Bunbury Water Resource Recovery Facility Ocean Outlet Monitoring Program

Annual Report 2024/2025

WATER CORPORATION

Document Management

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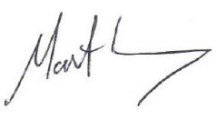
Quality Assurance

BMT Commercial Australia Pty Ltd has prepared this report in accordance with our Integrated Management System, in compliance with ISO9001, ISO45001 and ISO14001.

Status

This report is 'Draft' until approved for final release, as indicated below by the inclusion of signatures from (i) the author and (ii) a Director of BMT Commercial Australia Pty Ltd (BMT) or their authorised delegate.

Approved for final release:



Director (or delegate)

Date: 03/09/2025

Acronyms and Abbreviations

Acronym/Abbreviation	Description
ANZECC/ARMCANZ	Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.
BOD	Biochemical oxygen demand.
BOOM	Bunbury Ocean Outlet Monitoring.
DoF	Department of Fisheries.
E. coli	Escherichia coli.
EQC	Environmental Quality Criteria.
EQG	Environmental Quality Guideline.
EQMF	Environmental Quality Management Framework.
EQO	Environmental Quality Objective.
EQS	Environmental Quality Standard.
EV	Environmental Values.
HEPA	High Ecological Protection Area.
LAC	Light attenuation coefficient.
LEPA	Low Ecological Protection Area.
LoR	Limit of reporting.
MIMMP	Marine Impacts Monitoring and Management Plan.
MS	Ministerial Statement.
NA	Not applicable.
NOx	Nitrate and nitrite.
OHS	Occupational Health and Safety
pH	Potential of hydrogen.
SHEZ	Shellfish Harvesting Exclusion Zone.
TAN	Total ammonium-nitrogen.
TDS	Total dissolved solids.
TN	Total nitrogen.
TP	Total phosphorus.
TSS	Total suspended solids.
TTC	Thermotolerant coliforms.
TTM	Total toxicity of the mixture.
TWW	Treated wastewater.
WASQAP	Western Australia Shellfish Quality Assurance Program.
WRRF	Water Resource Recovery Facility.

Executive Summary

This report documents the results of the 2024-2025 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 assess potential effects on the receiving marine environment. Results are reported in the context of the Environmental Quality Management Framework (EQMF) (Environmental Protection Authority (EPA) 2017) 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 code
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 analytical limit of reporting and 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 1:79 expected at the LEPA boundary) was sufficient to reduce contaminant concentrations to below the associated ANZECC/ARMCANZ (2000) 99% species protection guideline trigger levels.	
	Total toxicity of the mixture (TTM)	EQG	The TTM for the additive effect of ammonia, copper and zinc after initial dilution was 0.47 and below the ANZECC/ARMCANZ (2000) guideline value of 1.0	

Environmental quality indicator		EQC	Comments	Compliance
Nutrient enrichment indicators of increased nutrients and algal growth potential	Chlorophyll-a	EQG	Median concentration of chlorophyll-a at compliance sites (0.2 µg/L) did not exceed (though was equal to) the 80th percentile of reference site data (0.2 µg/L)	■
	Phytoplankton biomass (measured as chlorophyll-a)	EQG	Chlorophyll-a concentration 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 at compliance sites was above the 80th percentile of reference site data.	■
	Seagrass health	EQS1	Median shoot density did not fall below the 20th percentile of reference sites in two consecutive years (2024 and 2025).	■
		EQS2	Median shoot density, at all sites in 2025, was greater than the 5th percentile of the pooled reference site data.	
Physico-chemical stressor	Dissolved oxygen % saturation	EQG	Dissolved oxygen saturation in bottom waters remained above 90% saturation at all sites over the defined 6-week monitoring period.	■

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 (DoH 2007)

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 (DoH 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 (DoH 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	Recreational compliance sites had a pooled *Enterococci* spp. concentrations below 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	■

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.

Contents

1 Introduction

1.1 Document purpose

The Water Corporation is required to ensure that the discharge of treated wastewater (TWW) from the Bunbury Water Resource Recovery Facility (WRRF) to the marine environment is environmentally sustainable and managed appropriately to protect both ecosystem and social values. To meet this outcome, Water Corporation undertakes its operations in accordance with environmental commitments and licence conditions 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.

This report describes the results and outcomes of the 2024–2025 Bunbury Ocean Outlet Monitoring (BOOM) program carried out in accordance with the methods and criteria in Water Corporation (2012). The program aims to determine the chemical and physical properties of the TWW plume and to determine the potential effects of TWW discharge on the receiving marine environment.

1.2 Plant infrastructure

The Bunbury WRRF primarily services the City of Bunbury. Ocean disposal of TWW from the Bunbury WRRF commenced in July 2002. Prior to disposal, the wastewater is treated using microbial processes to reduce nitrogen concentrations 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 1.1). TWW is discharged via a sub-sea diffuser, located 1.7 km perpendicular to the shoreline (Water Corporation 2012). The diffuser comprises a series of ports designed to maximise dispersion and dilution of the TWW with natural seawater. TWW is freshwater and less dense than seawater. After discharge via the ports, the buoyant TWW plume rises through the water column and continues to mix with surrounding seawater as it ascends.

Figure 1.1 Location of the Bunbury Water Resource Recovery Facility and ocean outlet

1.3 Conditions of operation

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

1.4 Environmental Quality Management Framework (EQMF)

Monitoring was conducted in accordance with Western Australia's EQMF (EPA 2017). The EQMF is based on:

- identifying Environmental Values (EVs) (Figure 1.2)
- establishing and spatially defining Environmental Quality Objectives (EQOs) that need to be maintained to ensure the associated EVs are protected (Figure 1.2)
- 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 that, 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 that, if exceeded, signify the EQO is at risk of not being met and that a management response may be required.

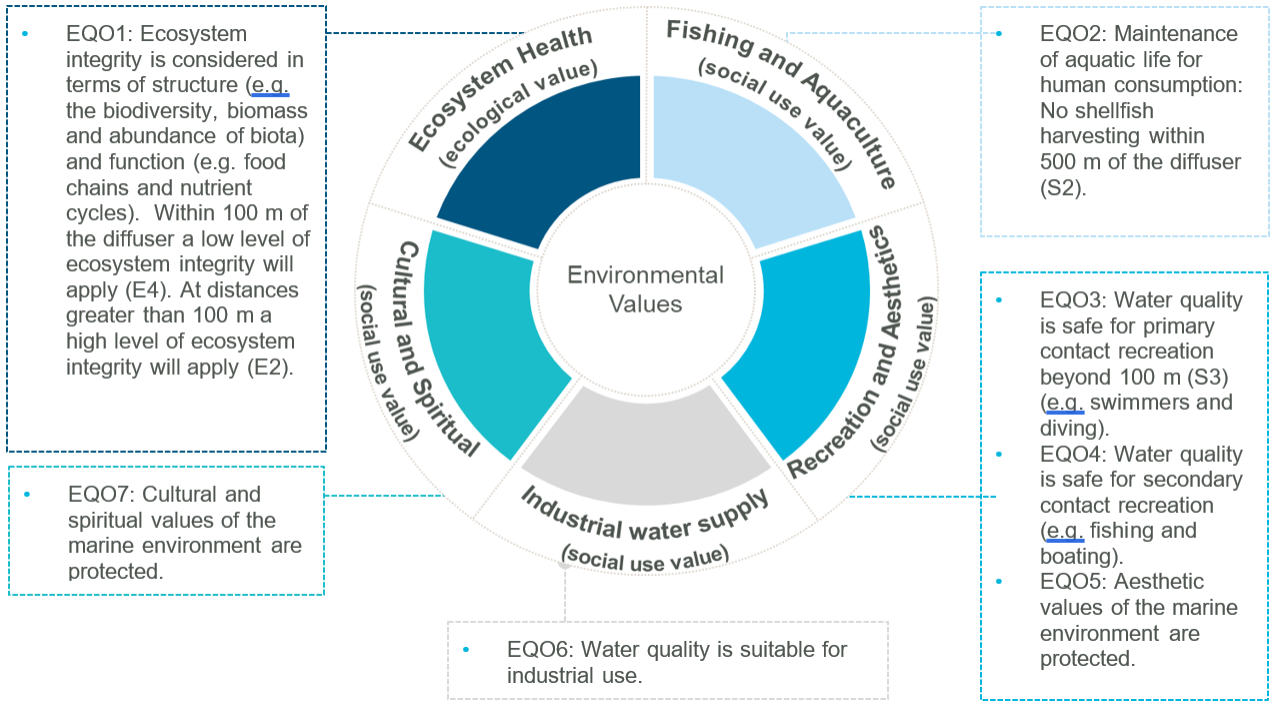


Figure 1.2 Establishing EVs and EQOs for the marine waters of Western Australia (EPA 2017)

1.5 BOOM program framework

MS 572 requires that the EVs for Ecosystem Health and Recreation, and Aesthetics are maintained, and the associated EQOs (EQO1, EQO3, EQO4, and EQO5; Figure 1.2) are met within 100 m of the Bunbury Ocean Outlet (Figure 1.3). MS 572 requires that the EVs for Fishing and Aquaculture are maintained and the associated EQOs (EQO2; Figure 1.2) are met within 500 m of the Bunbury Ocean Outlet (Figure 1.3).

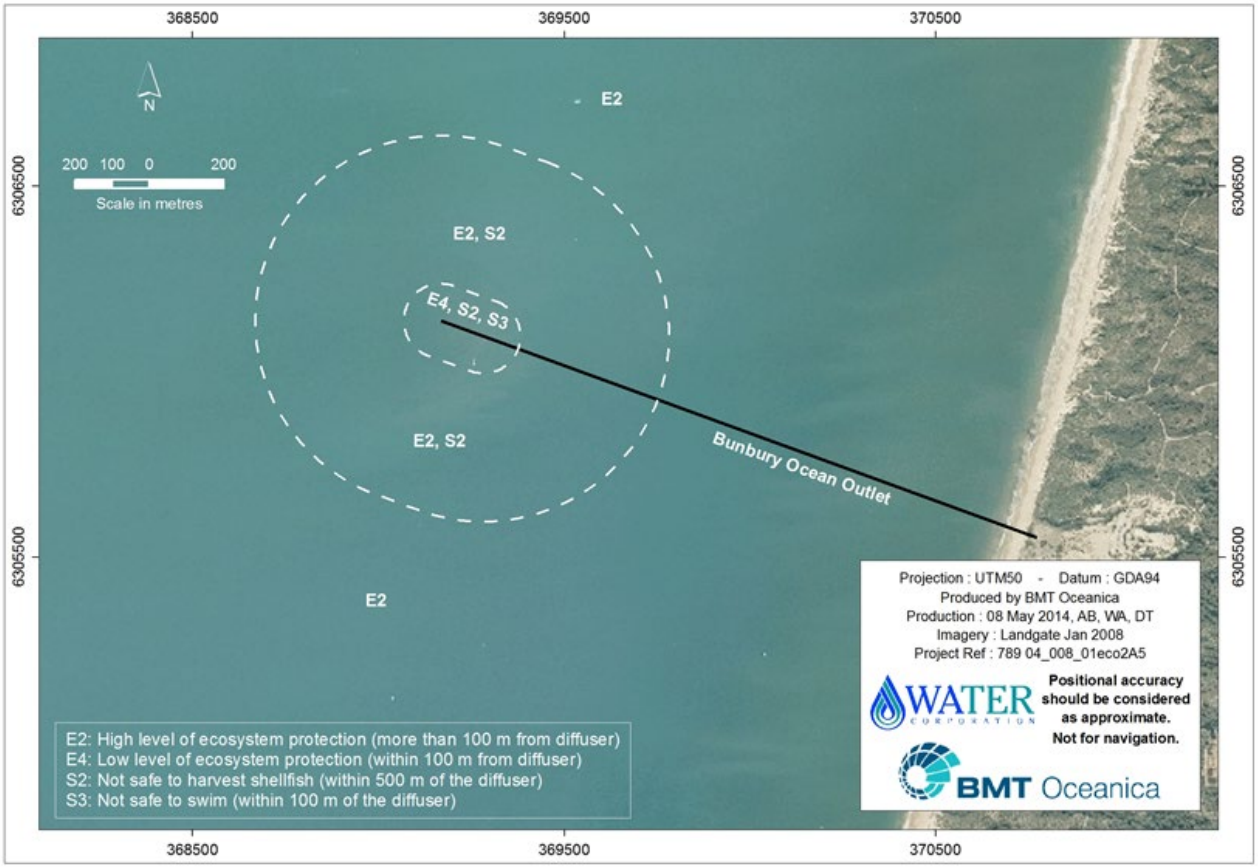


Figure 1.3 Environmental management areas as defined in Schedule 1 of MS 572

1.5.1 'Maintenance of ecosystem integrity' EQO

The intent of this EQO is to maintain a healthy and diverse ecosystem. The EQO applies designated levels of ecological protection: low, moderate, high, or maximum (Figure 1.4). A low level of ecological protection applies in the Low Ecological Protection Area (LEPA), which occupies the area within a 100 m radius of the diffuser at the Bunbury ocean outfall. Waters outside the LEPA are designated as a High Ecological Protection Area (HEPA) and are given a high level of ecological protection.

The extent to which the EQO for the Maintenance of Ecosystem Integrity was met during the 2024–2025 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).

