Perth Long Term Ocean Outlet Monitoring Program (PLOOM)

2017–2018 Annual Report: Ocean Reef

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BMT has prepared this report in accordance with our Health Safety Environment Quality Management System.

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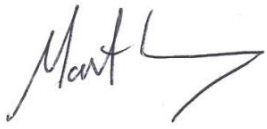

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Acronyms

ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
CFU	Colony-forming unit
CTWWC	Comprehensive treated wastewater characterisation
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
LAC	Light attenuation coefficient
LEPA	Low ecological protection area
MPN	Most probably 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
WWTP	Wastewater treatment plant

Executive Summary

This report documents the findings of the 2017–2018 Ocean Reef ocean monitoring program. Results are reported in the context of the Environmental Quality Management Framework (EQMF) described in EPA (2016). The results are summarised in Report Card format (Table ES.1). The report cards contain 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[1]	Colour
Monitor: EQG met (continue monitoring)	
Investigate: EQG not met (investigate against the EQS), EQS met (continue monitoring)	
Action: EQS not met (management response required)	

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

All the Environmental Quality Guidelines for the Environmental Quality Objective (EQO) Maintenance of Ecosystem Integrity were 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 ANZECC/ARMCANZ (2000) values for 80% species protection	■
	Non-bioaccumulating toxicants and initial dilution		The rate of initial dilution on 13 February 2018 (1:351) was sufficient to reduce non bioaccumulating contaminant concentrations to below their ANZECC/ARMCANZ (2000) values for 99% species protection	■
	Total toxicity of the mixture (TTM)		The TTM for the additive effect of ammonia, copper and zinc after initial dilution (0.42) was below the ANZECC/ARMCANZ (2000) guideline value of 1.0	■
	Whole of effluent toxicity testing		The lowest NOEC during the reporting period was 100%. No dilution of the TWW was required to achieve this NOEC.	■
Nutrient enrichment	Chlorophyll-a	EQG	Median chlorophyll-a concentration within the high ecological protection area (HEPA) was lower than the 80th percentile of historical reference site data.	■
	Light attenuation coefficient (LAC)		Median LAC within the HEPA was lower than the 80th percentile of historical reference site data.	■
Phytoplankton blooms	Phytoplankton biomass (measured as chlorophyll-a)	EQG	1. There were no instances where median chlorophyll-a concentrations in the HEPA exceeded 3-times the median of reference sites.	■
			2. Chlorophyll-a did not exceed 3 times the median concentration of reference sites at any site on any occasion.	■
Physical-chemistry	Organic enrichment	EQG	Dissolved oxygen saturation remained above 90% saturation at all times.	■
	Salinity	EQG	Within the HEPA, median salinity was within the 20th and 80th percentile of reference site data.	■

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. NOEC = no observed effect concentration; the highest concentration of TWW at which there is no statistically significant observed effect on gamete fertilisation.
3. EQO = Environmental Quality Objective.

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

Environmental quality indicator		EQC	Comments	Compliance[1]
Microbiological contaminants	Thermotolerant coliforms (TTC)	EQG	The median value for TTC concentrations derived from 120 samples collected over the 2015–2016, 2016–2017 and 2017–2018 sampling seasons was at the limit of detection (<10 CFU/100 mL)[2]	■
		EQG	The 90th percentile was 10 CFU/100 mL and less than 21 CFU/100 mL thus meeting the EQG	■
Algal biotoxins	Toxic phytoplankton species	EQG	Toxic phytoplankton species were not recorded in excess of WASQAP guidelines values during the 2017–2018 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 (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 values

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

Environmental Quality Indicator		Comments	EQC	Compliance
Faecal streptococci	*Enterococci* spp.	The 95th percentile of *Enterococci* spp. concentrations was 10 MPN/100 mL	EQG (primary contact)	■
			EQG (secondary contact)	■
Algal biotoxins	Phytoplankton (cell concentration)	Estimated total phytoplankton cell count at individual sites were <10 000 cells/mL at each site and sampling occasion during 2017–2018 monitoring	EQG	■

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.

