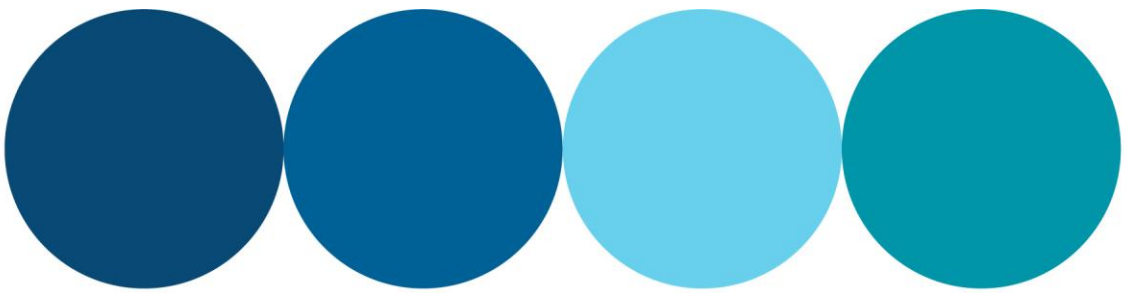
Sepia Depression Ocean Outlet Landline (SDOOL) & Perth Long Term Ocean Outlet Monitoring Program (PLOOM)

2022-2023 Annual Report



WATER CORPORATION

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Document history

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

Status

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Approved for final release:

Author
Date: 13/10/2023

Director (or delegate)
Date: 13/10/2023

Contents

Acronyms

ANZG	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
CFU	Colony forming unit
DO	Dissolved oxygen
DoF	Western Australian Department of Fisheries
DoH	Western Australian Department of Health
DPIRD	Western Australia Department of Primary Industries and Regional Development
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
KWRP	Kwinana Water Reclamation Plant
LAC	Light attenuation coefficient
LEPA	Low ecological protection area
LoR	Limit of reporting
MMP	Marine Management Plan
MPN	Most probable number
NATA	National Association of Testing Authorities
NOEC	No observed effect concentration
PLOOM	Perth Long Term Ocean Outlet Monitoring
SDOOL	Sepia Depression Ocean Outlet Landline
SHEZ	Shellfish Harvest Exclusion Zone
TTC	Thermotolerant coliforms

TTM	Total toxicity of the mixture
TWW	Treated wastewater
WASQAP	Western Australian Shellfish Quality Assurance Program
WET	Whole of effluent toxicity
WRRF	Water Resource Recovery Facility
WWTP	Wastewater Treatment Plant

Executive Summary

This report documents the findings of the 2022–2023 Sepia Depression Ocean Outlet Landline (SDOOL) Monitoring and Management Plan (M&MP; BMT Oceanica 2014) within the Perth Long-Term Ocean Outer Monitoring (PLOOM) Program, fulfilling commitment no. 4 of the Ministerial Statement 665. The report outlines the findings of three environmental monitoring programs:

- Compliance Monitoring
- Whole of Effluent Toxicity testing
- Comprehensive Treated Wastewater Characterisation.

Results are reported in the context of the Environmental Quality Management Framework (EQMF) described in EPA (2017). Under the EQMF, Water Corporation is required annually to demonstrate achievement against Environmental Quality Objectives (EQOs):

- Maintenance of Ecosystem Integrity
- Maintenance of Seafood for Human Consumption
- Maintenance of Primary and Secondary Recreation
- Maintenance of Aesthetic Values.

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 1–Table ES 4).

Table ES 1 Summary report card legend

Management response	Colour
Monitor: EQG & EQS 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.

EQO 'Maintenance of Ecosystem Integrity'

There are several EQC relevant to the 'EQO Maintenance of Ecosystem Integrity': the first are assessed based on in-line measurements of the constituents of the treated wastewater (TWW) stream and its potential toxicity, while the remainder are based on in-situ monitoring (water column nutrients, phytoplankton abundance and physical-chemical stressors) of the receiving environment.

Toxicants in treated wastewater: There are four Environmental Quality Guidelines (EQGs) relating to toxicants in the TWW, all of which are tested annually. EQG 1 and 2 relate to bioaccumulating and non-bioaccumulating toxicants, respectively. EQG 3 relates to the total toxicity of the mixture (TTM) and EQG4 the results of whole effluent toxicity (WET) testing.

To meet EQG 1, bioaccumulating toxicant (specifically, cadmium and mercury) concentrations must be below their respective ANZG (80%) 80% species protection guidelines prior to discharge and dilution with seawater. Concentrations of bioaccumulating toxicants were below the 80% species protection guidelines in all cases, thus meeting the EQG.

To meet EQG 2, non-bioaccumulating contaminants must not exceed their ANZECC/ARMCANZ (2000) 99% species protection guideline at the Low Ecological Protection Area (LEPA) boundary, 100 m from the diffuser. Dilution modelling found that the Sepia Depression outlets were achieving 5th percentile dilution at the LEPA boundary of 1:310. This was sufficient to dilute contaminants to concentrations below the respective 99% species protection guidelines. EQG 2 for toxicants in TWW was therefore met (Table ES 2).

EQG 3 requires that the TTM for the additive effect of ammonia, copper and zinc in the diluted TWW plume is less than 1.0. The calculated TTM following initial dilution (1:310) was 0.56, therefore EQG 3 was met.

To assess EQG 4 for TWW toxicants, WET testing is used to measure effluent toxicity by exposing sea urchin gametes to different concentrations of TWW and then measuring fertilisation success. The highest concentration of TWW at which there is no statistically significant observed effect on gamete fertilisation (NOEC) is used to establish whether the EQG was met; for this, the NOEC must be equal to or greater than 1.0% TWW concentration. WET tests were undertaken in July 2022, October 2022, January 2023 and April 2023. The lowest NOEC value across the four sampling events was 3.1%, thus meeting EQG 4. (Table ES 2).

Water quality monitoring – receiving environment: Ocean water quality was assessed fortnightly between December 2022 to March 2023 as part of the compliance monitoring program. Samples were collected at fixed distance intervals down-current of the outlets. Current direction was determined using a drogue to select the current vector (see Figure 5). The compliance monitoring program includes analyses of nutrients (ammonium, nitrate+nitrite and orthophosphate), chlorophyll-*a* (a measure of phytoplankton biomass) and physical properties (water temperature, salinity, dissolved oxygen and light attenuation coefficient). Data collected over the 2022–2023 monitoring period indicated that all EQGs apart from EQG2 for physical chemical stressors were met (Table ES 2). EQS2 for physical chemical stressors was met (Table ES 2).

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 (<0.1 and <0.05 µg/L, respectively) and ANZECC/ARMCANZ (2000) 80% species protection guideline (36 and 1.4 µg/L, respectively)	
	Non-bioaccumulating toxicants and initial dilution	EQG	Contaminant concentrations were lower than the ANZG (2018) triggers for 99% species protection guidelines after dilution equivalent to that expected at the LEPA boundary	
	Total toxicity of the mixture (TTM)	EQG	The TTM for the additive effect of ammonia, copper, and zinc after initial dilution (0.56) was below the ANZECC/ARMCANZ (2000) guideline value of 1.0	
	Whole of effluent toxicity testing	EQG	The lowest NOEC during the reporting period was 3.1%. Only 32 dilutions with background seawater are required to achieve this NOEC which is lower than the	

Environmental quality indicator		EQC	Comments	Compliance
			dilutions typically achieved at the LEPA boundary (310).	
Nutrient enrichment	Chlorophyll-a	EQG	Median chlorophyll-a concentration within the high ecological protection area (HEPA) (0.2 µg/L) was lower than the 80th percentile of historical reference site concentrations (0.4 µg/L)	■
	Light attenuation coefficient (LAC)	EQG	Median LAC within the HEPA (0.066 Log_{10}/m) was lower than the 80th percentile of historical reference sites (0.08 Log_{10}/m).	■
Phytoplankton blooms	Phytoplankton biomass (measured as chlorophyll-a)	EQG	Median chlorophyll-a concentrations did not exceed three times the median of reference on any sampling occasion.	■
			Median chlorophyll-a at any site did not exceed three times the median of reference sites on any sampling occasion during the summer monitoring period.	■
Physical chemical stressors	Organic enrichment	EQG	Dissolved oxygen saturation within the HEPA remained above 90% saturation at all times.	■
	Salinity	EQG	Median salinity at the 100 and 350 m sites did deviate beyond the 20th and 80th percentile of the natural salinity range within the HEPA	■
		EQS	There were no reported deaths of marine organisms from anthropogenically sourced salinity stress at the Sepia Depression Outfall over the summer monitoring period	■

Notes:

1. Green (■) symbols indicate the Environmental Quality Guideline (EQG) was met; amber (■) and red (■) symbols represent an exceedance of the EQG or Environmental Quality Standard (EQS), respectively.
2. LEPA = low ecological protection area.
3. HEPA = high ecological protection area.
4. LAC – light attenuation coefficient.
5. NOEC = no observed effect concentration; the highest concentration of TWW at which there is no statistically significant observed effect on gamete fertilisation.

EQO 'Maintenance of Seafood for Human Consumption'

There are two EQC for the EQO 'Maintenance of the Seafood for Human Consumption': the first is based on in-water concentrations of thermotolerant coliforms (TTC), and the second is based on in-water concentrations of toxic phytoplankton species (to monitor for algal biotoxins).

TTC were sampled fortnightly at fixed sites over the December 2022–March 2023 monitoring period. The EQG for 'Maintenance of Seafood for Human Consumption' states that median TTC concentrations at sites at the boundary

of the Shellfish Harvesting Exclusion Zone (SHEZ) are not to exceed 14 CFU/100 mL and the 90th percentile of TTC concentrations must not exceed 21 CFU/100 mL.

For the present reporting period, the EQC for microbiological contaminants (as TTC) were assessed based on pooled data from three sampling seasons (2020–21, 2021–22 and 2022–23), with a sample size (n=120) that allowed for appropriate comparison with the EQC (EPA 2005)[1]. The median value for TTC concentrations was at the limit of detection (<10 CFU/100 mL), and therefore below the 14 CFU/100mL trigger value. Over the three sampling periods, there were 4 instances where TTC exceeded 21 CFU/100 mL, representing 3.3% of samples meaning the EQG for microbiological contaminants (as TTC) was met (Table ES 3).

The EQG for 'Maintenance of Seafood for Human Consumption' states that concentrations of potentially toxic algae at sites at the boundary of the SHEZ must not exceed the Western Australian Shellfish Quality Assurance Program (WASQAP, DoH & DoF 2007) concentrations. For technical reasons, data for *Gymnodinium-Karenia* genus are now supplied for the complex,(see Section 4.2) and it is not possible to make a comparison with the specified WASQAP (DoH & DoF 2007) values for *Gymnodinium* spp. or *Karenia* spp. However, the most recent WASQAP guidelines (DoH, DPIRD, and Industries 2020) provide an updated trigger for the *Gymnodinium-Karenia* complex which was met. Consequently, the densities of toxic phytoplankton remained within the relevant WASQAP guidelines, meeting the EQG for toxic phytoplankton species (Table ES 3).

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

Environmental quality indicator		Comments	Compliance
Microbial contaminants	Thermotolerant coliforms (TTC)	Median TTC concentrations derived from 120 samples collected over the 2020–2021, 2021–2022 and 2022–2023 sampling seasons was at the limit of detection (<10 CFU/100 mL) and below the 14 CFU/100 mL criteria	■
		Over the three sampling periods, there were 4 instances where TTC exceeded 21 CFU/100 mL, representing 3.3% (≤10%).	■
Algal biotoxins	Toxic phytoplankton species	Toxic phytoplankton species were not recorded in excess of Western Australian Shellfish Quality Guidelines during the 2022–2023 monitoring.	■

Notes:

1. Green (■) symbols indicate the Environmental Quality Guideline (EQG) was met; amber (■) and red (■) symbols represent an EQG or Environmental Quality Standard (EQS), respectively.
2. TTC results below the analytical detection limit (<10 CFU/mL) were halved (=5 CFU/mL) to calculate median value.
3. TTC = Thermotolerant coliforms, CFU = colony forming units.

EQO 'Maintenance of Primary and Secondary Recreation'

There are two EQC for the EQO 'Maintenance of Primary and Secondary Recreation': the first is based on in-water concentrations of faecal pathogens (*Enterococci* spp.), and the second is based on in-water measures of total phytoplankton cell densities.

The EQG for primary contact recreation requires that the 95th percentile value of faecal pathogens (*Enterococci* spp.) does not exceed 200 MPN/100 mL outside the Primary and Secondary Recreation boundary. To meet the EQG for secondary contact recreation, the 95th percentile is not to exceed 2000 MPN/100 mL. The EQS for primary contact recreation requires that the 95th percentile value of faecal pathogens (*Enterococci* spp.) not exceed

[1] *NHMRC (2008) guidelines and EPA (2005) suggest that a minimum of 100 samples over the non-river flow period (pooled from multiple years if required) are needed for accurate assessment of microbial water quality EQC.*

500 MPN/100 mL outside the CSZ boundary. To meet the EQS for secondary contact recreation, the 95th percentile is not to exceed 5000 MPN/100 mL.

The EQG for microbiological contaminants was assessed based on pooled data (n=120) from three sampling seasons (2020–2021, 2021–2022 and 2022–2023). The 95th percentile of *Enterococci* spp. concentrations was 2105 MPN/100 mL and exceeded EQG for both primary and secondary contact recreation (Table ES 4). The EQS for primary contact recreation was also exceeded but the EQS for secondary contact recreation was met (Table ES 4).

The EQG for algal biotoxins requires median total phytoplankton cell concentration for the area of concern should not exceed 15 000 cells/mL. The median total phytoplankton cell concentration was 26 cells/mL and therefore the EQG was met (Table ES 4).