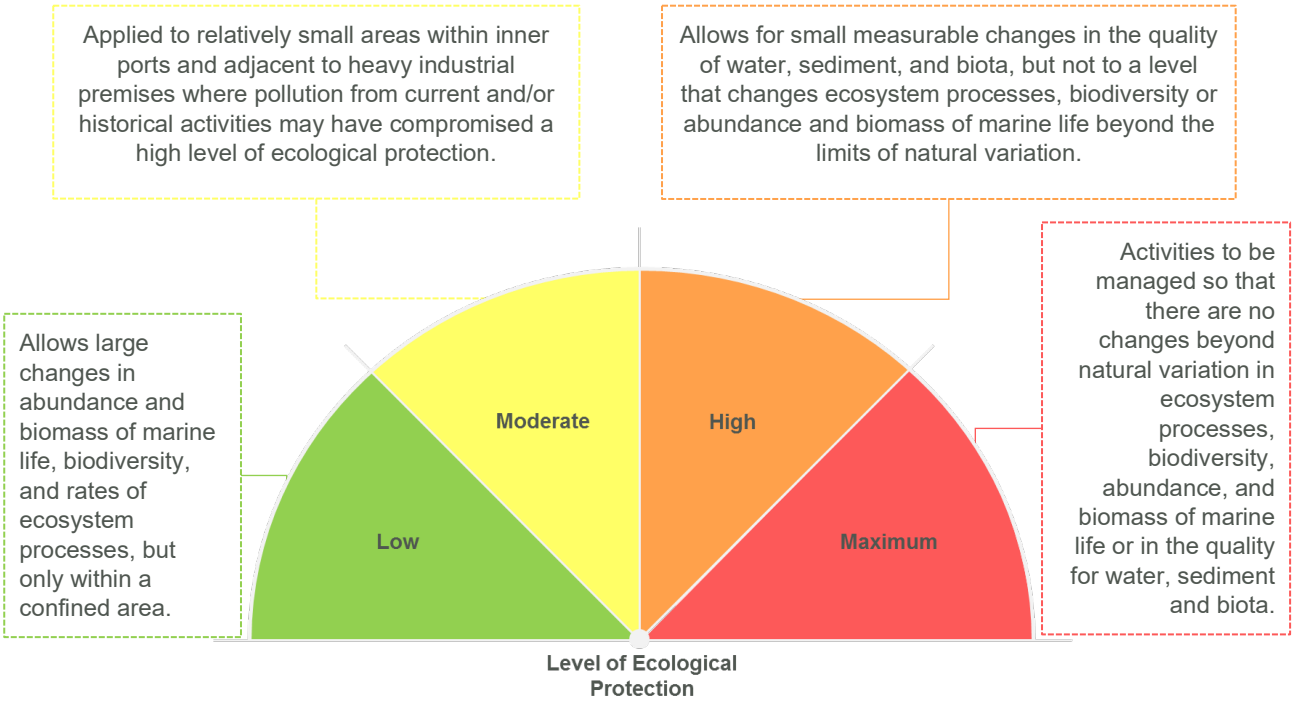


Figure 1.4 Level of ecological protection (EPA 2017)

1.5.2 '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) except for within the area surrounding the ocean outlet within 500 m of the Bunbury Ocean Outlet (S2; Figure 1.3), where shellfish may be unsafe to eat.

1.5.3 'Maintenance of primary and secondary contact recreation' EQO

Primary contact recreation EQO will be maintained beyond 100 m of the Bunbury Ocean Outlet (S3; Figure 1.3). 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 have also been met.

2 Waste Stream Monitoring

Monitoring of TWW prior to discharge consisted of:

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

2.1 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:

- pH
- total dissolved solids (TDS)
- total suspended solids (TSS)
- total ammonium-nitrogen (TAN)
- biochemical oxygen demand (BOD)
- 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 WRRF operating licence L5972/1992/14. The operating licence limit for TP of 10 mg/L was met during the July 2024–June 2025 reporting period (Table 2.1). All other discharge limits in the Schedule 1 Table of MS 572 (suspended solids, BOD, TN, TP, faecal coliform bacteria counts and TN load) are reported by Water Corporation separately.

Table 2.1 Regulatory monthly water quality parameters measured at Bunbury Water Resource Recovery Facility Pond 2 Discharge Weir

Month	pH	TDS	TSS	TAN	BOD	NOx	TN	TP	*E.coli*
Unit		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Cells/100mL
LoR	NA	<10	<5	NA	<5	NA	NA	NA	NA
Jul 24	7.69	590	<5	3.1	<5	1.60	7.1	2.3	>24,000
Aug 24	7.90	570	<5	3.6	<5	1.40	6.9	2.3	2,500
Sep 24	7.50	550	5	2.3	<5	1.50	6.1	1.5	>24,000
Oct 24	7.84	530	<5	1.7	<5	1.20	5.1	2.7	>24,000
Nov 24	7.83	540	<5	1.9	<5	1.30	5.2	1.9	20,000
Dec 24	7.66	550	<5	1.5	<5	1.30	4.7	1.5	4,400
Jan 25	7.69	600	5	2.3	<5	0.72	4.5	1.7	>24,000
Feb 25	7.89	600	<5	1.9	<5	0.87	4.7	3.1	>24,000
Mar 25	7.78	570	5	1.7	<5	1.20	4.5	2.8	14,000
Apr 25	7.55	560	<5	1.1	<5	1.50	4.5	2.4	>24,000
May 25	7.56	570	<5	1.5	<5	1.60	5.5	2.2	>24,000
Jun 25	7.81	630	10	1.3	<5	2.40	5.5	2.1	>24,000
Mean	7.73	572	3.75	2.0	<5	1.40	5.4	2.2	10,225

Note:

1. LoR = Limit of reporting, pH = potential of hydrogen, TDS = total dissolved solids, TSS = total suspended solids, TAN = total ammonia nitrogen, BOD = biological oxygen demand, NOx = nitrate+nitrite, TN = total nitrogen, TP = total phosphorus, *E. coli* = *Escherichia coli*, NA = not applicable.
2. Where results were below LoR, they were considered to be half the LoR for statistical analysis (ANZG 2018).

2.2 Quarterly comprehensive treated wastewater characterisation

In addition to the monthly sampling outlined in Section 2.1, TWW (final effluent) from the Bunbury WRRF was also analysed quarterly for a suite of potential contaminants of concern:

- metals (Ag, As, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Se, Zn)
- pesticides
- herbicides.

A majority of results were below the limit of detection, with the exception of zinc (40 ug/L) and copper (2 and 3 ug/L) (Table 2.2 and Table 2.3). The most conservative (lowest) estimate of the two initial dilution methods (1:79) was used in further calculations and comparisons (Water Corporation 2012). Once the dilution factor of 1:79 (Section 2.2.2) is applied, the zinc concentration dilutes to 0.5ug/L, which is below the ANZECC/ARMCANZ (2000) 99% species protection guideline trigger level of 7ug/L.

Table 2.2 Undiluted TWW concentration of metals

Parameter	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Molybdenum	Nickel	Selenium	Silver	Zinc
	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
August 2024	<10	<20	<20	3	<20	<0.5	<20	<20	<20	<20	40
November 2024	<10	<20	<20	<2	<20	<0.5	<20	<20	<20	<20	40
February 2025	<10	<20	<20	2	<20	<0.5	<20	<20	<20	<20	40
May 2025	<10	<20	<20	<2	<20	<0.5	<20	<20	<20	<20	40

Table 2.3 Undiluted TWW concentration of pesticides and herbicides

Parameter	2,4-dichlorophenoxyacetic	4-chloro-2-methylphe	Aldrin	Atrazine	Chlordane	Chlorpyrifos	DDT (total isomers)	Dieldrin	Heptachlor & heptachlor	Hexachlorobenzene	Lindane	Simazine
	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
August 2024	<0.8	<0.8	<0.003	<0.4	<0.006	<0.007	<0.005	<0.004	<0.005	<0.004	<0.004	<0.4
November 2024	<0.8	<0.8	<0.003	<0.4	<0.006	<0.007	<0.005	<0.004	<0.005	<0.004	<0.004	<0.4
February 2025	<0.8	<0.8	<0.003	<0.4	<0.006	<0.007	<0.005	<0.004	<0.005	<0.004	<0.004	<0.4

2.2.1 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 times of sampling (Water Corporation 2012). The most conservative (lowest) estimate of the two initial dilution methods is used in further calculations and comparisons (Water Corporation 2012).

2.2.2 Initial dilution using model simulation

Initial dilution modelling (using plume dispersion model VPLUMES) was used to predict the near-field dilution of the TWW plume around the Bunbury 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 14 January 2025 (concurrent to the first summer water quality survey), the flow rate into Bunbury WRRF was 12.054 ML/day. To determine the current velocity and direction at the time of sampling, a surface drogue was released above the outlet diffuser and the location of the drogue was recorded at intervals over time using an on-board Global Positioning System. Surface current velocities were calculated based on the distance and time between the drogue deployment and the drogue retrieval.

Modelling using VPLUMES indicated an average initial dilution of 1:712 and a centreline dilution of 1:302 on 14 January 2025 (Figure 2.1). The full model output is included in Appendix 1.

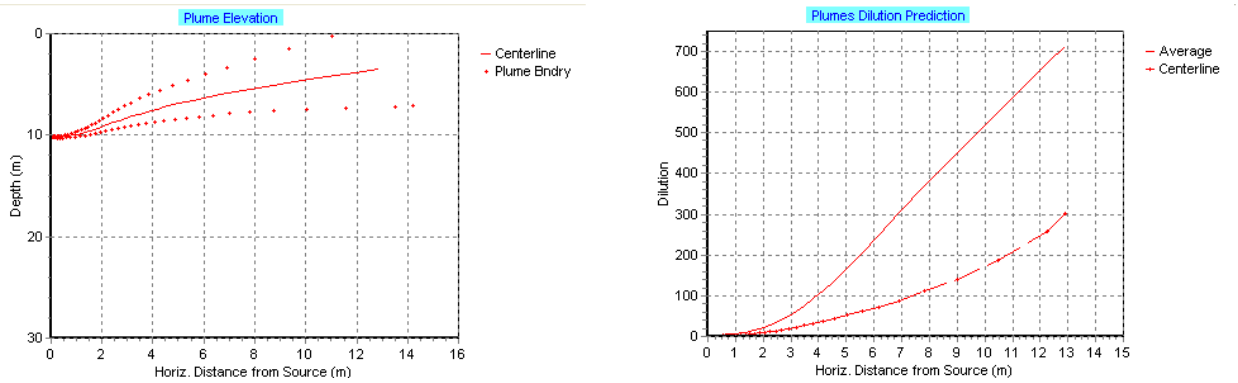


Figure 2.1 Initial dilution modelling output showing predicted plume elevation trajectory (left) and predicted average and centreline dilutions (right)

2.2.3 Initial dilution using in-field nutrient concentrations

The lowest dilution expected to occur at the Bunbury Ocean Outlet based on measurement of in-water nutrient concentrations was 1:79 for nitrate+nitrite (Table 2.4). The most conservative estimate of initial dilution was the average initial dilution modelled via nutrient concentrations, which was 1:79 and was the dilution factor applied to calculations for non-bioaccumulating toxicants and total toxicity of the mixture (Section 2.2.5 and Section 2.2.6).

Table 2.4 Minimum initial dilution achieved for total ammonia, nitrate+nitrite and total phosphorus

Parameter	Undiluted TWW concentration (µg/L)	Surface maximum[1] (µg/L)	Surface background[2] (µg/L)	Minimal initial dilution achieved[3]
Total ammonia	2100	5	1.5	600
Nitrate+nitrite	550	9	2	79
Total phosphorus	1900	10	4	317

Notes:

1. Average surface concentration of five reference sites (WQR1-WQR5); where this value was <LoR, the LoR was used to calculate the average surface concentration.
2. Minimum initial dilution = treated wastewater (TWW) concentration/surface maximum – surface background.

2.2.4 Bioaccumulating toxicants

The EQG for bioaccumulating toxicants (cadmium and mercury) in the TWW is outlined in Table 2.5. Concentrations of cadmium and mercury (i.e. bioaccumulating toxicants) in the TWW sample before dilution were both below their analytical limit of reporting and the ANZECC/ARMCANZ (2000) 80% species protection guideline trigger levels. The EQG for bioaccumulating toxicants was met (Table 2.6).

Table 2.5 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)

Table 2.6 Undiluted bioaccumulating toxicants

Parameter	Trigger (µg/L)[1]	Undiluted TWW concentration (µg/L)
Cadmium	36	<0.1
Mercury	1.4	<0.6

Notes:

1. Assessment against ANZECC/ARMCANZ (2000) 80% species protection guideline trigger levels for non-bioaccumulating toxicants; guideline values for marine waters.

2.2.5 Non-bioaccumulating toxicants

With the exception of ammonia, copper, and zinc, non-bioaccumulating toxicant concentrations were below the ANZECC/ARMCANZ 99% species protection guideline trigger levels, where available, in the TWW prior to discharge (Table 2.7). Lead has an LoR greater than the ANZECC/ARMCANZ (2000) 99% guideline trigger levels for marine waters; therefore, to ensure compliance, the LoR value was used and the concentration after initial dilution was calculated. Concentrations of ammonia, copper, zinc, and lead were lower than the ANZECC/ARMCANZ (2000) 99% species protection guideline trigger levels after dilution (1:79, Table 2.7), which is equivalent to what is expected at the LEPA boundary, and the EQG for non-bioaccumulating toxicants was met (Table 2.7).

