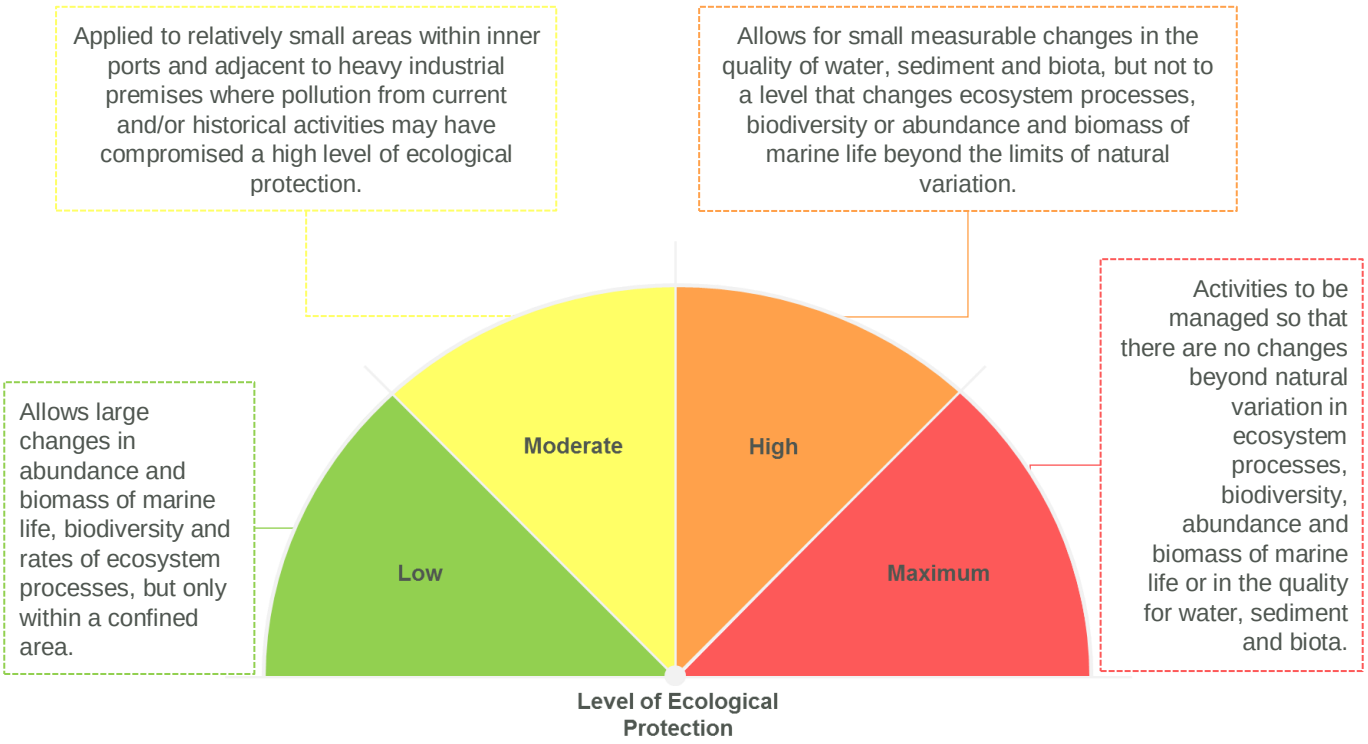


Figure 4 Level of Ecological Protection

'Maintenance of aquatic life for human consumption' EQO

The intent of this EQO is to maintain aquatic life safe for human consumption (a social value) with the exception of a small area surrounding the ocean outlet within 500 m of the diffuser (S2; Figure 3), where shellfish may be unsafe to eat.

'Maintenance of primary and secondary contact recreation' EQO

Primary contact recreation will be maintained outside 100 m of the diffuser (S3; Figure 3). Secondary contact recreation is not to be affected by the presence of the Bunbury ocean outlet. As the EQO for maintenance of primary contact recreation uses a higher water quality standard than secondary contact recreation, it is assumed that if the primary contact criteria are met, then the secondary contact criteria are also met by default.

Waste stream monitoring

Monitoring of TWW prior to discharge consisted of:

- TWW flows
- monthly TWW characterisation
- annual comprehensive TWW characterisation
- initial dilution monitoring.

Treated wastewater flows

The Licence allows inflow to the WWTP to serve as a surrogate for discharge volume. The monthly cumulative and average daily flow data are determined using a magflow meter measuring raw wastewater inflow into the treatment plant.

Inflow to the plant increased between May 2000 and December 2008. A decline in the inflow between 2008 and 2011 was due to a change from extrapolating inflows to the use of calibrated flow meters. Since 2011, the daily inflow has fluctuated (blue line in Figure 5), while the daily average for the year (red line in Figure 4) has generally increased. The notable increase to inflows from January 2017 onwards is attributable to the diversion of approximately 50% (or 2 ML/day) of the inflow from Kemerton WWTP to Bunbury WWTP (R Munro, pers. comm., 3 October 2018).

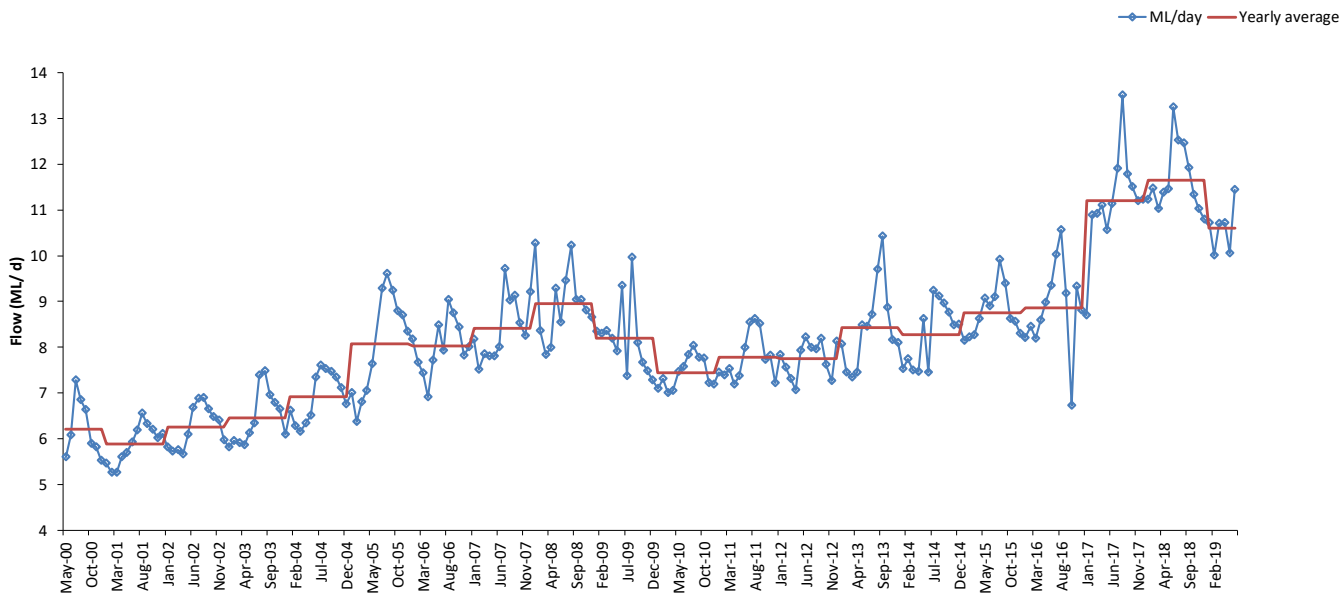


Figure 5 **Mean daily flow volumes of treated wastewater measured between May 2000 and June 2019**

Monthly treated wastewater characterisation

TWW from Pond 2 Discharge Weir was sampled on the second Tuesday of each month by Water Corporation and analysed for:

- total ammonium
- filtered biochemical oxygen demand (BOD)
- conductivity at 25 C
- total suspended solids (TSS)
- total nitrogen (TN)
- total phosphorus (TP)
- Nitrate and nitrite (NOx)
- Escherichia coli (E. coli)

This regulatory monthly sampling is carried out in accordance with Bunbury No.2 WWTP operating licence L5972/1922/14. The operating licence limit for total phosphorus of 10 mg/L was met during the July 2018–June 2019 reporting period (Table 1). All other discharge limits in the Schedule 1 Table of MS 572 (suspended solids, biochemical oxygen demand, total nitrogen and total nitrogen load), and are reported separately.

Table 1 Regulatory monthly parameter results from Pond 2 Discharge Weir

Month	Total ammonium	Filtered BOD	TSS	TN	TP	pH	NOx	E. coli
LoR	**NA**	**<5**	**<5**	**NA**	**NA**	**NA**	**NA**	**NA**
Jul 18	13	<5	<5	17	2.1	7.9	2.0	24000
Aug 18	9.7	<5	<5	16	2.2	8.0	1.6	>24000
Sept 18	10	<5	5	17	3.1	7.8	3.1	13000
Oct 18	8.0	<5	<5	16	4.6	7.8	5.4	>24000
Nov 18	4.5	<5	<5	13	4.9	7.7	5.5	9200
Dec 18	3.3	<5	<5	10	5.3	7.8	5.0	9800
Jan 19	2.8	<5	5	13	7.7	7.6	7.4	20000
Feb 19	1.6	<5	10	12	5.6	7.8	7.8	16000
Mar 19	1.5	<5	<5	8.8	3.3	7.8	5.2	16000
Apr 19	1.5	<5	<5	9.8	3.6	7.8	6.8	24000
May 19	6.9	<5	<5	12	5.8	7.8	3.5	>24000
Jun 19	3.8	<5	<5	8.3	4.9	7.7	2.2	6900
Mean	**5.6**	**<5**	**NA**	**12.7**	**4.4**	**7.8**	**4.6**	**NA**

Note:

1. LoR = Limit of reporting, BOD = biological oxygen demand, TSS = total suspended solids, TN = total nitrogen, TP = total phosphorus, NOx = nitrate+nitrite, E. coli = Escherichia coli, NA = not applicable.