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 (primary contact; 200 MPN/100 mL)	The 95th percentile of *Enterococci* spp. was 2105 MPN/100 mL and exceeded the EQG	■
		EQS (primary contact; 500 MPN/100 mL)	The 95th percentile of *Enterococci* spp. was 2105 MPN/100 mL and exceeded the EQS	■
		EQG (secondary contact; 2000 MPN/100 mL)	The 95th percentile of *Enterococci* spp. was 2105 MPN/100 mL and exceeded the EQG	■
		EQG (secondary contact 5000 MPN/100 mL)	The 95th percentile of *Enterococci* spp. was 2105 MPN/100 mL and the EQS was met	■
Algal biotoxins	Phytoplankton (cell concentration)	EQG (15 000 cells/mL)	Estimated total phytoplankton cell count at individual sites were <15000 cells/mL at each site and sampling occasion during 2022–2023 monitoring.	■

Note:

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

EQO 'Maintenance of Aesthetic Values'

The EQO for the EV 'Recreation and Aesthetics' is to ensure that Perth's coastal waters are aesthetically pleasing and that the aesthetic value is protected. To ensure this EQO is being met, monitoring routinely assesses the quality of surface water appearance. The EQG for maintenance of aesthetic values requires that questionnaires are completed by field personnel on eight occasions during the non-river flow period to determine aesthetic appearance. Water clarity at sites around and at distance from the ocean outlet is measured and the presence of fish tainting substances in the TWW is also determined and a complaints register regarding aesthetic values is maintained by the Water Corporation.

The results of the measurements for aesthetics, water clarity and fish tainting substances demonstrated that all EQGs for aesthetics were (Table ES 5).

Table ES 5 Summary report card for the Environmental Quality Objective 'Maintenance of Aesthetic Values'

Environmental Quality Indicator	EQC	Comments	Compliance[1]
Nuisance organisms	EQG	Nuisance organisms were not present in excessive amounts.	■
Faunal deaths	EQG	There were no instances of dead marine organisms observed.	■
Water clarity	EQG	Measurements of light attenuation determined that the natural visual clarity of the water was reduced by ~6% (i.e. > 20%).	■
Colour	EQG	There was a slight noticeable colour variation on 1 sampling occasion. No noticeable colour was recorded on any other sampling events.	■
Surface films	EQG	No surface films or oil were recorded on any sampling event.	■
Surface debris	EQG	No floating debris or matter was visible on the surface on any sampling occasion.	■
Odour	EQG	No noticeable odour was detected on any sampling occasion.	■
Fish tainting substances	EQG	There were no recorded exceedances of fish tainting substances in the 2022-2023 monitoring period.	■

Note:

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

1 Introduction

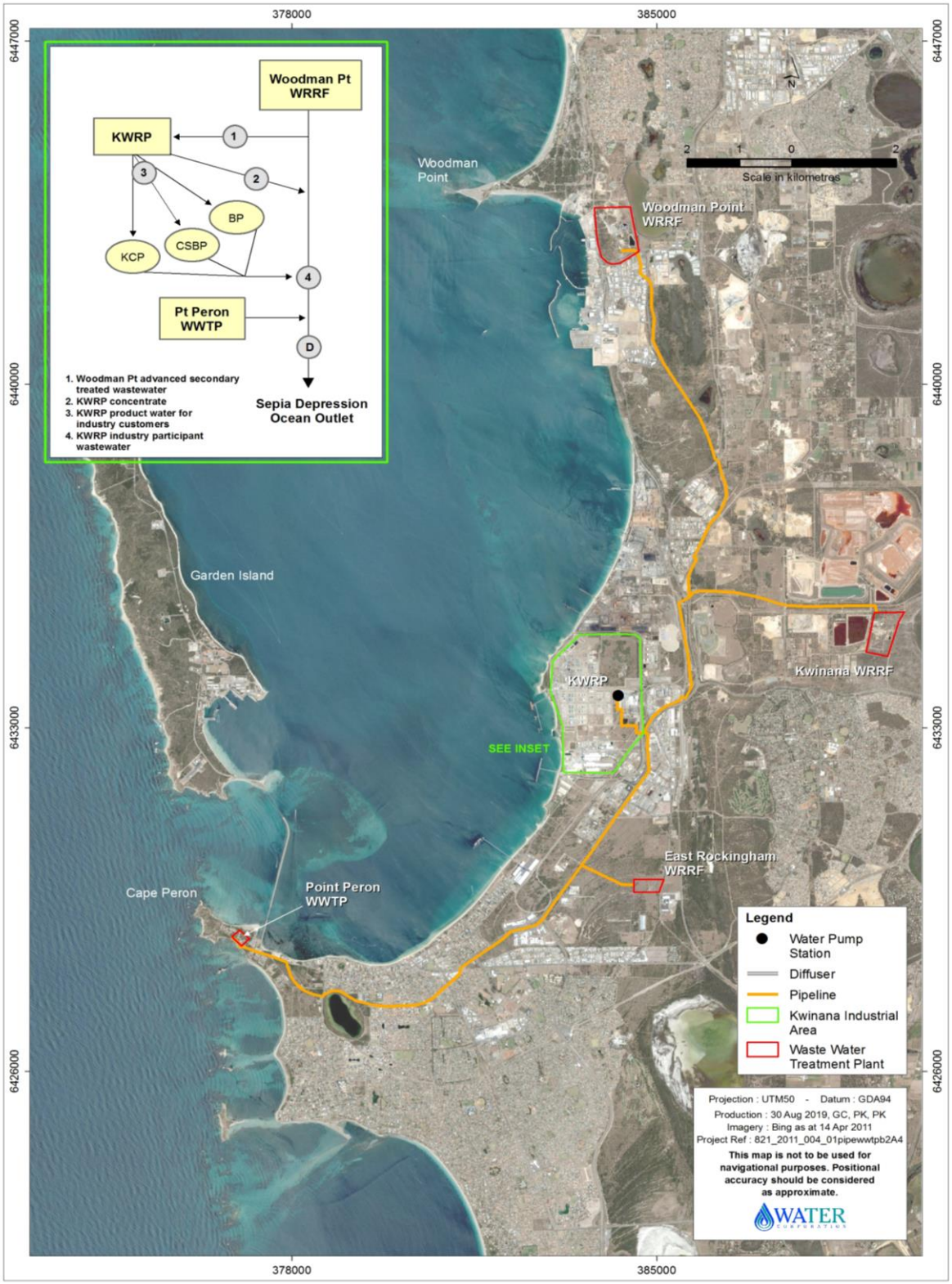
1.1 Document purpose

This annual report documents the findings of the 2022–2023 ocean monitoring around the Sepia Depression ocean outlet. Monitoring was completed according to the Sepia Depression Ocean Outlet Landline (SDOOL) Monitoring and Management Plan (SDOOL MMP; BMT Oceanica 2014).

1.2 Wastewater treatment plant infrastructure and discharge

Treated wastewater (TWW) discharged through the Sepia Depression ocean outlet comes from the Woodman Point Water Resource Recovery Facility (WRRF), East Rockingham WRRF, Kwinana WRRF, Point Peron Wastewater Treatment Plant (WWTP), and the Kwinana Water Reclamation Plant (KWRP) (Figure 1). Most TWW discharged to the Sepia Depression is from the Woodman Point WRRF.

The Woodman Point WRRF services the southern Perth metropolitan area and receives predominantly domestic wastewater (from kitchen, bathroom, toilet and laundry uses), with ~8% received from light industrial wastewater. A small volume of primary TWW is discharged from the Point Peron WWTP, located downstream of the Woodman Point WRRF (Figure 1). The KWRP processes secondary TWW from the Woodman Point WRRF to a quality suitable for use as high-grade industrial processing water by industries in the Kwinana industrial area. This high-grade industrial water is supplied to industry participants to reduce consumption of potable scheme water. The KWRP process concentrate is disposed of via the SDOOL (refer to Figure 1).

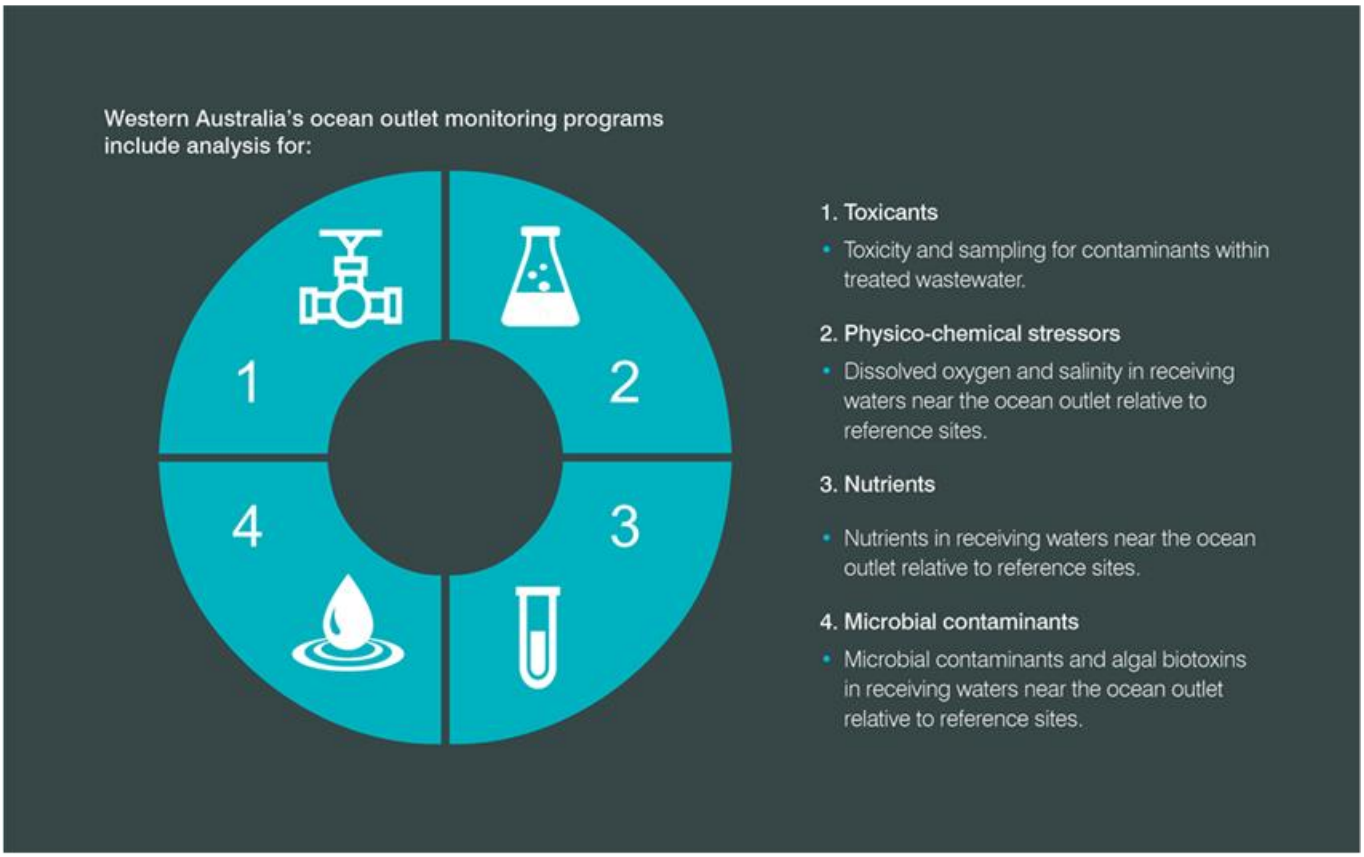


Notes:

1. WWTP = wastewater treatment plant; WRRP = Water Resource Recovery Facility; KWRP = Kwinana Water Reclamation Plant; BP = BP Refinery; KCP = Kwinana Cogeneration Plant; CSBP = CSBP Limited
2. Point D is the composite treated wastewater sample point prior to discharge.

Figure 1 Location of Sepia Depression Ocean Outlet Landline (SDOOL) and surrounding contributing waste streams

1.3 Potential stressors in treated wastewater



1.3.1 Toxicants

Metals and persistent organic compounds may be toxic to marine species or accumulate in biota at concentrations sufficient to pose a risk to human health when consumed. TWW is screened for bioaccumulating and non-bioaccumulating toxicants prior to discharge. To account for the synergistic effect of multiple toxicants and toxicants without guidelines, the overall toxicity of the discharge is determined using whole of effluent toxicity (WET) testing.

1.3.2 Physico-chemical stressors

TWW contains organic matter, decomposition of which by microorganisms uses oxygen. If more dissolved oxygen (DO) is consumed than is produced, DO levels decline. DO saturation in receiving waters near the outfalls provides an indication of the risk posed by deoxygenation.

Reduced salinity near the outfalls, resulting from freshwater in the TWW plume, may cause osmotic stress in marine biota. Salinity in receiving waters near the outfalls is compared to the salinity at appropriate reference sites to determine whether salinity near the outfalls is within the range of natural variability.

1.3.3 Nutrients

TWW contains elevated concentrations of the biologically available nutrients, ammonia, nitrite, nitrate and orthophosphate. At times, the addition of nutrients may stimulate phytoplankton growth beyond natural levels, which can lead to shading of photosynthetic organisms such as seagrasses and macroalgae. The potential for shading is measured using in-water measures of chlorophyll-a (a measure of phytoplankton biomass) and light attenuation (a measure of water clarity).

Although most algal blooms are harmless, some contain species that produce toxins that may be harmful to swimmers (via ingestion or skin contact) or contaminated seafood. Phytoplankton species composition and cell concentrations are monitored to ensure concentrations are within acceptable limits.

1.3.4 Microbial contaminants

Disease-causing organisms in the TWW pose a risk to humans if exposed during primary and/or secondary contact activities (i.e. swimming and boating). The same organisms if ingested by marine fauna may reduce their suitability for human consumption. To assess the risk, concentrations of indicator organisms are routinely compared to the Environmental Protection Authority's (EPA's; EPA 2017) criteria for primary and secondary contact, and the criteria for seafood safe for human consumption.