1. Introduction

1.1 Document purpose

This annual report documents the findings of the 2017–2018 ocean monitoring around the Ocean Reef ocean outlets. Monitoring was completed according to Western Australia's Environmental Quality Management Framework (EQMF; EPA 2016).

1.2 Wastewater treatment plant infrastructure and discharge

Water Corporation operates the Beenyup wastewater treatment plant (WWTP) in metropolitan Perth, which treats approximately ~116 ML wastewater per day to produce advanced secondary treated wastewater (TWW). The TWW was traditionally discharged to the sea through two ocean outlets at Ocean Reef (Figure 1.1). The outlets are 1.65 km (Outlet A) and 1.85 km (Outlet B) in length and located in ~10 m of water (Figure 1.1). Discharge commenced from Outlet A in 1978 and Outlet B in 1992.

Stage 1 of Water Corporation's Perth Groundwater Replenishment Scheme (GWRS) consists of a 14 GL/year capacity plant. Secondary TWW from the Beenyup WWTP is diverted into the Advanced Water Recycling Plant (AWRP) and further treated via ultrafiltration (UF), reverse osmosis (RO) and ultraviolet (UV) disinfection processes to drinking water standard for recharge the confined aquifers.

The AWRP reduces the environmental impact of potable water extraction from the aquifer but with a corresponding reduction in the volume and change to the composition of the TWW being discharged to the marine environment through the Ocean Outlets. A proposed expansion (Stage 2 of the GWRS) will increase the capacity of the AWRP to 28 GL/year, treat a larger proportion of the secondary TWW from the Beenyup WWTP for groundwater recharge and further reduce/alter the discharge to the ocean. A formal approvals process (including development of a management plan) is underway.

