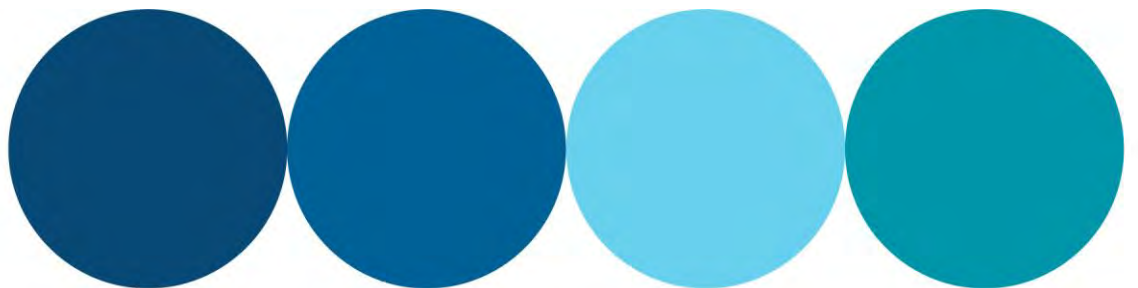


# Perth Long Term Ocean Outlet Monitoring Program (PLOOM)

2020-2021 Annual Report

Swanbourne





This report has been prepared for Water Corporation by BMT, June 2021 Report Number R-10172-3.

## Document history

### Distribution

Revision	Author	Recipients	Organisation	No. copies & format	Date
A	A Sherwood	G Shiell	BMT	1 x docm	26/08/2021
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### Review

Revision	Reviewer	Intent	Date
A	G Shiell	Editorial and technical review	26/08/2021
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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 OHSAS18001, ISO14001 and ISO9001.

### Status

This report is 'Draft' until approved for final release, as indicated below by inclusion of signatures from: (i) the author and (ii) a Director of BMT Commercial Australia Pty Ltd (BMT) or their authorised delegate. A Draft report may be issued for review with intent to generate a 'Final' version, but must not be used for any other purpose.

### Approved for final release:

**Author**

Date: 02/09/2021

**Director (or delegate)**

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## Acronyms




ANZG	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
CFU	Colony forming unit
DoH	Western Australian Department of Health
EPA	Environmental Protection Authority
EQC	Environmental Quality Criteria
EQG	Environmental Quality Guideline
EQMF	Environmental Quality Management Framework
EQO	Environmental Quality Objective
EQS	Environmental Quality Standard
EV	Environmental Value
HEPA	High ecological protection area
MPN	Most probable number
NATA	National Association of Testing Authorities
NOEC	No observed effect concentration
OZI	Observed zone of influence
PLOOM	Perth Long Term Ocean Outlet Monitoring
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



## Executive Summary

This report documents the findings of the 2020–2021 Swanbourne ocean monitoring program. Results are reported in the context of the Environmental Quality Management Framework (EQMF) described in EPA (2017). 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
<b>Monitor:</b> EQG & EQS met (continue monitoring)	
<b>Investigate:</b> EQG not met (investigate against the EQS)	
<b>Action:</b> 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 limit of reporting and the ANZG (2018) 80% species protection guideline (36 and 1.4 µg/L, respectively)	
	Non-bioaccumulating toxicants and initial dilution	EQG	Initial dilution of 1:104 was sufficient to reduce non-bioaccumulating contaminant concentrations to below their ANZG (2018) 99% species protection guidelines	
	Total toxicity of the mixture (TTM)	EQG	The TTM for the additive effect of ammonia, copper and zinc after initial dilution (0.79) did not exceed the ANZG (2018) guideline value of 1.0	
	Whole of effluent toxicity testing	EQG	The lowest NOEC during the reporting period was 12.5%. Eight dilutions with background seawater are required to achieve this NOEC which is lower than	



			the dilutions typically achieved at the LEPA boundary.	
Nutrient enrichment	Chlorophyll-a	EQG	Median chlorophyll-a concentration within the high ecological protection area (HEPA) (0.20 µg/L) was lower than the 80 <sup>th</sup> percentile of historical reference site concentrations (0.5 µg/L).	
	Light attenuation coefficient (LAC)	EQG	Median LAC within the HEPA (0.075 Log <sub>10</sub> /m) was lower than the 80 <sup>th</sup> percentile of historical reference sites (0.094 Log <sub>10</sub> /m).	
Phytoplankton blooms	Phytoplankton biomass (measured as chlorophyll-a)	EQG	There were no instances where median chlorophyll-a concentrations in the HEPA exceeded 3-times the median of reference sites.	
			Chlorophyll-a did not exceed 3 times the median concentrations of reference sites at any site on any occasion.	
Physical chemistry	Organic enrichment	EQG	Dissolved oxygen saturation within the HEPA remained above 90% saturation at all times.	
	Salinity	EQG	Median salinity at individual sites within the HEPA were below the 20 <sup>th</sup> percentile of the natural salinity range at 100 m and 350 m.	
		EQS	There were no reported deaths of marine organisms from anthropogenically sourced salinity stress at Swanbourne over the summer 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. NOEC = no observed effect concentration; the highest concentration of TWW at which there is no statistically significant observed effect on gamete fertilisation.



**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 2018–2019, 2019–2020 and 2020–2021 sampling seasons was at the limit of detection (<10 CFU/100 mL) and less than 14 CFU/100 mL	
		The 90 <sup>th</sup> percentile was equal to the limit of detection (<10 CFU/100 mL), and less than the 21 CFU/100 mL criteria	
Algal biotoxins	Toxic phytoplankton species	Toxic phytoplankton species were not recorded in excess of Western Australian Shellfish Quality Guidelines during the 2020–2021 monitoring.	

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. TTC results below the analytical detection limit (<10 CFU/mL) were halved (=5 CFU/mL) to calculate median value.

**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 streptococci	<i>Enterococci</i> spp.	EQG (primary contact)	The 95 <sup>th</sup> percentile of <i>Enterococci</i> spp. concentrations (10 MPN/100 mL) was lower than the 200 MPN/100 ml EQG	
		EQG (secondary contact)		
Algal biotoxins	Phytoplankton (cell concentration)	EQG	Estimated total phytoplankton cell count at individual sites were <10 000 cells/mL at each site and sampling occasion during 2020–2021 monitoring.	

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) and Environmental Quality Standard (EQS), respectively.





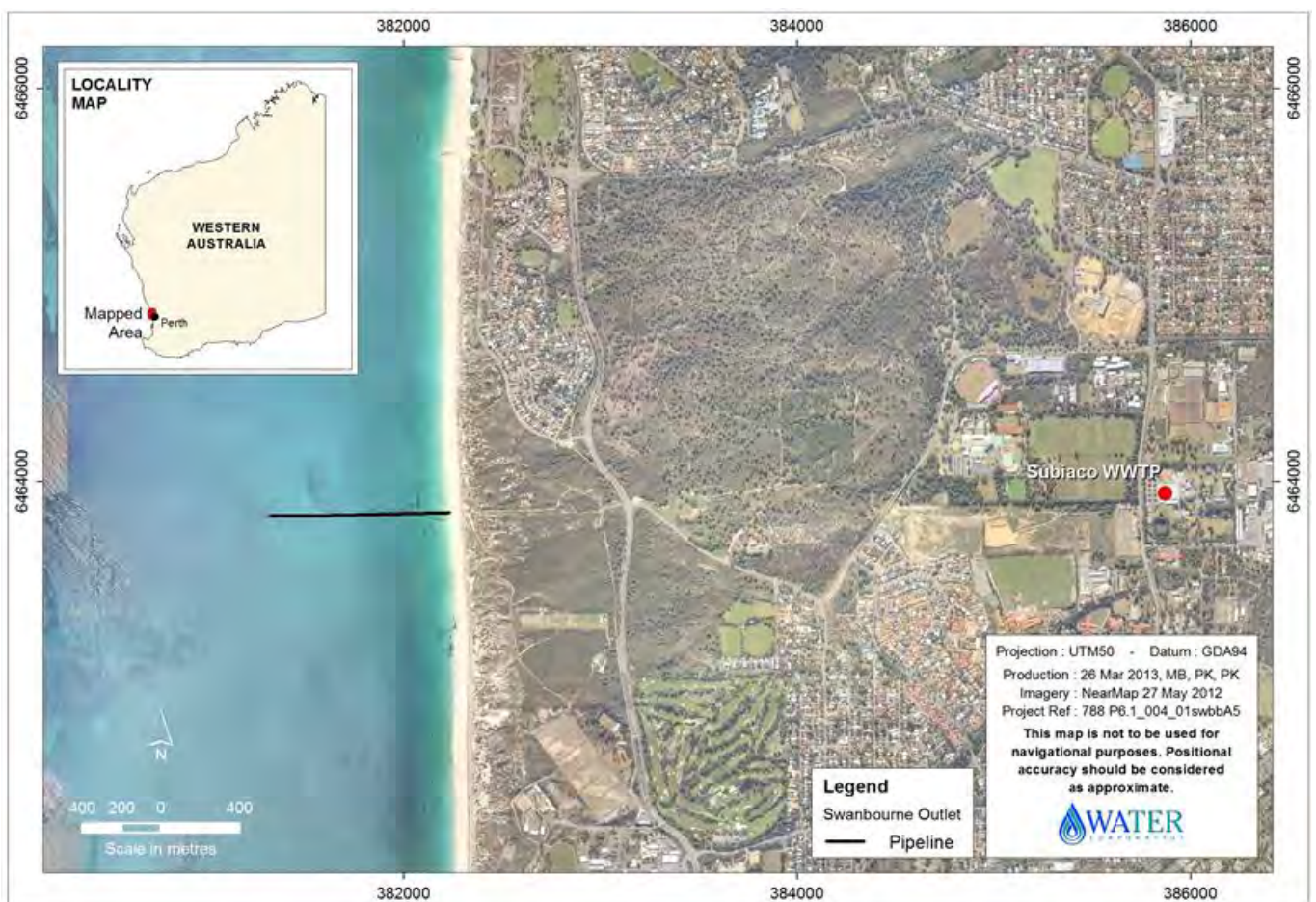
## Introduction

### Document purpose

This annual report documents the findings of the 2020–2021 ocean monitoring around the Swanbourne ocean outlet. Monitoring was completed according to Western Australia’s Environmental Quality Management Framework (EQMF; EPA 2016).