Table 2.7 Toxicants in the Bunbury treated wastewater prior to and after initial dilution compared to ANZECC/ARMCANZ (2000) 99% guideline trigger levels for marine waters

Toxicant (µg/L, unless indicated)	Bunbury TWW[1] concentration (µg/L)	Concentration after initial dilution (µg/L)[1]	Trigger (µg/L)[2]
Ammonia-N	**2100**	26.58	500
Nitrate+Nitrite	550	-	ID
Total phosphorus	1900	-	n/a
Total suspended solids	5000	-	<103
Arsenic	<20	-	n/a
Chromium	<1	-	0.14 (Cr VI)
Copper	**2**	0.02	0.3
Lead	<10[3]	0.13	2.2
Nickel	<7	-	7
Selenium	<20	-	ID[4]
Silver	<10	-	0.8
Zinc	**59**	0.74	7
Molybdenum	<4	-	ID
Salinity (psu)	0.5	-	n/a
BOD (mg/L)	<5	-	n/a
Chloropyrifos	<0.1	-	0.0005
Endrin	<0.001	-	0.004
Endosulfan sulfate	<0.001	-	0.005

Notes:

1. Concentration after initial dilution and natural surface background. Initial dilution = 1:79. Natural surface background ammonia 1.5 µg/L; copper 0.08 µg/L and zinc 0.15 µg/L. 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 trigger levels were not the trigger (i.e. total suspended solids), TWW=treated wastewater.
2. Assessment against ANZECC/ARMCANZ (2000) 99% species protection guideline trigger levels for non-bioaccumulating toxicants; guideline values for marine waters.
3. LoR is greater than trigger value.
4. ID = insufficient data to derive a reliable national trigger value.
5. Bold text represents an exceedance of guideline values prior to initial dilution.

2.2.6 Total toxicity of the mixture

The potential for additive toxic effects of TWW on 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 does not have a unit of measurement. The EQG for the TTM is outlined in Table 2.8.

Table 2.8 Environmental Quality Guideline for the Total Toxicity of the Mixture

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.

Source: Water Corporation (2012)

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 for the additive effect of ammonia, copper and zinc after initial dilution (1:79) was 0.47 in the TWW (Table 2.9) and below the ANZECC/ARMCANZ (2000) guideline value of 1.0 meeting the EQG. It is not anticipated that the combined additive effect of these contaminants will have an adverse effect on the receiving marine environment surrounding the Bunbury Ocean Outlet.

Table 2.9 Total toxicity of treated wastewater at the edge of the initial mixing zone associated with the Bunbury Ocean Outlet

Natural concentrations in Perth`s coastal waters			Initial dilution of	Total toxicity of the
Ammonia (µg/L)	Copper (µg/L)	Zinc (µg/L)	TWW with seawater	mixture (TTM)
1.5	0.08	0.15	1:79	0.47

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. TTM = [ammonia]/guideline + [copper]/guideline + [zinc]/guideline.

3 Water Quality Monitoring – Receiving Environment

Water Corporation (2012) requires the assessment of indicators of nutrient enrichment and physico-chemical stress in receiving waters to monitor and better understand local water quality. Indicators for 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 also measured, serving as an indicator of physico-chemical stress due to potential increases in organic matter load.

Sampling procedures were followed at compliance monitoring, plume tracking, periphyton monitoring and seagrass health sites over the summer monitoring period (Appendix 2). Nutrients, phytoplankton biomass, light attenuation, and DO as a physico-chemical stressor were monitored during three separate surveys on 14 January, 13 February, and 11 March 2025, down current of the Bunbury Ocean Outlet (Appendix 2). Periphyton was monitored using collector plates deployed15 January 2025 to 14 February 2025 (Appendix 2). Seagrass health was monitored as shoot density on 15 and 16 January 2025. Details on the sampling methods, laboratory analysis and transport methods are available in the Bunbury Ocean Outlet Marine Impacts Monitoring and Management Plan (Water Corporation 2012).

Nutrient concentrations (ammonia, ortho-phosphate, and nitrate+nitrite) in receiving marine waters were measured downcurrent from the Bunbury Ocean Outlet, for contextual purposes only (to identify nutrient gradients) (see Appendix 3 for results).

3.1 Nutrient enrichment

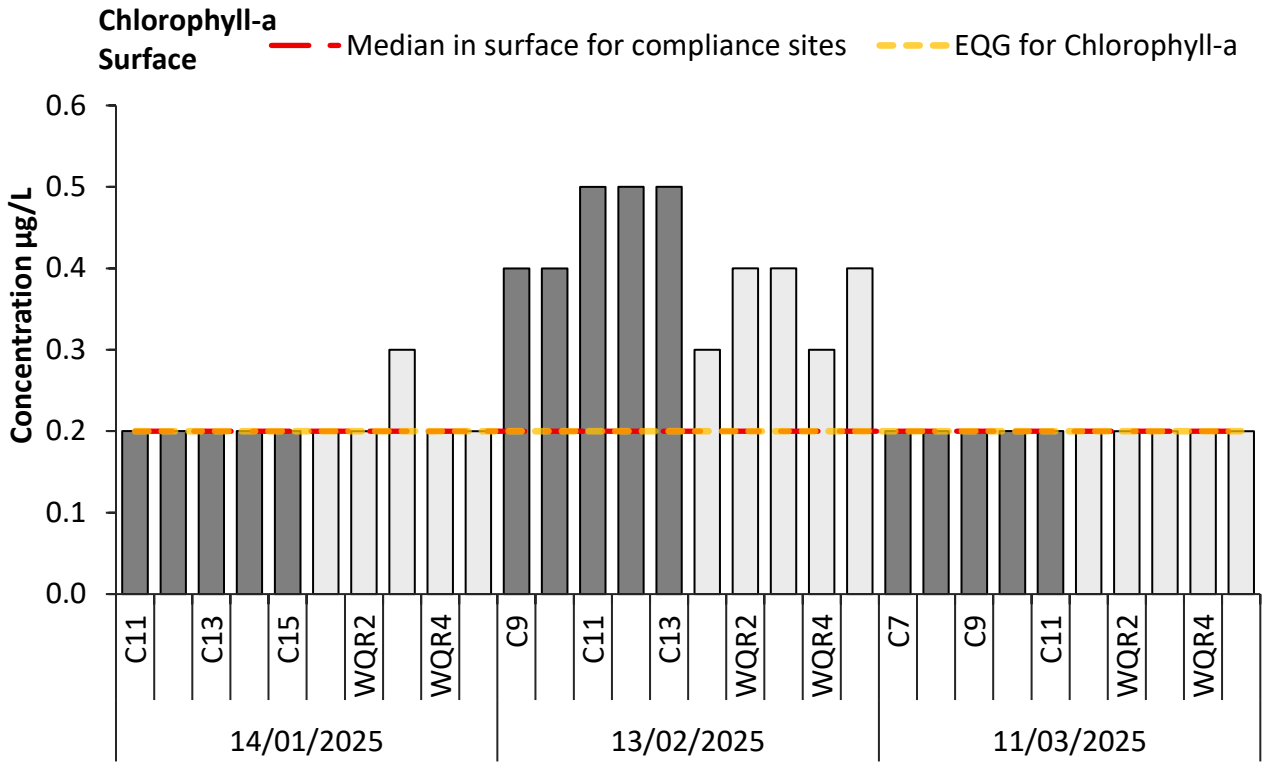
3.1.1 Surface water chlorophyll-a

The EQG for surface water chlorophyll-a is outlined in Table 3.1. Chlorophyll-a in surface waters ranged from 0.2–0.5 µg/L across all sites (Figure 3.1). The median chlorophyll-a concentration in surface waters at compliance monitoring sites at the boundary of the LEPA was 0.2 µg/L and equal to the 80th percentile of historical reference site data measured from 2003–2025 (0.2 µg/L; Figure 3.1) and did not exceed the EQG.

Table 3.1 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.

Source: Water Corporation (2012)
Notes:
1. EQG = Environmental Quality Guideline; LEPA = Low Ecological Protection Area.



Notes:
1. Water quality monitoring occurred at compliance sites C11–15 on 14 January, C9–C13 on 13 February and C7–C11 on 11 March 2025, down current of the surface drogue based on prevailing current direction at the time of sampling.
2. Dark grey bars indicate sites relevant to the Environmental Quality Guideline (EQG) for chlorophyll-a.
3. Yellow dashed line represents the 80th percentile of historical reference site data which is the Environmental Quality Guideline (0.2 µg/L) for surface chlorophyll-a.
4. Red dashed line represents the median in surface for compliance sites relevant to the Environmental Quality Guideline (EQG) (also 0.2 µg/L) for chlorophyll-a.

Figure 3.1 Surface chlorophyll-a concentrations at compliance and reference sites down current of the Bunbury Ocean Outlet compared to the 80th percentile of long-term reference data

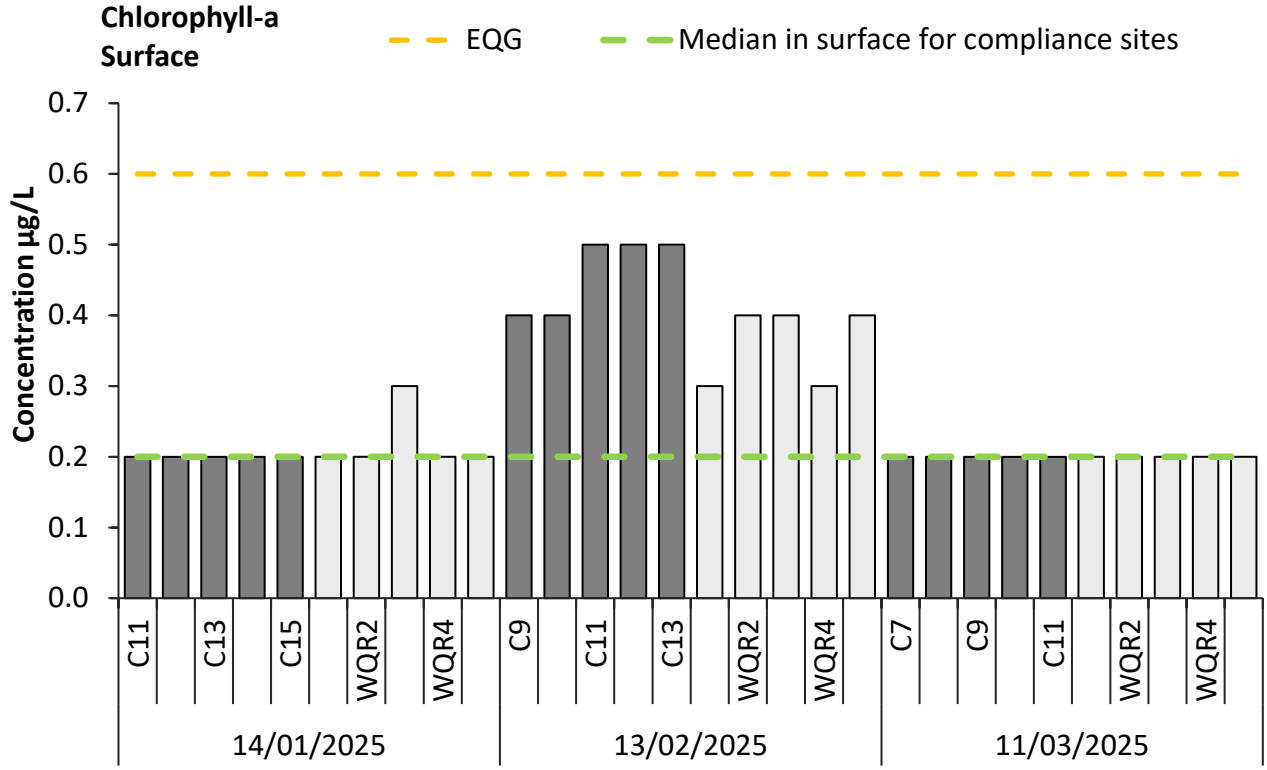
3.1.2 Phytoplankton biomass

The EQG for phytoplankton biomass (also measured as concentration of chlorophyll-a) is outlined in Table 3.2. Phytoplankton biomass (measured as chlorophyll-a) ranged from 0.2–0.5 µg/L in surface waters across all compliance sites. Phytoplankton biomass did not exceed three times the median of historical reference site data measured from 2003–2025 (0.6 µg/L; Figure 3.2) on any occasion during the non-river flow period and the EQG was met (Figure 3.2).

Table 3.2 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.

Source: Water Corporation (2012)
Note:
1. EQG = Environmental Quality Guideline



Notes:
1. Water quality monitoring occurred at compliance sites C11–15 on 14 January, C9–C13 on 13 February and C7–C11 on 11 March 2025, down current of the surface drogue based on prevailing current direction at the time of sampling.
2. Dark grey bars indicate sites relevant to the Environmental Quality Guideline (EQG) for phytoplankton biomass.
3. Yellow dashed line represents 3 times the median chlorophyll-a concentration of historical reference site data which is the Environmental Quality Guideline (0.6 µg/L) for phytoplankton biomass.