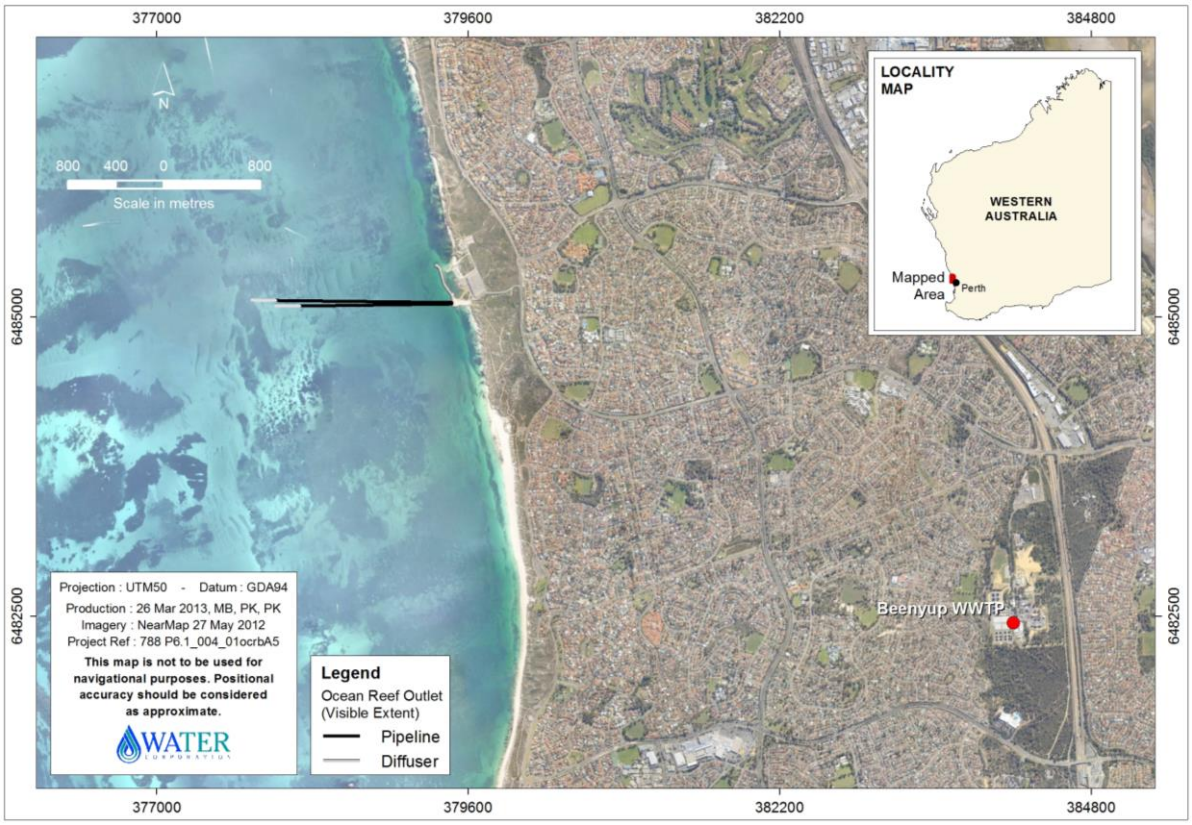


Figure 1.1 Location of the Beenyup WWTP and Ocean Reef ocean outlets

1.3 Potential stressors in treated wastewater

1.3.1 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 prior to discharge. To account for 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).

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. Measurements of DO saturation in receiving waters near the outfalls, relative to measurements at reference sites, 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. Measurements of salinity in receiving waters near the outfalls are compared to the salinity at appropriate reference sites. The comparison allows evaluation of whether any reduction in salinity near the outfalls is within the range of natural variability, as recorded at the reference sites.

1.3.3 Nutrients

TWW contains elevated concentrations of biologically available nutrients, including ammonia, nitrite, nitrate and orthophosphate. At times, the addition of nutrients may stimulate phytoplankton growth beyond natural levels, which under some circumstances may 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 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 to seafood. For this reason, 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, numbers of indicator organisms are routinely compared to the Environmental Protection Authority's (EPA) criteria for primary and secondary contact, and the criteria for seafood safe for human consumption.

1.4 Environmental management approach

The Ministerial Statement (Appendix A) outlines Water Corporation's environmental commitments for the Beenyup wastewater ocean outlets to Ocean Reef. To maintain consistency with other metropolitan ocean outfall monitoring programs, the Beenyup wastewater ocean outlets are also part of the Perth Long Term Ocean Outlet Monitoring (PLOOM) program. 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).

Stage 1 of the AWRP/GWRS operates under existing approvals. The change in discharge characteristics associated with Stage 2 requires a change to conditions under Section 46 of the Environmental Protection Act 1986 (EP Act). The approvals process includes development of an Environmental Monitoring and Management Plan (EMMP), which will bring the management framework into line with contemporary Department of Water and Environmental Regulation policy (EPA 2017) and establish formal management areas around the discharge location (Marmion Marine Park). The EMMP and associated formal management zones do not apply until the stage 2 facility reaches full capacity. To maintain consistency with previous years, the existing informal monitoring approach will remain in place until then.

1.4.1 Environmental Quality Management Framework (EQMF)

The EQMF is based on:

- Identifying **Environmental Values** (EVs) (Table 1.1)
- Establishing and spatially defining **Environmental Quality Objectives** (EQOs) that need to be maintained to ensure the associated EVs are protected (Table 1.1)
- 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:

2. **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 EQS is triggered.
3. **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.

Table 1.1 Environmental Values and Environmental Quality Objectives for the marine waters of Western Australia

Environmental Values	Environmental Quality Objectives
Ecosystem Health (ecological value)	• EQO 1: Maintain ecosystem integrity at a maximum level of ecological protection. • EQO 1: Maintain ecosystem integrity at a high level of ecological protection. • EQO 1: Maintain ecosystem integrity at a moderate level of ecological protection. • EQO 1: Maintain ecosystem integrity at a low level of ecological protection. This means maintaining the structure (e.g. the variety and quantity of life forms) and functions (e.g. the food chains and nutrient cycles) of marine ecosystems to an appropriate level.
Fishing and Aquaculture (social use value)	• EQO 2: Seafood (caught or grown) is of a quality safe for eating. • EQO 3: Water quality is suitable for aquaculture purposes.
Recreation and Aesthetics (social use value)	• EQO 4: Water quality is safe for primary contact recreation (e.g. swimming and diving). • EQO 5: Water quality is safe for secondary contact recreation (e.g. fishing and boating). • EQO 6: Aesthetic values of the marine environment are protected.
Industrial Water Supply (social use value)	• EQO 7: Water quality is suitable for industrial use.
Cultural and Spiritual (social use value)	• EQO 8: Cultural and spiritual values of the marine environment are protected.