### Wastewater treatment plant infrastructure and discharge

The Subiaco Water Resource Recovery Facility (WRRF) treats predominantly domestic wastewater from the central Perth area. The treated wastewater (TWW) comprises ~95% domestic wastewater and less than 5% industrial wastewater. The Subiaco WRRF discharges ~56 ML/day of secondary TWW to the ocean through a sub-marine ocean outlet (~11 m depth) offshore from Swanbourne Beach (Figure 1).



**Figure 1** Location of the Subiaco water resource recovery facility (WRRF) and Swanbourne ocean outlet



## Potential stressors in treated wastewater

Western Australia's ocean outlet monitoring programs include analysis for:



### 1. Toxicants

- Toxicity and sampling for contaminants within treated wastewater.

### 2. Physico-chemical stressors

- Dissolved oxygen and salinity in receiving waters near the ocean outlet relative to reference sites.

### 3. Nutrients

- Nutrients in receiving waters near the ocean outlet relative to reference sites.

### 4. Microbial contaminants

- Microbial contaminants and algal biotoxins in receiving waters near the ocean outlet relative to reference sites.

### Toxicants

Metals and persistent organic compounds may be directly toxic to marine biota and/or may accumulate in marine biota at concentrations sufficient to pose a risk to humans if consumed. Under the PLOOM program, TWW is screened for bioaccumulating and non-bioaccumulating toxicants and the concentrations are compared to relevant EPA guidelines. To account for the synergistic effects of multiple toxicants and toxicants without guidelines, the overall toxicity of the TWW is determined using whole of effluent toxicity (WET) testing (also known as direct toxicity assessment).

### 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. Measurements of DO saturation in receiving waters near the outfall, relative to measurements at reference sites, provide an indication of the risk posed by deoxygenation.

Reduced salinity near the outfall, resulting from freshwater in the TWW plume may cause osmotic stress in marine biota. Measurements of salinity in receiving waters near the outfall are compared to the salinity at appropriate reference sites. The comparison allows evaluation of whether salinity near the outfall is within the range of natural variation.

### Nutrients

TWW contains elevated concentrations of 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/or macroalgae. The potential for shading is measured using in-water measures of chlorophyll-a (a proxy for phytoplankton biomass) and light attenuation (a measure for water clarity).





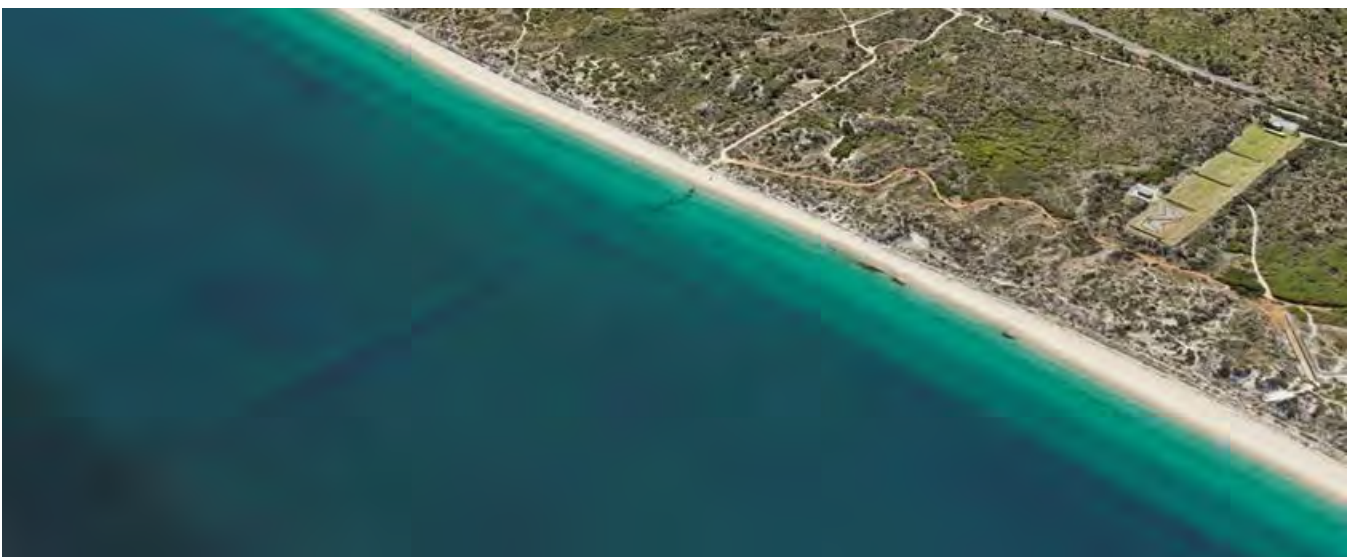
Although most algal blooms are harmless, some contain species that produce toxins that may be harmful to swimmers (via ingestion or skin contact) or poison seafood. Phytoplankton species composition and cell concentrations are monitored to ensure concentrations are within acceptable limits.

### **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) criteria for primary and secondary contact, and the criteria for seafood for human consumption.

### **Environmental management approach**

To maintain consistency with other metropolitan ocean outfall monitoring programs, the Swanbourne ocean outlet (Figure 2) is part of the Perth Long Term Ocean Outlet Monitoring (PLOOM) program.



Source: GoogleEarth

### **Figure 2 Aerial image of Swanbourne ocean outlet**

The ocean monitoring program is consistent with the approach advocated under the State Government's EQMF, which is applied to Western Australia's coastal waters (EPA 2016).

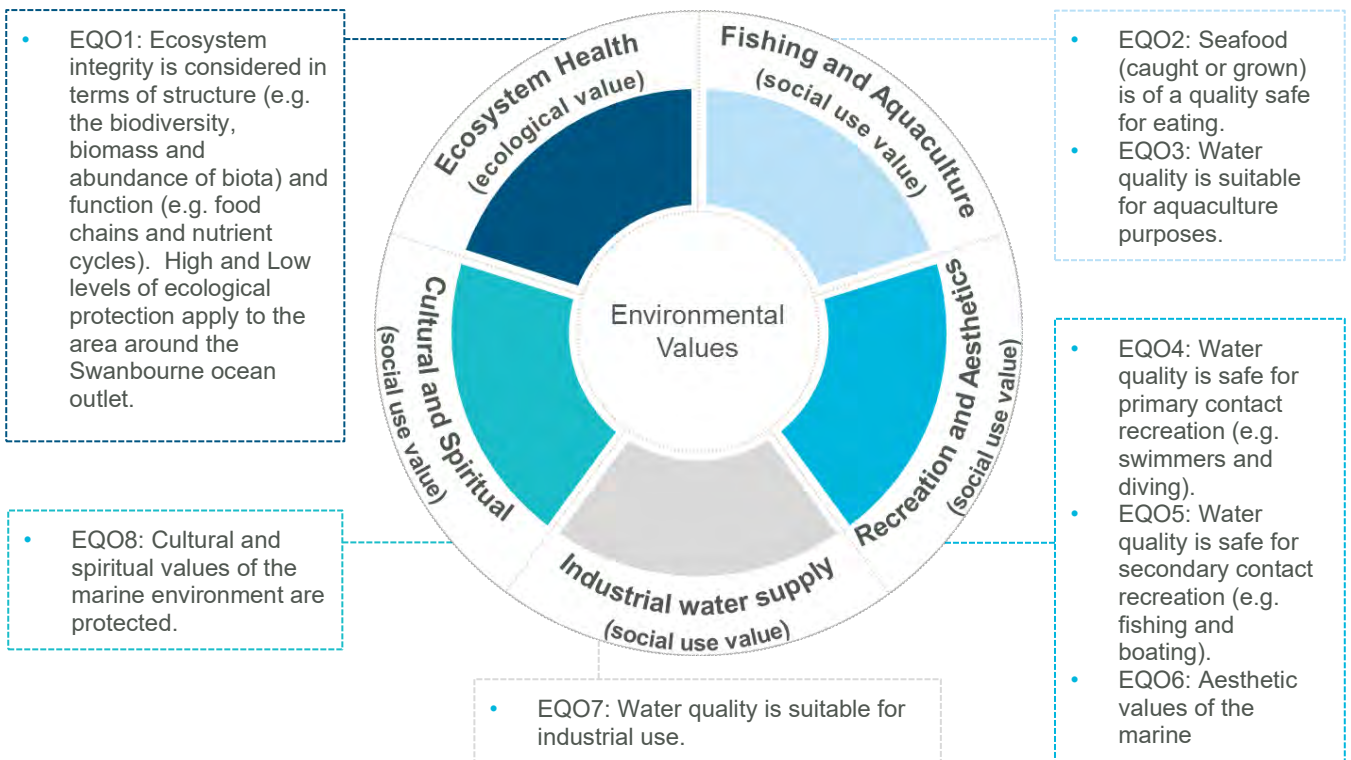
The EQMF is based on:

- identifying Environmental Values (EVs) (Figure 3)
- establishing and spatially defining Environmental Quality Objectives (EQOs) that need to be maintained to ensure the associated EVs are protected (Figure 4)
- monitoring and managing to ensure the EQOs are achieved and/or maintained in the long-term in the areas they have been designated
- establishing Environmental Quality Criteria (EQC) which are quantitative benchmarks or 'trigger values' against which monitoring results can be compared.