Comprehensive treated wastewater characterisation

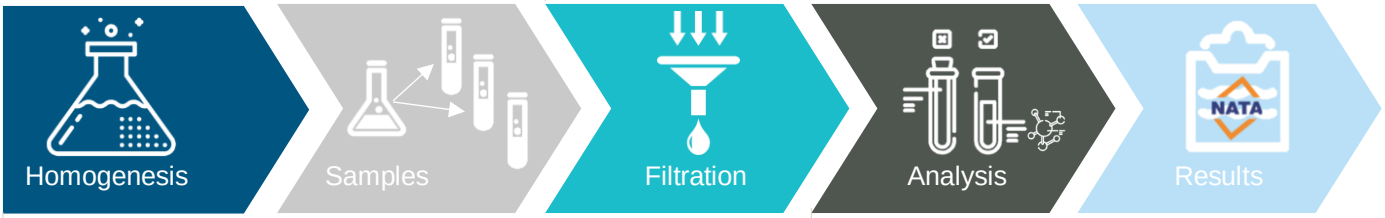
TWW (final effluent) from the Bunbury WWTP was analysed for a suite of potential contaminants of concern:

- ammonium as nitrogen
- NOx as nitrogen
- TP

- TSS
- BOD (5-day)
- salinity
- metals (Ag, As, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Se, Zn)
- pesticides
- herbicides

A 24-hour flow weighted composite sample was obtained from the Bunbury WWTP on 16 January 2019.

Samples for bioavailable metals were filtered through a 0.45 µm filter prior to analyses.



The bulk sample was homogenised (agitated), split into individual sample containers and sent to a National Association of Testing Authorities (NATA)-accredited laboratory for analysis.

Samples were handled according to the NATA accredited laboratory requirement. Analyses were completed using NATA-accredited methods.

Initial dilution monitoring

The MIMMP requires the initial dilution of TWW to be estimated using two different methods: (i) using an internationally recognised mixing model (in this case VPLUMES) simulation of the conditions at the time of sampling, and (ii) using the concentrations of nutrients within TWW compared to the in-water estimates at the time of sampling (Water Corporation 2012). The most conservative (lowest) estimate of the two is used in further calculations and comparisons (Water Corporation 2012).

Initial dilution using model simulation

Initial dilution modelling (using plume dispersion model VPLUMES) was used to predict the near-field dilution of the wastewater plume around the Bunbury TWW ocean outlet. Initial dilution is the dilution between the point of discharge and the point of maximum rise or fall of the plume (in this case when the buoyant plume reaches the surface).

On 16 January 2019 (concurrent to the first summer water quality survey), ambient data (i.e. temperature and flow) were collected for input into the plume dispersion model. To determine the current velocity and direction at the time of sampling, a surface drogue was released above the outlet diffusers and the location of the drogue recorded at intervals over time using an on-board Global Positioning System. Surface current velocities were used to synthesise a vertical velocity profile based on the gradient determined by current meters deployed at 2 m and 7.5 m above the seabed ~900 m offshore from the diffuser at the Bunbury TWW ocean outlet (WNI 2000).

Modelling using VPLUMES indicated an average initial dilution of 1:607 and a centreline dilution of 1:283 on 16 January 2019 (Figure 6). The full model output is included in Appendix A.

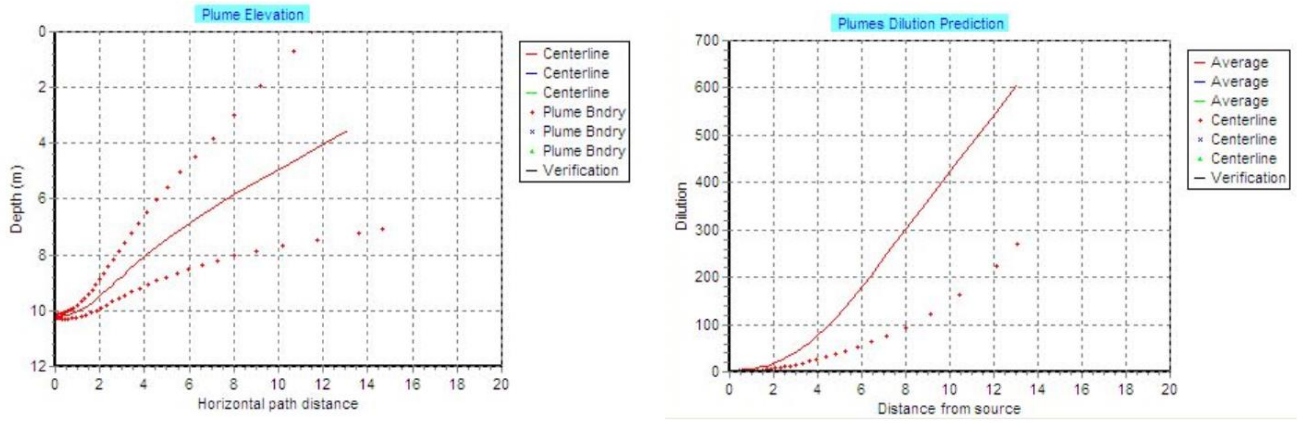


Figure 6 **Initial dilution modelling output showing predicted plume elevation trajectory (left) and predicted average and centreline dilutions (right)**

Initial dilution using nutrient concentrations within TWW

The lowest dilution expected to occur at the Bunbury TWW outlet based on dilution of nitrate and nitrite was 1:521 (Table 2). This is the most conservative estimate of initial dilution (more conservative than the average initial dilution modelled via VPLUMES of 1:607) and it will be used in calculations below.

Table 2 **Minimum initial dilution achieved for total ammonia, nitrate+nitrite and total phosphorus**

Parameter	Undiluted TWW concentration	Surface maximum	Surface background	Minimum initial dilution achieved
Total ammonia	2400	4	1.5	960
Nitrate+nitrite	7300	15	1	521
Total phosphorus	7000	12	1.2	648

Notes:

1. Highest surface concentration recorded at the nutrient dilution sites.
2. Average surface concentration of five reference sites (WQR1–WQR5); where this value was <LoR, the LoR was used to calculate the average surface concentration.
3. Minimum initial dilution = treated wastewater (TWW) concentration/(Surface Maximum – Surface Background).

Bioaccumulating toxicants

The EQG for bioaccumulating toxicants (cadmium and mercury) in the TWW is outlined in Table 3.

Table 3 **Environmental Quality Guideline for bioaccumulating toxicants**

EQG	Concentrations of contaminants will not exceed the ANZECC/ARMCANZ (2000) 80% species protection guideline trigger levels for bioaccumulating toxicants in wastewater stream before dilution

Source: Water Corporation (2012)

Concentrations of cadmium and mercury (i.e. bioaccumulating toxicants) in the TWW sample before dilution were both below the analytical limit of reporting (and the ANZECC/ARMCANZ (2000) 80% species protection guideline trigger levels) and the EQG for bioaccumulating toxicants was met (Table 4).

Non-bioaccumulating toxicants

Non-bioaccumulating toxicant concentrations were generally below the analytical limit of reporting and the ANZECC/ARMCANZ 99% species protection guidelines with the exception of ammonia, copper and zinc (Table 4). After initial dilution of 1:521 (a conservative estimate of the dilution expected at the LEPA

boundary; Appendix A), contaminant concentrations of ammonia, copper and zinc were below ANZECC/ARMCANZ (2000) 99% species protection guidelines (Table 4) and the EQG for non-bioaccumulating toxicants was met.

Table 4 Toxicants in the Bunbury TWW compared with relevant guideline trigger levels after initial dilution

Toxicant	Bunbury TWW concentration (µg/L)	Concentration after initial dilution (µg/L)[1]	Trigger (µg/L)[2]
Ammonia-N	**2400**	6.1	500
Nitrate+Nitrite	7300	–	ID
Total phosphorus	7000	–	n/a
Total suspended solids	**6000**	–	<10[3]
Arsenic	<20	–	
Cadmium*	<0.6	–	36
Chromium*	<1	–	0.14 (Cr VI)
Copper*	**3**	0.09	0.3
Lead*	<10	–	2.2
Mercury*	<0.1	–	1.4
Nickel*	<7	–	7
Selenium	<20	–	
Silver*	<10	–	0.8
Zinc*	**64**	0.3	7
Molybdenum	<4	–	ID
Salinity (psu)	0.3	–	n/a
BOD	<5	–	n/a
Chloropyrifos	<0.1	–	0.0005
Endrin	<0.01	–	0.004
Endosulfan sulfate	<0.01	–	0.005

Notes:

1. Initial dilution = 1:521. Contaminant dilution calculations were not performed (–) on any toxicants where concentrations were below the analytical limit of reporting or where the 99% species protection guideline value was not the trigger (i.e. cadmium, mercury and total suspended solids).
2. Assessment against ANZECC/ARMCANZ (2000) 99% species protection guidelines for non-bioaccumulating toxicants; guideline values for marine waters.
3. Guideline value for the protection of aquaculture species in saltwater production (ANZECC/ARMCANZ (2000))
4. The bioaccumulating toxicants cadmium and mercury must meet the 80% species protection guidelines at the diffuser (i.e. prior to initial dilution), and therefore a diluted concentration was not calculated.
5. ID = insufficient data to derive a reliable national trigger value.
6. Amber bold text represents an exceedance of guideline values prior to initial dilution.