1.4 Environmental management approach

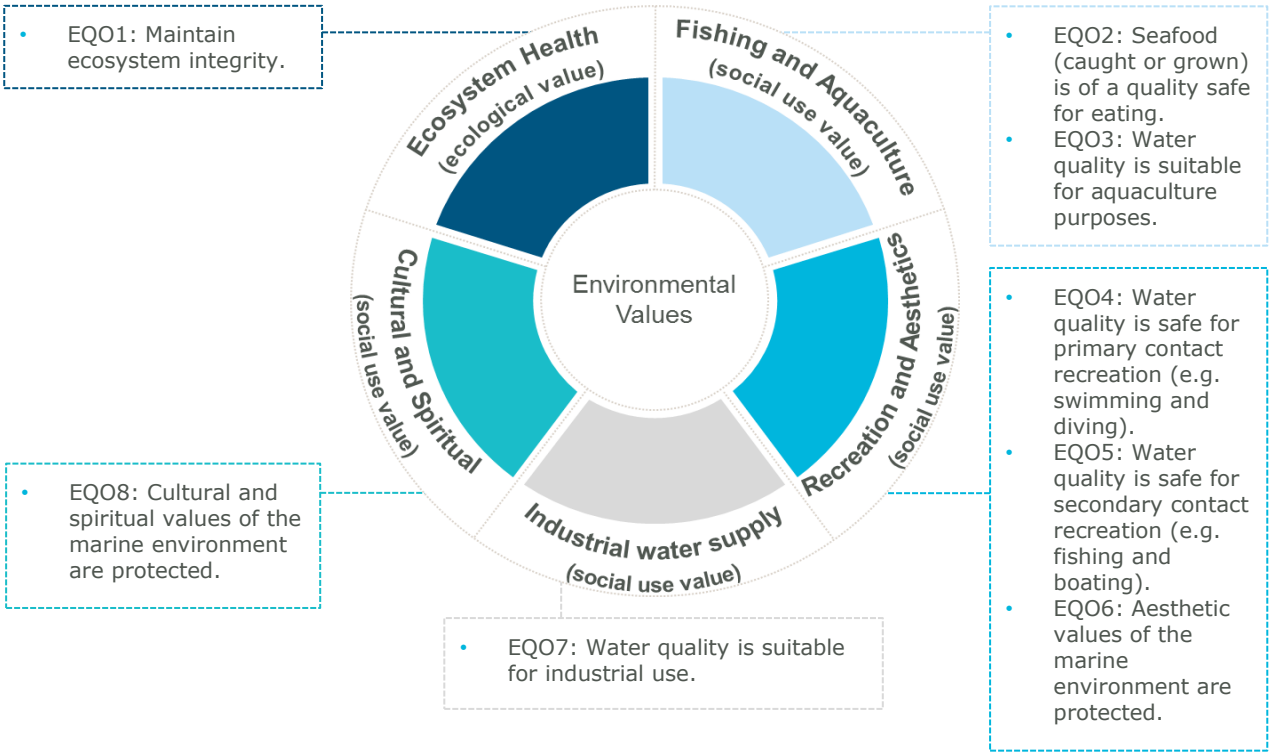
The Sepia Depression Long Term Ocean Outlet (SDOOL) and Perth Long Term Ocean Outlet Monitoring (PLOOM) programs are underpinned by the State Governments Environmental Quality Management Framework (EQMF; EPA 2017).

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 that the associated EQO has been achieved. If the guideline is not met a more detailed assessment against the Environmental Quality Standard (EQS) is triggered.
2. **Environmental Quality Standards** (EQSs) are management triggers which, if exceeded, signify that the EQO is at risk of not being met and that a management response may be required.



Source: EPA (2016)

Figure 2 **Environmental Values and Environmental Quality Objectives for the marine waters off Western Australia**

1.4.1 Maintenance of Ecosystem Integrity EQO

The intent of this EQO is to maintain a healthy and diverse ecosystem. There are four levels of ecological protection, with each applied depending on the designated level required: low, moderate, high or maximum (Figure 3). A low ecological protection area (LEPA) has been established at the Sepia Depression outfall and occupies the area within a 100 m radius of the diffuser (BMT Oceanica 2014). Waters outside the LEPA are maintained to a high level of ecological protection (HEPA; Figure 4).

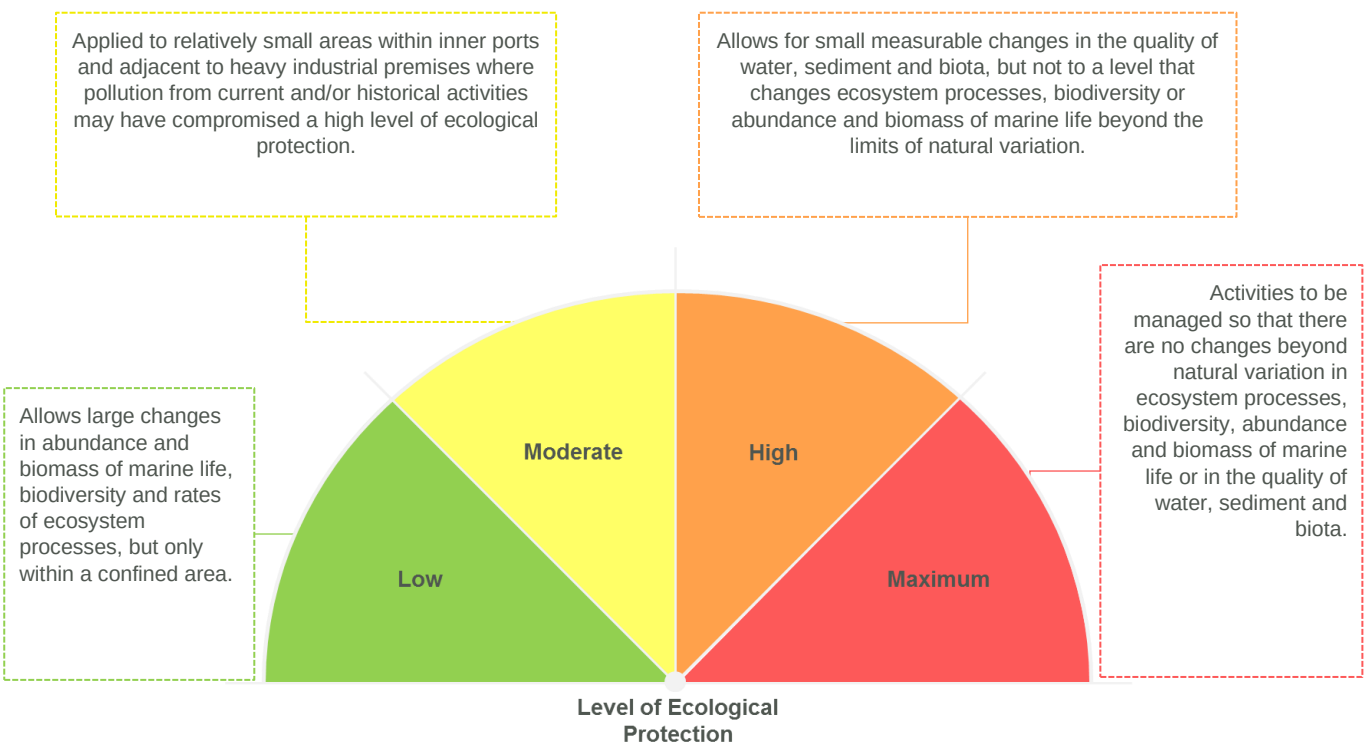


Figure 3 **Levels of ecological protection**

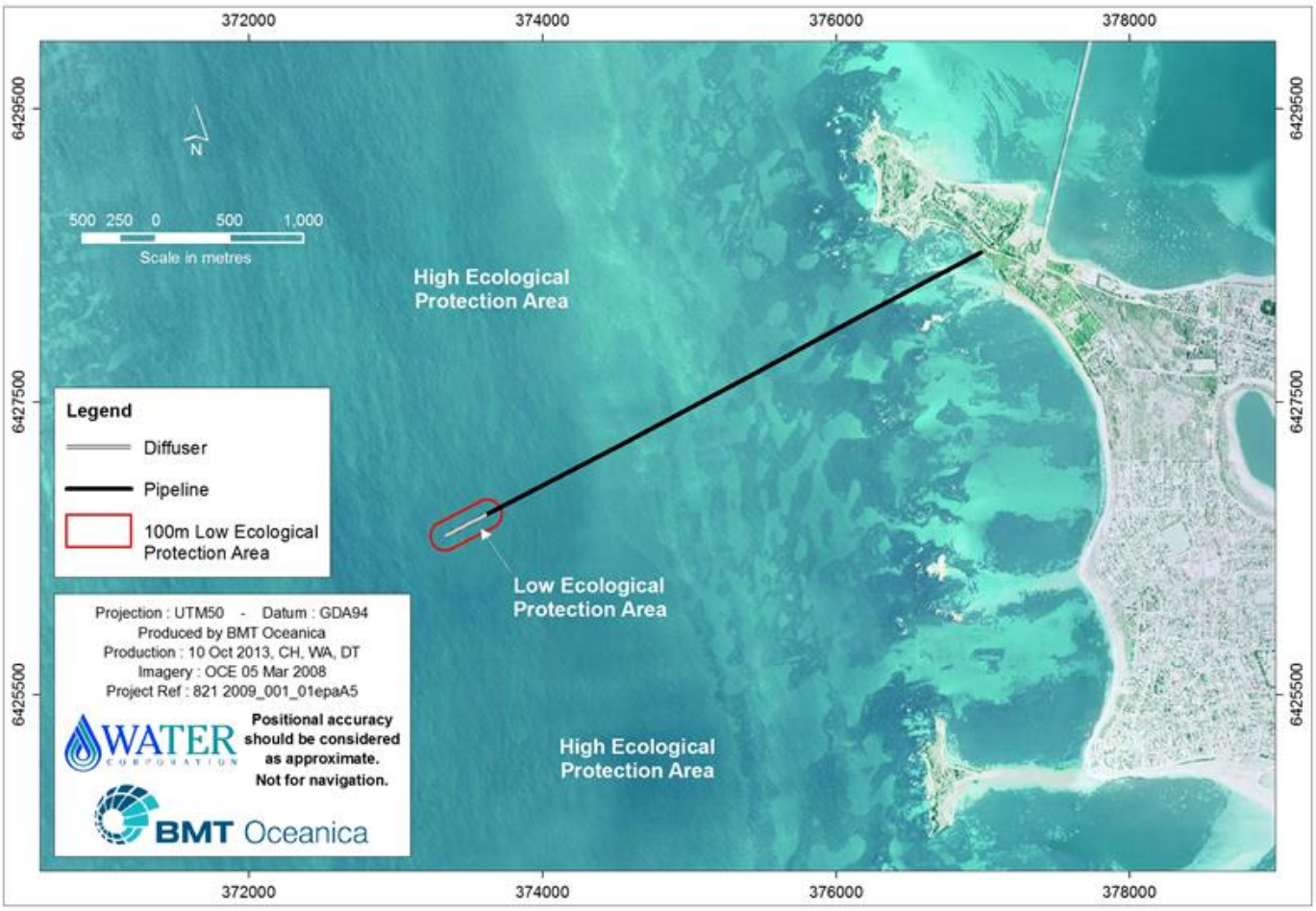


Figure 4 Sepia Depression ocean outlet and Low Ecological Protection Area

1.4.2 Maintenance of Seafood Safe for Human Consumption EQO

The intent of this EQO is to maintain seafood safe for human consumption (a social value), except for a small area surrounding the ocean outlet where EQO 2 may not apply and seafood may be unsafe to eat. Formal management zones have been established for the Sepia Depression ocean outlet (Figure 5). Microbiological contaminants and algal biotoxins are monitored at the boundary of the Shellfish Harvesting Exclusion Zone (SHEZ), to ensure the EQO is being met.

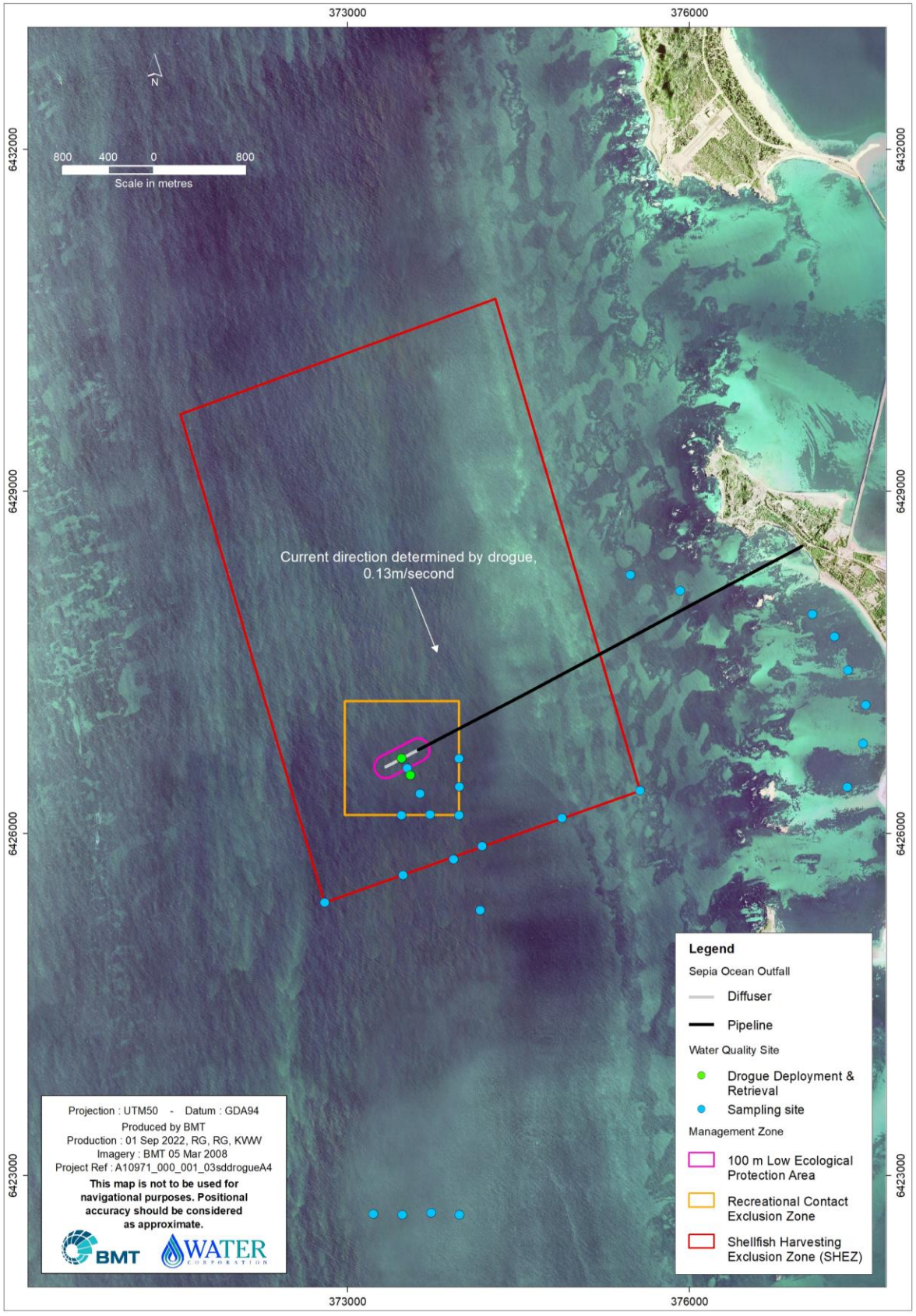


Figure 5 Sepia depression ocean outlet ecological protection areas and an example of a drogue deployment and sampling trip.