There are two levels of EQC:

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

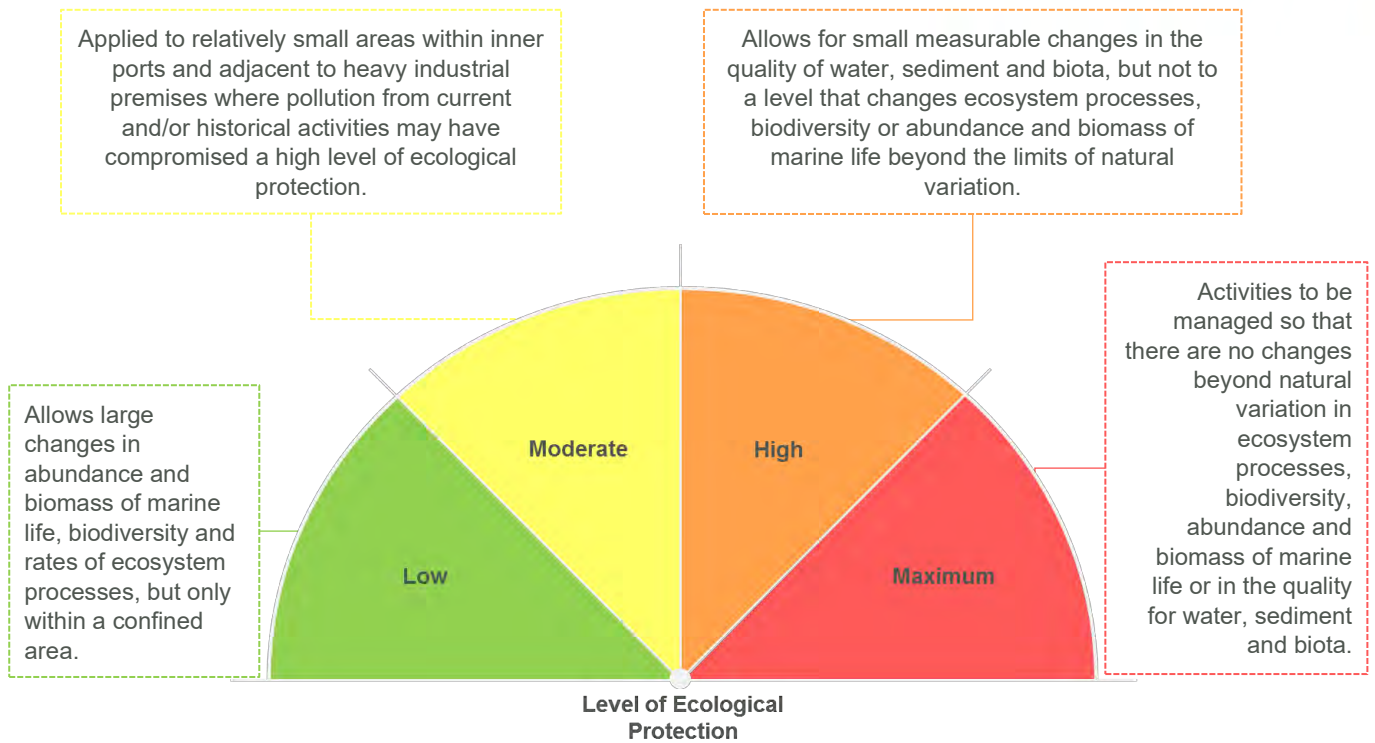


Source: EPA (2016)

**Figure 3 Environmental Values and Environmental Quality Objectives (EQO) for the marine waters of Western Australia**

### ‘Maintenance of Ecosystem Integrity’ EQO

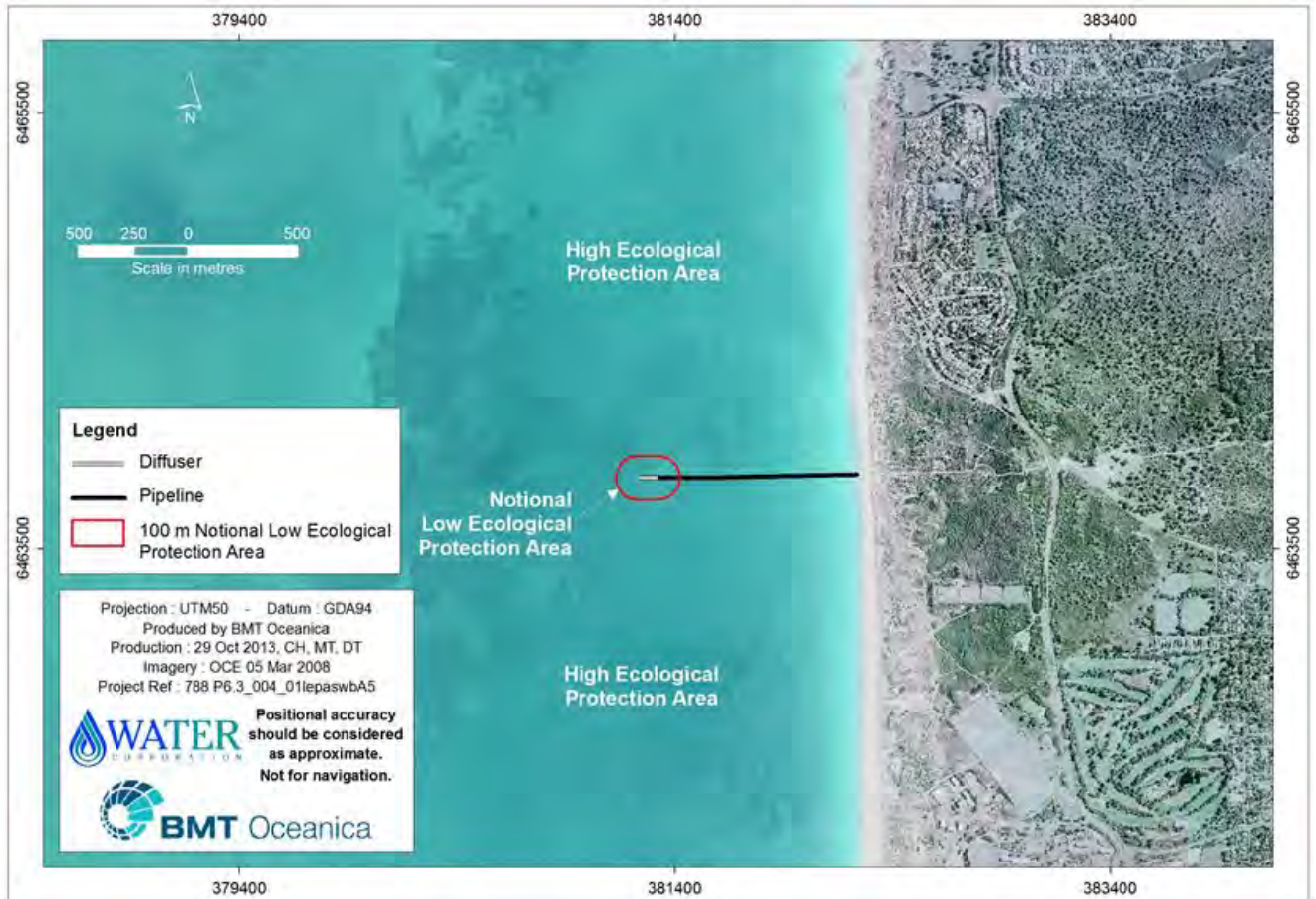
The intent of this EQO is to maintain a healthy and diverse ecosystem. The EQO is applied depending on the designated level of ecological protection: low, moderate, high or maximum (Figure 4).



**Figure 4 Level of Ecological Protection**

In the absence of mandated management zones, a notional low ecological protection area (LEPA) has been established at the Swanbourne outfall, as per technical guidance (EPA 2016). The LEPA occupies the area within a 100 m radius of the diffuser (Figure 5). Waters outside the LEPA are maintained to a high level of ecological protection (HEPA; Figure 5).





**Figure 5 Swanbourne ocean outlet notional ecological protection boundaries**

### **‘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 seafood may be unsafe to eat. Formal management zones have not been established for the Swanbourne outlet. However, an informal zone has been established based on microbiological observations from historical monitoring. The zone represents the area where microbiological organism concentrations are most likely to exceed the EPA’s criteria for seafood safe for human consumption under worst-case conditions.

### **‘Maintenance of Primary and Secondary Contact Recreation’ EQOs**

The primary and secondary contact EQOs support swimming and boating activities, respectively. The EQOs apply throughout Perth’s coastal waters, except for areas around the ocean outlets where water quality may not be suitable for swimming.