Source: EPA (2016)

1.4.2 'Maintenance of Ecosystem Integrity' EQO

The intent of this EQO is to maintain a healthy and diverse ecosystem. This EQO has four EQOs with each applied depending on the designated level of ecological protection low, moderate, high or maximum (Table 1.2).

Table 1.2 Levels of ecological protection

Level of Ecological Protection	Definition
Low	Allows large changes in abundance and biomass of marine life, biodiversity and rates of ecosystem processes, but only within a confined area
Moderate	Applied to relatively small areas within inner ports and adjacent to heavy industrial premises where pollution from current and/or historical activities may have compromised a high level of ecological protection.
High	Allows for small measurable changes in the quality of water, sediment and biota, but not to a level that changes ecosystem processes, biodiversity or abundance and biomass of marine life beyond the limits of natural variation.
Maximum	Activities to be managed so that there are no changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota.

In the absence of mandated management zones, a notional low ecological protection area (LEPA) has been established at the Ocean Reef outfall, as per technical guidance (EPA 2016). The notional LEPA occupies the area within a 100 m radius of the diffuser. Waters outside the LEPA are maintained to a high level of ecological protection (HEPA; Figure 1.2).

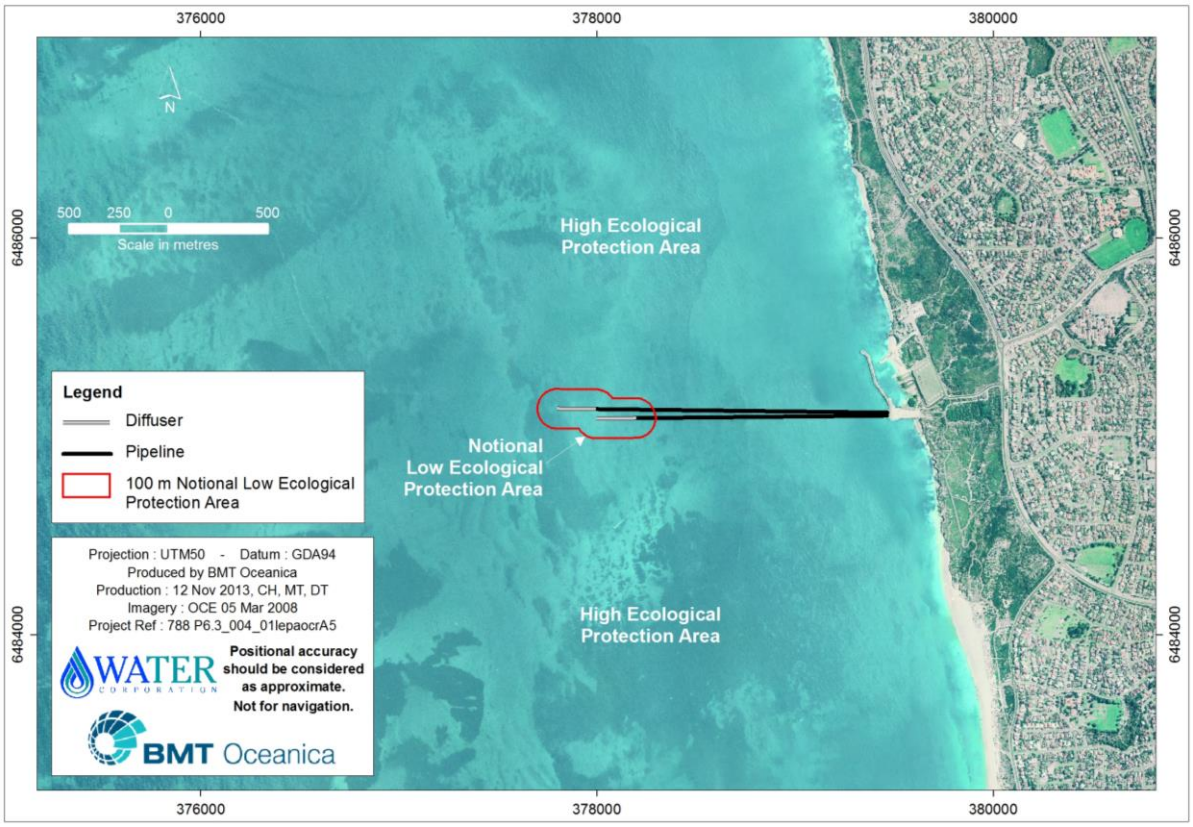
1.4.3 'Maintenance of Seafood Safe for Human Consumption' EQO