Total toxicity of the mixture

The potential for additive toxic effects of TWW to marine organisms at the edge of the initial mixing zone (i.e. after initial dilution of the TWW with seawater) was assessed as per the ANZECC/ARMCANZ (2000) calculation for the total toxicity of the mixture (TTM). TTM is a relative score and consequently does not have a unit of measurement. The EQG for the TTM is outlined in Table 5.

Table 5 Environmental Quality Guideline for the Total Toxicity of the Mixture (TTM)

EQG	Where there are mixtures of toxicants, the TTM at a single site or for a defined area, should not exceed 1, using the TTM formula.

Notes:

1. EQG = environmental quality guideline; TTM = total toxicity of the mixture
2. TTM = Σ(Ci/EQGi) where Ci is the concentration of the 'i'th component in the mixture and the EQGi is the guideline for that component.

The TTM following minimum initial dilution of 1:521 was 0.34 (Table 6) and was below the ANZECC/ARMCANZ (2000) guideline, meeting the EQG. As such, it is not expected that the combined additive effect of these contaminants will have an adverse effect on marine flora and fauna on the area surrounding the Bunbury TWW ocean outlet.

Table 6 Total toxicity of treated wastewater (TWW) at the edge of the initial mixing zone associated with the Bunbury ocean outlet

Natural concentrations in Perth's coastal waters			Initial dilution of TWW with seawater	Total toxicity of the mixture (TTM)
Ammonia	Copper	Zinc		
1.5	0.08	0.15	1:521	0.34

Notes:

1. Background concentrations for copper and zinc from McAlpine et al. (2005); Perth marine waters (99. 19; Table 12). Surface background concentration for ammonia calculated as the average surface concentration of the five reference sites (WQR1-WQR5); where this value was less than the limit of reporting (LoR), half the LoR was used in calculations.
2. TMM = [ammonia]/guideline + [copper]/guideline + [zinc]/guideline.

Water quality monitoring – receiving environment

Water Corporation (2012) requires the assessment for indicators of nutrient enrichment and physico-chemical stress in receiving waters. Indicators of nutrient enrichment that were measured in receiving waters to assess marine water quality are:

- Surface chlorophyll-a
- Phytoplankton biomass
- Light attenuation coefficient (LAC)
- Periphyton
- Seagrass shoot density.

Dissolved oxygen (DO) was measured and is the primary indicator of physico-chemical stress.

Sampling procedures were followed at compliance monitoring, plume tracking, periphyton monitoring and seagrass health sites over the summer monitoring period (Appendix B). Nutrients, phytoplankton biomass, light attenuation and the physico-chemical stressor DO were monitored during three separate surveys on 16 January, 6 February and 19 March 2019, along a down-current gradient away from the diffuser (Appendix B). Periphyton was monitored using collector plates deployed from 17 January to 15 February 2019 (Appendix B). Seagrass health was monitored through measuring shoot density on 17 and 18 January 2019 (Appendix B).

Nutrient concentrations (ammonia, ortho-phosphate, nitrate+nitrite) in receiving waters were measured with distance from the outlet (to test for nutrient gradients), for contextual purposes only (see Appendix C for results).

Nutrient enrichment

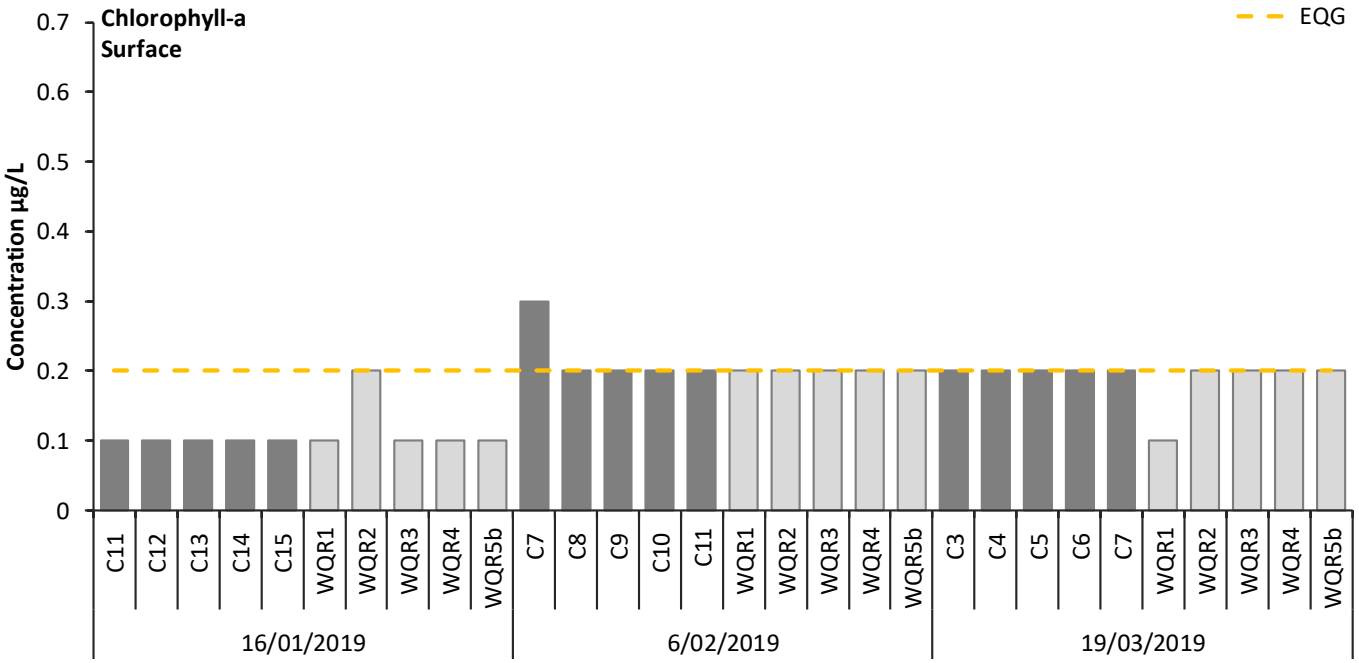
Surface water chlorophyll-a

The EQG for surface water chlorophyll-a is outlined in Table 7.

Table 7 Environmental quality guideline for surface water chlorophyll-a

EQG	The median surface chlorophyll-a concentration at the boundary of the LEPA is not to exceed the 80th percentile of historical reference site data.

Chlorophyll-a in surface waters ranged from 0.1 to 0.3 µg/L across all sites (Figure 7). The median chlorophyll-a concentration in surface waters for compliance monitoring sites was 0.2 µg/L. This was equal to the 80th percentile of historical reference site data (0.2 µg/L from 2003–2018; yellow dashed line in Figure 7), meeting the EQG for surface water chlorophyll-a



Notes:

1. Water quality monitoring occurred at compliance sites C11–C15 on 16 January, C7–C11 on 6 February and C3–C7 on 19 March 2019, as a result of the prevailing currents at the time of sampling.
2. Dark grey bars indicate sites relevant to the Environmental Quality Guideline (EQG) for phytoplankton biomass.
3. Surface chlorophyll-a was measured 1 m below the surface.
4. Yellow dashed line represents the 80th percentile of historical reference site data (0.2 µg/L = the Environmental Quality Guideline).

Figure 7 Surface chlorophyll-a concentrations at compliance and reference sites in 2019 around Bunbury ocean outlet