A formal area where primary contact recreation is not recommended has not been established for the Swanbourne outlet. However, an informal zone has been developed for the Swanbourne outlet encompassing the area containing elevated microbiological concentrations – this was derived from ten years of field data. As the EQO for maintenance of primary contact recreation uses a higher water quality standard than secondary contact recreation, it is assumed that if the primary contact criteria are met, then the secondary contact criteria are also met by default.

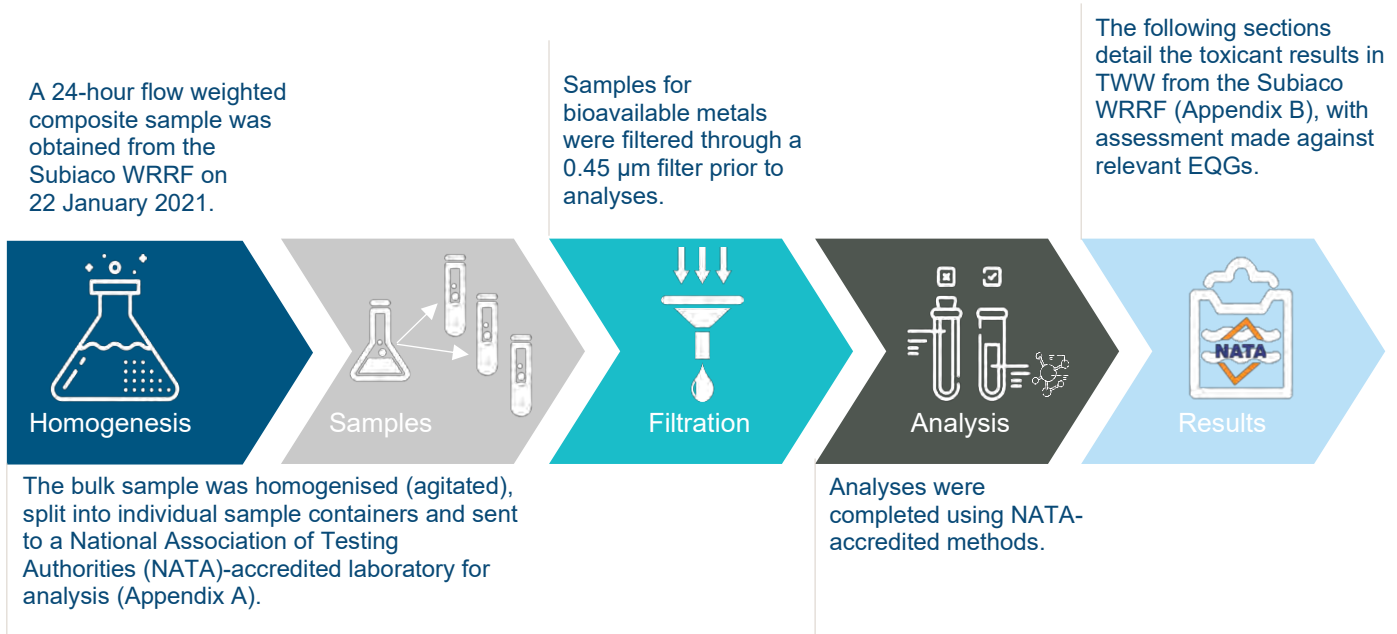


## Toxicants in treated wastewater

### Comprehensive treated wastewater characterisation

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

- nutrients (total nitrogen, ammonia, nitrate+nitrite, 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.



### Bioaccumulating toxicants

Concentrations of cadmium and mercury (i.e. bioaccumulating toxicants) in the TWW sample were both below the analytical limit of reporting (<0.1 µg/L; Table 3) and their respective 80% species protection guidelines (36 and 1.4 µg/L, respectively) (ANZG 2018) meeting the EQG for bioaccumulating toxicants (Table 1).

**Table 1 Environmental Quality Guideline for bioaccumulating toxicants**

<b>EQG</b>	Concentrations of contaminants will not exceed the ANZG (2018) 80% species protection guideline trigger levels for bioaccumulating toxicants in wastewater stream
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Note:

1. EQG = Environmental Quality Guideline



## Non-bioaccumulating toxicants

Non-bioaccumulating toxicant concentrations were generally below the analytical limit of reporting except for copper and zinc (Table 3). After initial dilution of 1:104 (a conservative estimate of the dilution expected at the LEPA boundary; Appendix C), contaminant concentrations of ammonia, copper, nickel and zinc were below ANZG (2018) 99% species protection guidelines (Table 3) and the EQG for non-bioaccumulating toxicants (Table 2) was met.

**Table 2 Environmental Quality Guideline for non-bioaccumulating toxicants**

<b>EQG</b>	Wastewater contaminant concentrations, in conjunction with initial dilution modelling, will be evaluated to determine that the ANZG (2018) 99% species protection guideline trigger levels for toxicants (with the exception of cobalt, where the 95% guideline trigger level will apply) is achieved at the boundary of the low ecological protection area (LEPA) (i.e. a high level of protection is met beyond a 100 m radius of the diffuser).
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Note:

1. EQG = Environmental Quality Guideline





**Table 3 Toxicants in the Swanbourne TWW stream compared with relevant guideline trigger levels after initial dilution**

Toxicant	Swanbourne TWW concentration (µg/L)	Concentration after initial dilution (µg/L)	Trigger (µg/L)
Ammonia-N	160	3.038	500
Cadmium*	<0.1	-	36
Chromium*	<1	-	0.14 (Cr VI)
Copper*	<b>13</b>	0.205	0.3
Lead*	<1	-	2.2
Mercury*	<0.1	-	1.4
Nickel*	1.6	0.515	7
Silver*	<0.8	-	0.8
Zinc*	<b>61</b>	0.737	7
Chloropyrifos	<0.1	-	0.0005
Endrin	<0.001	-	0.004
Endosulfan sulfate	<0.001	-	0.005
Benzene	<1	-	500
Naphthalene	<0.01	0.050	50
Benzo(g,h,i)perylene	<0.01	-	50

Notes:

1. Assessment against ANZG (2018) 99% species protection guideline values was undertaken only for those toxicants where trigger levels were available.
2. TWW = Treated wastewater
3. Initial dilution = 1:104 (predicted average value for Swanbourne outlet). Contaminant dilution calculations were not performed (–) on any toxicants where concentrations were below the analytical limit of reporting.
4. The trigger values for marine waters are from ANZG (2018). 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. Bold text indicates exceedance of trigger values
7. Analytical limits for Chloropyrifos were not low enough to confirm exceedance of, or compliance with, the ANZG (2018) 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).
8. Trigger values are for endosulfan, not endosulfan sulfate (ANZG 2018).
9. \*= dissolved metals 0.45 µm filtered.

### Total toxicity of the mixture (TTM)

The total toxicity of the mixture (TTM, an indicator of the potential for cumulative toxic effects on marine organisms) for the combined effect of ammonia, copper and zinc following initial dilution (0.79; Table 5), did not exceed the ANZG (2018) guideline value of 1.0, and therefore, the EQG for TTM (Table 4) was met.



**Table 4 Environmental Quality Guideline for the total toxicity of the mixture**

<b>EQG</b>	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.
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Source EPA (2017)

Notes:

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

**Table 5 Total toxicity of treated wastewater (TWW) at the edge of the initial mixing zone associated with the Swanbourne ocean outlet**

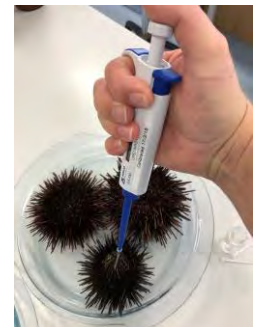
Natural concentrations in Perth's coastal waters			Initial dilution of TWW with seawater	Total toxicity of the mixture (TTM)
Ammonia	Copper	Zinc		
0.16	13	61	1:104	0.79

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 median of reference site data from 2004–2019 (BMT, unpublished data).
2.  $TMM = [ammonia]/guideline + [copper]/guideline + [zinc]/guideline$ .