The intent of this EQO is to maintain seafood safe for human consumption (a social value) with the exception of a small area surrounding the ocean outlets where EQO 2 may not be achieved and seafood may be unsafe to eat. Formal management zones have not been established for the Ocean Reef outlet. However, an informal zone has been established at Ocean Reef based on microbiological observations from years of ocean monitoring data. The zone represents the area where microbiological organism counts are most likely to exceed the EPA's criteria for seafood safe for human consumption under worst-case conditions.

1.4.4 '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 with the exception of areas around 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 Ocean Reef outlet.

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



Note:

1. A formal LEPA will apply from 2018 after approvals associated with the Advanced Water Recycling Plant.

Figure 1.2 Ocean Reef ocean outlets notional ecological protection boundaries

2. Maintenance of Ecosystem Integrity

2.1 Environmental Quality Objective

The EQO for the EV 'Ecosystem Health' is aimed at maintaining ecosystem integrity and biodiversity and ensuring the continued health and productivity of Perth's coastal waters (EPA 2016). The EQC for the EQO 'Maintenance of Ecosystem Integrity' are outlined in Table 2.1.

Table 2.1 Environmental Quality Criteria for the EQO of Maintenance of Ecosystem Integrity (EQO1)

Environmental quality indicator	Environmental Quality Criteria (EQC)2	
	Environmental Quality Guideline	Environmental Quality Standard
Toxicants in treated wastewater • ammonia • metals • pesticides • herbicides • other chemicals	**Treated wastewater characterisation – bioaccumulating toxicants** Concentrations of contaminants will not exceed the ANZECC/ARMCANZ (2000) 80% species protection guideline trigger levels for bioaccumulating toxicants in the wastewater stream.	**Sentinel mussel monitoring** The median concentrations of metals that may bioaccumulate (cadmium and mercury) within mussel tissue from sites at the boundary of the low/high ecological protection areas will not exceed the 80th percentile of reference site data.
	Treated wastewater characterisation – non-bioaccumulating toxicants Wastewater contaminant concentrations, in conjunction with the initial dilution modelling, will be evaluated to determine whether: The ANZECC/ARMCANZ (2000) 99% species protection guideline trigger levels for toxicants (with the exception of cobalt, where the 95% guideline trigger level will apply), are being 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). 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 (refer to Table 2.3 Note that for metals, the assessment is to be based on bioavailable concentrations of metals in the wastewater (i.e. concentrations after filtering through a 0.45 µm filter). If any EQGs are exceeded, assessment against the EQS will commence.	**Whole of effluent toxicity (WET) testing** Undertake the full suite of WET testing of the waste stream in accordance with ANZECC/ARMCANZ (2000) guidelines. The EQS will be exceeded where: $\frac{DALEPA}{DR99\%BurrliOZ} \leq 1$ where *DALEPA* = dilutions achieved at the boundary of the LEPA; *DR99%BurrliOZ* = number dilutions required to achieve the 99% species protection guideline specific to treated wastewater that is calculated with BurrliOZ software using the results of the full suite of WET tests, as per ANZECC/ARMCANZ (2000).
	Whole of effluent toxicity (WET) testing 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 100-fold dilution) DRNOEC = number of dilutions required to achieve the no observed effects concentration (NOEC). 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).	**Whole of effluent toxicity (WET) testing** As per EQS above.
Receiving water physical-chemical measures • nutrient enrichment • organic enrichment • salinity	**Nutrient enrichment** 1. Median of defined area[4] during non-river flow period[5] not to exceed chlorophyll-a: 80th percentile of reference sites data. 4. Median of defined area[4] during non-river flow period[5] not to exceed light attenuation: 80th percentile of reference sites data.	Not applicable. No suitable EQS available.
	Organic enrichment Median dissolved oxygen in bottom waters (0–0.5 m above the sediment surface) greater than 90% saturation at any site for a defined period of not more than 6 weeks.	**Organic enrichment** Median dissolved oxygen in bottom waters (0–0.5 m above the sediment surface) greater than 60% saturation at any site for a defined period of not more than 6 weeks. No deaths of marine organisms resulting from de-oxygenation.
	Salinity Median salinity (0.5 m below the water surface) at an individual site over any period not to deviate beyond the 20th and 80th percentile of natural salinity range over the same period.	**Salinity** No deaths of marine organisms resulting from anthropogenically-sourced salinity stress.
Receiving water direct biological measures (algal growth potential) • phytoplankton biomass (chlorophyll-a)	**Phytoplankton blooms** 1. Median phytoplankton biomass measured as chlorophyll-a not to exceed 3 times median chlorophyll-a concentration of reference sites, on any occasion during non-river flow period[5]. 2. Phytoplankton biomass measured as chlorophyll-a at any site does not exceed 3 times median chlorophyll-a concentration of reference sites, on 25% or more occasions during the non-river flow period[5]. If either of these EQGs are exceeded, assessment will proceed against the EQS.	**Phytoplankton blooms** 1. Median for phytoplankton biomass measured as chlorophyll-a not to exceed 3 times median chlorophyll-a concentration of reference sites, on more than one occasion during non-river flow period[5] and in two consecutive years. 2. Phytoplankton biomass measured as chlorophyll-a at any site does not exceed 3 times median chlorophyll-a concentration of reference sites, on 25% or more occasions during the non-river flow period[6] and in two consecutive years.