1.4.3 Maintenance of Primary and Secondary Contact Recreation EQO

The intent of the primary and secondary contact EQOs are to support swimming and boating activities, respectively. The EQOs apply throughout Perth's coastal waters except to areas around ocean outlets, where water quality may not be suitable for swimming. An area where primary contact recreation is not recommended has been established for the Sepia Depression ocean outlet. This is known as the Recreational Contact Exclusion Zone (Figure 5).

1.4.4 Maintenance of Aesthetic Value EQO

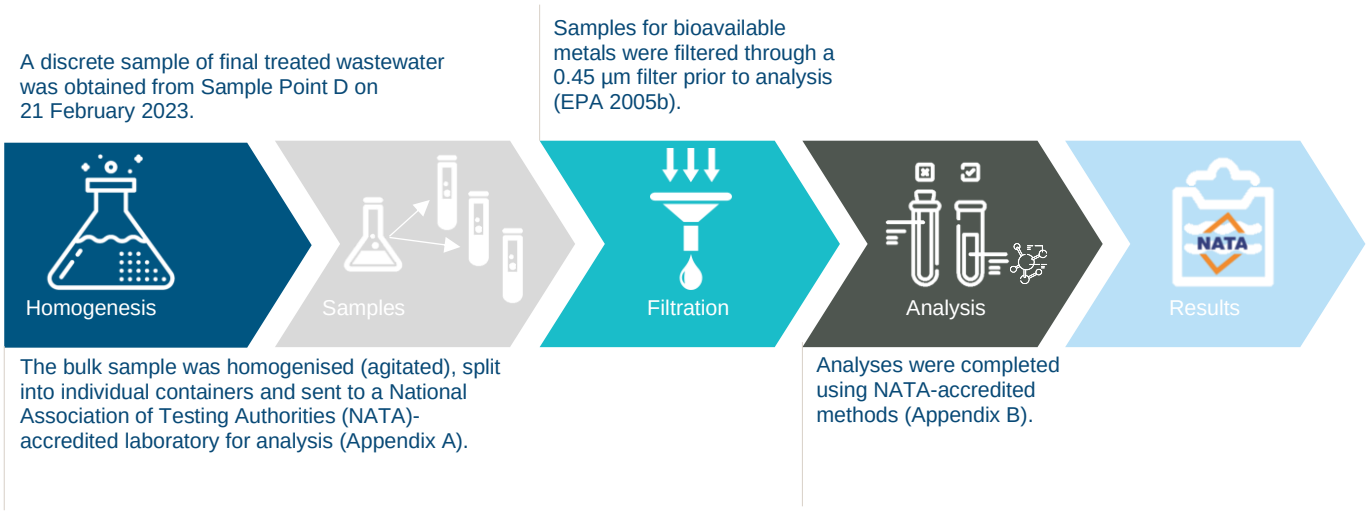
The objective of this EQO is to ensure that the aesthetic value of Perth's coastal waters is protected. To ensure this EQO is being met, monitoring routinely assesses the quality of the surface water appearance.

2 Toxicants in treated wastewater

2.1 Comprehensive treated wastewater characterisation

TWW (final effluent) from the SDOOL was analysed for a suit of parameters comprising the major contaminants of concern for the Sepia Depression ocean outlet:

- nutrients (total nitrogen, ammonia, nitrate+nitrite (NO_x), total phosphorus, orthophosphate)
- microbiological contaminants (thermotolerant coliforms and *Enterococci* spp.)
- bioavailable metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc)
- pesticides and herbicides (organophosphate pesticides, organochlorine pesticides, triazine herbicides)
- polyaromatic hydrocarbons
- phthalates
- polychlorinated biphenyls
- benzene, toluene, ethylbenzene, and xylenes
- petroleum hydrocarbons
- surfactants
- dissolved organic carbon.



2.1.1 Bioaccumulating toxicants

Concentrations of cadmium and mercury (i.e. bioaccumulating toxicants) in the TWW sample were both below their analytical limit of reporting (LoR; 0.1 µg/L) and the EQG for cadmium and mercury as bioaccumulating toxicants (36 and 1.4 µg/L, respectively) was met (Table 6).

Table 6 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 at the diffuser.

Source: BMT Oceanica 2014

Note:

1. EQG = Environmental Quality Guideline.

2.1.2 Non-bioaccumulating toxicants

Contaminant concentrations were below their waste stream triggers based on the ANZECC/ARMCANZ (2000) 99% species protection guidelines scaled for dilution equivalent to that expected at the LEPA boundary (1:310; BMT Oceanica 2014). Therefore, the EQG (Table 7) was met (Table 8).

Table 7 Environmental Quality Guideline for non-bioaccumulating toxicants

EQG	Wastewater contaminant concentration corrected for minimum dilution at the Low Ecological Protection Area (LEPA) boundary will ensure the ANZECC/ARMCANZ (2000) 99% species protection guideline trigger levels for toxicants are being achieved at the boundary of the LEPA (i.e. a high level of protection is met beyond a 100 m radius of the diffuser).

Source: BMT Oceanica 2014

Table 8 Toxicants in the Sepia Depression treated wastewater stream compared with relevant trigger levels

Toxicant	Sepia Depression TWW concentration (µg/L)	Waste stream trigger (µg/L)[1,2]
Ammonia-N	9600	154 537
Cadmium*	<0.1	36
Chromium*	1.7	43
Copper*	17	68
Lead*	<1	679
Mercury*	<0.05	1.4
Nickel*	3.9	2016
Silver*	<0.8	248
Zinc*	59	2124
Chloropyrifos	<0.1	0.16
Endrin	<0.001	1.24
Endosulfan sulfate	<0.001	1.55
Benzene	<1	110 890
Naphthalene	<0.03	15 485

Toxicant	Sepia Depression TWW concentration (µg/L)	Waste stream trigger (µg/L)[1,2]
Benzo(g,h,i)perylene	<0.01	15 485

Notes

1. ANZECC/ARMCANZ (2000) guidelines used as per SDOOL M&MP (BMT Oceanica 2014). Assessment against ANZECC/ARMCANZ (2000) 99% species protection guideline values was undertaken only for those toxicants where trigger levels were available.
2. ANZECC/ARMCANZ (2000) scaled based on 5th percentile dilution (1:310) at the LEPA boundary.
3. TWW = treated wastewater.
4. The trigger values for marine waters are from Table 3.4.1 in ANZECC/ARMCANZ (2000). The EPA has provided advice that in WA waters where a high level of protection applies, 99% species protection levels should be used.
5. 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.
6. Analytical limits for chloropyrifos were not low enough to confirm exceedance of, or compliance with, the ANZECC/ARMCANZ (2000) guidelines. Until detection limits required for direct comparison can be attained by commercial laboratories, WET testing will provide a test of the toxicity of the wastewater stream (See Appendix D).
7. Trigger values are for endosulfan, not endosulfan sulfate (Table 3.4.1; ANZECC/ARMCANZ [2000]).
8. *= dissolved metals 0.45 µm filtered.

2.1.3 Total toxicity of the mixture

The total toxicity of the mixture (TTM) is an indicator of the potential for cumulative toxic effects on marine organisms. For the combined effect of ammonia, copper and zinc following dilution (0.34, Table 10) was less than the ANZECC/ARMCANZ (2000) guideline value of 1.0 and the EQG for TTM (Table 9) was met.

Table 9 Environmental Quality Guideline for the total toxicity of the mixture

EQG	The total toxicity of the mixture (TTM) for the additive effect of ammonia, copper and zinc, calculated as per ANZECC/ARMCANZ (2000), will not exceed the trigger value of 1.0.

Source: BMT Oceanica 2014

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.

Table 10 Total toxicity of treated wastewater at the edge of the initial mixing zone associated with the Sepia Depression ocean outlet

Toxicant	TWW concentration (µg/L)	Background concentration (µg/L)[1]	Dilution	Concentration after dilution (µg/L)	contaminant /guideline	TTM[2]
Ammonia	9600	1.5	1:310	32.47	0.06	0.56
Copper	17	0.08		0.14	0.45	
Zinc	59	0.15		0.34	0.05	

Notes:

1. Background concentrations for copper and zinc from McAlpine et al. (2005); Perth marine waters (pp.19). Surface background concentrations for ammonia calculated as median of reference site data from 2003–2023 (BMT Oceanica, unpublished data).
2. TTM = total toxicity of the mixture = [ammonia]/guideline + [copper]/guideline + [zinc]/guideline, TWW = treated wastewater.

2.2 Quarterly treated wastewater characterisation

Water Corporation conducts quarterly sampling of the final treated wastewater SDOOL waste stream from Sample Point D (Figure 1). Quarterly samples are analysed for a smaller set of the key contaminants of concern that are most likely to be present in the waste stream. Quarterly sampling occurred on 6 July 2022, 4 October 2022, 10 January 2023, 4 April 2023.

On each occasion, a composite sample (time weighted) was obtained from Sample Point D (Figure 1). This sample represents an average of the TWW discharged to the Sepia Depression ocean outlet for the 24-hours prior to and during the sample collection. The bulk sample was homogenised and split into separate sample containers for the various analyte groups. Samples were handled and analysed according to the National Association of Testing Authorities (NATA)-accredited laboratory requirements.

The bioaccumulating toxicants cadmium and mercury were measured below the LoR on all four dates and met the 80% species protection guidelines (36 µg/L and 1.4 µg/L, respectively) in the TWW stream prior to dilution on each sample (Table 11).

Contaminants measured quarterly in the Sepia Depression TWW at Sample Point D were all below their respective waste stream triggers based on the ANZECC/ARMCANZ (2000) 99% species protection scaled for dilution equivalent to that occurring at the LEPA boundary (Table 11).

Table 11 **Toxicants measured quarterly in the Sepia Depression treated wastewater compared with relevant guideline trigger levels after initial dilution**

Toxicant[1]	Sepia Depression TWW Sample Point D (µg/L)				Waste Stream Trigger[2] (µg/L)
	July 2022	October 2022	January 2023	April 2023	
Ammonia	4500	8500	1100	520	154 537
Cadmium[4]	<0.1	<0.1	<0.1	<0.1	36
Chromium	-	-	<2	2	43
Cobalt	<1	<1	<1	<1	307
Copper	14	5	7	4	68
Lead	<1	<1	<1	<1	679
Mercury[4]	<0.1	<0.1	<0.1	<0.1	1.4
Nickel	5	7	6	6	2016
Silver	<1	4	<1	<1	248
Vanadium	<10	<10	<10	<10	14 913
Zinc	61	95	51	55	2124
Phenols	60	<50	<50[5]	<50	83 685

Notes:

1. Assessment undertaken only for toxicants with ANZECC/ARMCANZ (2000) guideline values.
2. ANZG (2018) scale based on 5th percentile dilution at the LEPA boundary.
3. TWW = treated wastewater.
4. Bioaccumulating toxicants cadmium and mercury met the ANZECC/ARMCANZ (2000) 80% species protection guidelines (of 36 and 1.4 respectively) at the diffuser (i.e. prior to dilution).
5. Reporting recorded an LoR lower than 50, assumed as a mistake and should be <50.

Table 12 **Total toxicity of the quarterly treated wastewater characterisation for the Sepia Depression ocean outlet combined waste stream**

Quarterly sampling dates	Natural background concentration in Perth's coastal waters (µg/L)[1]			Dilution	Total toxicity of the mixture (TTM)[2]
	Ammonia	Copper	Zinc		
July 2022	1.5	0.08	0.15	1:310	0.43
October 2022					0.42
January 2023					0.39
April 2023					0.36

Notes:

1. Background concentrations for copper and zinc from McAlpine et al (2005); Perth marine waters (p.19). Surface concentrations for ammonia calculated as a median of reference site data from 2003–2023 (BMT Oceanica, unpublished data).
2. Total toxicity of mixture = [ammonia]/guideline + [copper]/guideline + [zinc]/guideline.