Figure 3.2 Phytoplankton biomass at compliance and reference sites down current of the Bunbury Ocean Outlet compared to historical reference data

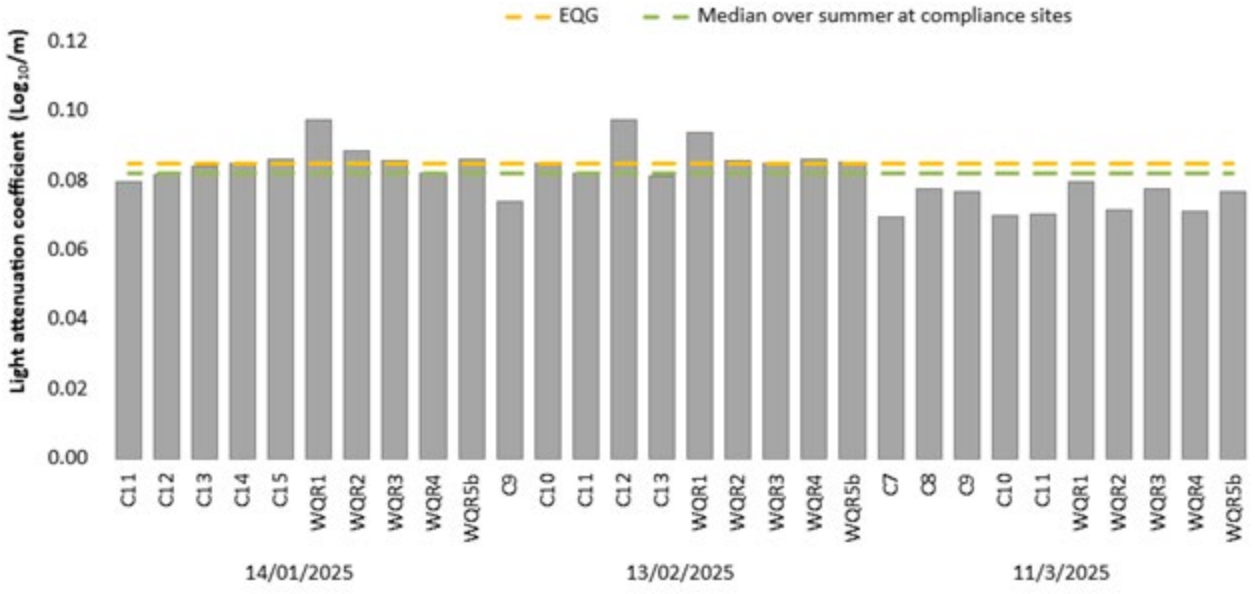
3.1.3 Light attenuation coefficient

The EQG relevant to the LAC is outlined in Table 3.3. Median LAC measured over summer 2025 at compliance sites (0.0824 Log_{10}/m) did not exceed the 80th percentile of historical reference site data measured from 2013–2025 (0.0859 Log_{10}/m; Figure 3.3) and the EQG was met (Figure 3.3).

Table 3.3 Environmental Quality Guideline for light attenuation coefficient

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

Notes:
1. EQG = Environmental Quality Guideline; LAC = light attenuation coefficient.



Notes:
1. Water quality monitoring occurred at compliance sites C11–15 on 14 January, C9–C13 on 13 February and C7–C11 on 11 March 2025, down current of the surface drogue based on prevailing current direction at the time of sampling.
2. Dark grey bars indicate sites relevant to the Environmental Quality Guideline (EQG) for light attenuation, median of which is 0.0824 Log_{10}/m.
3. Yellow dashed line is 80th percentile of historical reference site data, which is the Environmental Quality Guideline (0.0859 Log10/m).

Figure 3.3 Light attenuation coefficient measured at compliance and reference sites down current of the Bunbury Ocean Outlet compared to the 80th percentile of long-term reference data

3.1.4 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 3.4.

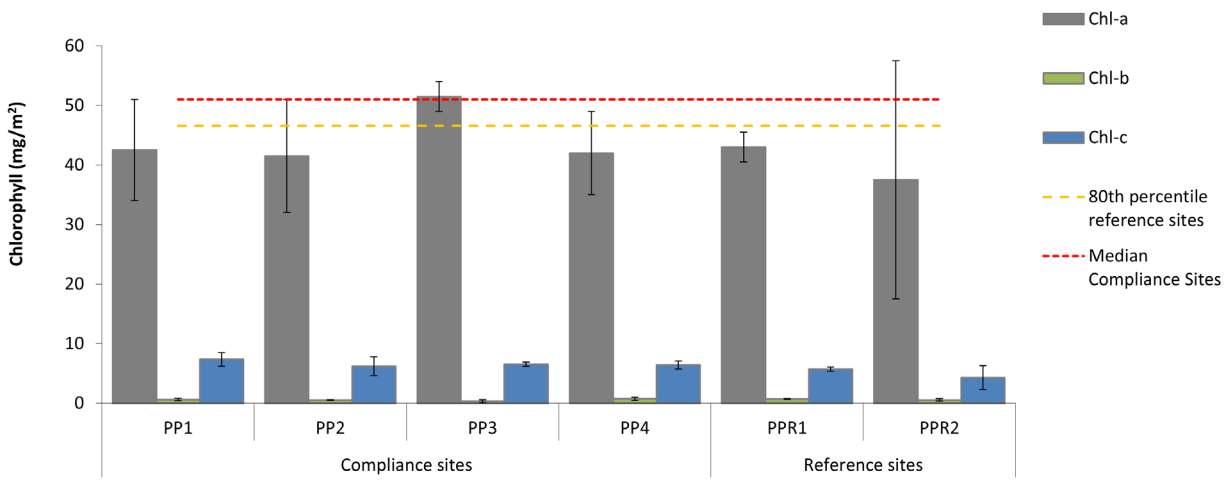
Table 3.4 Environmental Quality Guideline for periphyton biomass

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.

Notes:
1. EQG = Environmental Quality Guideline.

The median chlorophyll-a biomass from the 8 m depth was 51 mg/m^2 and above the 80th percentile of reference site data from the same 2025 sampling period at the 8 m depth (46.6 mg/m^2; Figure 3.4). 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 3.4). The dominant chlorophyll-a content is indicative of a periphyton assemblage dominated by diatoms and/or brown algae (SKM 1999).

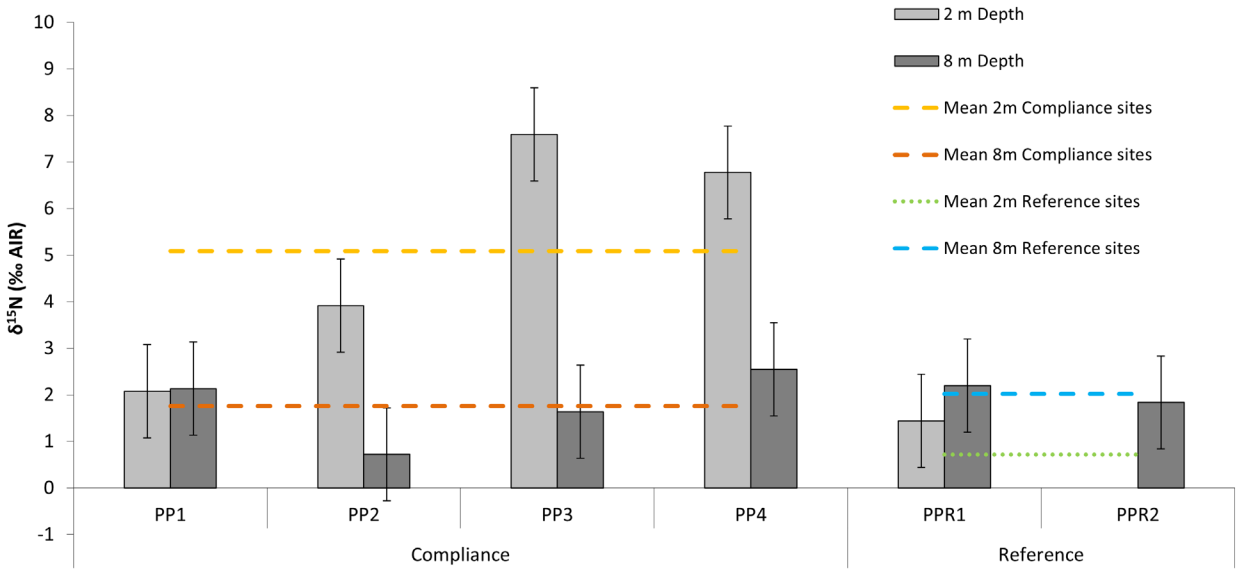


Notes:
1. Bars=mean (± standard error) chlorophyll-a, -b and -c concentration at compliance sites (PP1–PP4) and reference sites (PPR1–PPR4).
2. Red dashed line = median of chlorophyll-a concentration across compliance sites (51 mg/m^2 where n=8).
3. Yellow dashed line = 80th percentile of chlorophyll-a concentration at reference sites (46.6 mg/m^{2,} where n=4).

Figure 3.4 Periphyton chlorophyll-a, -b, and -c biomass at 8m depth for Bunbury Ocean Outlet compliance and reference sites and median biomass across compliance sites compared to the 80th percentile of reference sites

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 Ocean Outlet.

Mean $\delta^{15}N$ was higher in surface (2 m) samples at most compliance sites, except PP1, where the surface (2 m) and bottom (8 m) samples were comparable. The mean $\delta^{15}N$ of periphyton was higher in the surface samples of compliance sites than the mean $\delta^{15}N$ of the reference sites (Figure 3.5). The bottom mean $\delta^{15}N$ was similar between the compliance and reference site samples (Figure 3.5). The high mean periphyton $\delta^{15}N$ at the surface but not in bottom samples (Figure 3.5) suggests that the influence of the buoyant TWW plume is restricted to the surface waters (Figure 3.4).



Notes:
1. PP1–PP4 = periphyton compliance sites; PPR1 and PPR4 = periphyton reference sites.
2. Site PPR2 float was missing and line broken/cut on retrieval, mooring line found on seafloor with 2 m plates missing therefore no data and the 8 m plates were on the bottom, data likely compromised.
3. At each site (except PPR2) and each depth there was sufficient epiphyte growth on the collector plates for 2 replicates
4. Error bars represent ± standard error.

Figure 3.5 Mean δ1^{5}N content in periphyton collected at Bunbury Ocean Outlet compliance and reference sites in surface (2 m) and bottom (8 m) water depth

3.1.5 Seagrass health

The EQG for periphyton biomass was exceeded during the 2025 monitoring, and as a result, assessment against the EQS (seagrass health) was required. The EQS for seagrass health are outlined in Table 3.5.

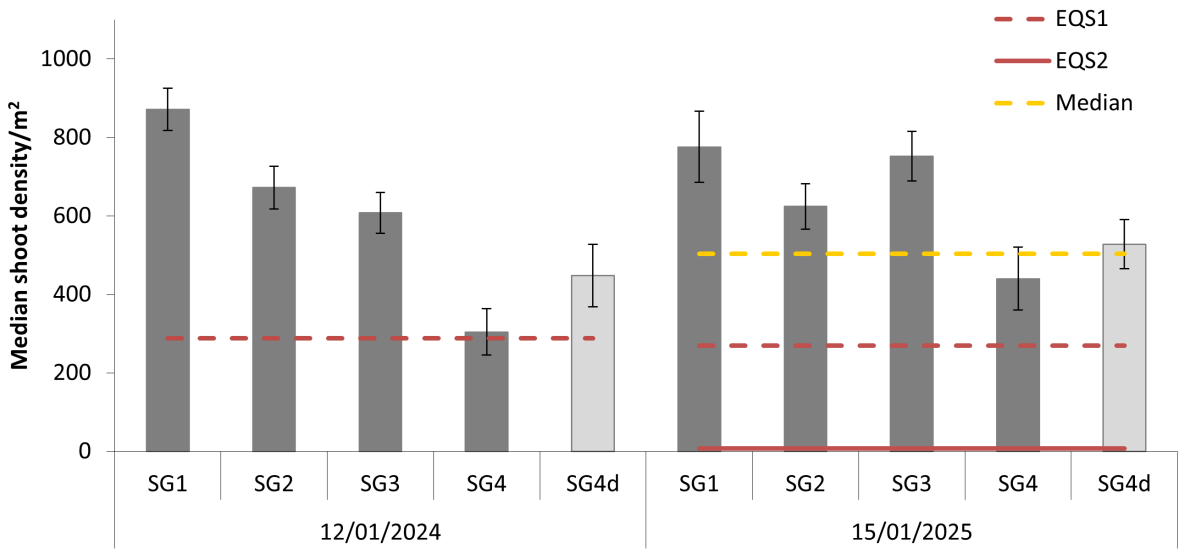
EQS1 is exceeded if the median shoot density measured over two consecutive years falls below the 20th percentile at an appropriate reference site (red dashed line; Figure 3.6). Median shoot density, at site SG4, was below the 20th percentile of reference sites (red dashed line; Figure 3.6) in 2023, but median shoot density has continued to increase through 2024 and 2025, and EQS1 was met.

In 2025, at all sites, the median shoot density was greater than the 5th percentile of the pooled reference site data (red solid line; Figure 3.6), meeting EQS2. Therefore, the EQS for seagrass health was met overall. The 5th percentile is lower in 2025 (7.2 shoots/m^2) compared to previous years (2024: 96 shoots/m^2 and 2022: 279 shoots/m^2), as several reference sites (SGR2, SGR3, and SGR5b) have been increasingly affected by erosion at the edge of the seagrass meadow adjacent to these sites.

Table 3.5 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, and
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.

Notes:
1. EQS = Environmental quality standard.
2. The EPA derived these EQS for seagrass shoot density specifically relevant for assessing the health of species of Posidonia (EPA 2005).