Notes:
1. Based on the EQC Reference Document for Cockburn Sound (EPA 2017).
2. Where there is more than one EQC for an indicator, each one is to be considered individually. If any one of these is exceeded then the guideline or standard for that indicator has not been met.
3. Defined area = area to be characterised for environmental quality against pre-determined Environmental Quality Objectives and levels of ecological protection. Non-river flow period = summer period December–March inclusive, when river flows are weak.

2.2 Toxicants in treated wastewater

2.2.1 Comprehensive treated wastewater characterisation (CTWWC)

TWW (final effluent) from the Beenyup WWTP is analysed for a suite of parameters comprising the major contaminants of concern for the Ocean Reef ocean outlets:

- Nutrients (total nitrogen, ammonia, nitrate+nitrite, total phosphorus, orthophosphate)
- Microbial contaminants
- Bioavailable metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc)
- Pesticides and herbicides (organophosphate pesticide, organochlorine pesticides, triazine herbicides)
- Polyaromatic hydrocarbons
- Phthalates
- Polychlorinated biphenyls
- Benzene, toluene, ethylbenzene, and xylenes
- Petroleum hydrocarbons
- Surfactants
- Dissolved organic carbon
- Per- and poly-fluoroalkyl substances including perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFAS)

A discrete sample was obtained from the Beenyup site on 13 February 2018. The sample was collected after the point where the Beenyup TWW and AWRP reject streams join and it is representative of the final (combined) discharge to the ocean. The bulk sample was homogenised (agitated), split into individual sample containers and sent to a National Association of Testing Authorities (NATA)-accredited laboratory for analysis. Samples for bioavailable metals were filtered through a 0.45 µm filter prior to analysis (EPA 2005b). Analyses were completed using NATA-accredited methods (Appendix B).

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; Appendix C), and consequently below their respective 80% species protection guidelines (ANZECC/ARMCANZ 2000), thus meeting the EQG.

Non-bioaccumulating toxicants

Modelling predicted average initial dilution of 1:377 at Outlet A and 1:351 at Outlet B (Appendix D). The worst-case scenario initial dilution of 1:351 was used in calculations. Contaminant concentrations after the initial dilution of 1:351 (a conservative estimate of the dilution expected at the LEPA boundary) were below the ANZECC/ARMCANZ (2000) 99% species protection guidelines (Table 2.2), with the potential exception of chromium. Total dissolved chromium concentrations exceeded the chromium VI guideline (Table 2.2). However, the dissolved chromium in the TWW sample is predominantly chromium III. While the total chromium concentration after initial dilution (0.2 µg/L) exceeded the chromium VI guideline, the concertation of chromium VI on its own is almost certainly below the guideline and the EQG met. Results for analytes with relevant trigger values are

provided in Table 2.2, while results for analytes without triggers are provided for contextual purposes in Appendix C and Appendix D.