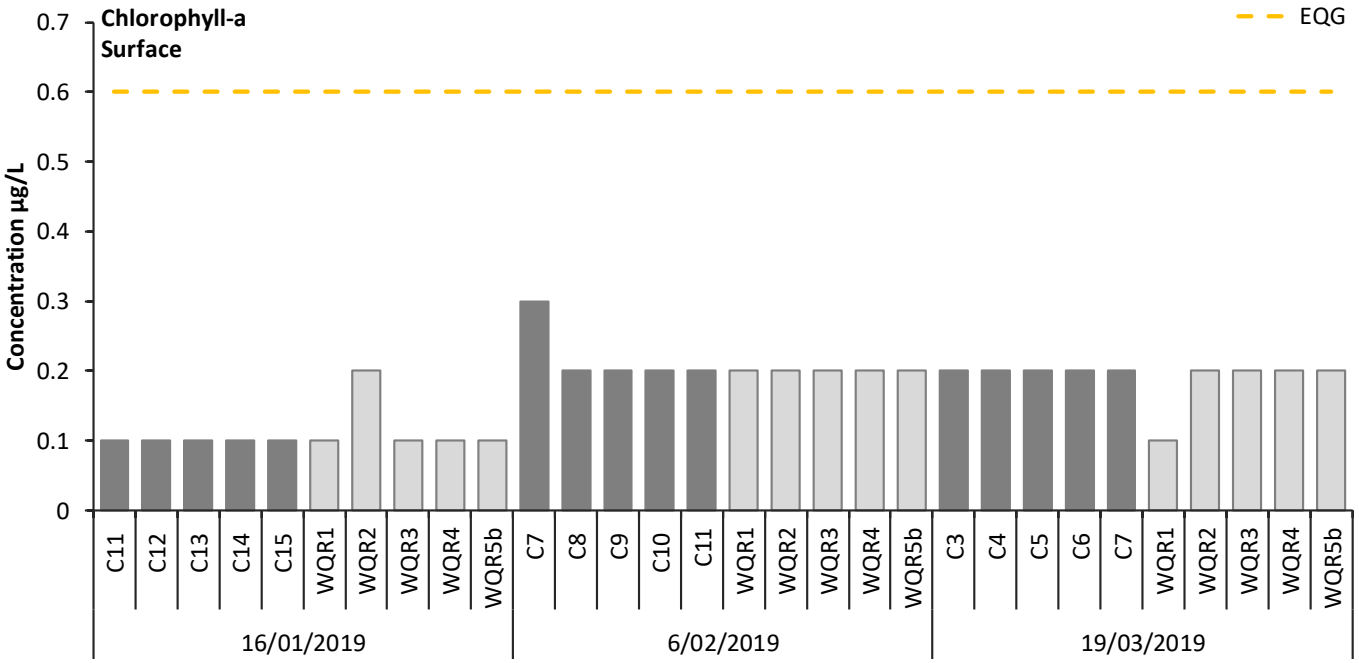
Phytoplankton biomass

The EQG for phytoplankton biomass (also measured as concentration of chlorophyll-a) is outlined in Table 8.

Table 8 Environmental quality guideline for phytoplankton biomass

EQG	Phytoplankton biomass (measured as chlorophyll-a concentration) does not exceed three times the median of chlorophyll-a concentrations of historical reference site data, on any occasion, during the non-river flow period

Phytoplankton biomass (measured as chlorophyll-a) ranged from 0.1-0.3 µg/L at compliance sites and did not exceed three times the median of historical reference site data (0.6 µg/L) at any site during 2019 (Figure 8), meeting the EQG for phytoplankton biomass.



Notes:

1. Water quality monitoring occurred at compliance sites C11–C15 on 16 January, C7–C11 on 6 February and C3–C7 on 19 March 2019, as a result of the prevailing currents at the time of sampling.
2. Dark grey bars indicate sites relevant to the Environmental Quality Guideline (EQG) for phytoplankton biomass.
3. Surface chlorophyll-a was measured 1 m below the surface.
4. Yellow dashed line represents 3 times the median chlorophyll-a concentration of historical reference site data which is the EQG for phytoplankton biomass.

Figure 8 Phytoplankton biomass at compliance and reference sites in 2019 around Bunbury ocean outlet

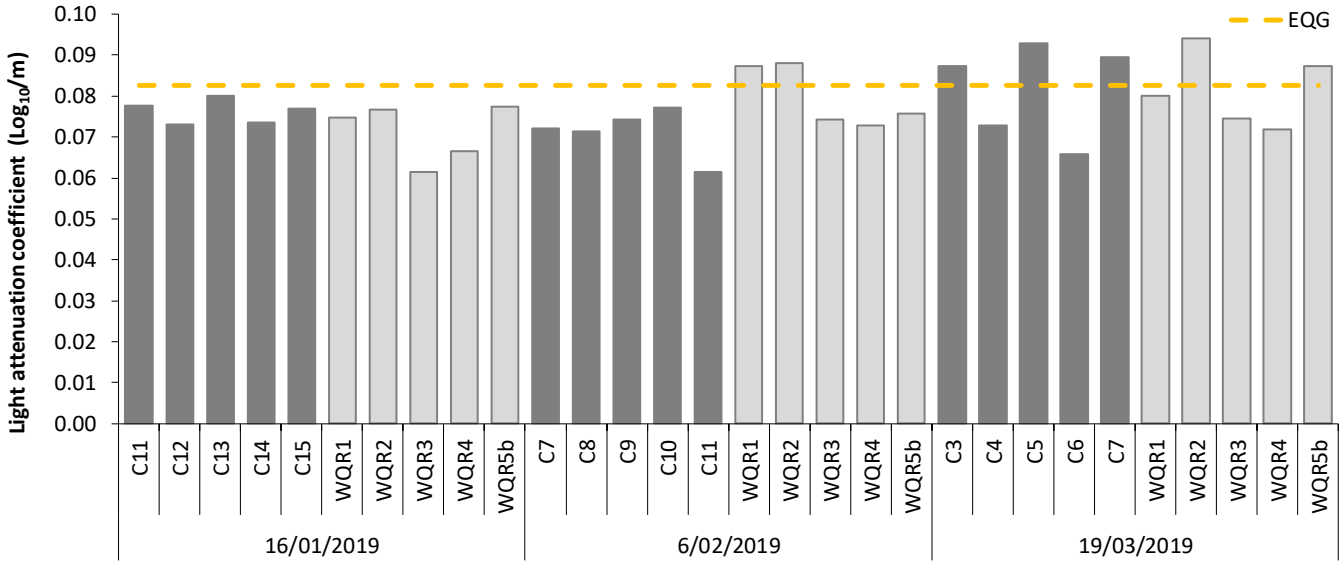
Light attenuation coefficient

The EQG relevant to the LAC is outlined in Table 9.

Table 9 Environmental Quality Guideline for light attenuation

EQG	The median LAC, during the summer period, is not to exceed 80th percentile of historical reference site data.

Median LAC measured over summer at compliance sites (0.0744 Log_{10}/m) did not exceed the 80th percentile of historical reference site data (0.0825 Log_{10}/m), meeting the EQG for this indicator (Figure 9).



Notes:

1. Water quality monitoring occurred at compliance sites C11-C15 on 16 January, C7-C11 on 6 February and C3-C7 on 19 March, as a result of prevailing currents at the time of sampling.
2. Dark grey bards indicate sites relevant to the Environmental Quality Guideline (EQG) for light attenuation; median of which is 0.0744 Log_{10}/m.
3. Yellow dashed line is 80th percentile of historical reference site data which is the Environmental Quality Guideline (0.0825 Log_{10}m).

Figure 9 Light attenuation coefficient measured at compliance and reference sites in 2019

Periphyton biomass

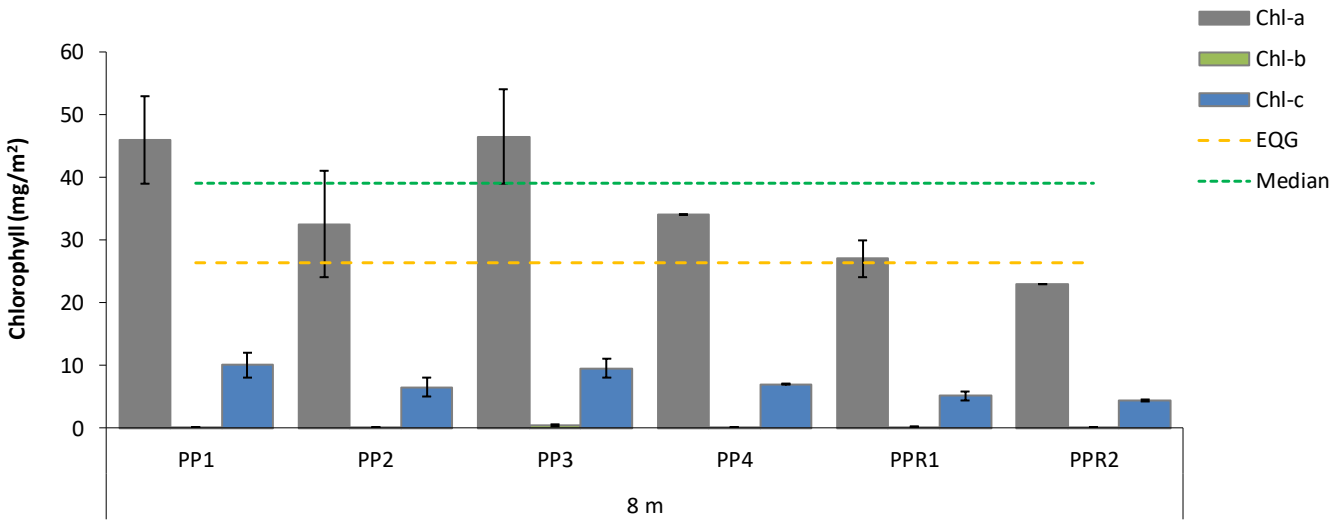
Periphyton collectors provide a time-integrated measure of attached algal growth (epiphytes). Increased periphyton biomass on artificial substrata (measured as chlorophyll-a, -b and -c) in response to nutrient enrichment has been confirmed as an indicator of enhanced productivity resulting from wastewater discharge in Perth's coastal waters (Cosgrove et al. 2004). The EQG for periphyton biomass is in Table 10.

Table 10 Environmental Quality Guideline for periphyton biomass

EQG	Median periphyton biomass (measured as chlorophyll a) from compliance sites is not to exceed the 80th percentile of reference site data from the same sampling period at 8 m depth.

The median chlorophyll-a concentration for the 8 m depth was 39 mg/m^2 and exceeded the 80th percentile of reference site data at the 8 m depth (26.4 mg/m^2) (Figure 10). Therefore, the EQG was not met and further assessment against the EQS (seagrass health) was triggered.