Notes
1. SG1–SG4 = seagrass compliance sites and SG4d = seagrass reference site

Figure 3.6 Median seagrass shoot density at seagrass health monitoring sites

3.2 Physico-chemical stressor

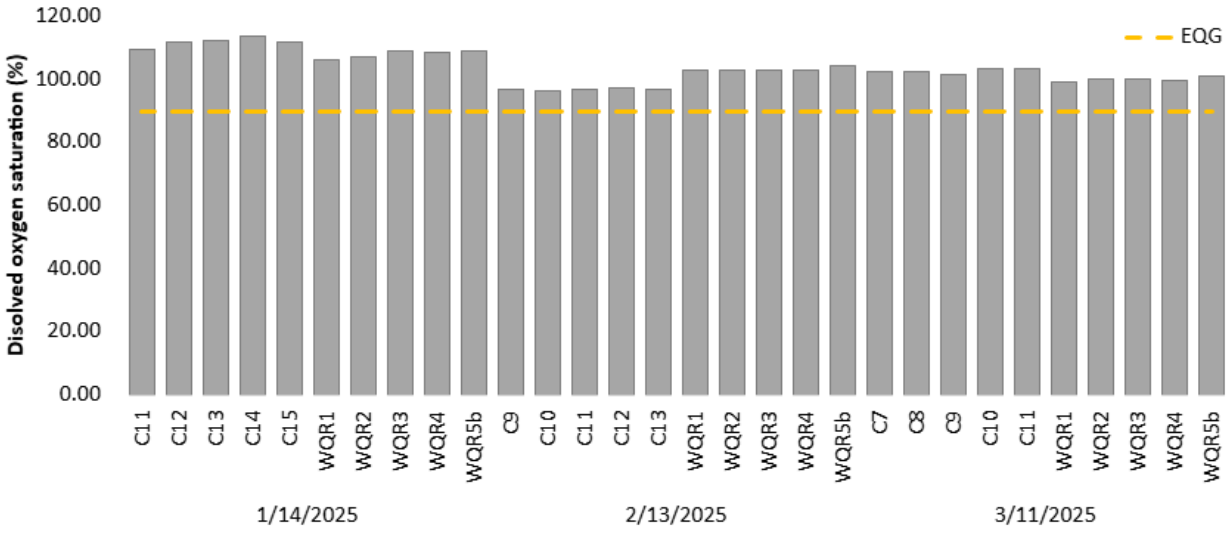
3.2.1 Dissolved oxygen

The EQG for DO is outlined in Table 3.6. The EQG for DO in the bottom waters remained above 90% saturation at all compliance monitoring sites over the defined 6-week monitoring period and the EQG was met (Figure 3.7).

Table 3.6 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.

Source: Water Corporation (2012)
Notes:
1. EQG = Environmental Quality Guideline



Notes:
1. Water quality monitoring occurred at compliance sites C11–15 on 14 January, C9–C13 on 13 February and C7–C11 on 11 March 2025, down current of the surface drogue based on prevailing current direction at the time of sampling.
2. Dark grey bars indicate sites relevant to the Environmental Quality Guideline (EQG) for dissolved oxygen (DO).
3. Yellow dashed line is the EQG for DO (90% saturation).
4. DO was measured from the seabed to 0.5 m above the seabed.

Figure 3.7 Dissolved oxygen in bottom waters at compliance and reference sites over the defined 6 week monitoring period

4 Seafood Safe for Human Consumption

4.1 Sampling approach and site locations

The EQO for the EV 'Fishing and Aquaculture' is designed to ensure 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 4.1). Shellfish compliance monitoring sites (C17–C32) are positioned at the boundary of the SHEZ; however, only the five compliance sites directly downstream of the outlet are sampled during each monitoring period (January, February, and March).

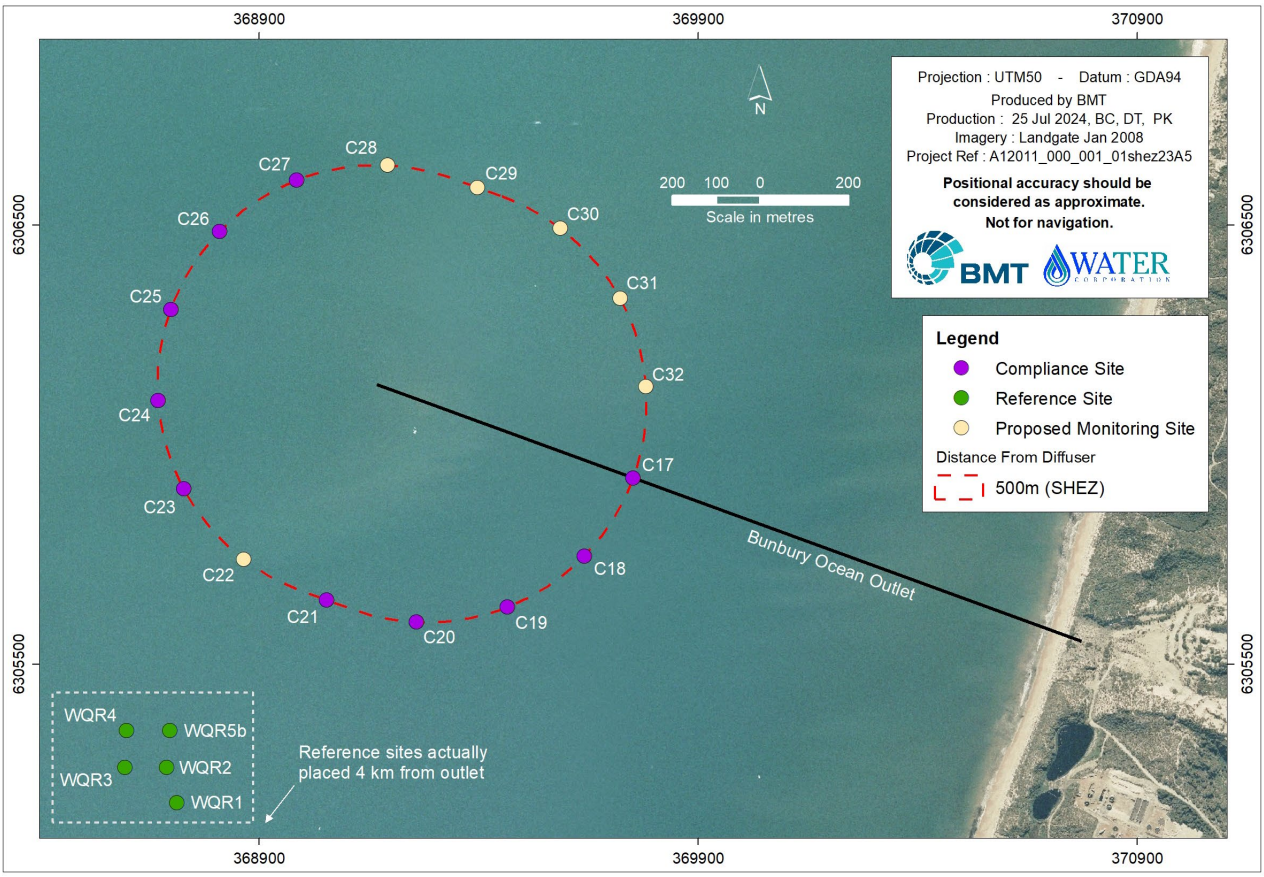


Figure 4.1 Compliance (C17–C32) monitoring sites on the boundary of the Bunbury Ocean Outlet Shellfish Harvesting Exclusion Zone and reference monitoring sites (WQR1–WQR5b)

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 shellfish be only consumed if grown commercially under strict monitoring programs. There is no aquaculture within 250 m of the diffuser, and there are no licenced shellfish-growing areas located in the Bunbury region (DoH 2015). The DoH has further stated 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 notified the Department of Environment Regulation (DER), now DWER, that, in the absence of such a full monitoring program, the application of the TTC criteria (EPA 2005) is not sufficient to protect those who wish to collect and eat wild shellfish.

4.2 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 analysing for TTC, it can be assessed whether the ocean water around the Bunbury Ocean Outlet has been exposed to faecal contamination.

Water samples were collected 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 on the three sampling occasions: 14 January, 13 February and 11 March 2025. 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 within the recommended holding time (<24 hours) and analysed using National Association of Testing Authorities (NATA) accredited methods.

4.3 Thermotolerant coliforms results

The EQG for microbial contaminants for the protection of aquatic life, safe for human consumption, is outlined in Table 4.1. Concentrations of TTC in both surface and bottom waters and at compliance monitoring sites were below the analytical limit of detection (<10 CFU/100 mL; Table 4.2). Median concentrations of TTC were below 14 CFU/100 mL, and no samples exceeded 21 CFU/100 mL (Table 4.2), meeting the EQG (Table 4.1). Full results are available in Appendix 5.

Table 4.1 Environmental Quality Guideline for thermotolerant coliforms

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

Source: Water Corporation (2012)
Note:
1. EQG = Environmental Quality Guideline; TTC = thermotolerant coliforms, CFU = colony forming unit

Table 4.2 Confirmed thermotolerant coliform concentrations at compliance monitoring sites down current of the Bunbury Ocean Outlet

Date	Compliance site	TTC in surface water (CFU/100 mL)	TTC in bottom waters (CFU/100 mL)
14 January 2025	C23	<10	<10
	C24	<10	<10
	C25	<10	<10
	C26	<10	<10
	C27	<10	<10
13 February 2025	C17	<10	<10
	C18	<10	<10
	C19	<10	<10
	C20	<10	<10
	C21	<10	<10
11 March 2025	C23	<10	<10
	C24	<10	<10
	C25	<10	<10
	C26	<10	<10
	C27	<10	<10
Median		<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. Water quality monitoring occurred at compliance sites C23–C27 on 14 January 2025, C17–C21 on 13 February 2025 and at C23–C27 on 11 March 2025, down current of the surface drogue based on prevailing current direction at the time of sampling.
3. TTC = thermotolerant coliforms.

4.4 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 DoH 2007) in the area surrounding Bunbury 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.

Water samples were analysed for toxic species of phytoplankton (defined by Western Australian Shellfish Quality Assurance Program (WASQAP) guidelines; DoH 2007). Phytoplankton samples were preserved in Lugol's iodine solution and identified to the lowest taxonomic level possible. The results for phytoplankton are presented in Appendix 4.

4.5 Algal biotoxins results

The EQG for toxic phytoplankton species (Table 4.3) states that concentrations of potentially toxic algae are not to exceed the WASQAP trigger concentrations in any samples (DoH 2007). Table 4.4 lists the phytoplankton species known to produce toxins that may be concentrated in shellfish and their WASQAP (DoH 2007) guideline trigger concentrations.

Table 4.3 Environmental Quality Guideline for toxic phytoplankton species

	Phytoplankton species	Concentration of potentially toxic algae at the boundary of the SHEZ are not exceed the WASQAP[1] trigger concentrations in any sample
EQG	*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

Source: Water Corporation (2012)
Note:
1. Western Australian Shellfish Assurance Program (WASQAP; DoH 2007) as stipulated by Water Corporation 2012.

The phytoplankton *Gymnodinium* spp. had estimated cell density greater than the WASQAP trigger concentration (DoH 2007) at sites C25 surface and C26 bottom on 13 February 2025 (1200 and 1840 cells/L, respectively; Table 4.4) and sites C21 and C23 bottom on 11 March 2025 (1760 and 3280 cells/L, respectively; Table 4.4). The laboratory did not identify *Gymnodinium* spp. *to* a specific species of the genera; however, it was confirmed the identification was not *Gymnodinium catenatum*, the species to which the WASQAP trigger concentration applies[1] and therefore the EQG was met. No phytoplankton species were present in the remaining samples at densities greater than WASQAP (DoH 2007) trigger concentrations (Table 4.4).

[1] The identified phytoplankton species was deemed highly unlikely to be *Gymnodinium catenatum* primarily because all observed *Gymnodinium* cells were solitary, contrasting sharply with *G. catenatum*'s characteristic formation of long, swimming chains typically comprising up to 32 cells, and occasionally 64. Furthermore, the encountered cells were generally smaller than the typical size range for *G. catenatum*. This determination is supported by the historical rarity of *G. catenatum* detection along the South-west Australian coast (Dalcon Environmental, pers. comm., 24 July 2025)

Table 4.4 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 (cells/L)	WASQAP[1] (cells/L)	Compliance[2]
14 January 2025	C27	Surface	*Pseudo-nitzschia "delicatissima"* group (PT)	80	250,000	■
			Pseudo-nitzschia "seriata" group (PT)	80	250,000	■
			Gymnodium spp.	160	1000	■
	C28	Surface	*Pseudo-nitzschia "delicatissima"* group (PT)	160	250,000	■
			Gymnodium spp.	240	1000	■
	C29	Surface	*Gymnodinium* spp.	320	1000	■
			Protoceratium reticulatum	160	500	■
	C30	Surface	*Gymnodium* spp.	240	1000	■
	C31	Surface	*Pseudo-nitzschia "delicatissima"* group (PT)	80	250,000	■
			Gymnodium spp.	320	1000	■
	C27	Bottom	*Gonyaulax* spp.	80	1000	■
			Pseudo-nitzschia "delicatissima" group (PT)	80	1000	■
	C28	Bottom	*Gymnodium* spp.	240	1000	■
	C29	Bottom	*Gymnodium* spp.	80	1000	■
	C30	Bottom	*Gymnodinium* spp.	160	1000	■
			Pseudo-nitzschia "delicatissima" group	80	250,000	■
			Alexandrium spp.	80	100	■
	C31	Bottom	*Gymnodinium* spp.	80	1000	■
13 February 2025	C25	Surface	*Pseudo-nitzschia "delicatissima"* group	320	250,000	■
			Gymnodium spp.	1200[3]	1000	■
	C26	Surface	*Gymnodium* spp.	240	1000	■

Date	Site	Depth	Species	Estimated cell density (cells/L)	WASQAP[1] (cells/L)	Compliance[2]
	C27	Surface	*Pseudo-nitzschia "delicatissima"* group	160	250,000	■
	C28	Surface	Nil	–[4]	–	–
	C29	Surface	*Gymnodinium* spp.	80	1000	■
			Pseudo-nitzschia "delicatissima" group	80	250,000	■
	C25	Bottom	*Gymnodinium* spp.	480	1000	■
			Pseudo-nitzschia "delicatissima" group	80	250,000	■
	C26	Bottom	*Gymnodinium* spp.	1840[3]	1000	■
			Pseudo-nitzschia "delicatissima" group	80	250,000	■
	C27	Bottom	*Gymnodinium* spp.	400	1000	■
			Prorocentrum lima	80	500	■
			Pseudo-nitzschia "delicatissima" group	160	250,000	■
	C28	Bottom	*Gymnodinium* spp.	480	1000	■
	C29	Bottom	*Gymnodinium* spp.	320	1000	■
11 March 2025	C21	Surface	*Gymnodinium* spp.	480	1000	■
	C22	Surface	*Gymnodinium* spp.	160	1000	■
	C23	Surface	*Pseudo-nitzschia "delicatissima"* group	80	250,000	■
	C24	Surface	*Gymnodinium* spp.	160	1000	■
	C25	Surface	*Gymnodinium* spp.	800	1000	■
			Pseudo-nitzschia "delicatissima" group	160	250,000	■
			Protoceratium reticulatum	80	500	■
	C21	Bottom	*Gymnodinium* spp.	1760[3]	1000	■
			Gonyaulax spp.	80	100	■
			Pseudo-nitzschia "delicatissima" group	240	250,000	■