### Whole of effluent toxicity (WET) testing

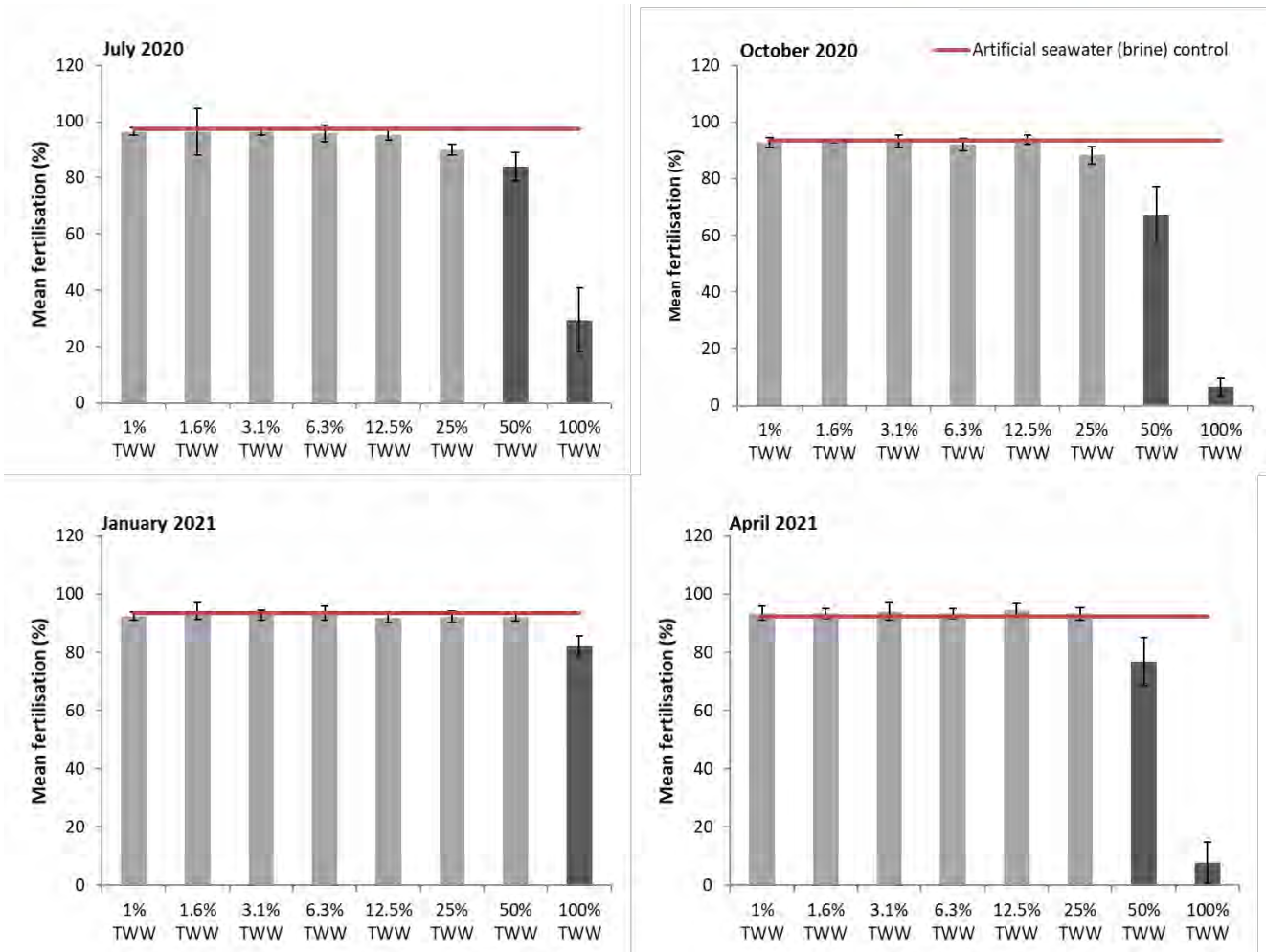
WET testing is useful for assessing toxicity in the absence of reliable guidelines, for toxicants that occur in low concentrations, or where the toxicity effects of contaminants are poorly understood. Fertilisation success in sea urchins (*Heliocidaris tuberculata*) exposed to salt adjusted dilutions (1.0, 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 wastewater concentration where no significant effect is observed) (Appendix D).



In January 2021, sea urchin fertilisation in samples exposed to 100% TWW was significantly lower than the artificial seawater control. Fertilisation in all other dilutions were not significantly different to the control (Figure 6). In July 2020, October 2020 and April 2021 sea urchin fertilisation in samples exposed to 50 and 100% TWW dilutions was significantly lower than the artificial seawater control (with all other dilutions not significantly different to the control; Figure 6). The NOEC was greater than 1% in TWW (i.e.  $\leq 100$ -fold dilution) in all four samples (Table 7; Appendix D), and the EQG for WET testing (Table 6) was met.

**Table 6 Environmental Quality Guideline for whole of effluent toxicity testing**

<b>EQG</b>	<p>The EQG will be exceeded if following the 1-hour sea urchin test:</p> <div style="background-color: white; padding: 10px; margin: 10px 0;"> <math display="block">\frac{TDA}{DRNOEC} \leq 1.0</math> </div> <p>where TDA = Typical Dilutions Achieved (constant based on 100-fold dilution)  DRNOEC = number of dilutions required to achieve the no observed effects concentration (NOEC).</p> <p>Breaching the above triggers investigations against the EQS, which would comprise the full suite of WET tests (minimum of five species from four trophic groups).</p>
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Notes:

1. Error bars represent  $\pm$  standard deviation
2. TWW = treated wastewater
3. Light grey bars represent concentrations of treated wastewater (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 of effluent toxicity TWW dilution results to artificial seawater control**



**Table 7** Calculated parameters from whole of effluent toxicity tests

Indicator	July 2020	October 2020	January 2021	April 2021
NOEC	12.5%	25%	50%	25%
Dilutions required to meet the NOEC	8	4	2	4
Dilutions required/dilutions achieved	0.077	0.038	0.019	0.038
≤1	Yes	Yes	Yes	Yes

Note:

1. NOEC = No observed effect concentration.

## Water quality monitoring – receiving environment

Nutrients, phytoplankton biomass and physical and chemical stressors were monitored approximately fortnightly from the beginning of December 2020 to the end of March 2021 (coinciding the summer non-river flow period) along a down-current gradient away from the diffuser (Table 8; Appendix E and Appendix F).

**Table 8** Water quality monitoring dates near the Swanbourne ocean outlet between December 2020 and March 2021

Sample day	Date
1	1/12/20
2	17/12/20
3	5/01/21
4	22/01/21
5	12/02/21
6	26/02/21
7	12/03/21
8	25/03/21

Wind direction, strength, current direction grid and cloud cover on the day of sampling were recorded (Table 9).

**Table 9** Weather and current grid during water quality monitoring near the Swanbourne ocean outlet

Date	Wind direction	Wind strength (knots)	Cloud cover (%)	Current grid
1/12/20	E, SE	3–8	10–30	N
17/12/20	SE, SSE	10–14	0	NW
5/1/21	SE, ESE	10–27	0	NW
22/1/21	ENE, SW	2–14	0	W
12/2/21	E	10–12	0	NW
26/2/21	S	8–14	70	NW



12/3/21	S, SSE	10–15	50–100	SW
25/3/21	E, SE, S	2–20	0–20	NE

Notes:

1. N = north, S = south, W = west, E = east, SW = south-west, SE = south-east, NE = north-east; NW = north-west; SSE = south-south-east; ESE = east-south-east; ENE = east-north-east
2. Winds are designated by the direction they come from while currents are designated by the direction they flow to.

## Nutrient enrichment

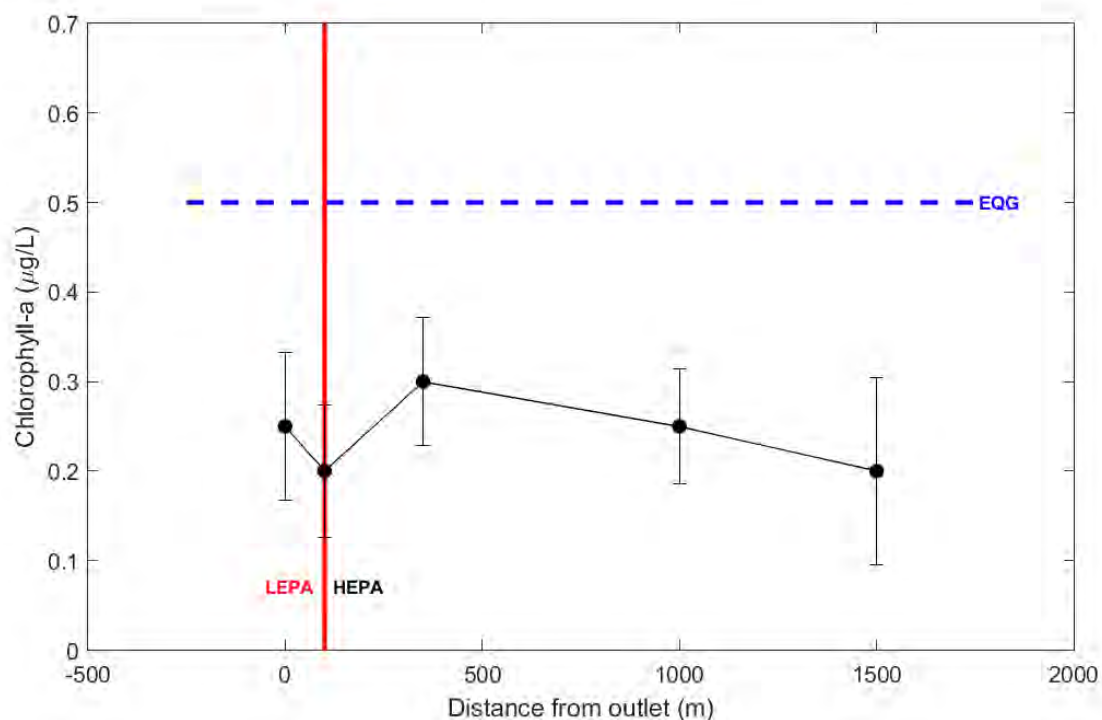
The median chlorophyll-a concentration in the Swanbourne HEPA ( $\geq 100$  m) was  $0.20 \mu\text{g/L}$  and below the 80<sup>th</sup> percentile of historical reference site data ( $0.5 \mu\text{g/L}$ ; Figure 7), meeting the EQG (Table 10).

**Table 10 Environmental quality guidelines for nutrients**

<b>EQG</b>	The median chlorophyll-a concentration in the HEPA (100 m plus) during the non-river flow period is not to exceed the 80 <sup>th</sup> 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 80 <sup>th</sup> percentile of historical reference site data.