2.3 Whole of effluent toxicity (WET) testing

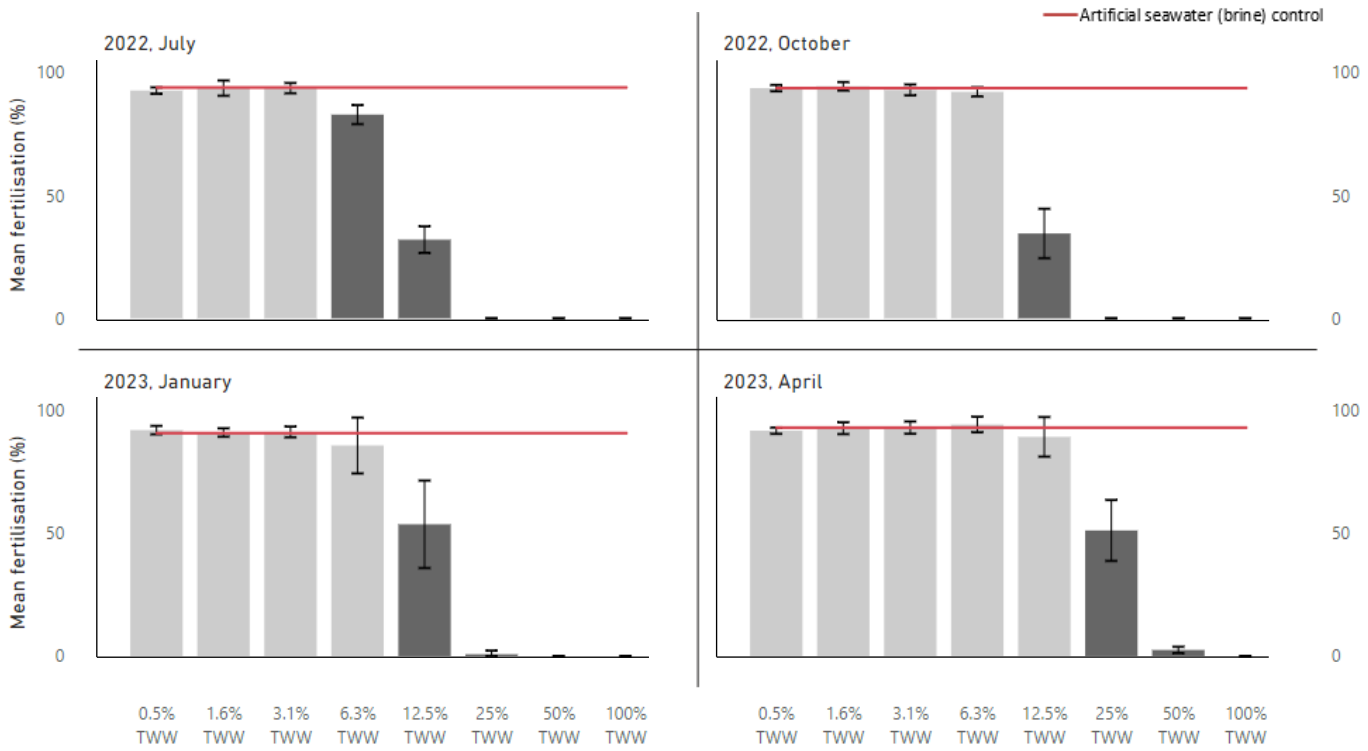
WET testing is useful for assessing the toxicity of potential contaminants without guidelines, or where the effects may be cumulative. Fertilisation success in sea urchins (*Heliocidaris tuberculata*) exposed to salt-adjusted dilutions (0.5, 1.6, 3.1, 6.3, 12.5, 25, 50 and 100%) of TWW was used to calculate a No Observed Effect Concentration (NOEC; the highest concentration where no significant effect is observed; Appendix D).

In April 2023, sea urchin fertilisation was significantly lower in samples exposed to 25%, 50% and 100% TWW dilutions than the artificial seawater control. All other concentrations were not significantly different to the control (Figure 6). In October 2022 and January 2023, sea urchin fertilisation was significantly lower in samples exposed to 12.5 %, 25%, 50% and 100% TWW dilutions than the artificial seawater control. All other concentrations were not significantly different to the control (Figure 6). In July 2022, sea urchin fertilisation success exposed to TWW dilutions 6.3%, 12.5%, 25%, 50% and 100% was significantly lower than the artificial seawater control (with all other concentrations not significantly different to the control; Figure 6). For all four sampling dates, the NOEC was greater than 1% TWW (Table 14) and the EQG for WET testing (Table 13) was met.

Table 13 Environmental Quality Guideline for whole of effluent toxicity testing

EQG	The EQG will be exceeded if following the 1-hour sea urchin test: $\frac{TDA}{DRNOEC} \leq 1.0$ where TDA = Typical Dilutions Achieved (constant based on 200-fold dilution) DRNOEC = number of dilutions required to achieve the no observed effects concentration (NOEC). Breaching the above triggers an investigation against the EQS, which would comprise the full suite of WET tests (minimum of five species from four trophic groups).

Source: BMT Oceanica 2014



Notes:

1. Error bars represent ±1 standard deviation; n = 4.
2. TWW = treated wastewater.
3. Light grey bars represent concentrations of TWW at which there is no observed significant effect on fertilisation. Dark grey bars represent concentrations of TWW that acted to significantly reduce the success of sea urchin fertilisation.

Figure 6 Comparison of whole effluent toxicity TWW dilution results to artificial seawater control

Table 14 Calculated parameters from whole of effluent toxicity tests

Indicator	July 2022	October 2022	January 2023	April 2023
NOEC (%)	3.1%	6.3%	6.3%	12.5%
Dilutions required to meet the NOEC	32.3	15.9	15.9	8
Dilutions required/dilution achieved	0.16	0.08	0.08	0.04
≤1	Yes	Yes	Yes	Yes

Notes:

1. NOEC = no observed effect concentration.
2. Calculation based on 310 dilutions achieved, which is expected at the LEPA boundary.

2.4 Diffuser Performance

Diffuser performance was calculated by comparing discharge concentrations from annual TWW sampling with nutrient samples and physical profiling performed at the same time. Salinity, ammonia, orthophosphate, and nitrate+nitrite concentrations were used to assess diffuser performance. Dilution factors were calculated for 0 m (initial dilution), 100 m, 350 m, 1000 m and 1500 m utilising the following formula:

$$Dilution\ Factor = \frac{Effulent\ Concentration}{Plume\ Sampling\ Concentration - Reference\ Concentration}$$

Dilution factors were not calculated where concentrations at the plume sampling site were equal to or lower than the mean reference sites concentration. Results of the diffuser performance dilution calculations are shown in Table 15.

Table 15 Dilution factor calculation results

Site	Salinity (psu)	Ammonia (µg/L)	Ortho-P (µg/L)	NOx (µg/L)
Reference	36.15	1.86	4.5	4.25
Effluent	0.51	9600	6600	8400
0 m	35.95	22.5	24.88	42.88
100 m	36.11	21.6	27.88	18.38
350 m	36.15	11.6	12.25	17
1000 m	36.24	7.19	8.75	11.88
1500 m	36.32	2.6	6.25	7.75
Dilution at 0 m	-	1:465	1:311	1:207
Dilution at 100 m	-	1:485	1:448	1:329
Dilution at 350 m	-	1:983	1:768	1:572
Dilution at 1000 m	1:6	1:1801	1:1297	1:878
Dilution at 1500 m	1:3	1:12468	1:2548	1:1544

Notes:

1. NOx = nitrate+nitrite.
2. Ortho-P = orthophosphate.
3. - = Dilutions were not calculated because concentrations at these sites was less than the mean of reference sites.

3 Water quality monitoring – receiving environment

Nutrients, phytoplankton biomass and physical and chemical stressors were monitored approximately fortnightly from the beginning of December 2022 to the end of March 2023 (coinciding the summer non-river flow period) along a down-current gradient away from the diffuser (Table 16; Appendix E).

Table 16 Water quality monitoring dates near the Sepia Depression ocean outlet between December 2022 and March 2023

Sample day	Date
1	07/12/2022
2	12/12/2022
3	05/01/2023
4	23/01/2023
5	02/02/2023
6	21/02/2023
7	03/03/2023
8	24/03/2023

Wind direction, strength, current grid direction and cloud cover on the day of sampling were recorded (Table 17).

Table 17 Weather and current grid during water quality monitoring near the Sepia Depression ocean outlet

Date	Wind direction	Wind strength (knots)	Cloud cover (%)	Current grid
07/12/2022	SE	10-18	10-20%	SW
12/12/2022	ESE, SE, SSE	8-15	0	SW
05/01/2023	ESE, E, ENE, NNE, NE	0-18	0	S
23/01/2023	S, W, NW, WSW, SSW	0-13	0	N
02/02/2023	SSE, SE, ESE	10-17	0	SE
21/02/2023	SE, NNE	0-12	5-10	NE
03/03/2023	SSW, S	3-7	0	N
24/03/2023	SE, S, N	0-5	10-95	NW

Notes:

1. N = north, S = south, W = west, E = east, SW = south-west, SE = south-east, NW = north-west, NE = north-east, ENE = east north-east, ESE = east south-east, SSE = south south-east, NNE = north north-east, SSW = south south-west, WNW = west, north-west, WSW = west south-west, NNW = north north-west
2. Winds are designated by the direction they come from while currents are designated by the direction they flow to.
3. Wind direction and strength are obtained from field observations.

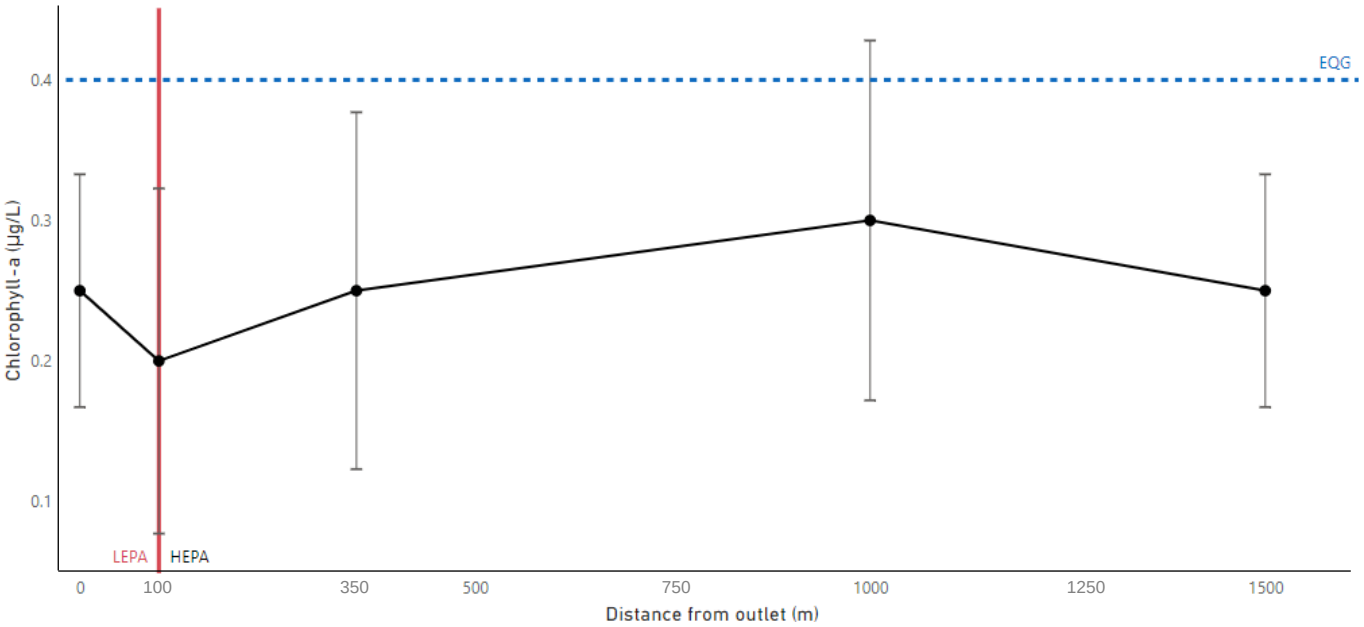
3.1 Nutrient enrichment

The median chlorophyll-a concentration in the Sepia Depression HEPA (≥100 m) was 0.2 µg/L and below the 80th percentile of historical reference site data (0.4 µg/L; Figure 7), meeting the EQG (Table 18, Appendix F).

Table 18 Environmental Quality Guidelines for nutrients

EQG	The median chlorophyll-a concentration in the High Ecological Protection Area (HEPA; 100 m plus) during the non-river flow period is not to exceed the 80th percentile of historical reference site data.
	The median light attenuation coefficient in the HEPA (100 m plus) during the non-river flow period is not to exceed the 80th percentile of historical reference site data.

Source: BMT Oceanica 2014

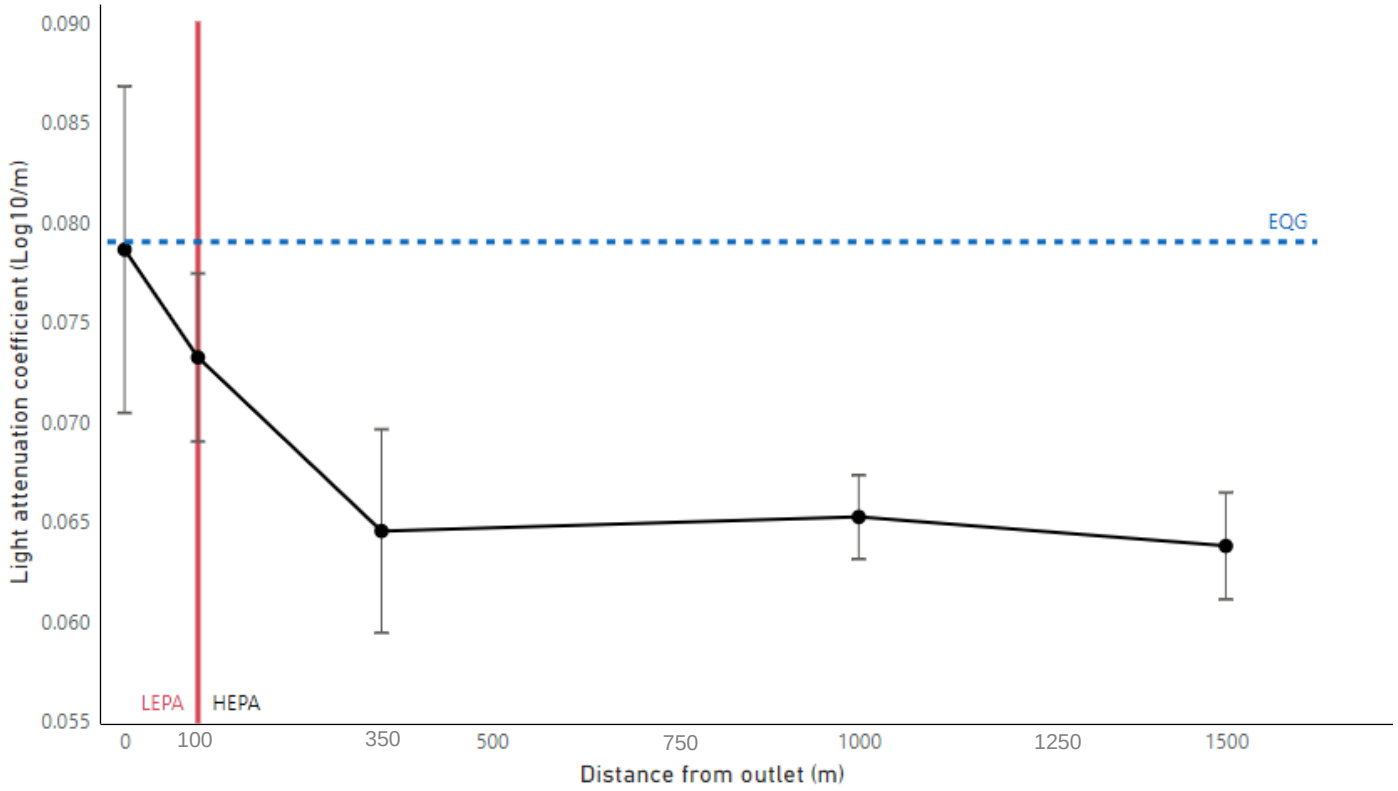


Notes:

1. Error bars represent ±95% confidence intervals; n = 32.
2. Dark blue dashed line = Environmental Quality Guideline (EQG) is the 80th percentile of historical reference site data.
3. LEPA = low ecological protection area; HEPA = high ecological protection area.
4. Data were pooled across eight sampling days (n=8) over December 2022–March 2023.