Of the three chlorophyll types (chlorophyll-a, -b and -c) measured on periphyton collector plates, chlorophyll-a was present in the highest biomass, followed by chlorophyll-c and then chlorophyll-b (Figure 9). The more dominant chlorophyll-a and chlorophyll-c content are indicative of a periphyton assemblage dominated by diatoms and/or brown algae (SKM 1999).



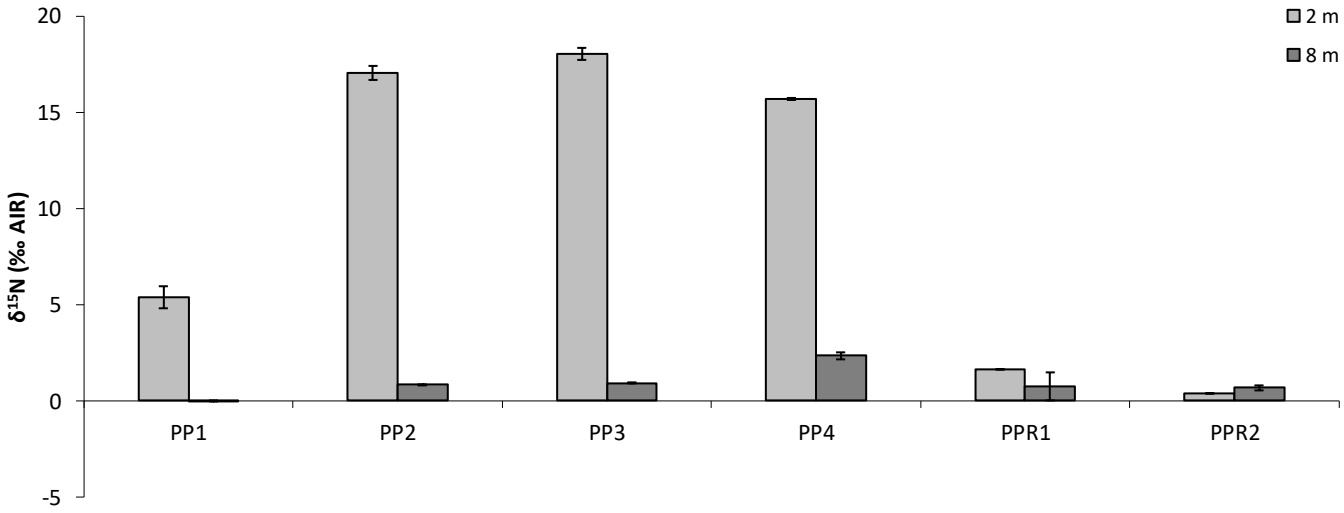
Notes:

1. Bars=mean (± standard error) chlorophyll-a, -b and -c concentration at compliance sites (PP1-PP4) and reference sites (PPR1 and PPR2).
2. Green dashed line = median of chlorophyll-a concentration across compliance sites (39 mg/m^2 pooled across n=8).
3. Yellow dashed line = 80th percentile of chlorophyll-a concentration at reference sites (26.4 mg/m^2 where n=4).

Figure 10 Periphyton chlorophyll-a, -b and -c content at compliance and reference sites at 8m depth

Assimilation of dissolved nitrogen from wastewater by periphyton generally leads to a higher tissue nitrogen stable isotope analysis (δ15N) in microalgae than that associated with the assimilation of naturally occurring nitrogen from seawater (Costanzo et al. 2001). Therefore, the nitrogen isotopic signature of periphyton can be used as evidence that elevated periphyton growth may have been stimulated from nutrients in wastewater (Costanzo et al. 2001, DALSE 2003). Accordingly, the periphyton samples were analysed for nitrogen isotopic composition, to determine if the periphyton growth patterns can be attributed to nutrient-rich wastewater around the Bunbury TWW ocean outlet.

Mean δ15N was higher in surface samples at all compliance sites (PP1–PP4), compared to surface samples from the two reference sites (PPR1 and PPR2) (Figure 11). At each site, mean δ15N of periphyton was higher in the surface samples than for the bottom samples, with the exception of reference site PPR2 (Figure 11). δ15N in bottom water samples is very low compared to surface samples and similar to the reference sites. The high periphyton δ15N at the surface but not in bottom samples suggests that the influence of the buoyant TWW plume is restricted to the surface and evidently not responsible for the elevated bottom water chlorophyll-a concentrations at compliance sites.



Notes:

1. PP1-PP4 = periphyton compliance sites; PPR1 and PPR2 = periphyton reference sites
2. At 2m depth PPR1 and PPR2 only had 1 replicate (due to low epiphyte growth). At all other sites and depths there was sufficient epiphyte growth on the collector plates for 2 replicates.
3. Error bars represent ± standard error.

Figure 11 Mean δ15 content in periphyton collected at compliance and reference sites

Seagrass health

The EQG for periphyton biomass was exceeded during the 2019 monitoring and assessment against the EQS (seagrass health) was required. The EQS for seagrass health are outlined in Table 11.

Table 11 Environmental Quality Standards for seagrass health

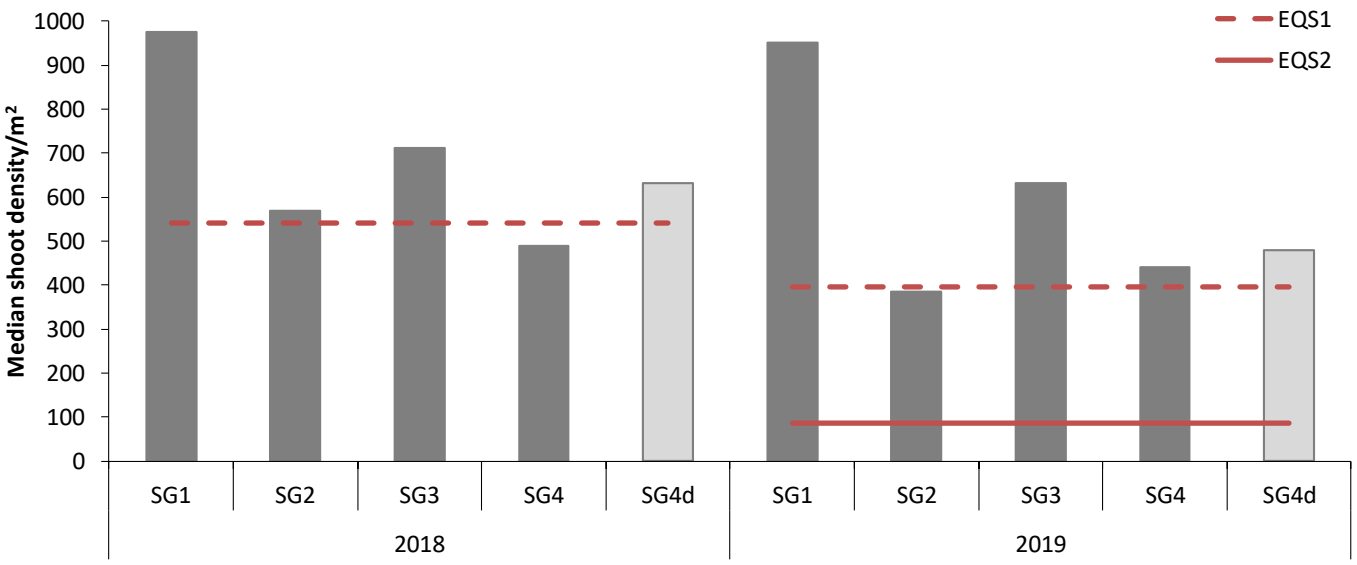
EQS1	Median seagrass meadow shoot density measured during January and in two consecutive years is greater than the 20th percentile of shoot density measured at an appropriate reference site.
EQS2	Median seagrass meadow shoot density in any one year is greater than the 5th percentile of meadow shoot density measured at an appropriate reference site.

Note:

1. The EPA derived these EQS for seagrass shoot density specifically relevant for assessing the health of species of *Posidonia* (EPA 2005).

EQS1 is exceeded if median shoot density at the same site over two consecutive years fall below the 20th percentile of reference sites (red dashed line; Figure 12). Although median shoot density was individually below the 20th percentile of reference sites (red dashed line; Figure 12) in 2018 at SG4 and in 2019 at SG2, median shoot density did not fall below the EQS1 at any site, in the two consecutive years of 2018 and 2019. Therefore, EQS1 was met.

In 2019, at all sites, the median shoot density was greater than the 5th percentile of the pooled reference site data (red solid line; Figure 12), meeting EQS2. These results suggest seagrass health is not compromised at the Bunbury ocean outlet.



Notes:

1. EQS for seagrass shoot density specifically relevant for assessing the health of species of *Posidonia* (as set by EPA 2005 outlined in Water Corporation 2012).
2. Dark grey bars indicate sites relevant to the Environmental Quality Standard (EQS) for seagrass health.
3. Red dashed line = EQS1 = 20th percentile of shoot density at reference sites, in that year.
4. Red solid line = EQS2 = 5th percentile of shoot density at reference sites, in that year.
5. 2018 data from BMT 2018.