Note:

1. EQG = Environmental Quality Guideline



Notes:

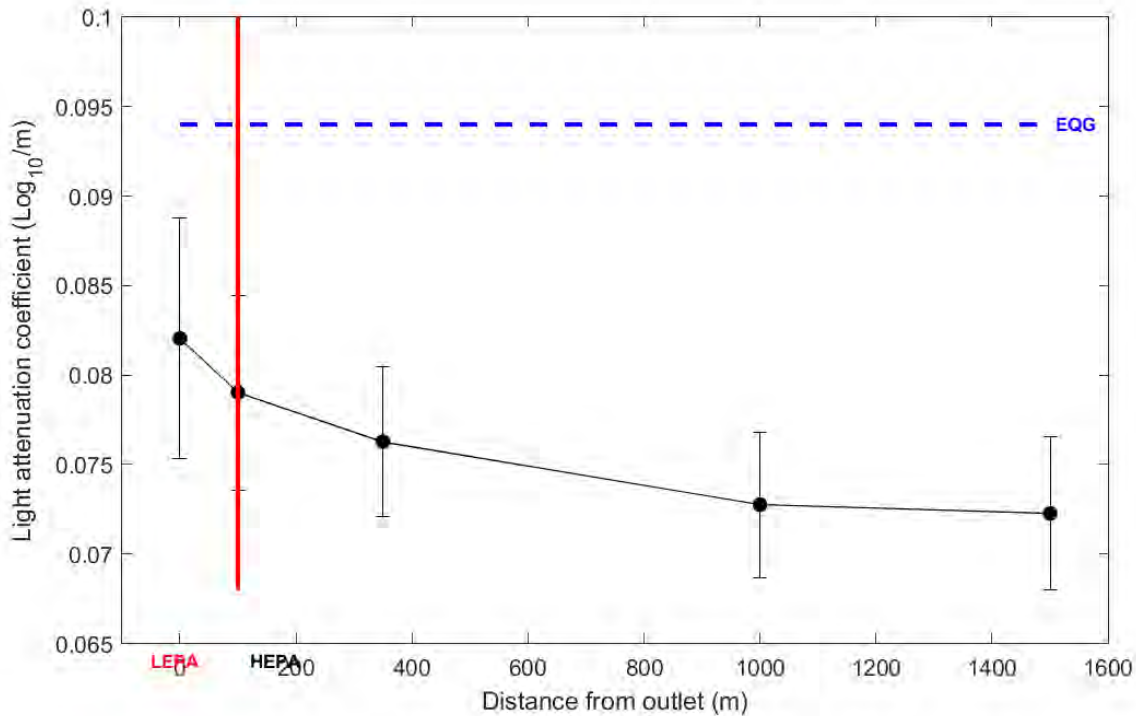
1. Error bars represent  $\pm 95\%$  confidence intervals.
2. Environmental Quality Guideline (EQG) is the 80<sup>th</sup> percentile of historical reference site data ( $0.5 \mu\text{g/L}$  chlorophyll-a).



3. LEPA = notional low ecological protection area; HEPA = high ecological protection area.
4. Data for each distance were pooled across eight sampling days over December 2020–March 2021; (Appendix G).

**Figure 7 Median chlorophyll-a concentrations obtained at fixed monitoring sites above and down-current of the Swanbourne outlet during the summer monitoring period**

The median light attenuation in the Swanbourne HEPA (100 m plus) was 0.075 Log<sub>10</sub>/m and lower than the 80<sup>th</sup> percentile of historical reference site data (0.094 Log<sub>10</sub>/m; Figure 8), meeting the EQG.



Notes:

1. Error bars represent ±95% confidence intervals
2. Environmental Quality Guideline (EQG) is the 80<sup>th</sup> percentile of historical reference site data (0.094 Log<sub>10</sub>/m)
3. LEPA = notional low ecological protection area; HEPA = high ecological protection area.
4. Data for each distance were pooled across seven sampling days over December 2020–March 2021.

**Figure 8 Median light attenuation coefficient obtained at fixed monitoring sites above and down-current of the Swanbourne outlet during the summer monitoring period**

### Phytoplankton blooms

Median chlorophyll-a concentration within the HEPA did not exceed three times the median of reference sites (0.9 µg/L; Figure 9) on any sampling occasion during the summer monitoring period and the EQG1 (Table 11) was met. Phytoplankton biomass, measured as 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 meeting the requirements of EQG2 (<25% of occasions).



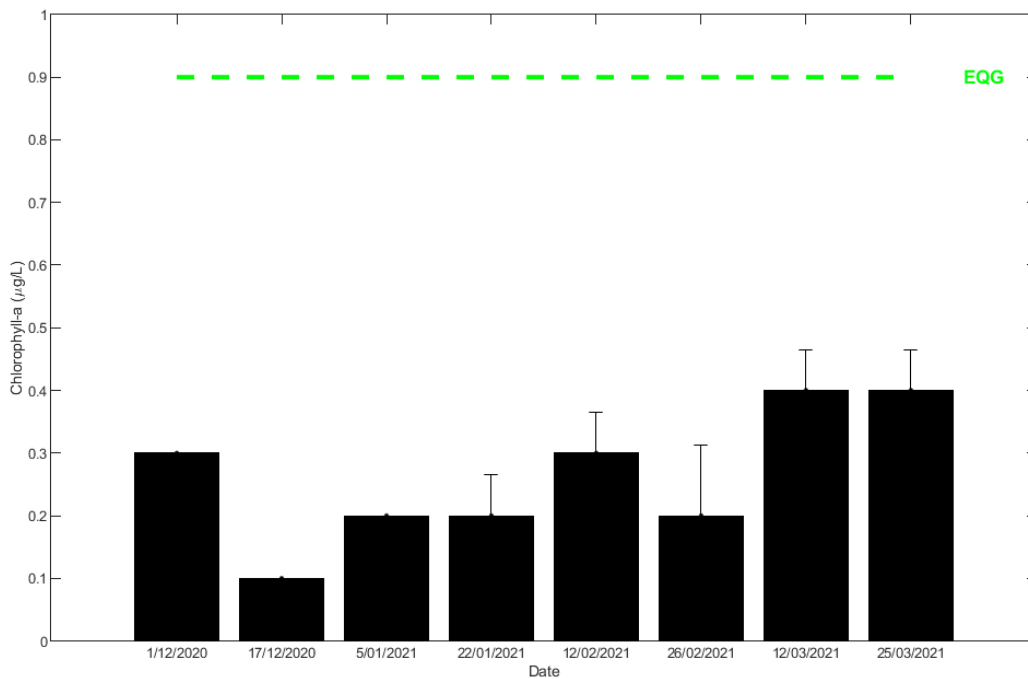


**Table 11 Environmental Quality Guidelines for phytoplankton in receiving waters**

<b>EQG1</b>	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.
<b>EQG2</b>	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.

Note:

1. EQG = Environmental Quality Guideline



Notes:

1. Error bars represent  $\pm 95\%$  confidence intervals.
2. Environmental Quality Guidelines (EQG) 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 EQG assessment, as the 0 m site is situated directly above the outlet within the notional low ecological protection area (LEPA).
4. Data were pooled across four sites within the high ecological protection area (HEPA).

**Figure 9 Median phytoplankton biomass during the summer monitoring period at fixed sites  $\geq 100$  m down-current of the Swanbourne ocean outlet**

## Physical-chemical stressors

### 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 12) was met.

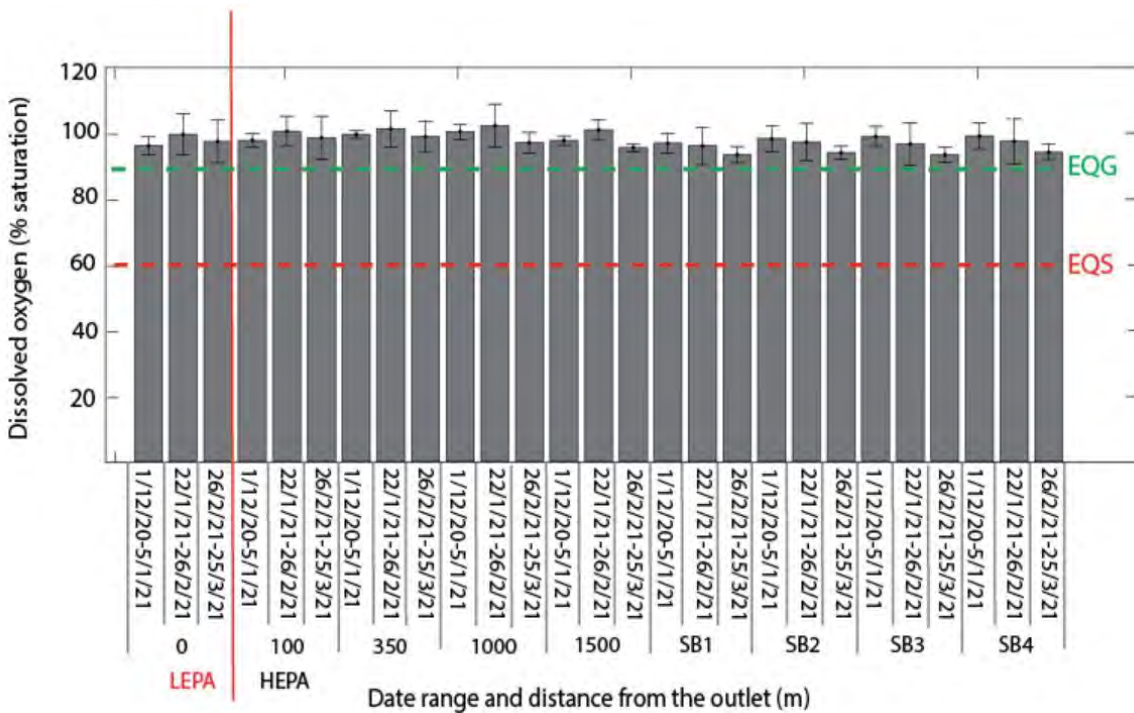


**Table 12 Environmental Quality Guidelines for dissolved oxygen**

<b>EQG</b>	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.
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Note:

1. EQG = Environmental Quality Guideline



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

### Salinity

Median salinity at individual sites within the HEPA was below the 20<sup>th</sup> percentile at 100 m and 350 m from the outlet and between the 20<sup>th</sup> and 80<sup>th</sup> percentiles of the natural salinity range at all other sites within the notional HEPA (at 1000 m and 1500 m from the outlet; Figure 11) over the summer monitoring period. As median salinity fell below the 20<sup>th</sup> percentile at 2 sites, the EQG was not met, triggering assessment against the EQS (Table 13). There were no reported deaths of marine organisms from anthropogenically sourced salinity stress at Swanbourne over the summer monitoring period, meeting the EQS.



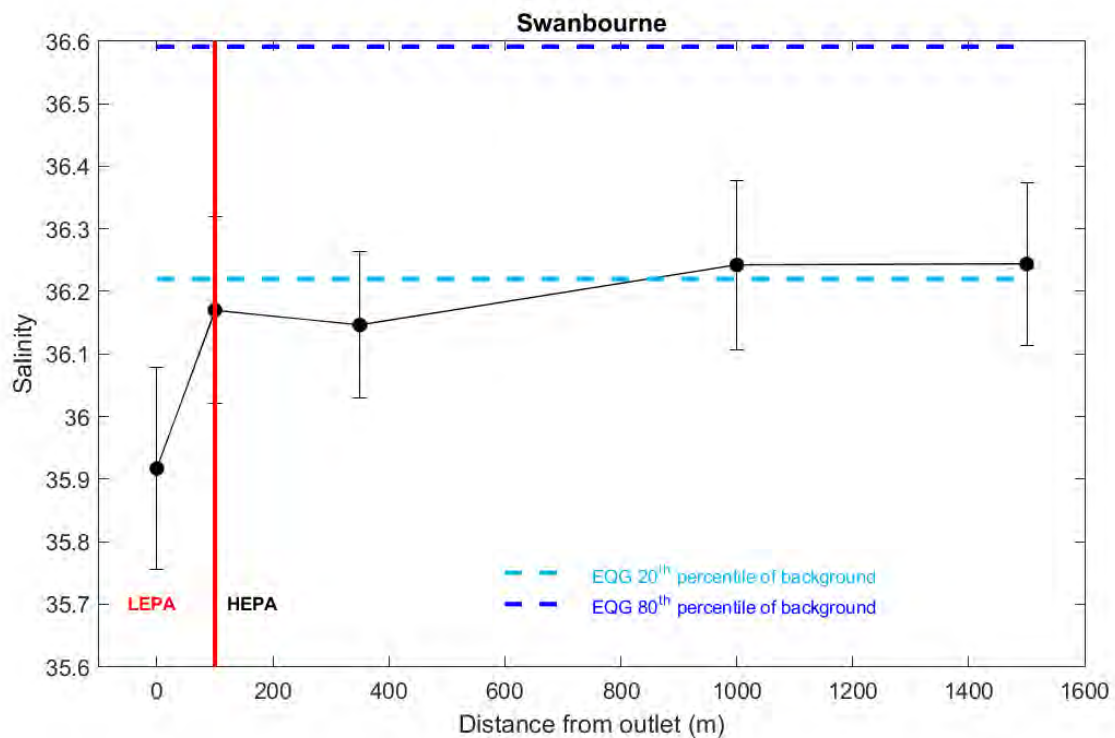


**Table 13 Environmental Quality Guideline for salinity**

<b>EQG</b>	Median salinity (0.5 m below the water surface) at an individual site over any period is not to deviate beyond the 20 <sup>th</sup> and 80 <sup>th</sup> percentile of natural salinity range over the same period.
<b>EQS</b>	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  $\pm 95\%$  confidence intervals.
2. Salinity measured 0–0.5 m below the sea surface.
3. Dark blue dashed line = 80th percentile background Environmental Quality Guideline
4. Light blue dashed line = 20th percentile background Environmental Quality Guideline
5. LEPA = notional low ecological protection area; HEPA = high ecological protection area.
6. Data for each distance was pooled across seven sampling occasions over December 2020–March 2021.

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



## Microbiological contaminants and algal biotoxins

### Thermotolerant coliforms

TTC were sampled eight times over the 2020–2021 summer period (yielding a total of 40 samples). NHMRC (2008) guidelines and EPA (2005) require a minimum of 100 samples 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 three summers (since 2018–2020) were pooled to yield 120 samples.

The median and 90<sup>th</sup> percentile TTC concentrations derived from the 3 years of pooled samples were both equal to the limit of detection (<10 CFU/100 mL; Table 15) and less than 14 and 21 CFU/100 mL, respectively, thus meeting the EQG (Table 14).


**Table 14 Environmental Quality Guideline for thermotolerant coliforms**

<b>EQG</b>	Median TTC concentrations at sites at the boundary of the Observed Zone of Influence (OZI) are not to exceed 14 CFU/100 mL and the 90 <sup>th</sup> percentile of TTC concentrations must not exceed 21 CFU/100 mL
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Notes:

1. OZI = Observed Zone of Influence; TTC = thermotolerant coliforms
2. TTC concentrations are measured using the membrane filtration method
3. Marine Biotoxin Monitoring and Management Plan 2016: Western Australian Shellfish Quality Assurance Program (WASQAP) (DoH 2016).

**Table 15 Median and 90<sup>th</sup> percentile thermotolerant coliform concentrations at the fixed monitoring sites for the Swanbourne ocean outlet for 2018–2021 and comparison to the EQC**

Sampling period	Median	90 <sup>th</sup> Percentile	Compliance
Dec 2018–Mar 2019 Dec 2019–Mar 2020 Dec 2020–Mar 2021	<10 CFU/100 mL	<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 90<sup>th</sup> percentile (Appendix H).
3. Environmental Quality Criteria are based on EPA (2017).

### Toxic phytoplankton species

There were no instances where toxic phytoplankton species were present at densities greater than the Western Australian Shellfish Quality Assurance Program (WASQAP; DoH 2016) guideline values (Table 16 and Table 17; Appendix I).



**Table 16 Environmental Quality guideline for toxic phytoplankton species**









<b>EQG</b>	<p>Cell counts of potentially toxic algae species at sites at the boundary of the OZI are not to exceed the WASQAP<sup>1</sup> trigger concentrations for any of the following:</p> <ul style="list-style-type: none"><li>• <i>Alexandrium</i> spp. (200 cells/L)</li><li>• <i>Gymnodinium catenatum</i> (2000 cells/L)</li><li>• <i>Karenia brevis</i> (1000 cells/L)</li><li>• Karenia/Karlodinium/Gymnodinium group (250 000 cells/L)</li><li>• <i>Dinophysis</i> spp. (1000 cells/L)</li><li>• <i>Prorocentrum lima</i> (500 cells/L)</li><li>• <i>Pseudo-nitzschia delicatissima</i> group (500 000 cells/L)</li><li>• <i>Pseudo-nitzschia seriata</i> group (50 000 cells/L)</li></ul>
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Note:

1. Marine Biotoxin Monitoring and Management Plan 2016: Western Australian Shellfish Quality Assurance Program (WASQAP) (DoH 2016).



**Table 17 Estimated cell densities of phytoplankton species known to produce toxins**

Date	Site <sup>1</sup>	Species	Estimated density	WASQAP Guideline <sup>2</sup>	Compliance
1/12/2020	SBR3	no toxic species recorded	-	-	na
	SB23	no toxic species recorded	-	-	
17/12/2020	SBR3	<i>Pseudo-nitzschia</i> "delicatissima group"	240	500 0000-	na
	SB26	no toxic species recorded	-	-	
8/1/2021	SBR3	<i>Pseudo-nitzschia</i> "delicatissima group"	160	500 000	na
	SB26	no toxic species recorded	-	-	
22/1/2021	SBR3	no toxic species recorded	-	-	na
	SB28	no toxic species recorded	-	-	
12/2/2021	SBR3	<i>Pseudo-nitzschia</i> "delicatissima group"	1120	500 000	na
	SB26	no toxic species recorded	-	-	
26/2/2021	SBR3	no toxic species recorded	-	500 000	na
	SB26	<i>Pseudo-nitzschia</i> "delicatissima group"	320	500 000	
	SB26	<i>Gymnodinium catenatum</i>	80	2000	
12/3/2021	SBR3	<i>Pseudo-nitzschia</i> "delicatissima group"	160	500 000	na
	SB29	no toxic species recorded	-	-	
25/3/2021	SBR3	no toxic species recorded	-	-	na
	SB19	no toxic species recorded	-	-	

Notes:

1. Samples were analysed for one monitoring site and one reference site per sampling occasion. Reference results are not applicable (na) to compliance.
2. Marine Biotxin Monitoring and Management Plan 2016: Western Australian Shellfish Quality Assurance Program (WASQAP) (DoH 2016).
3. Green (■) symbols indicate the Environmental Quality Criteria (EQC) were met.