Figure 7 Median chlorophyll-a concentration obtained at fixed monitoring sites above and down-current of the Sepia Depression outlet during the summer monitoring period.

The median light attenuation coefficient (LAC) in the Sepia Depression HEPA (≥100 m) was 0.066 Log_{10}/m and was less than the 80th percentile of historical reference site data (0.079 Log_{10}/m; Figure 8), meeting the EQG (Table 18).



Notes:

1. Error bars represent ±95% confidence intervals; n = 8.
2. Dark blue dashed line = Environmental Quality Guideline (EQG) is the 80th percentile of historical reference site data.
3. LEPA = low ecological protection area; HEPA = high ecological protection area.
4. Data were pooled across eight sampling days (n=8) over December 2022 – March 2023.

Figure 8 **Median light attenuation coefficient obtained at fixed distances down current of the Sepia Depression outlet during the summer monitoring period**

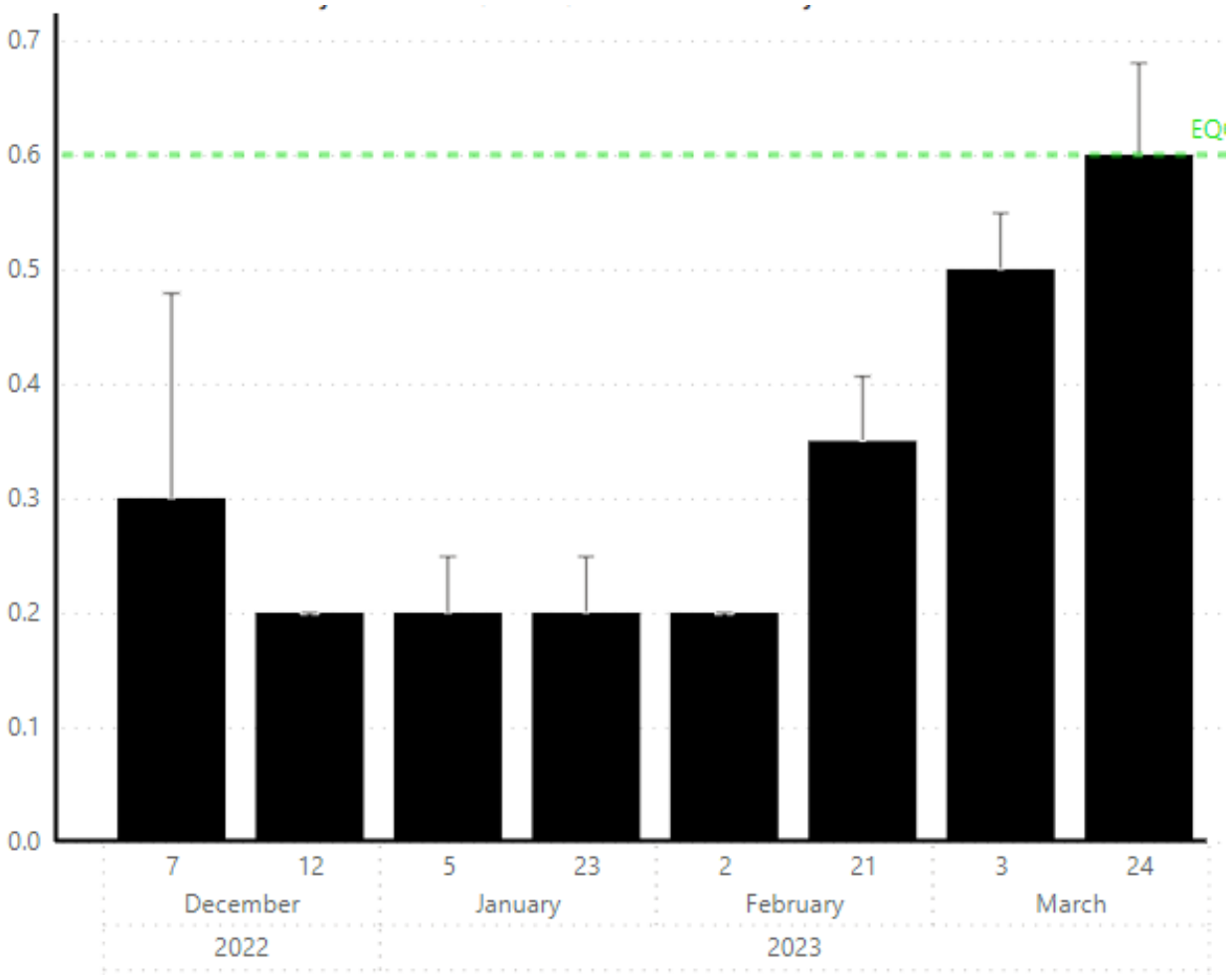
3.2 Phytoplankton biomass

Median chlorophyll-a concentration within the HEPA did not exceed three times the median of historical reference sites (0.60 µg/L) on any sampling occasion during the summer monitoring period and EQG1 (Table 19) was met (Figure 9).

Table 19 **Environmental Quality Guidelines for phytoplankton in receiving waters**

EQG1	Median phytoplankton biomass, measured as chlorophyll-a is not to exceed 3 times the median chlorophyll-a concentration of reference sites, on any occasion during the non-river flow period.
EQG2	Phytoplankton biomass measured as chlorophyll-a at any site does not exceed 3 times the median chlorophyll-a concentration of reference sites, on 25% or more occasions during the non-river flow period.

Median phytoplankton biomass measured as chlorophyll-a did not exceed three times the median of reference sites, on any sampling occasion during the summer monitoring period (Figure 9), meeting the requirements of EQG2 (<25% of occasions).



Notes:

1. Error bars represent ±95% confidence intervals; n = 9.
2. Green dashed line = Environmental Quality Guideline (EQO) is 3-times the median chlorophyll-a concentration of reference site data
3. Values measured at 0 m are not included in the figure or EQC assessment, as the 0 m site is situated directly above the outlets within the low ecological protection area (LEPA)

Figure 9 **Median phytoplankton biomass during the summer monitoring period, pooling data from fixed sites ≥100 m down-current of the Sepia Depression outlet**

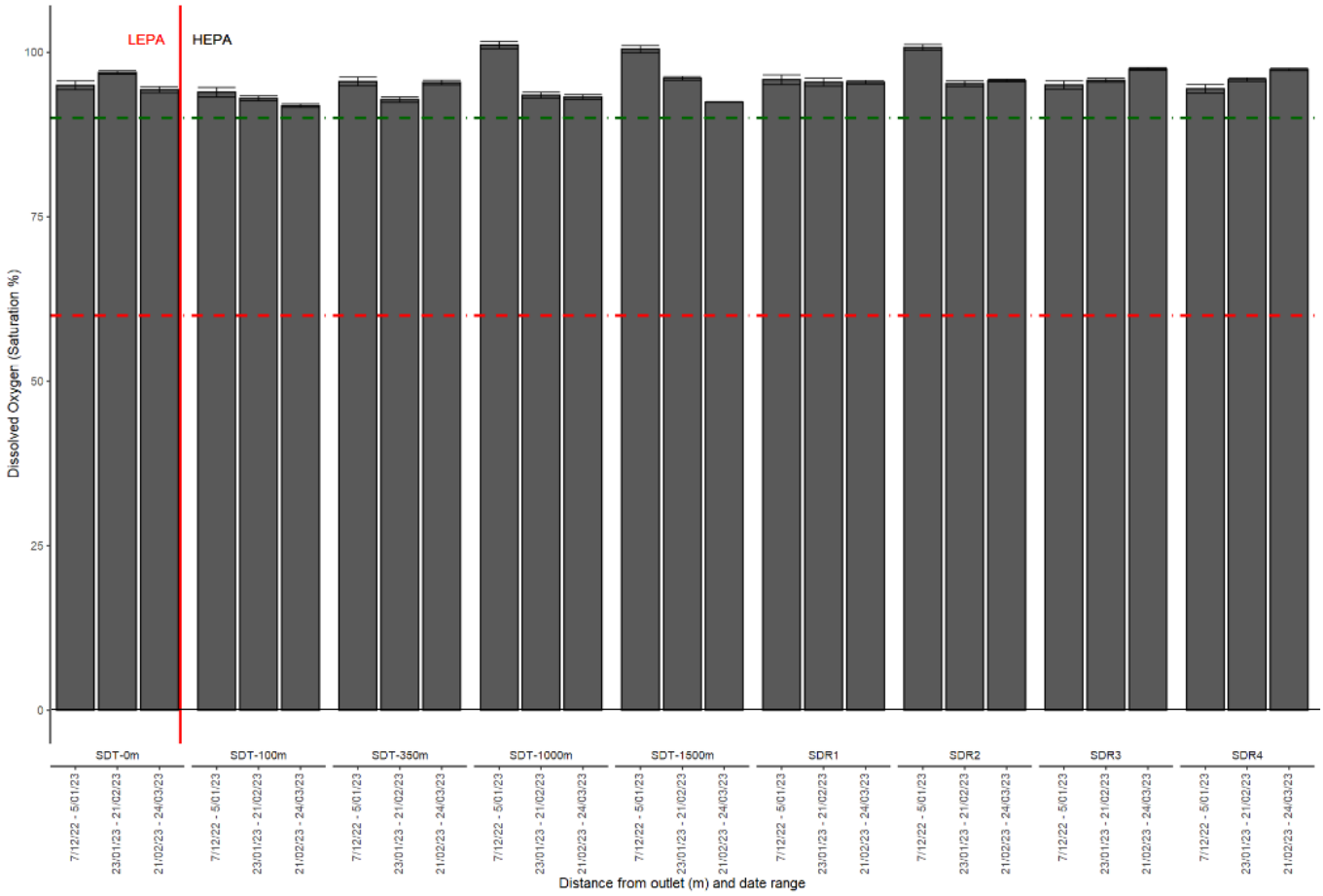
3.3 Physical-chemical stressors

3.3.1 Dissolved oxygen (DO)

Bottom (0-–0.5 m) DO saturation levels near the outlet were >90% at all times throughout the summer survey period (Figure 10) and the EQG for organic enrichment (Table 20) was met.

Table 20 Environmental Quality Guideline for dissolved oxygen

EQG	Median dissolved oxygen in bottom waters (0–0.5 m above the sediment surface) must be greater than 90% saturation at any site for a defined period of not more than 6 weeks during the non-river flow period.



Notes:

1. Error bars ±95% confidence intervals; n = 40.
2. Dissolved oxygen (DO) measured 0–0.5 m above the seabed
3. Green dashed line = Environmental Quality Guideline (EQG) = 90% DO saturation
4. Red dashed line = Environmental Quality Standard (EQS) = 60% DO saturation.
5. LEPA = low ecological protection area; HEPA = high ecological protection area.
6. Reference site data (SD1–SD4) are compared against EQG for contextual purposes only.

Figure 10 Median dissolved oxygen for defined periods of ≤6 weeks during the summer monitoring period

3.3.2 Salinity

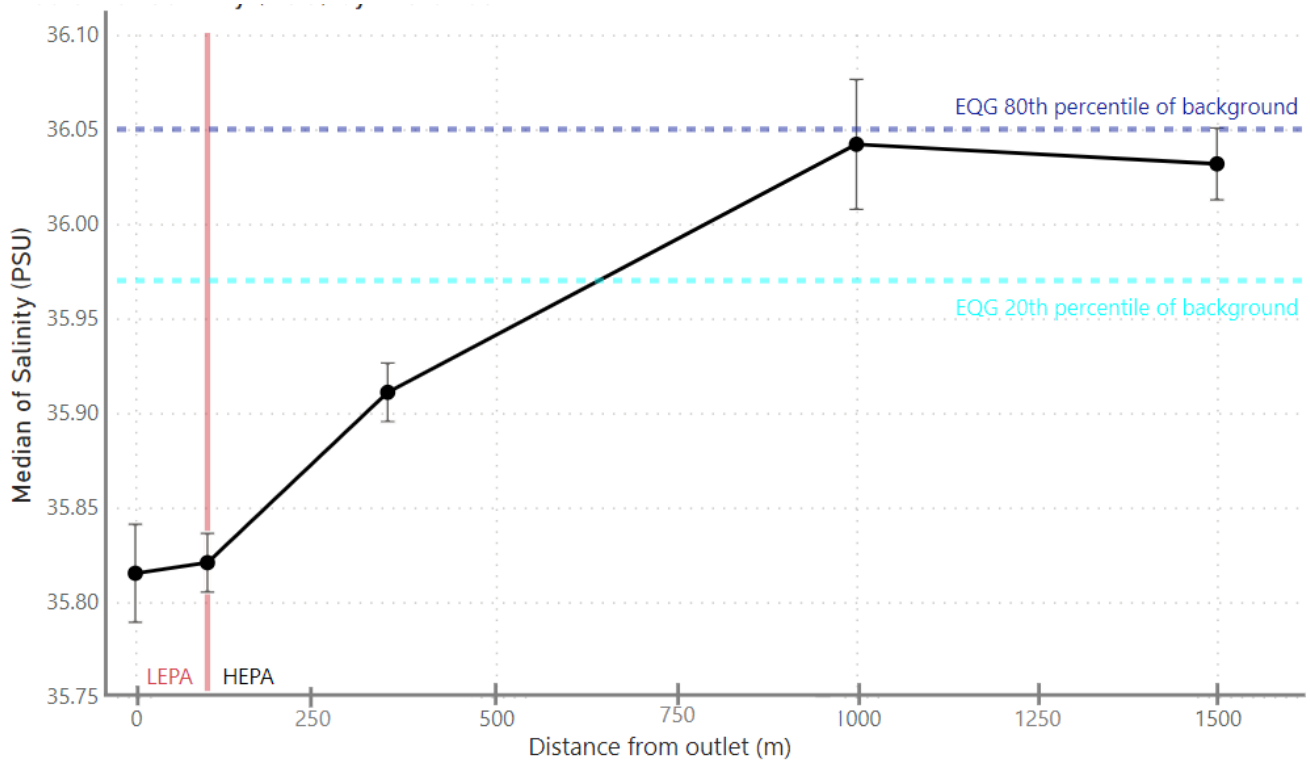
Median salinity was below the 20th percentile of the natural salinity range at the 100 m and 350 m sites within the HEPA and the EQG was not met triggering assessment against the EQS (Table 21 and Figure 11). There were no reports of deaths of marine organisms resulting from anthropogenically sourced salinity stress, thus the EQS was met.