Figure 12 Median seagrass shoot density at seagrass health monitoring sites (n=10)

Physico-chemical stressor

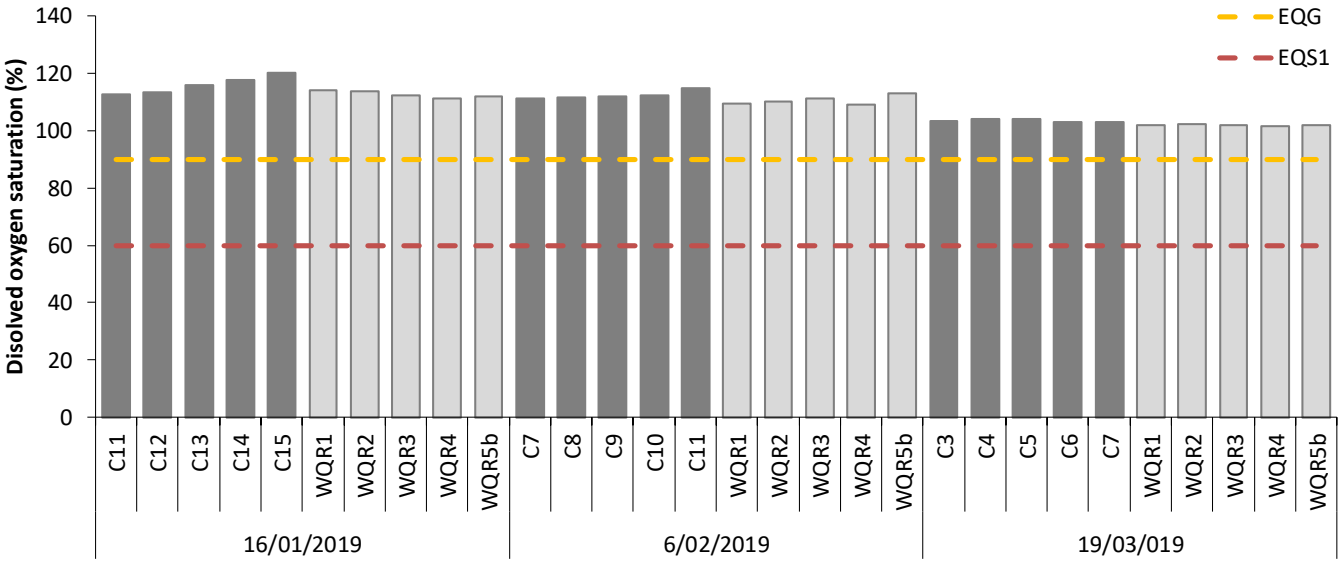
Dissolved oxygen

The EQG for DO is outlined in Table 12.

Table 12 Environmental Quality Guideline for dissolved oxygen

EQG	Ambient dissolved oxygen in bottom waters (0-0.5 m above the sediment surface) is greater than 90% saturation at any site for a defined period of not more than six weeks.

Percent saturation of dissolved oxygen in the bottom remained above the 90% saturation limit at compliance monitoring sites, at all times, meeting the EQG (Figure 13).



Notes:

1. Water quality monitoring occurred at compliance sites C11-C15 on 16 January, C7-C11 on 6 February and at C3-C7 on 19 March 2019, as a result of prevailing currents at the time of sampling.
2. Dark grey bars indicate sites relevant to the Environmental Quality Guideline for dissolved oxygen (DO).
3. Amber and ref dashed lines equate to the EQG and EQS for DO, respectively.
4. DO was measured from the seabed to 0.5 m above seabed.

Figure 13 Dissolved oxygen in bottom waters at compliance and reference sites

Seafood safe for human consumption

Sampling approach and site locations

The EQO for the EV 'Fishing and Aquaculture' is aimed at ensuring that seafood is safe for human consumption. To ensure the EQO is met, thermotolerant coliforms (TTC) and algal biotoxins are monitored. The social health EQO of 'Seafood Safe for Human Consumption' must be met at the boundary of the Shellfish Harvesting Exclusion Zone (SHEZ, or S2 area), represented by a concentric ring 500 m from the diffuser (Figure 14). Shellfish compliance monitoring sites (C17–C32) are positioned at the boundary of the SHEZ, but only the five compliance sites directly down-current of the outlet are sampled during each monitoring period.

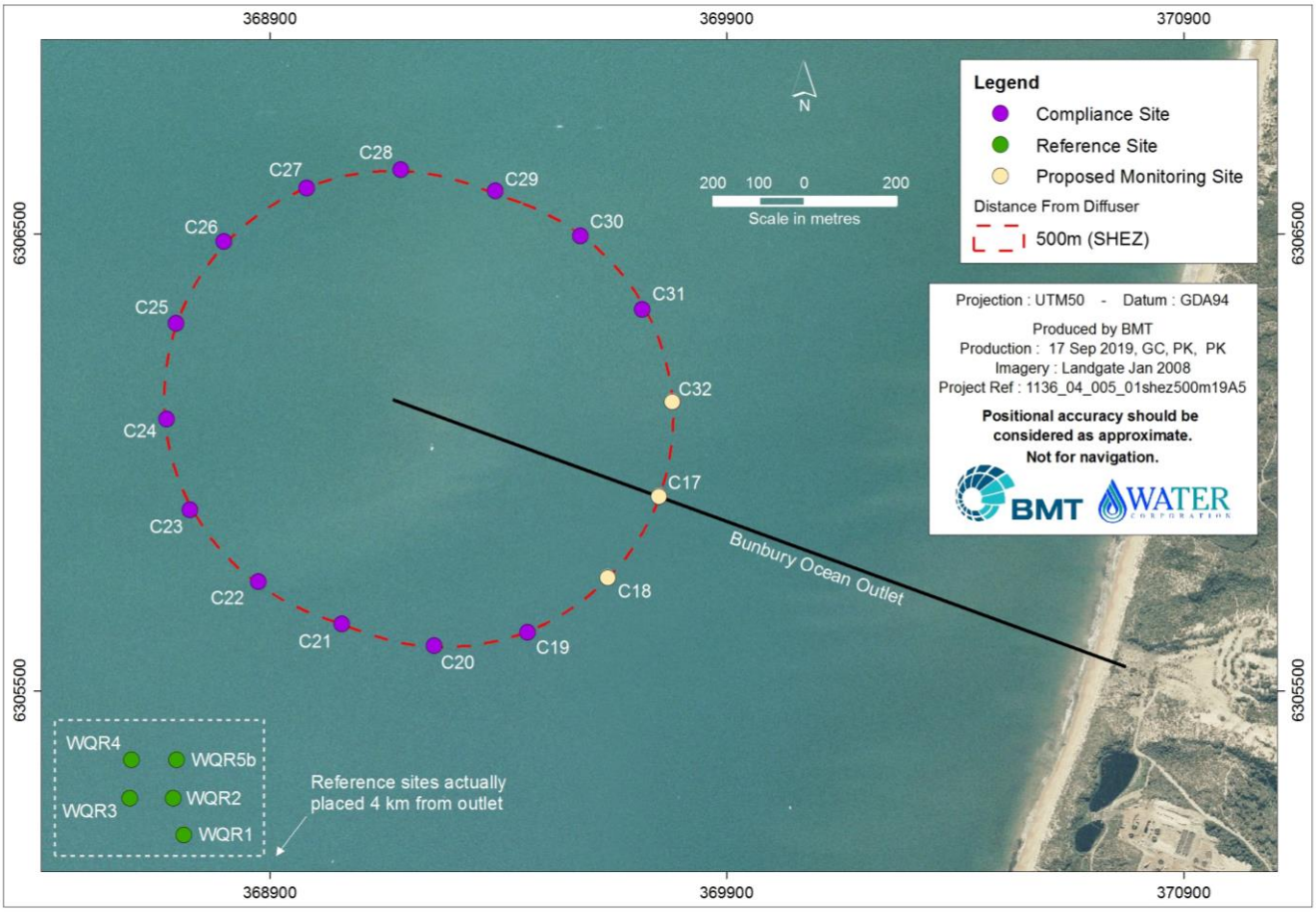


Figure 14 Aquatic life for human consumption compliance (C17-C32) and reference (WQR1-WQR5b) monitoring sites

The EQO, Maintenance of Seafood Safe for Human Consumption, is primarily concerned with the harvesting and consumption of raw shellfish (meaning filter-feeding bivalve molluscs including oysters, mussels, pipis, scallops, cockles and razor clams), and not other forms of seafood. The Department of Health (DoH) discourages the public from taking wild shellfish recommending that instead shellfish are only consumed if grown commercially under strict monitoring programs. There is no aquaculture within 250 m of the diffuser, and there are no licensed shellfish growing areas located in the Bunbury region (DoH 2015). The DoH has further indicated that "it is impossible to guarantee the safety of eating wild shellfish without having a comprehensive monitoring program that tests the waterway concerned for harmful microorganisms and toxins" (EPA 2005) and has formally advised the Department of

Environment Regulation (DER) that, in the absence of a full monitoring program, the application of the TTC criteria (EPA 2005) is insufficient to protect those who wish to collect and eat wild shellfish.

Thermotolerant coliforms sampling

Many disease-causing organisms are transferred from human and animal faeces to water via TWW and can then be ingested by marine fauna, adversely affecting the suitability of such fauna for human consumption. TTCs are bacteria that primarily originate in the intestines of warm-blooded animals. By testing for TTC, it can be determined whether the ocean water around the Bunbury TWW ocean outlet has been exposed to faecal contamination.

Water samples were taken from the surface and bottom of the water column for TTC analyses at compliance monitoring sites, shoreline monitoring sites, plume tracking sites and reference sites over the three sampling dates 16 January, 6 February and 19 March 2019. Samples were collected in pre-sterilised bottles before being chilled to 4 C and placed in the dark. On completion of sampling, the samples were transferred to the PathWest Laboratory and analysed to NATA-accredited methods.