Date	Site	Depth	Species	Estimated cell density (cells/L)	WASQAP[1] (cells/L)	Compliance[2]
	C22	Bottom	*Gymnodinium* spp.	640	1000	■
			Pseudo-nitzschia "delicatissima" group	80	250,000	■
	C23	Bottom	*Gymnodinium* spp.	3280[3]	1000	■
	C24	Bottom	*Gymnodinium* spp.	880	1000	■
			Pseudo-nitzschia "delicatissima" group	80	250,000	■
	C25	Bottom	*Gymnodinium* spp.	640	1000	■
			Protoceratium reticulatum	80	500	■
			Pseudo-nitzschia "delicatissima" group	320	250,000	■

Notes:

1. WASQAP = Western Australian Quality Assurance Program (DoH 2007, as per Water Corporation 2012).
2. Green symbols indicate the estimated cell density was below the WASQAP toxic algae trigger concentration, red symbols indicate the estimated cell density exceeded the WASQAP toxic algae trigger concentration.
3. Dalcon Environmental reported the identified phytoplankton species was highly unlikely to be *Gymnodinium catenatum* primarily because all observed *Gymnodinium* cells were solitary, contrasting sharply with *G. catenatum*'s characteristic formation of long, swimming chains typically comprising up to 32 cells, and occasionally 64 (Dalcon Environmental, pers. comm., 24 July 2025). The WASQAP limit is only applicable to *Gymnodinium catenatum,* and therefore, these are not exceedances.
4. – = no phytoplankton recorded in the sample.

5 Primary and secondary contact recreation

5.1 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 Ocean Outlet is to be maintained so that primary and secondary contact recreation is safe in all waters except those areas designated otherwise.

To test for the presence of pathogens, water samples were collected from the surface and bottom of the water column and analysed for faecal pathogens and algal biotoxins at compliance monitoring sites, shoreline monitoring sites, plume tracking sites and reference sites on three sampling occasions: 14 January, 13 February and 11 March 2025. Samples were collected in pre-sterilised bottles before being chilled and placed in the dark. Upon completion of the samples, they were transported to the PathWest Laboratory and Dalcon Environmental for analysis (Appendix 5).

Water quality monitoring sites (C1–C16) are positioned along the boundary of the LEPA; however, only the five compliance sites directly down current of the outlet are sampled during each monitoring period (January, February, and March) for faecal pathogens (Figure 5.1).

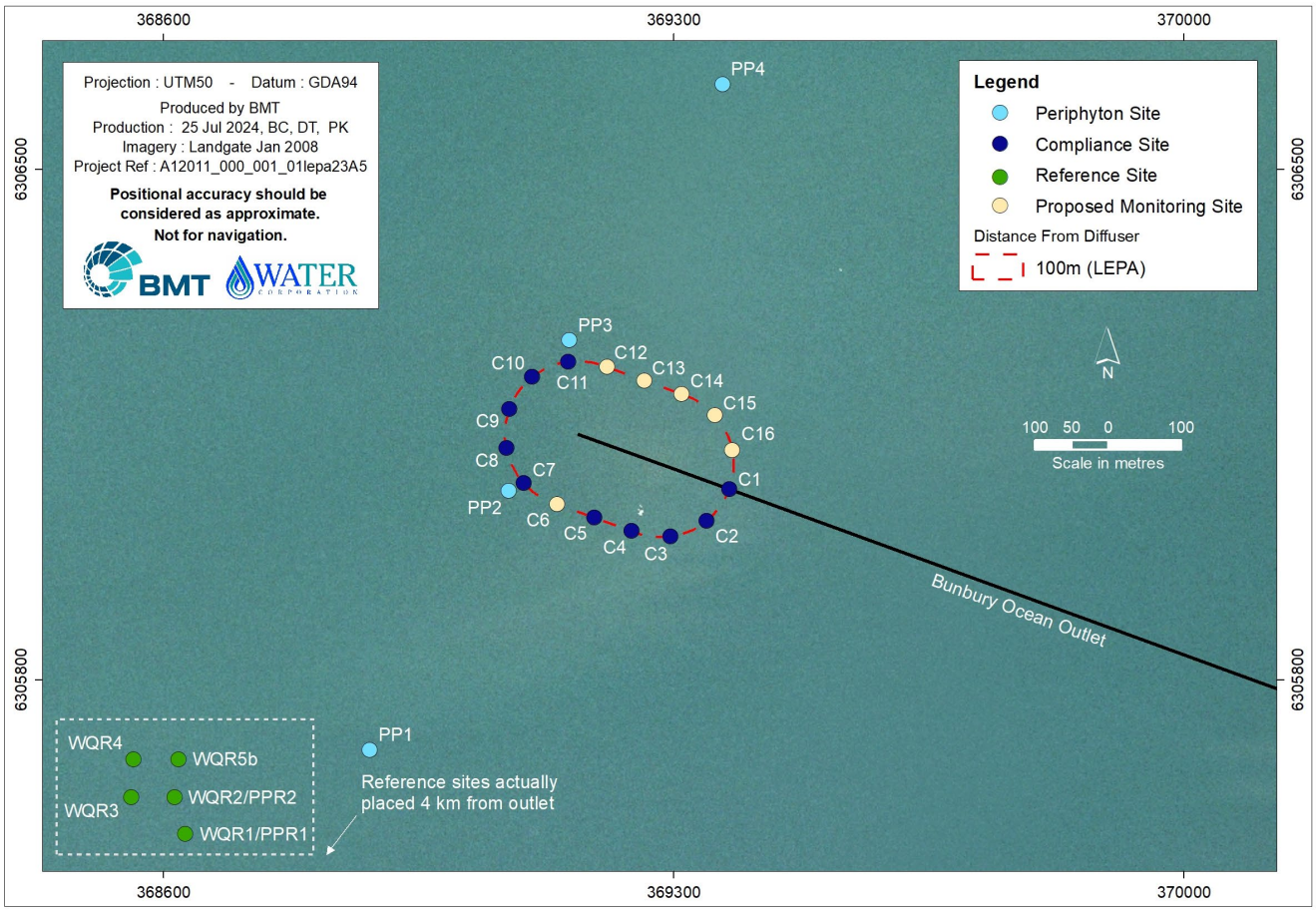


Figure 5.1 Primary and secondary recreational contact compliance monitoring sites (C1–C16) on the boundary of the Bunbury Ocean Outlet Low Ecological Protection Area and reference monitoring sites (WRQ1–WQR5b)

5.2 Faecal pathogens sampling

Disease-causing microorganisms (pathogens) associated with bathing areas include *salmonellae sp*, *Shigellae sp,* 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 waterborne 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).

5.3 Faecal pathogen results

The EQG for faecal pathogens is outlined in Table 5.1. The 95th percentile of the pooled *Enterococci* spp. concentrations in surface waters were 16.3 MPN/100 mL (Table 5.2) and the EQG was met.

Table 5.1 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)
Note:
1. EQG = Environmental Quality Guideline; MPN = most probable number; LEPA = Low Ecological Protection Area.

Table 5.2 *Enterococci* spp. concentrations at compliance monitoring sites down current of the Bunbury Ocean Outlet

Date	Compliance site	*Enterococci* spp. in surface waters (MPN/100 mL)	Enterococci spp. in bottom waters (MPN/100 mL)
14 January 2025	C7	5	<10
	C8	5	<10
	C9	5	<10
	C10	10	<10
	C11	31	<10
13 February 2025	C1	5	<10
	C2	5	<10
	C3	5	<10
	C4	5	<10
	C5	5	<10
11 March 2025	C7	5	<10
	C8	5	<10
	C9	5	<10
	C10	5	<10
	C11	5	<10
95th percentile of compliance sites		16.3	5

Note:
1. MPN = most probable number
2. Where results were below LoR, they were considered to be half the LoR for statistical analysis (ANZG 2018)

Table 5.3 *Enterococci* spp. concentrations at the shoreline monitoring sites down current of the Bunbury Ocean Outlet

Date	Shoreline site	*Enterococci* spp. (MPN/100 mL)
14 January 2025	<10	<10
	<10	<10
	<10	<10
	<10	<10
	<10	<10
	<10	<10
	<10	<10
	<10	<10
	<10	<10
13 February 2025	<10	<10
	<10	<10
	<10	<10
	<10	<10
	<10	<10
	<10	<10
	<10	<10
	<10	<10
	<10	<10
11 March 2025	<10	<10
	10	10
	<10	<10
	<10	<10
	<10	<10
	<10	<10
	<10	<10
	<10	<10
	<10	<10
95th percentile of shoreline sites	5	5

Note:
1. MPN = most probable number
2. Where results were below LoR, they were considered to be half the LoR for statistical analysis (ANZG 2018)

5.4 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: 14 January, 13 February, and 11 March 2025 to assess if counts were within acceptable guideline limits (NHMRC 2008).

5.5 Algal biotoxins results

The EQG for algal biotoxins is outlined in Table 5.4. No toxic algae species including: *Lyngbya majuscule*, *Pfiesteria spp or Karenia brevis* were not recorded at compliance monitoring sites during the 2025 summer monitoring. The EQG relevant to algal biotoxins (for the EQO, Maintenance of Primary and Secondary Contact Recreation) was met.

Table 5.4 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* sp. present in high numbers outside the LEPA

Source: Water Corporation (2012)
Note:
1. EQG = Environmental quality guideline, LEPA = Low Ecological Protection Area

6 References

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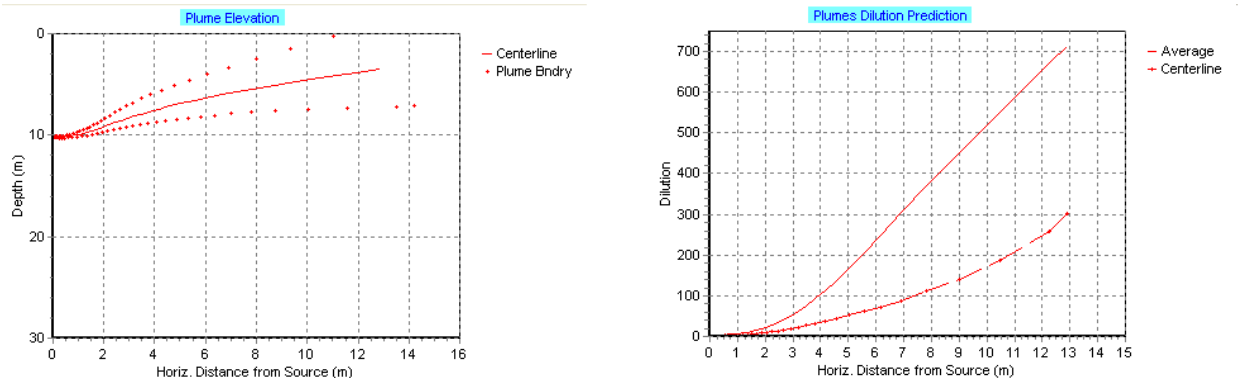
Appendix 1 – Initial Dilution Modelling

Initial dilution modelling for the ambient conditions and treated wastewater flows for the 14 January 2025 was completed using the VPLUMES initial dilution model. The VPLUMES model is accepted for use by the United States Environmental Protection Agency (http://www.epa.gov) and captures simple features concerning the surrounding environment such as depth at point of discharge, net current and wind speed. VPLUMES is designed to predict the near-field behaviour of wastewater effluent plumes in the region where the plume first jets into the surrounding waters and then, in the case of positively buoyant plumes, rises and mixes with the surrounding waters (generally <10 m from the diffuser). Additional dilution is expected between the point that the plume reaches the surface and the notional low ecological protection area (LEPA) boundary. Although initial dilution therefore underestimates the dilution at the notional LEPA boundary, it is favoured as it represents a highly conservative approach.

For the ambient conditions at the time of the survey, the modelling predicted an average initial dilution of 1:712 and a centreline dilution of 1:302 on 14 January 2025 (Figure 1 and Figure 2).