Table 21 Environmental Quality Guideline for salinity

EQG	Median salinity (0.5 m below the water surface) at an individual site over any period is not to deviate beyond the 20th and 80th percentile of natural salinity range over the same period.
EQS	No deaths of marine organisms resulting from anthropogenically sourced salinity stress.

Note:

1. EQG = Environmental Quality Guideline; EQS = Environmental Quality Standard



Notes:

1. Error bars represent ±95% confidence intervals; n = 40.
2. Salinity measured 0–0.5 m below the sea surface.
3. Dark blue line = 80th percentile of historical reference sites; light blue dashed line = 20th percentile of historical reference sites
4. LEPA = low ecological protection area; HEPA = high ecological protection area.
5. Data for each distance were pooled across eight sampling occasions (n=8) over December 2022–March 2023.

Figure 11 Median salinity compared to the 20th and 80th percentile of reference site data during the summer monitoring period

4 Microbiological contaminants and algal biotoxins

4.1 Thermotolerant coliforms

TTC were sampled eight times over the 2022–2023 summer period (yielding a total of 40 samples). NHMRC (2008) and EPA (2005) guidelines require a minimum of 100 samples for accurate assessment of the EQC. Data from multiple years can be pooled where there are <100 samples provided local pollution conditions have not changed (NHMRC 2008). Assuming conditions have not changed, data collected over three summers (summer 2020–23) were pooled to yield 120 samples.

The median concentration of TTC derived from three years of pooled sampled was equal to the limit of detection (<10 CFU/100 mL; Table 23), meeting the EQG. Over the three sampling periods, there were 4 instances where TTC exceeded 21 CFU/100 mL, representing 3.3% of samples and thus meeting the EQG (Table 22 and Table 24).

Table 22 Environmental Quality Guideline for thermotolerant coliform concentrations

EQG	Median TTC concentrations at sites at the boundary of the Shellfish Harvesting Exclusion Zone (SHEZ) are not to exceed 14 CFU/100 mL with no more than 10% of the samples exceeding 21 CFU/100 mL as measured using the membrane filtration method

Notes:

1. TTC = thermotolerant coliforms.

Table 23 Median thermotolerant coliform concentration and for the Sepia Depression outlet for 2020–2023

Sampling period	Median	Compliance
Dec 2020–Mar 2021 Dec 2021–Mar 2022 Dec 2022–Mar 2023	<10 CFU/100 mL	■

Note:

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

Table 24 Thermotolerant coliforms on the boundary of Sepia Depression SHEZ that exceed 21 CFU/100 mL

Sampling season	Date	Site	TTC Concentration (CFU/100 mL)	Compliance
2020–2021	05/02/2020	SD30	40	
2021–2022	14/02/2022	SD24	30	
		SD27	40	
2022–2023	24/03/2023	SD28	60	
% total samples (n = 120) > 21 CFU/100 mL = 3.3%				

Notes:

1. Green (■) symbols indicate the Environmental Quality Criteria (EQC) were met; amber (■) and red (■) symbols represent an exceedance of the Environmental Quality Guideline (EQG) or Environmental Quality Standard (EQS), respectively.
2. CFU = colony forming units; EQG = Environmental Quality Guideline; SHEZ = Shellfish Harvesting Exclusion Zone; TTC = thermotolerant coliforms.

4.2 Toxic phytoplankton species

Cell densities of toxic phytoplankton were below relevant Western Australian Shellfish Quality Assurance Program (WASQAP; DoH & DoF 2007) guidelines (Table 26; Appendix H) meeting the EQG for toxic phytoplankton species (Table 25). For technical reasons phytoplankton samples are now analysed for the *Gymnodinium-Karenia* genera complex (GK Complex) rather than as individual species (Table 25). The accurate identification of both *Gymnodinium* and *Karenia* genera (also including the *Karlodinium* genus) can be challenging due to subtle taxonomic differences (Daugbjerg et al., 2000; Heimann, 2012). The Western Australian Shellfish Quality Assurance Program (WASQAP), as outlined in the Department of Health and Department of Fisheries (2007), lacks a guideline for the GK Complex. An updated *Gymnodinium-Karenia* guideline has been developed (DoH, DPIRD, and Industries, 2020). The criteria outlined in the most recent WASQAP guidelines (DoH, DPIRD, and Industries, 2020) were met.

Table 25 Environmental Quality Guideline for toxic phytoplankton species

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

Note:

1. Western Australian Shellfish Quality Assurance Program (WASQAP) Operations Manual (DoF 2007), as outlined in the Management Plan (BMT Oceanica 2014).
2. SHEZ = Shellfish Harvesting Exclusion Zone.

Table 26 **Estimated cell densities of phytoplankton species known to produce toxins**

Date	Site[1]	Species	Estimated density (cells/L)	WASQAP guideline[2] (cells/L)	Compliance
07/12/2022	SDR2	*Gymnodinium* spp	80	1,000	
	SD14	No toxic species	NA	NA	
	SD28	*Pseudo-nitzschia* spp.	80	250,000	
12/12/2022	SDR3	*Gymnodinium* spp	80	1,000	
		Prorocentrum dentatum	80	500	
	SD9	*Gymnodinium* spp	320	1,000	
	SD26	*Alexandrium* spp.	80	100	
		Gymnodinium spp.	400	1,000	
05/01/2023	SDR1	*Pseudo-nitzschia* delicatissima group	240	250,000	
		Gymnodinium spp.	160	1,000	
		Karlodinium armiger	240	250,000[5]	
		Karlodinium veneficum	1,120	250,000[5]	
		Prorocentrum micans	160	500	
	SD13	*Pseudo-nitzschia* delicatissima group	560	250,000	
		Gymnodinium spp.	240	1,000	
		Karlodinium veneficum	720	250,000[5]	
		Prorocentrum dentatum	80	500	
	SD29	*Pseudo-nitzschia* delicatissima group	880	250,000	
		Gymnodinium spp.	400	1,000	
		Karlodinium veneficum	560	250,000[5]	
		Prorocentrum dentatum	80	500	
23/01/2023	SDR2	*Pseudo-nitzschia* delicatissima group	18,640	250,000	
		Gymnodinium spp.	960	1,000	
		Prorocentrum cordatum	80	500	
		Prorocentrum dentatum	400	500	
		Prorocentrum micans	160	500	

Date	Site[1]	Species	Estimated density (cells/L)	WASQAP guideline[2] (cells/L)	Compliance
		Prorocentrum triestinum	80	500	
	SD1	*Pseudo-nitzschia* delicatissima group	6,720	250,000	
		Pseudo-nitzschia seriata group	240	250,000	
		GK Complex (*Gymnodinium-Karenia* Complex)	80	250,000[5]	
		Gymnodinium spp.	400	1,000	
		Prorocentrum dentatum	160	500	
		Prorocentrum micans	160	500	
		Prorocentrum triestinum	80	500	
	SD31	*Pseudo-nitzschia* delicatissima group	16,400	250,000	
		Gymnodinium spp.	880	1,000	
02/02/2023	SDR2	*Pseudo-nitzschia* delicatissima group	80	250,000	
		Gonyaulax spinifera	80	100	
		Gymnodinium spp.	160	1,000	
		GK Complex (*Gymnodinium-Karenia* Complex)	160	250,000[5]	
	SD7	*Pseudo-nitzschia* delicatissima group	80	250,000	
		Gymnodinium spp.	160	1,000	
	SD23	*Pseudo-nitzschia* delicatissima group	160	250,000	
		Gymnodinium spp.	160	1,000	
21/02/2023	SDR2	*Pseudo-nitzschia* delicatissima group	480	250,000	
		Dinophysis spp.	80	500	
		GK Complex (*Gymnodinium-Karenia* Complex)	160	250,000[5]	
		Gymnodinium spp.	80	1,000	
		Prorocentrum dentatum	80	500	
		Prorocentrum micans	80	500	
		Prorocentrum spp.	80	500	
	SD6	*Pseudo-nitzschia* delicatissima group	1,840	250,000	
		GK Complex (*Gymnodinium-Karenia* Complex)	1,520	250,000[5]	

Date	Site[1]	Species	Estimated density (cells/L)	WASQAP guideline[2] (cells/L)	Compliance
		Prorocentrum micans	240	500	
	SD19	GK Complex (*Gymnodinium-Karenia* Complex)	240	250,000[5]	■
		Prorocentrum micans	160	500	
		Prorocentrum rhathymum	80	500	
03/03/2023	SDR2	*Pseudo-nitzschia* delicatissima group	400	250,000	■
		Gonyaulax spinifera	160	100	
		Gymnodinium spp.	240	1,000	
	SD8	*Pseudo-nitzschia* delicatissima group	80	250,000	
		Gymnodinium spp.	400	1,000	
	SD22	*Pseudo-nitzschia* delicatissima group	240	250,000	
		GK Complex (*Gymnodinium-Karenia* Complex)	80	250,000[5]	
		Gymnodinium spp.	400	1,000	
		Prorocentrum micans	80	500	
24/03/2023	SDR2	*Pseudo-nitzschia* delicatissima group	240	250,000	■
		Pseudo-nitzschia seriata group	160	250,000	
	SD7	*Pseudo-nitzschia* delicatissima group	480	250,000	
		Pseudo-nitzschia seriata group	240	250,000	
		Gymnodinium spp.	80	1,000	
	SD24	*Pseduo-nitzschia* delicatissima group	800	250,000	

Notes:

1. Samples were analysed for one monitoring site and one reference site per sampling occasion.
2. Western Australian Shellfish Quality Assurance Program (WASQAP) (DoH & DoF 2007).
3. – = no toxic species detected, NA = not applicable.
4. Green (■) symbols indicate the Environmental Quality Criteria (EQC) were met; amber (■) and red (■) symbols represent an exceedance of the Environmental Quality Guideline (EQG) or Environmental Quality Standard (EQS), respectively.
5. *Karenia/Karlodinium/Gymnodinium* group trigger from DoH, DPIRD and Industry (2020)

4.3 Faecal pathogens (*Enterococci* spp.)

Samples were collected eight times over the 2022–2023 summer monitoring period (yielding a total of 40 samples) for faecal pathogen analyses. NHMRC (2008) guidelines and EPA (2005) require a minimum of 100 samples over the monitoring period for accurate assessment of the EQC. Data from multiple years can be pooled where there are less than 100 samples provided local pollution conditions have not changed (NHMRC 2008). Assuming conditions have not changed, data from the past three summers (2020–2023) were pooled to yield 120 samples. The EQG for primary and secondary contact recreation are outlined in Table 27.

The 95th percentile of *Enterococci* spp. concentrations based on 120 samples was 2105 MPN/100 mL (Table 28), exceeding the EQG (Table 27) for primary contact recreation (200 MPN/100 mL) and triggering assessment against the EQS. The 95th percentile of *Enterococci* spp. (2105 MPN/100 mL) also exceeded the EQS for primary contact recreation (500 MPN/100 mL) (Table 28).

Table 27 Environmental Quality Criteria for contact recreation

Primary	EQG	The 95th percentile of bacterial contact of marine waters should not exceed 200 *Enterococci*/100 mL
Primary	EQS	The 95th percentile of bacterial contact of marine waters should not exceed 500 *Enterococci*/100 mL
Secondary	EQG	The 95th percentile of bacterial contact of marine waters should not exceed 2000 *Enterococci*/100 mL
Secondary	EQS	The 95th percentile of bacterial contact of marine waters should not exceed 5000 *Enterococci*/100 mL

Until 2013/14, primary contact recreation had been managed (albeit informally) against the ANZECC (1992) criteria (median *Enterococci spp*. concentrations <35 MPN/100 mL). Development of the MMP formalised the monitoring regime and updated the approach to the contemporary and best practice EQMF including adopting the EPA (2005) criteria (the 95th percentile *Enterococci* spp. concentration <200 MPN/100 mL). The informal management boundaries that applied historically were not altered accordingly and exceedance of the EPA's recreational contact criteria is an artefact of the change of criteria. The historical discharge footprint is unchanged, and the exceedances are not indicative of an increased risk to EQO.

Exceedance of the EQG and EQS for primary contact recreation was reported to the Department of Health and the Department of Water and Environmental Regulation (previously the Department of Environment Regulation and the Office of the Environmental Protection Authority) as per the SDOOL MMP (BMT Oceanica 2014).

Table 28 The 95th percentile of *Enterococci* spp. concentrations at the boundary recreational contact exclusion zone for the Sepia Depression ocean outlet

Date	95th percentile	Environmental Quality Criteria		Compliance
Dec 2020–Mar 2021 Dec 2021–Mar 2022 Dec 2022–Mar 2023	2105 MPN/100 mL	EQG (primary contact)	95th percentile <200 MPN/100 mL	
		EQS (primary contact)	95th percentile <500 MPN/100 mL	
		EQG (secondary contact)	95th percentile <2000 MPN/100 mL	
		EQS (secondary contact)	95th percentile <5000 MPN/100 mL	

Notes:

1. Green symbols (■) indicate Environmental Quality Guideline (EQG) were met, amber (■) and red (■) symbols represent an exceedance of the EQG and Environmental Quality Standard (EQS) respectively.
2. MPN = most probably number of *Enterococci* spp.