Thermotolerant coliforms results

The EQG for microbial contaminants for the protection of aquatic life for human consumption is outlined in Table 13.

Table 13 Environmental Quality Guideline for thermotolerant coliforms

EQG	Median TTC concentrations across compliance sites are not to exceed 14 CFU/100 mL and that no more than 10% of samples are to exceed 21 CFU/100 mL

The concentration of TTC in both surface and bottom waters at all compliance monitoring sites were below the analytical limit of detection (<10 CFU/mL; Table 14). Median concentrations of TTC were below 14 CFU/100 mL and less than 10% of samples exceeded 21 CFU/100 mL (Table 14), meeting the EQG (Table 13).

Table 14 Confirmed thermotolerant coliform concentrations downstream of the Bunbury treated wastewater ocean outlet

Date	Compliance Site	TTC is surface waters	TTC in bottom waters
16 January 2019	C27	<10	<10
	C28	<10	<10
	C29	<10	<10
	C30	<10	<10
	C31	<10	<10
6 February 2019	C23	<10	<10
	C24	<10	<10
	C25	<10	<10
	C26	<10	<10
	C27	<10	<10
19 March 2019	C19	<10	<10
	C20	<10	<10
	C21	<10	<10
	C22	<10	<10
	C23	<10	<10

Notes:

1. Water quality samples for microbiological contaminants were sampled ~1 m below the surface of the water and 2 m above the seabed (Water Corporation 2012).
2. TTC = thermotolerant coliforms.

Algal biotoxins sampling

Nutrient enrichment (as a result of the TWW discharge) can induce shifts in the naturally occurring planktonic algae community to more harmful species. Water Corporation (2012) includes a requirement to monitor for potentially toxic phytoplankton species (as per DoF 2007) in the area surrounding Bunbury TWW ocean outlet. Although most algal blooms are non-toxic, some may contain species that produce toxins and/or have a potentially harmful effect on the surrounding marine environment. For example, algae species *Heterosigma akashiwo* and *Prymnesium parvum (Prymnesiophyta)* cause large and recurrent fish mortalities. In terms of trophic consequences of algal biotoxins (i.e. flow-on effects up the food chain), there are ~2000 species that can induce poisonings in humans (DoF 2013).

Water samples were taken from the surface and bottom of the water column at compliance monitoring sites and reference sites (outlined in Figure 14), at the SHEZ – 500 m, boundary from the diffuser, and analysed for toxic species of phytoplankton (defined by Western Australian Shellfish Quality Assurance Program (WASQAP) guidelines; DoF 2007). Phytoplankton samples were preserved in Lugol's iodine solution and transported to the lowest taxonomic level possible.

Algal biotoxins results

The EQG for toxic phytoplankton species (Table 15) states that concentrations of potentially toxic algae are not to exceed the WASQAP trigger concentrations in any samples (DoF 2007). Table 15 lists the phytoplankton species known to produce toxins that may be concentrated in shellfish and their WASQAP (DoF 2007) guideline trigger concentration.

Table 15 Environmental Quality Guideline for toxic phytoplankton species

EQG	Concentrations of potentially toxic algae at the boundary of the SHEZ are not to exceed the WASQAP[1] trigger concentrations in any sample for any of the following: • *Alexandrium* spp. (100 cells/L) • *Gymnodinium catenatum* (1000 cells/L) • *Karenia* spp. (1000 cells/L) • *Dinophysis* spp. (500 cells/L) • *Dinophysis acuminata* (3000 cells/L) • *Prorocentrum lima* (500 cells/L) • *Pseudo-nitzschia* spp. (250 000 cells/L) • *Gonyaulax cf. spinifera* (100 cells/L) • *Protoceratium reticulatum* (50 000 cells/L)

Notes:

1. Western Australian Shellfish Assurance Program (WASQAP; DoF 2007) as stipulated by Water Corporation 2012.

There were no instances where toxic phytoplankton species were present at densities greater than the Western Australian Shellfish Quality Assurance Program (WASQAP; DoF 2007) guidelines values (Table 16).

Table 16 Estimated cell density of phytoplankton species known to produce toxins that may be concentrated in shellfish downstream of the Bunbury treated wastewater ocean outlet

Date	Site	Depth	Species	Estimated cell density	WASQAP[1]	Compliance
16 January 2019	C27	S	Pseudo-nitzschia "delicatissima group"	2604	250 000	■
	C27	B	Pseudo-nitzschia "delicatissima group"	930	250 000	■
	C28	S	Pseudo-nitzschia "delicatissima group"	3906	250 000	■
	C28	B	Pseudo-nitzschia "delicatissima group"	2418	250 000	■
	C29	S	Pseudo-nitzschia "delicatissima group"	3348	250 000	■
	C29	B	Pseudo-nitzschia "delicatissima group"	3348	250 000	■
	C30	S	Pseudo-nitzschia "delicatissima group"	4650	250 000	■
	C30	B	Pseudo-nitzschia "delicatissima group"	4092	250 000	■
	C31	S	Pseudo-nitzschia "delicatissima group"	2976	250 000	■
	C31	B	Pseudo-nitzschia "delicatissima group"	1488	250 000	■
	WQR1	S	No toxic species detected	NA	NA	NA
	WQR1	B	Pseudo-nitzschia "delicatissima group"	3906	NA	NA
	WQR2	S	No toxic species detected	NA	NA	NA
	WQR2	B	Pseudo-nitzschia "delicatissima group"	2418	NA	NA
	WQR3	S	No toxic species detected	NA	NA	NA
	WQR3	B	Pseudo-nitzschia "delicatissima group"	3162	NA	NA
	WQR4	S	No toxic species detected	NA	NA	NA
	WQR4	B	Pseudo-nitzschia "delicatissima group"	2790	NA	NA
	WQR5	S	No toxic species detected	NA	NA	NA
	WQR5	B	Pseudo-nitzschia "delicatissima group"	1488	NA	NA
6 February 2019	C23	S	Pseudo-nitzschia "delicatissima group"	3348	250 000	■
	C23	B	Pseudo-nitzschia "delicatissima group"	3906	250 000	■
	C24	S	Pseudo-nitzschia "delicatissima group"	4836	250 000	■
	C24	B	Pseudo-nitzschia "delicatissima group"	4836	250 000	■
	C25	S	Pseudo-nitzschia "delicatissima group"	3906	250 000	■
	C25	B	Pseudo-nitzschia "delicatissima group"	3534	250 000	■
	C26	S	Pseudo-nitzschia "delicatissima group"	3348	250 000	■
	C26	B	Pseudo-nitzschia "delicatissima group"	6138	250 000	■
	C27	S	Pseudo-nitzschia "delicatissima group"	1860	250 000	■
	C27	B	Pseudo-nitzschia "delicatissima group"	5766	250 000	■
	WQR1	S	Pseudo-nitzschia "delicatissima group"	4278	NA	NA
			Pseudo-nitzschia "seriata group"	558		
	WQR1	B	Pseudo-nitzschia "delicatissima group"	4902	NA	NA
	WQR2	S	Pseudo-nitzschia "delicatissima group"	2790	NA	NA
			Pseudo-nitzschia "seriata group"	372		
	WQR2	B	Pseudo-nitzschia "delicatissima group"	1674	NA	NA
	WQR3	S	Pseudo-nitzschia "delicatissima group"	3348	NA	NA
	WQR3	B	Pseudo-nitzschia "delicatissima group"	1116	NA	NA
	WQR4	S	Pseudo-nitzschia "delicatissima group"	1674	NA	NA
			Pseudo-nitzschia "seriata group"	558		

	WQR4	B	Pseudo-nitzschia "delicatissima group"	4464	NA	NA
	WQR5	S	Pseudo-nitzschia "delicatissima group"	5022	NA	NA
	WQR5	B	Pseudo-nitzschia "delicatissima group"	3348	NA	NA
19 March 2019	C19	S	Pseudo-nitzschia "delicatissima group"	5580	250 000	■
			Pseudo-nitzschia "seriata group"	465		
	C19	B	Pseudo-nitzschia "delicatissima group"	2790	250 000	■
	C20	S	Pseudo-nitzschia "delicatissima group"	2604	250 000	■
			Pseudo-nitzschia "seriata group"	558		
	C20	B	Pseudo-nitzschia "delicatissima group"	15438	250 000	■
	C21	S	Pseudo-nitzschia "delicatissima group"	4092	250 000	■
	C21	B	Pseudo-nitzschia "delicatissima group"	5022	250 000	■
	C22	S	Pseudo-nitzschia "delicatissima group"	3720	250 000	■
			Pseudo-nitzschia "seriata group"	186		
	C22	B	Pseudo-nitzschia "delicatissima group"	5394	250 000	■
	C23	S	Pseudo-nitzschia "delicatissima group"	5580	250 000	■
			Pseudo-nitzschia "seriata group"	186		
	C23	B	Pseudo-nitzschia "delicatissima group"	7068	250 000	■
	WQR1	S	Pseudo-nitzschia "delicatissima group"	4278	NA	NA
			Pseudo-nitzschia "seriata group"	1302		
	WQR1	B	Pseudo-nitzschia "delicatissima group"	1674	NA	NA
	WQR2	S	Pseudo-nitzschia "delicatissima group"	3348	NA	NA
			Pseudo-nitzschia "seriata group"	930		
	WQR2	B	Pseudo-nitzschia "delicatissima group"	3348	NA	NA
	WQR3	S	Pseudo-nitzschia "delicatissima group"	6138	NA	NA
			Pseudo-nitzschia "seriata group"	558		
	WQR3	B	Pseudo-nitzschia "delicatissima group"	558	NA	NA
	WQR4	S	Pseudo-nitzschia "delicatissima group"	2604	NA	NA
			Pseudo-nitzschia "seriata group"	372		
	WQR4	B	Pseudo-nitzschia "delicatissima group"	372	NA	NA
	WQR5	S	Pseudo-nitzschia "delicatissima group"	4092	NA	NA
			Pseudo-nitzschia "seriata group"	372		
	WQR5	B	Pseudo-nitzschia "delicatissima group"	1860	NA	NA

Notes:

1. WASQAP = Western Australian Quality Assurance Program (DoF 2007, as per Water Corporation 2012).
2. C = compliance sites, WQR = reference sites.
3. Compliance only assessed against compliance monitoring sites (not reference sites).
4. NA = not applicable.
5. Green symbols indicate the estimated cell density was below the WASQAP toxic algae trigger concentration.