Table 2.2 Toxicants in the Ocean Reef TWW stream compared with relevant guideline trigger levels after initial dilution

Toxicant[1]	Ocean Reef TWW[2]	TWW value after initial dilution[3]	Trigger[4]
Nutrients (µg/L)			
Ammonia-N	740	3.61	500
Dissolved metals (0.45 µm filtered) (µg/L)			
Chromium[5]	1.4	**0.20**	0.14 (Cr VI) 7.7 (Cr III)
Copper	9.8	0.16	0.3
Lead	<1	–	2.2
Nickel	5.9	–	7
Silver	<1	–	0.8
Zinc	82	0.79	7
Organophosphate pesticides (µg/L)			
Chlorpyrifos[6]	<0.1	–	0.0005
Organochlorine pesticides (µg/L)			
Endrin	<0.001	–	0.004
Endosulfan sulfate[7]	<0.001	–	0.005
BTEX (µg/L)			
Benzene	<1.0	–	500
Poly aromatic hydrocarbons (µg/L)			
Naphthalene	<0.01	–	50
Benzo(g,h,i)perylene	<0.01	–	50

Notes:
1. Assessment against ANZECC/ARMCANZ (2000) 99% species protection guideline values was undertaken only for those toxicants where trigger levels were available.
2. TWW = treated wastewater.
3. Initial dilution = 1:351 (predicted average value at Ocean Reef Outlet B). 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 Table 3.4.1 in ANZECC/ARMCANZ (2000). The EPA has provided advice that in WA waters where a high level of protection applies, the 99% species protection levels should be used.
5. Measured values are total chromium (Cr) – while dissolved Cr in TWW is predominantly Cr III, a conservative approach was taken and assessment is against the Cr III and VI trigger.
6. Analytical limits for chlorpyrifos 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 Section 2.2.2).
7. Trigger values are for endosulfan, not endosulfan sulfate (Table 3.4.1; ANZECC/ARMCANZ 2000).

Total toxicity of the mixture (TTM)

The potential for cumulative effects on marine organisms is assessed after initial dilution as per ANZECC/ARMCANZ (2000), based on the effects of ammonia, copper and zinc (the contaminants of concern most likely to exceed their respective guidelines).

$$\text{Total Toxicity of Mixture} = \frac{[\text{ammonia}]}{[\text{Trigger Value}]} + \frac{[\text{copper}]}{[\text{Trigger Value}]} + \frac{[\text{zinc}]}{[\text{Trigger Value}]}$$

The TTM following initial dilution (0.42; Table 2.3) was less than the ANZECC/ARMCANZ (2000) guidelines value of 1.0, and thus met the EQG.

Table 2.3 Total toxicity of treated wastewater (TWW) at the edge of the initial mixing zone associated with the Ocean Reef ocean outlets