4.4 Phytoplankton cell concentrations

The median total phytoplankton cell concentration was 26 cells/mL (Table 30) and the EQG (Table 29) was met.

Table 29 Environmental Quality Guideline for phytoplankton cell count

EQG	Median total phytoplankton cell concentration for the area of concern should not exceed 15 000 cells/mL

Table 30 Estimated phytoplankton total cell densities collected at fixed monitoring sites for contact recreation down-current of the Sepia Depression outlet

Date	Site	Total density (cells/mL)	Compliance
07/12/2022	SD14	40	
12/12/2022	SD9	14	
05/01/2023	SD13	66	
23/01/2023	SD1	49	
02/02/2023	SD7	4	
21/02/2023	SD6	12	
03/03/2023	SD8	8	
24/03/2023	SD7	16	
Median (all data)		**26**	

5 Aesthetics

Aesthetic quality was assessed fortnightly via a questionnaire completed by field personnel on eight occasions during the non-river flow period (Table 31). On each occasion, the questionnaire was completed at one location on the post upgrade boundary down-current of the diffuser. Water clarity around the outlet (mean LAC at 350 m from the diffuser, pooled from all days) was compared against water clarity at a greater distance from the outlet (mean LAC at 1500 m from the diffuser from all days pooled) to assess whether aesthetic differences exist. Water Corporation also maintains a complaints register for the SDOOL program.

Table 31 Environmental Quality Criteria for Recreation and Aesthetics

Indicator	Environmental Quality Criteria	
	EQG	EQS
Nuisance organisms	Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae and sewage fungus should not be present in excessive amounts	There should be no overall decrease in the aesthetic water quality values of Cockburn Sound using direct measures of the community's perception of aesthetic value.
Faunal deaths	There should be no reported incidents of large-scale deaths of marine organisms relating from unnatural causes.	
Water clarity	The natural visual clarity of the water should not be reduced by more than 20%	
Colour	The natural hue of the water should not be changed by more than ten points on the Munsell scale.	
Surface films	Oil and petrochemicals should not be noticeable as a visible film on the water or detectable by odour.	
Surface debris	Water surfaces should be free of floating debris, dust and other objectionable matter, including substances that cause foaming.	
Odour	There should be no objectionable odour.	
Fish tainting substances	Concentrations of contaminants will not exceed the aesthetics guidelines for fish tainting substances at the Shellfish Harvesting Safety Zone boundary.	There should be no detectable tainting of edible fish harvested outside the Shellfish Harvesting Safety Zone boundary.

The field surveys found algae/plant material visible on the surface on 37.5% of occasions (Table 32). No dead marine organisms were visible on any occasion (Table 32). There was noticeable colour variation on 12.5% of occasions (Table 32). There were no films or oil on the surface on any sampling occasion. Floating debris was visible on the surface on 12.5% of occasions sampling occasion (Table 32). There was no noticeable odour associated with the water on any of the sampling occasions (Table 32). There was no overall decrease in the aesthetic water quality values of Cockburn Sound using direct measures of the community's perception of aesthetic value.

Mean LAC at 350 m from the ocean outlet (0.067 Log_{10}/m) was slightly higher than at 1500 m distance from the outlet (0.063 Log_{10}/m) suggesting that light was more quickly attenuated at 350 m than 1500 m (Table 33). Overall water clarity was reduced by ~6% and therefore the EQG that the natural visual clarity of the water should not be reduced by more than 20% was met.

Fish tainting substances in the comprehensive TWW characterisation sample collected on 21 February 2023 did not exceed the EPA (2005) aesthetic guidelines for fish tainting substances (Table 34). Hexachlorocyclopentadiene concentration in the TWW sample was below the limit of reporting, but the LoR was greater than the aesthetic guideline for fish tainting substances (Table 34). Any potential exceedance would be considered negligible after initial dilution.

Table 32 Aesthetic observations and measurements near the Sepia Depression ocean outlet from December 2022 to March 2023

Date	Site	Algae/plant material?	Dead marine organisms?	Secchi depth (m)	Colour variation?	Oil or other films?	Floating debris?	Odour?
7/12/2022	SD13	Yes, macrolgal and seagrass wrack	No	10.7	No	No	Yes, macroalgae and seagrass	No
12/12/2022	SD10	Yes, wrack	No	8.5	Yes	No	No	No
5/01/2023	SD14	No	No	15	No	No	No	No
23/01/2023	SD2	No	No	14	No	No	No	No
2/02/2023	SD6	Yes, brown algae and seagrass	No	11.5	No	No	No	No
21/02/2023	SD5	Yes, seagrass	No	9.5	No	No	No	No
3/03/2023	SD6	No	No	12.1	Yes, slightly green	No	No	No
24/03/2023	SD10	No	No	11	No	No	No	No

Table 33 Light attenuation coefficient at sites 350 m and 1500 m from the Sepia Depression ocean outlet from December 2022 to March 2023

Date	Light attenuation coefficient (Log10/m)	
	350 m (site SDT-350 m)	1500 m (site SDT – 1500 m)
7/12/2022	0.062	0.064
12/12/2022	0.066	0.061
5/01/2023	0.064	0.064
23/01/2023	0.062	0.067
2/02/2023	0.065	0.061
21/02/2023	0.074	0.069
3/03/2023	0.082	0.066
24/03/2023	0.060	0.057
Mean	**0.067**	**0.063**

Table 34 **Guidelines for fish tainting substances and parameters measured on 21 February 2023 in the SDOOL wastewater stream**

Parameter (µg/L)	Aesthetics guidelines	2022/2023 treated wastewater sampling
Metals and Metalloids		
Copper (Cu)	1000	17
Zinc (Zn)	5000	59
Phenols		
Phenol	300	<1
2,4 – Dichlorophenol	0.3	<1
2,4,6 – Trichlorophenol	2	<2
Pentachlorophenol (PCP)	30	<2
Chlorinated hydrocarbons		
Hexachlorocyclopentadiene	1	**<20**
Ethers		
Nitrobenzene	30	<20
BTEX		
Toluene	250	<1
Ethylbenzene	250	<1
PAHs		
Naphthalene	1000	<0.01
Acenaphthene	20	<0.01

Note:

1. BTEX = Benzene, toluene, ethylbenzene and xylene; PAHs = polycyclic aromatic hydrocarbons.
2. Bold numbers are where the limit of reporting is greater than the guideline.
3. Guideline values obtained from EPA (2005)

6 Shoreline monitoring

6.1 Thermotolerant coliforms

TTC were sampled at eight shoreline monitoring sites eight times over the 2022–2023 summer period (yielding a total of 64 samples). NHMRC (2008) guidelines and EPA (2005) recommend that a minimum of 100 samples is needed for accurate assessment of the EQG. Data from multiple years can be pooled where there are <100 samples provided local pollution conditions have not changed (NHRMC 2008). Assuming conditions have not changed, data collected over two summers (since summer 2021–22) were pooled to yield 128 samples.

The shoreline sites are not formally assessed against the EQC but the median and 90th percentile TTC concentrations derived from the 128 samples were less than the limit of detection (<10 CFU/100 mL; Table 35, Appendix G) and less than the 14 and 21 CFU/100 mL criteria, respectively meeting the EQG (Table 22).

Median TTC concentrations at 0m down current of the diffuser were 375 MPN/100 mL. All other distances had median concentrations of 5 CFU/100 mL (the proxy concentrations below the LoR) (Figure 12).

Table 35 **Median and 90th percentile of thermotolerant coliform concentrations at the shoreline monitoring sites for the Sepia Depression outlet for 2021–2023 and comparison to the EQG**

Sampling period	Median (CFU/100 mL)	90th percentile	Compliance (EQG)
Dec 2021–Mar 2022 Dec 2022–Mar 2023	<10	<10	■

Notes:

1. Green symbols (■) indicate the Environmental Quality Criteria (EQC) were met, amber (■) and red (■) symbols represent an exceedance of the Environmental Quality Guideline (EQG) and Environmental Quality Standard (EQS), respectively.
2. Thermotolerant coliform results below the analytical detection limit (<10 CFU/100 mL) were halved (=5 CFU/100 mL) to calculate the median and 90th percentile.
3. CFU = Colony forming unit.
4. Environmental Quality Criteria are based on EPA (2017).

6.2 Faecal pathogens (*Enterococci* spp.)

Samples were collected eight times at eight shoreline monitoring sites over the 2022–2023 summer monitoring period (yielding a total of 64 samples) for faecal pathogens analyses. NHMRC (2008) and EPA (2005) recommend a minimum of 100 samples over the monitoring period are required for accurate assessment of the EQC. Data from multiple years can be pooled where there are less than 100 samples provided local pollution conditions have not changed (NHMRC 2008). Assuming conditions have not changed, data collected over two summers (summer 2021–2022 and 2022–23) were pooled to yield 128 samples.

Shoreline sites are not formally assessed against the EQC but over the 2022–2023 summer monitoring programs, the 95th percentile of *Enterococci* spp. concentrations at the shoreline monitoring sites for the Sepia Depression ocean outlets was <10 MPN/100 mL (Table 36), and met both the primary (<200) and secondary (<2000 /100mL) contact recreation EQGs (Table 27) .

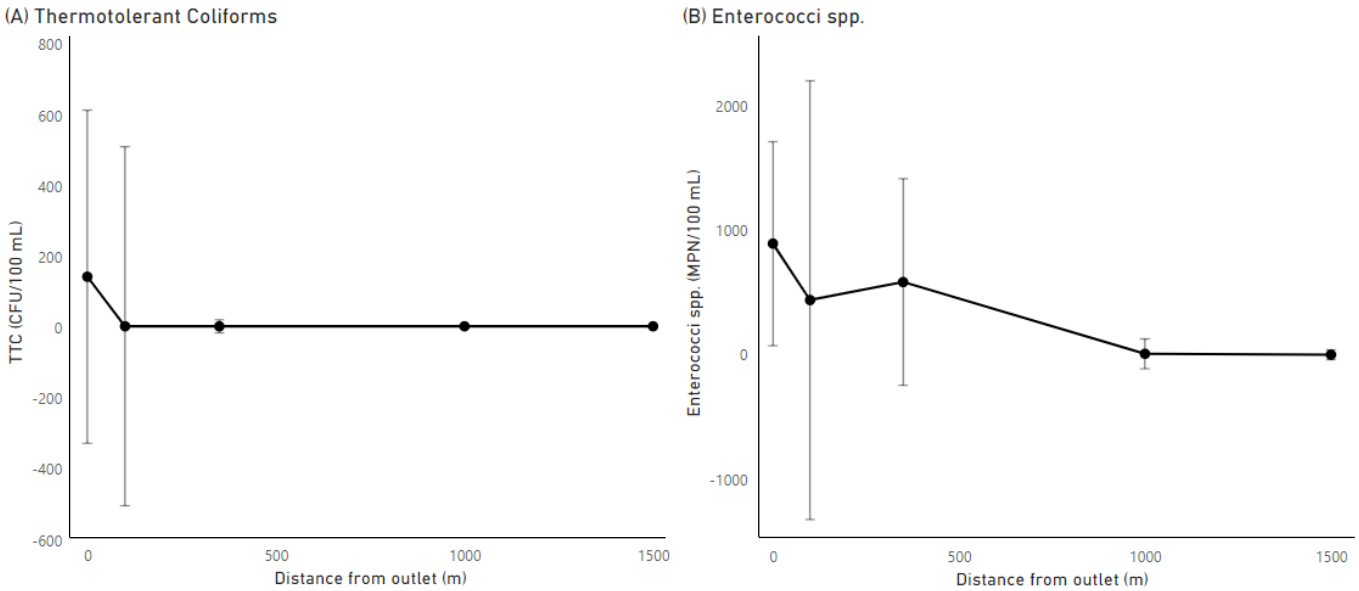
Table 36 **The 95th percentile of *Enterococci* spp. concentrations at the shoreline monitoring sites for the Sepia Depression ocean outlet for 2021–2023 and comparison to the EQG**

Sampling period	95th percentile (MPN/100 mL)	Compliance	
		Primary contact	Secondary contact
Dec 2021–Mar 2022 Dec 2022–Mar 2023	<10	■	■

Notes:

1. MPN = most probable number of *Enterococci* spp.
2. *Enterococci* spp. concentrations below the analytical detection limit (<10 *Enterococci* spp. MPN/100 mL) were halved (=5 MPN/100 mL) to calculate the 95th percentile.
3. Green symbols (■) indicate the Environmental Quality Criteria (EQC) were met; amber (■) and red (■) symbols represent an exceedance of the Environmental Quality Guideline (EQG) and Environmental Quality Standard (EQS), respectively.
4. Environmental Quality Criteria (EQC) based on EPA (2017) water quality guidelines for recreation waters.

Median *Enterococci* spp. concentrations between 0 and 1000 m down current of the diffuser were 580 (0 m), 445 (100 m), 170 (350 m) and 7.5 MPN/100 mL (1000 m). Median *Enterococci* spp. concentrations at 1500 m down current of the diffuser were 5 MPN/100 mL (the proxy for concentrations below the LoR) (Figure 12). The down gradient sampling is contextual information in support of the shoreline sampling. Therefore, median concentrations were calculated to provide contextual data for an indication of "typical" concentrations after dilution rather than the 95th percentile which is linked to compliance.



Notes:

1. Error bars represent ±95% confidence intervals; n = 40.
2. Only 2022/23 sampling results were graphed.

Figure 12 **Median a) thermotolerant coliforms and b) *Enterococci* spp. at 0, 100, 350, 1000 and 1500 m from the Sepia Depression outlet December 2022 to March 2023.**

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Appendices

The following Appendices are available from Water Corporation on request:

Appendix A Analytical laboratories

Appendix B Treated wastewater laboratory results

Appendix C Initial dilution model output

Appendix D Whole of effluent toxicity testing results

Appendix E Site coordinates

Appendix F Nutrients results

Appendix G Microbiology results

Appendix H Phytoplankton results