Primary and secondary contact recreation

Sampling approach and site locations

The EQO for the EV 'Recreation' [and Aesthetics'] is aimed at ensuring coastal waters are safe for primary and secondary contact recreation activities such as swimming and boating, respectively. To meet the EQO, water quality around the Bunbury TWW ocean outlet is to be maintained so that primary and secondary contact recreation is safe in all waters except those areas designated otherwise.

Water quality monitoring sites (C1–C16) are positioned along the boundary of the LEPA, but on any one sampling occasion, only the five directly down current of the diffuser are sampled (Figure 15).

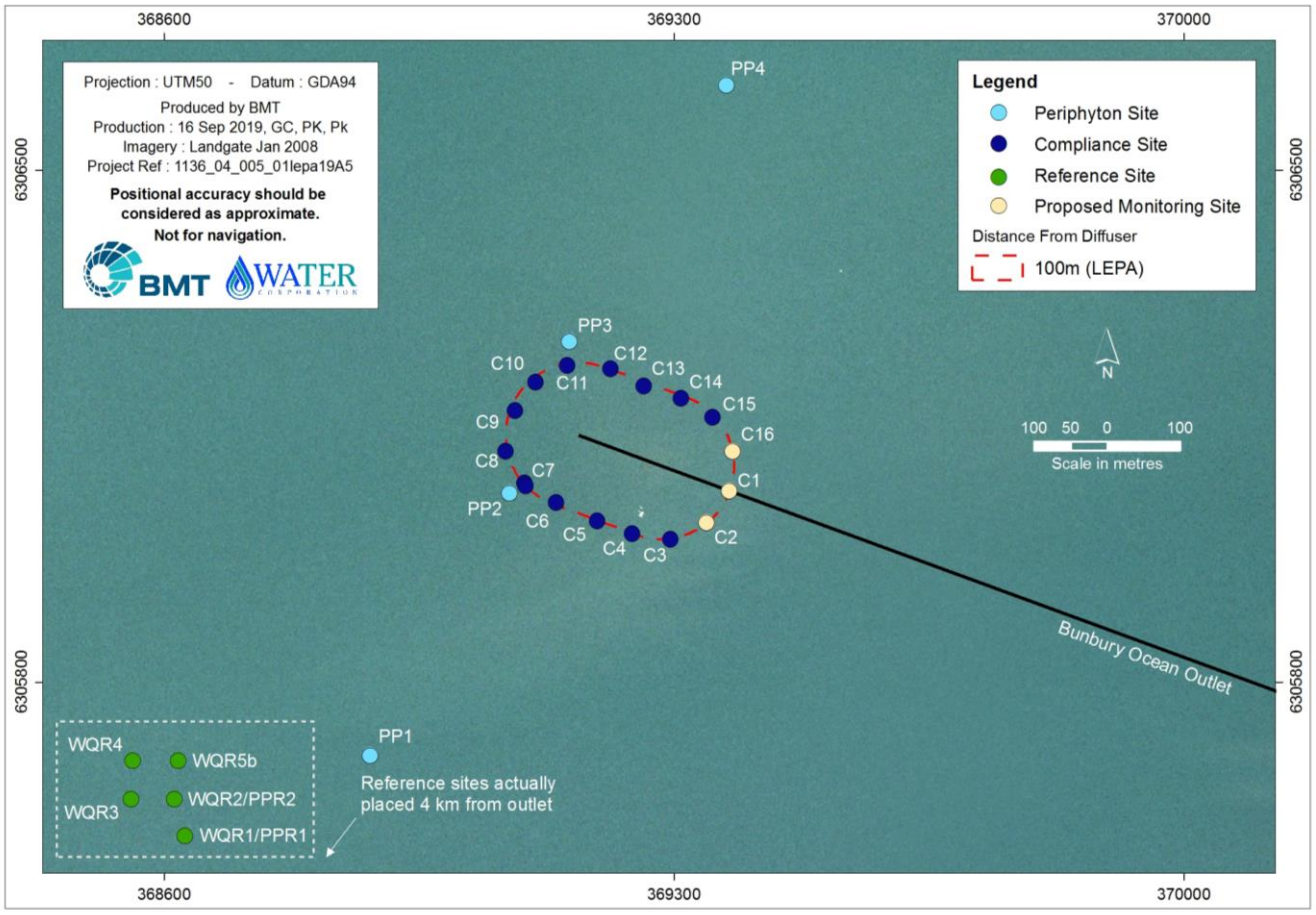


Figure 15 Primary and secondary recreational contact compliance (C1-C16) site and reference monitoring sites (WQR1–WQR5b)

Faecal pathogens sampling

Disease-causing microorganisms (pathogens) associated with bathing areas include salmonellae, shigellae, enteropathogenic *Escheria coli*, cysts of *Entamoeba histolytica*, parasite ova and infectious hepatitis (Hart 1974, McNeil 1985; cited in ANZECC/ARMCANZ 2000). The most common types of diseases associated with water borne pathogens are eye, ear, nose and throat infections, skin diseases and gastrointestinal disorders (ANZECC/ARMCANZ 2000). Detecting faecal pathogens within water samples is difficult, therefore 'indicator' micro-organisms are used to assess the health risks associated with pathogens in recreational waters (Elliot& Colwell 1985; cited in ANZECC/ARMCANZ 2000).

To test for presence of pathogens, water samples were taken from the surface and bottom of the water column at compliance monitoring sites, shoreline monitoring sites, plume tracking sites and reference sites on 16 January, 6 February and 19 March 2019 and analysed for *Enterococci* spp. Samples were collected in pre-sterilised bottles before being chilled and placed in the dark. On completion of sampling, the samples were transferred to the PathWest Laboratory and analysed according to NATA-accredited methods.

Faecal pathogens results

The EQG for faecal pathogens is outlined in Table 17.

Table 17 Environmental Quality Guideline for faecal pathogens

EQG	The 95th percentile of pooled Enterococci spp. concentrations in surface waters is not to exceed 40 MPN/100 mL outside the LEPA boundary

Source: Water Corporation (2012)

Notes:

1. MPN = most probable number; LEPA = low ecological protection area.

Enterococci spp. concentrations were below the analytical detection limit of 10 MPN/100 mL at all sites, in both surface and bottom water samples (Table 18) and the EQG was met (Table 18).

Table 18 *Enterococci* spp. concentrations downstream of the Bunbury ocean outlet

Date	Compliance Site	*Enterococci* spp. in surface waters MPN/100 mL	*Enterococci* spp. in bottom waters MPN/100 mL
16 January 2019	C11	<10	<10
	C12	<10	<10
	C13	<10	<10
	C14	<10	<10
	C15	<10	<10
6 February 2019	C7	<10	<10
	C8	<10	<10
	C9	<10	<10
	C10	<10	<10
	C11	<10	<10
19 March 2019	C3	<10	<10
	C4	<10	<10
	C5	<10	<10
	C6	<10	<10
	C7	<10	<10

Algal biotoxins sampling

Algal biotoxins resulting from increased nutrient loads can be harmful to human/animal health if encountered via ingestion or skin contact. Although most algal blooms are considered harmless, some may contain species that produce toxins that are harmful to humans. For this reason, phytoplankton cell counts were monitored on three sampling occasions during summer (16 January, 6 February and

19 March 2019) to ensure concentrations are occurring within acceptable guideline limits (NHMRC 2008).

Algal biotoxin results

The EQG for algal biotoxins is outlined in Table 19.

Table 19 Environmental Quality Guideline for algal biotoxins

EQG	Median total phytoplankton cell count (either from one sampling occasion or from a single site over an agreed period of time) should not exceed 10 cells/mL *Karenia brevis* and/or have *Lyngbya majuscula* and/or *Pfiesteria* present in high numbers outside the LEPA

Source: Water Corporation (2012)

Note:

1. LEPA = low ecological protection area

Toxic algal species *Karenia brevis, Lyngbya majuscula* and *Pfiesteria* spp. were not recorded at compliance monitoring sites at the boundary of the LEPA during the 2018 summer monitoring and the EQG relevant to algal biotoxins (for the EQO, Maintenance of Primary and Secondary Contact Recreation) was met.

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The following Appendices are available from Water Corporation on request:

Appendix A Initial dilution modelling

Appendix B Detailed methods for water quality in the receiving environment

Appendix C Contextual nutrient results

Appendix D Microbiological results

Appendix E Phytoplankton results