## Faecal streptococci (*Enterococci* spp.)

Samples were collected eight times over the 2020–2021 summer monitoring period (yielding a total of 40 samples) for faecal streptococci 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 were pooled to yield 120 samples. The EQG for primary and secondary contact recreation are outlined in Table 18.

**Table 18 Environmental quality guidelines for contact recreation**



<b>Primary<sup>1</sup></b>	<b>EQG</b>	The 95 <sup>th</sup> percentile bacterial content of marine waters should not exceed 200 <i>Enterococci</i> /100 mL
<b>Secondary<sup>2</sup></b>	<b>EQG</b>	The 95 <sup>th</sup> percentile bacterial content of marine waters should not exceed 2000 <i>Enterococci</i> /100 mL

Notes:

1. Primary contact recreation = activities where humans are in direct contact with the water (e.g. swimming, snorkelling and diving).
2. Secondary contact recreation = activities where humans are in secondary contact with the water (e.g boating and fishing).
3. EQG = Environmental Quality Guideline.

Over the past three summers, the 95<sup>th</sup> percentile of *Enterococci* spp. concentrations at the boundary of the observed zone of influence for the Swanbourne ocean outlet was 10 MPN/100 mL (Table 19) and both the primary (<200 MPN/100 mL) and secondary (<2000 MPN/100 mL) contact recreation EQG for faecal pathogens in water (Table 18) were met.

**Table 19 The 95<sup>th</sup> percentile of *Enterococci* spp. concentrations at the boundary of the observed zone of influence for the Swanbourne ocean outlet**

Sampling period	95 <sup>th</sup> percentile (MPN/100 mL)	Compliance	
		Primary contact	Secondary contact
Dec 2018–Mar 2019 Dec 2019–Mar 2020 Dec 2020–Mar 2021	10		

## Phytoplankton cell concentrations

Phytoplankton densities at individual sites monitored during 2020–2021 were below 10 000 cells/mL (Table 21), meeting the EQG (Table 20).

**Table 20 Environmental Quality Guideline for phytoplankton cell count**

<b>EQG</b>	The phytoplankton cell count from a single site should not exceed 10 000 cells/mL; or detect the Department of Health watch list species or exceed their trigger levels
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**Table 21** Estimated phytoplankton total cell densities collected at one of the fixed monitoring sites for contact recreation down-current of the Swanbourne outlet

Date	Site	Total density (cells/mL)	Compliance
1/12/2020	SB7	7	
17/12/2020	SB9	3	
8/1/2021	SB9	4	
22/1/2021	SB11	0.5	
12/2/2021	SB9	6	
26/2/2021	SB9	4	
12/3/2021	SB13	164	
25/3/2021	SB5	2	

Note:

- 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.

## Shoreline monitoring

### Thermotolerant coliforms


TTC were sampled at eight shoreline monitoring sites eight times over the 2020–2021 summer period (yielding a total of 64 samples). NHMRC (2008) guidelines and EPA (2005) recommend that a minimum of 100 samples are required 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). However, this is the first year that these sites were sampled, and there is only 1 year’s data available.

The shoreline sites are not formally assessed against the EQC but the median and 90<sup>th</sup> percentile TTC concentrations derived from the 64 samples were at the limit of detection (Table 22) (<10 CFU/100 mL; Table 14, Appendix H) and less than 14 and 21 CFU/100 mL, respectively meeting the EQG criteria (Table 14).

Median TTC concentrations were 5 CFU/100 mL (the proxy for concentrations below the LoR) at all sites down current of the diffuser (Figure 12).



**Table 22 Median and 90<sup>th</sup> percentile of thermotolerant coliform concentrations at the shoreline monitoring sites for the Swanbourne outlet for 2020–2021 and comparison to the EQG**

Sampling period	Median (CFU/100 mL)	90 <sup>th</sup> percentile	Compliance (EQG)
Dec 2020–Mar 2021	<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 90<sup>th</sup> percentile.
3. Environmental Quality Criteria are based on EPA (2017).

### Faecal streptococci (*Enterococci* spp.)

Samples were collected eight times at eight shoreline monitoring sites over the 2020–2021 summer monitoring period (yielding a total of 64 samples) for faecal streptococci analyses. NHMRC guideline and EPA (2005) recommends that 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). However, this was the first year that these sites were sampled, and there is only 1 year’s data available.

Shoreline sites are not formally assessed against the EQC but over the 2020–2021 summer monitoring period, the 95<sup>th</sup> percentile of *Enterococci* spp. concentrations at the shoreline monitoring sites for the Swanbourne ocean outlets was <10 MPN/100 mL (Table 23), and met both the primary (<200) and secondary (<2000 *Enterococci* spp./100mL) contact recreation EQG criteria (Figure 12) in water were met.

Median *Enterococci* spp. concentrations at 0 and 100m down current from the diffuser were 20 and 7.5 MPN/100 mL, respectively. All other sites down current of the diffuser had median concentrations of 5 MPN/100 mL (the proxy for concentrations below the LoR) (Figure 12).



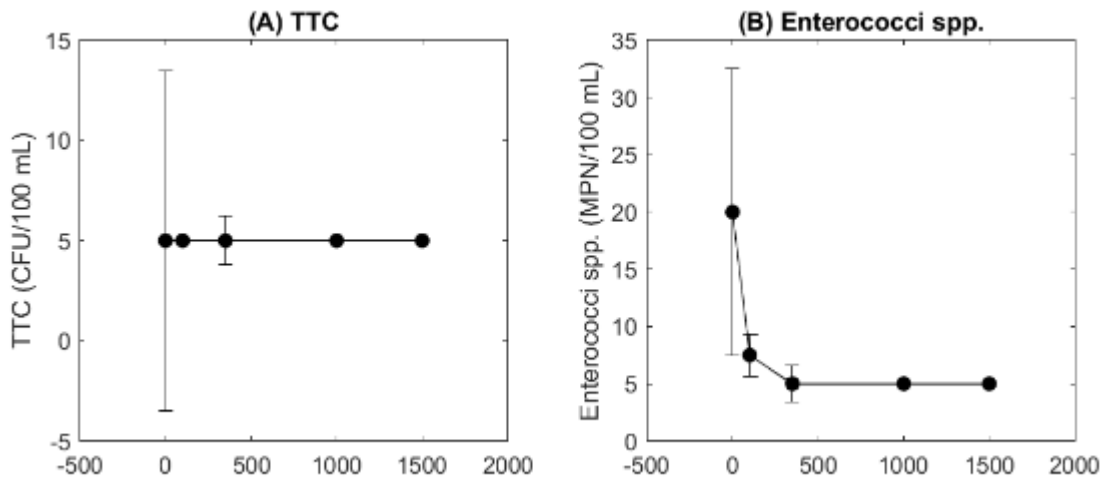


**Table 23** The 95<sup>th</sup> percentile of *Enterococci* spp. concentrations at the shoreline monitoring sites for the Swanbourne ocean outlet

Sampling period	95 <sup>th</sup> percentile (MPN/100 mL)	Compliance	
		Primary contact	Secondary contact
Dec 2020–Mar 2021	<10	■	■

Notes:

1. MPN = most probable number of *Enterococci* spp.
2. *Enterococci* spp. concentrations below the analytical detection limit (<10 *Enterococci* spp. MN/100 mL) were halved (=5 MPN/100 mL) to calculate the 95<sup>th</sup> 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.



Notes:

1. Error bars represent ±95% confidence intervals

**Figure 12** Median a) TTC and b) *Enterococci* spp. at 0, 100, 350, 1000, 1500 and 2000 metres from the Swanbourne outlet from December 2020 to March 2021





## References

- ANZG (2018) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at [www.waterquality.gov.au/anz-guidelines](http://www.waterquality.gov.au/anz-guidelines)
- DoH (2016) Marine Biotoxin Monitoring and Management Plan: Western Australian Shellfish Quality Assurance Program (WASQAP). Department of Health, Perth, Western Australia, May 2016
- EPA (2017) Environmental Quality Criteria Reference Document for Cockburn Sound – A supporting document to the State Environmental (Cockburn Sound) Policy 2015. Environmental Protection Authority, Perth, Western Australia, April 2017
- EPA (2016) Technical Guidance Protecting the Quality of Western Australia's Marine Environment. Environmental Protection Authority, Perth, Western Australia, December 2016
- EPA (2005) Manual of Standard Operating Procedures – For Environmental Monitoring against the Cockburn Sound Environmental Quality Criteria (2003–2004) – A supporting document to the State Environmental (Cockburn Sound) Policy 2005. Environmental Protection Authority, Report No. 21, Perth, Western Australia, January 2005
- McAlpine KW, Wenziker KJ, Apte SC, Masini RJ (2005) Background quality for coastal marine waters of Perth, Western Australia. Department of Environment, Report No. 117, Perth, Western Australia, March 2005
- NHMRC (2008) Guidelines for Managing Risks in Recreational Water. National Health and Medical Research Council, Canberra, Australian Capital Territory, February 2008



## 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 Detailed methodologies



Appendix F    Site coordinates





Appendix G    Nutrients results



## Appendix H    Microbiology results



Appendix I      Phytoplankton results