Notes:

a) predicted average and centreline dilution
b) predicted plume elevation

Figure 1 Initial dilution modelling output showing predicted plume elevation trajectory (left) and predicted average and centreline dilutions (right)

```
/ Windows UM3. 7/29/2025 11:43:59 AM
Case 1; ambient file c:\plumes\VP plume 15.001.db; Diffuser table record 1: ---------------------------------
      Depth    Amb-cur    Amb-dir    Amb-sal    Amb-tem    Amb-pol      Decay    Far-spd    Far-dir    Disprsn
         m        m/s        deg        psu          C      kg/kg        s-1        m/s        deg    m0.67/s2
       0.0      0.155      69.64      36.36      23.54        0.0        0.0  2.1416E+8  2.1416E+8        0.0
      10.2     0.0774      69.64      36.36      23.54        0.0        0.0  2.1416E+8  2.1416E+8        0.0
   P-dia  P-elev V-angle H-angle   Ports Spacing AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)      (m)   (deg) (N-deg)      ()      (m)      (m)      (m)      (m)   (MLD)    (psu)     (C) (kg/kg)
    0.08      0.8     0.0    20.36    26.0      4.0    100.0    150.0     10.2   11.15     0.57    22.1      0.1
Froude number:      6.831
        Depth   Amb-cur    P-dia  Polutnt    Dilutn  CL-diln    x-posn    y-posn
Step      (m)    (cm/s)      (m)  (kg/kg)       ()        ()       (m)       (m)
   0      10.2      7.74     0.08      0.1      1.0       1.0       0.0       0.0;
 100     9.936     7.933    0.436   0.0138    7.082     3.125      0.36     0.971;
 200     8.366     9.114    1.545  0.00191    51.15     19.68     1.014     2.732;
 287     5.995      10.9    4.005  0.00034    286.3     83.22     2.323     6.259; axial vel  0.0188 merging,
 300     5.471     11.29    4.687 0.000263    370.4     111.3     2.727     7.348;
 333     3.514     12.75    7.722 0.000137    712.0     302.1     4.486     12.09; surface,
 ;
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Figure 2 Initial dilution modelling tabulated output from Bunbury Ocean Outlet on 14 January 2025

Appendix 2 – Detailed Methods

Detailed methods for water quality in the receiving environment

A.1.1 Water quality sampling approach and site locations

A.1.1.1 Compliance monitoring

Water samples were collected during three separate surveys on 14 January, 13 February and 11 March 2025. During each survey, sampling was undertaken at compliance monitoring sites ~100 m from the TWW outlet diffuser (Figure 1). At each compliance monitoring site, water samples were collected from one of eight sampling grids – aligned either north, south, east, west, northeast, southeast or southwest of the diffuser. – depending on the direction of the prevailing surface currents at the time of sampling (Figure 2 and Figure 3). To determine the flow direction of surface currents, a drogue was released prior to each sampling survey. The bearing of the drogue drift was then used to select the sampling grid, according to the eight grid scenario bearings in Table 1, Figure 2 and Figure 3.

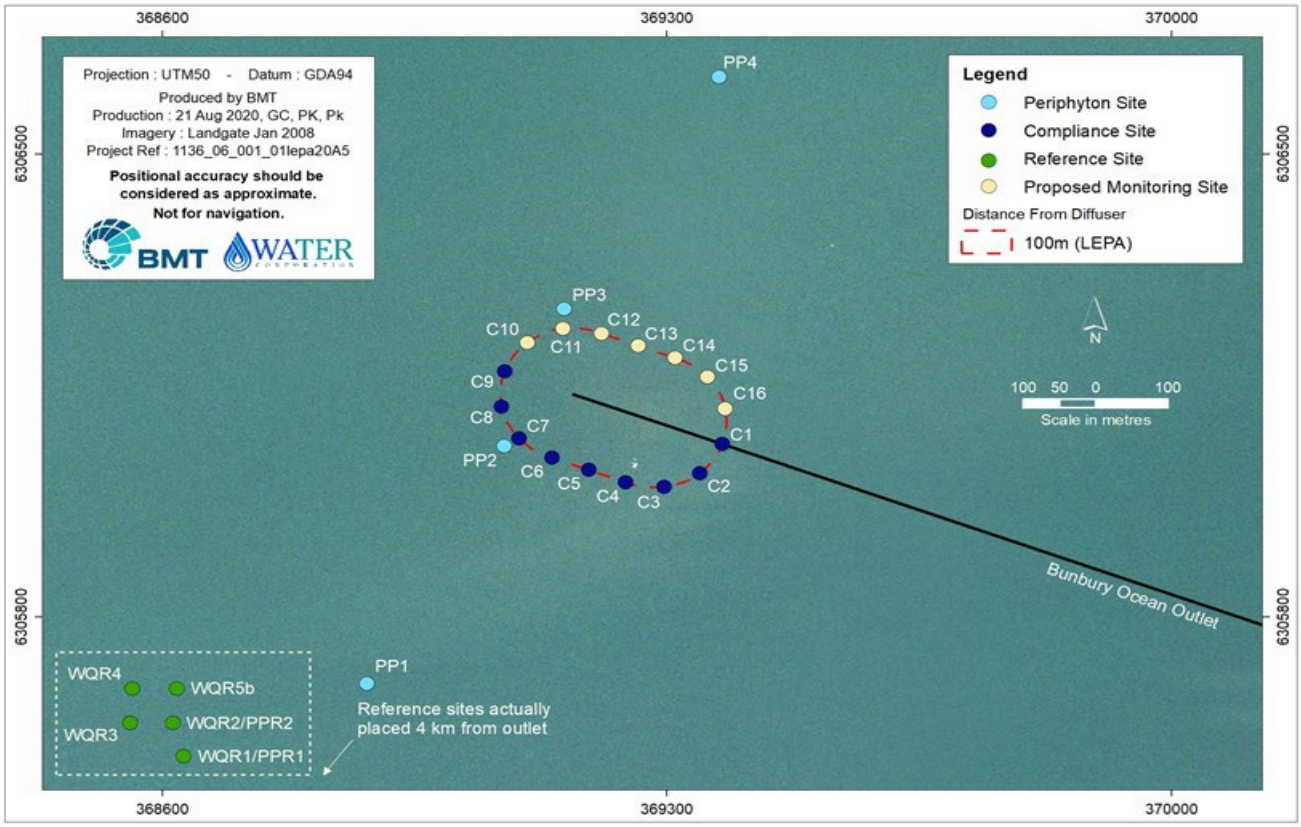

Figure 1 Compliance monitoring and reference sites around the Bunbury treated wastewater ocean outlet

Table 1 Grid scenarios based on drogue displacement bearings

Grid scenario	Bearing 1	Bearing 2
Northerly	357.5	42.5
North-easterly	42.5	87.5
Easterly	87.5	132.5
South-easterly	132.5	177.5
Southerly	177.5	222.5
South-westerly	222.5	267.5
Westerly	267.5	312.5
North-westerly	312.5	357.5

Source: Water Corporation (2012)

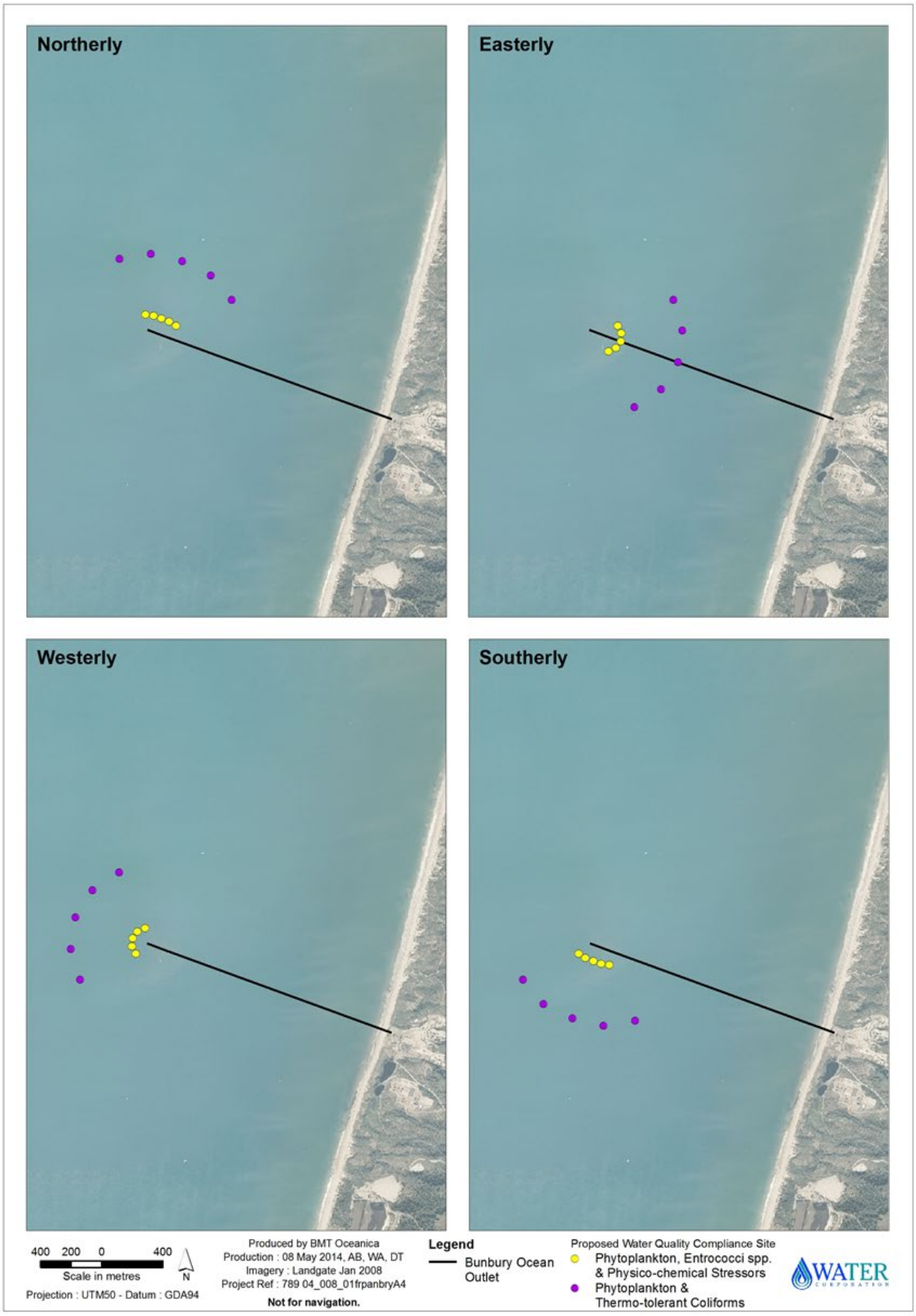

Figure 2 Compliance monitoring sites samples for the northerly, easterly, westerly and southerly sampling grid

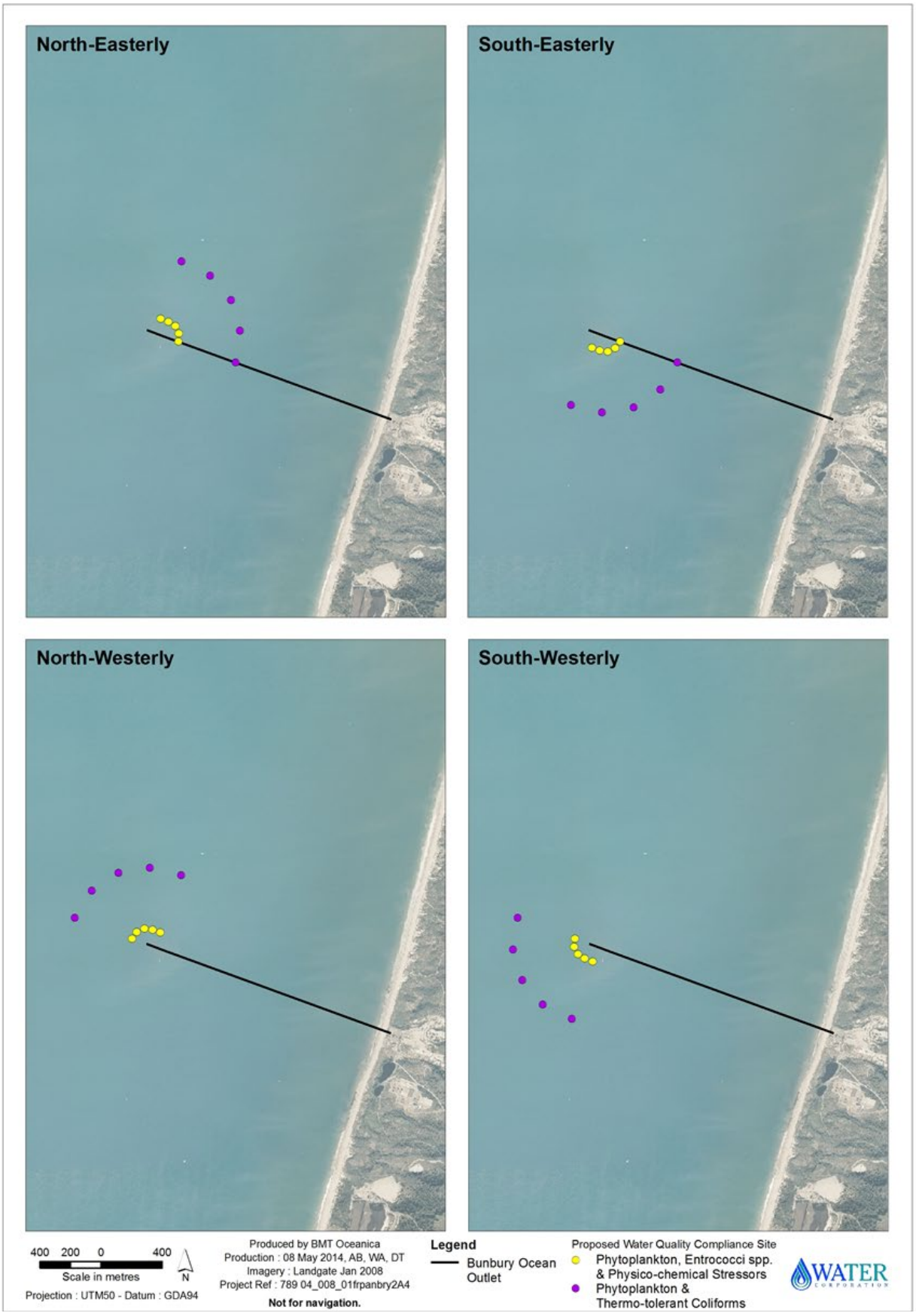

Figure 3 Compliance monitoring sites sampled for the north-easterly, south-easterly, north-westerly and south-westerly grid scenarios

The field design incorporates 16 possible fixed compliance monitoring sites (C1–C16) distributed along a 100 m radius from the diffuser, from which five are selected (using the drifter technique described above) that lie directly down-current of the outlet on each sampling occasion. Compliance sites sampled in 2025 are listed in Table 2. Five reference sites, located ~4km from the TWW outlet, were also sampled on each sampling occasion in 2025 (Figure 1, Table 2). The location of these sites is permanently fixed, they do not alter between sampling occasion.

Table 2 Compliance monitoring and reference sites for Bunbury treated wastewater ocean outlet sampling during 2025

Date	Compliance sites	Reference sites	Parameters
14 January	C11	WQR1	• Chlorophyll-a • Light attenuation • Dissolved oxygen
	C12	WQR2	
	C13	WQR3	
	C14	WQR4	
	C15	WQR5b	
13 February	C09	WQR1	
	C10	WQR2	
	C11	WQR3	
	C12	WQR4	
	C13	WQR5b	
11 March	C07	WQR1	
	C08	WQR2	
	C09	WQR3	
	C10	WQR4	
	C11	WQR5b	

Chlorophyll-a was measured 1 m below the surface and 2 m above the seabed at each compliance site. Chlorophyll-a was collected using the organic material retained on GF/C filters, chlorophyll-a samples were immediately placed on ice out of direct sunlight, before being transported to the laboratory for analysis.

Dissolved oxygen was measured at 1 m intervals from the surface down to the seabed using a Sea-Bird Electronics SBE19plusV2 vertical profiling sensor. At each site, light measurements were collected simultaneously at two locations within the water column (using a LI-COR Model LI-400 probe), with one sensor positioned 1 m below the surface and the second sensor 7 m below the surface (6 m apart) to assess change (attenuation) in light with depth. LAC was calculated using the formula:

LAC= [log10(irradiance at depth)–log10(irradiance at surface)/depth interval]

Plume tracking

On each sampling occasion (January, February and March), seven plume tracking sites were sampled using a gradient approach with distance from the outlet (Table 3). Site locations were determined by following the direction of the water movement from the diffuser (established by releasing a drogue; Table 3).

Water samples from each site were analysed for chlorophyll-a ammonia, nitrate+nitrite and ortho-phosphate (Table 3). Immediately following collection, water samples were passed through a 0.45 µm GF/C filter and then placed on ice out of direct sunlight, before being transported to the laboratory for analysis.

Table 3 Plume tracking sites for Bunbury treated wastewater ocean outlet sampling during 2025

Plume tracking site	Distance	Parameters
T0	0	• Chlorophyll-a • Ammonia • Nitrate+nitrite • Ortho-phosphate
T1	50	
T2	100	
T3	300	
T4	500	
T5	750	
T6	1000	

Periphyton monitoring

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 productivity resulting from wastewater discharge in Perth's coastal waters (Cosgrove *et al.* 2004).

Assimilation of dissolved nitrogen from wastewater by periphyton generally leads to a high tissue nitrogen stable isotope analysis (δ15N) in microalgae that is 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 by 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.

Periphyton biomass was measured using periphyton collectors at four monitoring sites (PP1–PP4) around the diffuser (two positioned ~100 m and two positioned ~500 m to the north and south of the diffuser, respectively), and at two reference sites ~4 km to the south of the diffuser (PPR1 and PPR2) (Figure 4). At each site, two collectors were deployed as follows:

- One collector with four settlement plates (150x150 mm) suspended at ~2 m depth (surface)
- One collector with four settlement plates (150x150 mm) suspended at 8 m depth (bottom), noting the water column depth was generally ~10-11 m across the study area.

The stratified sample design (depth and distance from the outlet) gives an indication of the spatial and vertical extent of epiphyte growth, which can be related to plume behaviour and hydrodynamics. Collector plates were deployed on mooring lines on 15 January and retrieved on 14 February 2025. After retrieval, the periphyton collected was split equally for chlorophyll analysis and isotopic nitrogen analysis.

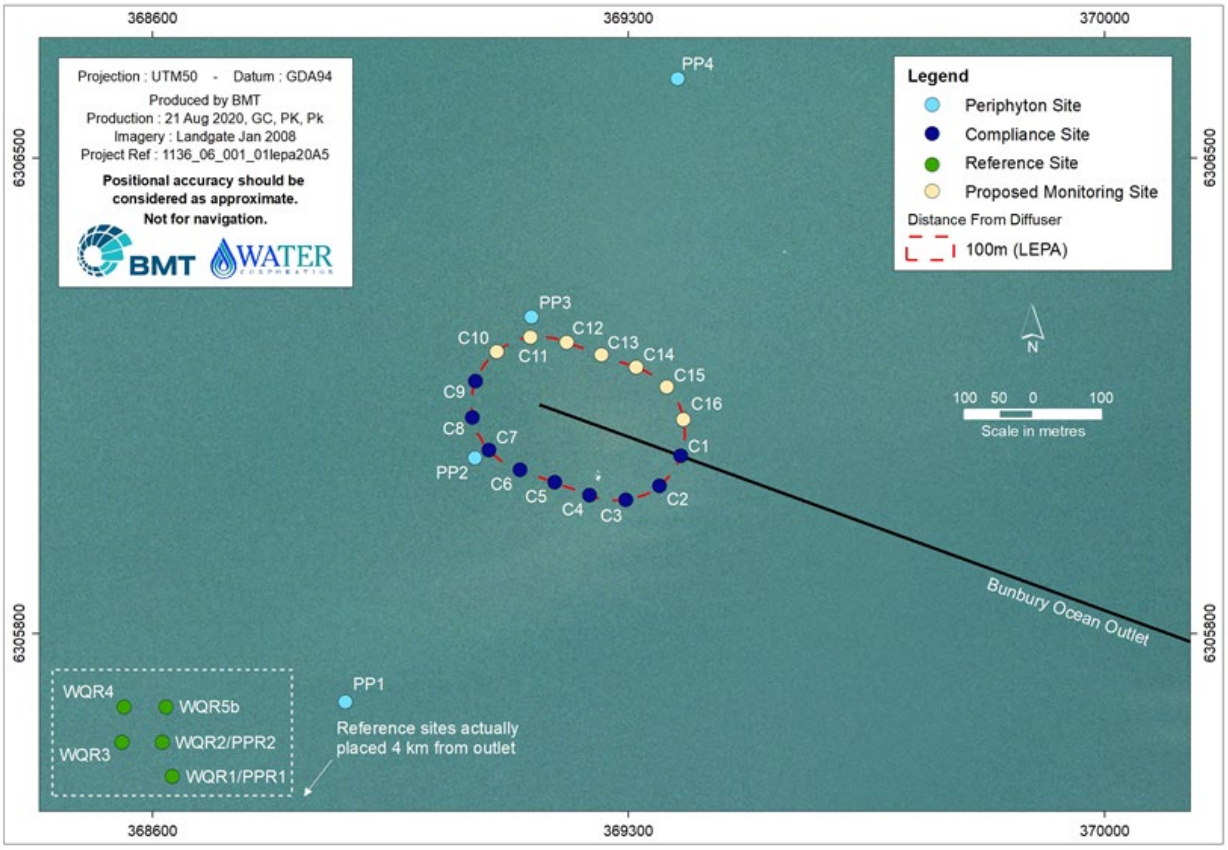

Figure 4 Periphyton compliance (PP1-PP4), ecological compliance (C1-C16) and water quality reference monitoring sites

Seagrass health

Seagrass shoot density is measured as part of the BOOM program to assess for potential sublethal responses by seagrass to elevated nutrients associated with wastewater discharges. The EPA has established two EQC for seagrass shoot density specifically relevant for assessing the health of species of Posidonia (in the Bunbury region, Posidonia angustifolia is the dominant species). The EQC from the BOOM Management Plan (Water Corporation 2012) were applied. These EQC have been set at the EQS level by the EPA and are:

- EQS 1: requires that the ambient [median] values for seagrass meadow shoot density measured in two consecutive years is greater than the 20th percentile of shoot density measured at an appropriate reference site.
- EQS 2: required that the ambient [median] values for seagrass meadow shoot density in any one year is greater than the 5th percentile of meadow shoot density measured at an appropriate reference site.

To ensure compliance with the EQO for ecosystem health, the nutrient enrichment EQG (surface chlorophyll-a, periphyton and light attenuation coefficient) must first be met. If any of the nutrient enrichment EQG are exceeded, assessment against the EQS is triggered and the EQS (seagrass health) must then be met. If no nutrient enrichment EQG are exceeded, then the EQO is met and assessment against the EQS is not triggered, however seagrass health results are still provided for contextual purposes.

A.1.1.2 Monitoring sites and sampling techniques

From 2002 to 2011, shoot density has been measured at five reference sites (SGR1–SGR5) ~4 km south of the outlet, and at four compliance sites in close proximity (≤500 m) to the north and south of the outlet (SG1–SG4). Seagrass monitoring around the outlet over this time generally revealed high natural spatial and temporal variability in shoot density at sites SG1–SG3, although site SG4 consistently had low seagrass shoot density relative to reference sites. In response to low shoot density at SG4, Water Corporation increased the level of spatial replication of seagrass monitoring around this site during 2011/2012, and site SG4d was added permanently to the seagrass health monitoring program (Figure 5).

On 15 and 16 January 2025, the density of seagrass shoots were measured at four compliance sites (SG1–SG4), five reference sites (SGR1–SGR5b) and at site SG4d. At each site, the number of *P.angustifolia* shoots in ten fixed, permanently located quadrats (n=10; 0.25 x 0.25 m^2), were counted by SCUBA divers. The number of *P.australis* and *Amphibolis antarctica* seagrass stems were also recorded for contextual purposes (i.e. where these were observed in quadrats).

During seagrass monitoring, additional qualitative measures of seagrass health were collected in situ, namely:

- Photograph of all quadrats
- Adjacent bare sand areas examined for remains of seagrass rhizome
- Visual observation index for epiphyte algae loading (rated on a scale of 0–3, where 0 = no algae and 3 = high algae cover)
- Visual assessment of the type of epiphyte algae: filamentous, encrusting and/or corticose (foliose)
- Visual observation of presence or absence of detritus and dead rhizome.

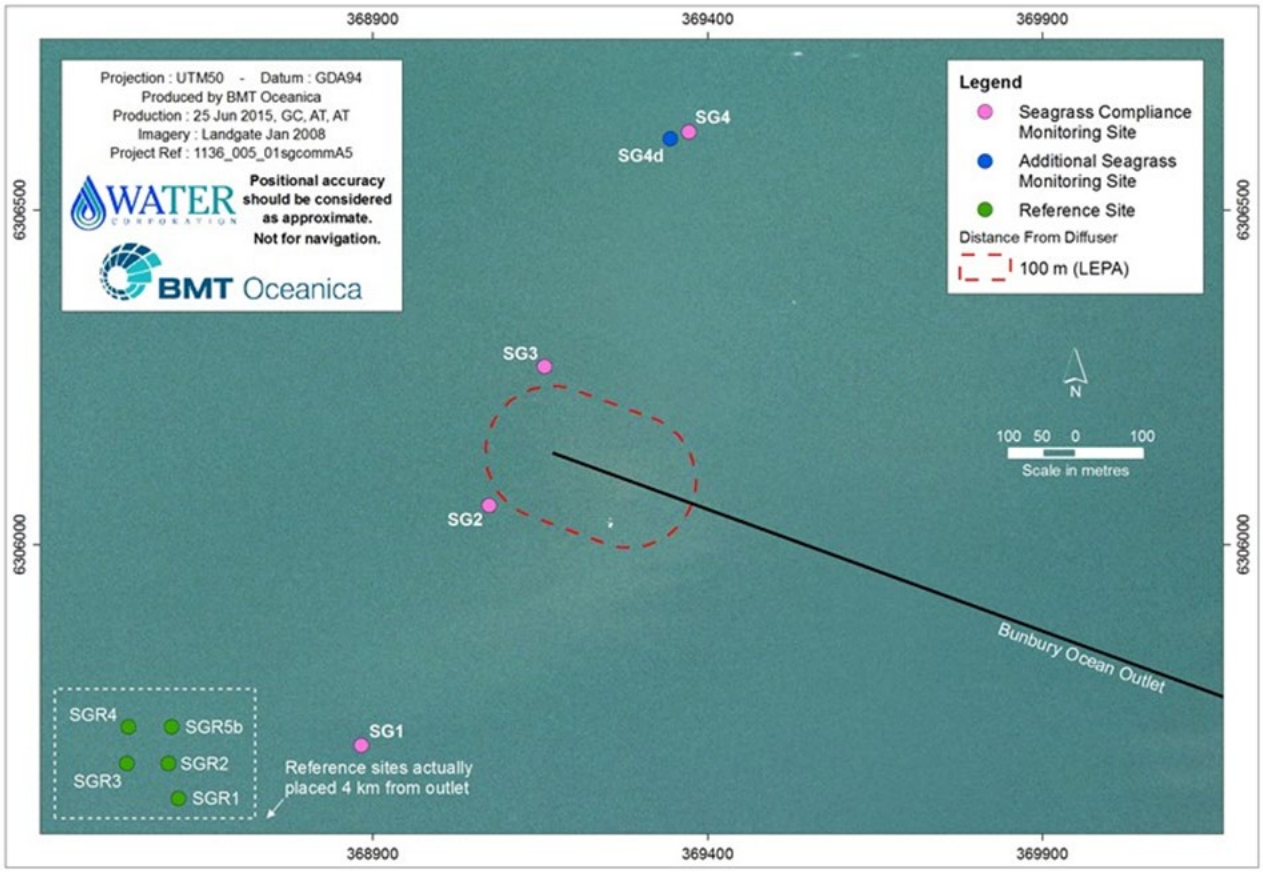

Figure 5 Seagrass health monitoring sites

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