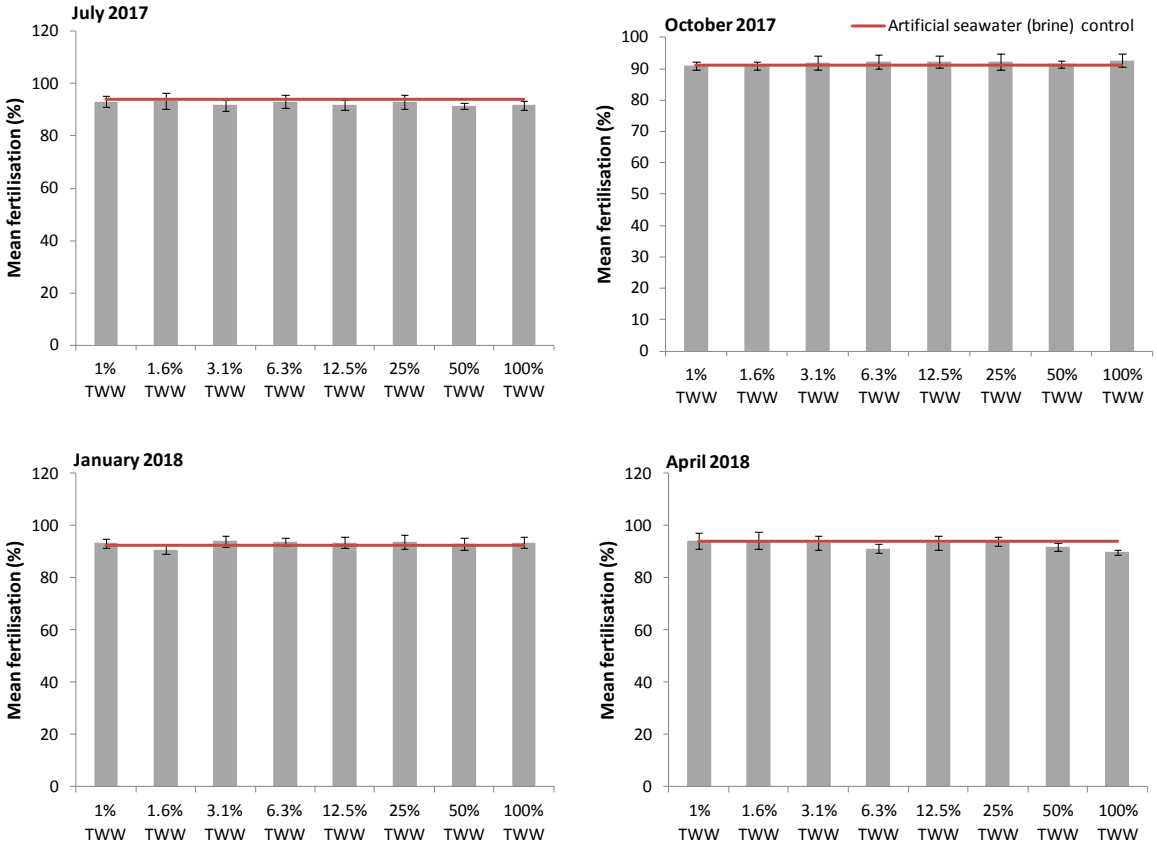
Natural concentrations in Perth's coastal waters (µg/L)			Initial dilution of TWW with seawater	Total toxicity of the mixture (TTM)[2]
Ammonia[1]	Copper[1]	Zinc[1]		
1.5	0.08	0.15	1:351	0.42

Notes:
1. Background concentrations for copper and zinc from McAlpine et al. (2005); Perth marine waters (pp.; Table 12). Surface background concentration for ammonia calculated as median of reference site data from 2004–2018 (BMT, unpublished data).
2. Initial dilution at Outlet B was used as a conservative estimate (Appendix D).
3. TTM = [ammonia]/guideline + [copper]/guideline + [zinc]/guideline.

2.2.2 Whole of effluent toxicity (WET) testing

WET testing is useful for assessing toxicity in the absence of guidelines, or where the effects may be cumulative. 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). Detailed methods are provided in Appendix F.

There were no significant differences in fertilisation between the artificial seawater control and any TWW dilutions of 24-hour flow-weighted composite samples collected in July 2017, October 2017, January 2018 and April 2018 (Figure 2.1, Appendix G). The NOEC was greater than 1% TWW (i.e. ≤100-fold dilution) in all four samples (Table 2.4; Appendix G), and thus the EQG for WET testing was met.



Notes:
1. Error bars are ±1 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.

Figure 2.1 Comparison of whole effluent toxicity TWW dilution results to artificial seawater control

Table 2.4 Calculated parameters from whole of effluent toxicity tests

Indicator	July 2017	October 2017	January 2018	April 2018
NOEC	100%	100%	100%	100%
Dilutions required to meet the NOEC	0	0	0	0
Dilutions require/dilutions achieved	0	0	0	0
≤1	yes	yes	yes	yes

Note:
1. NOEC = no observed effect concentration.

2.3 Water quality monitoring – receiving environment

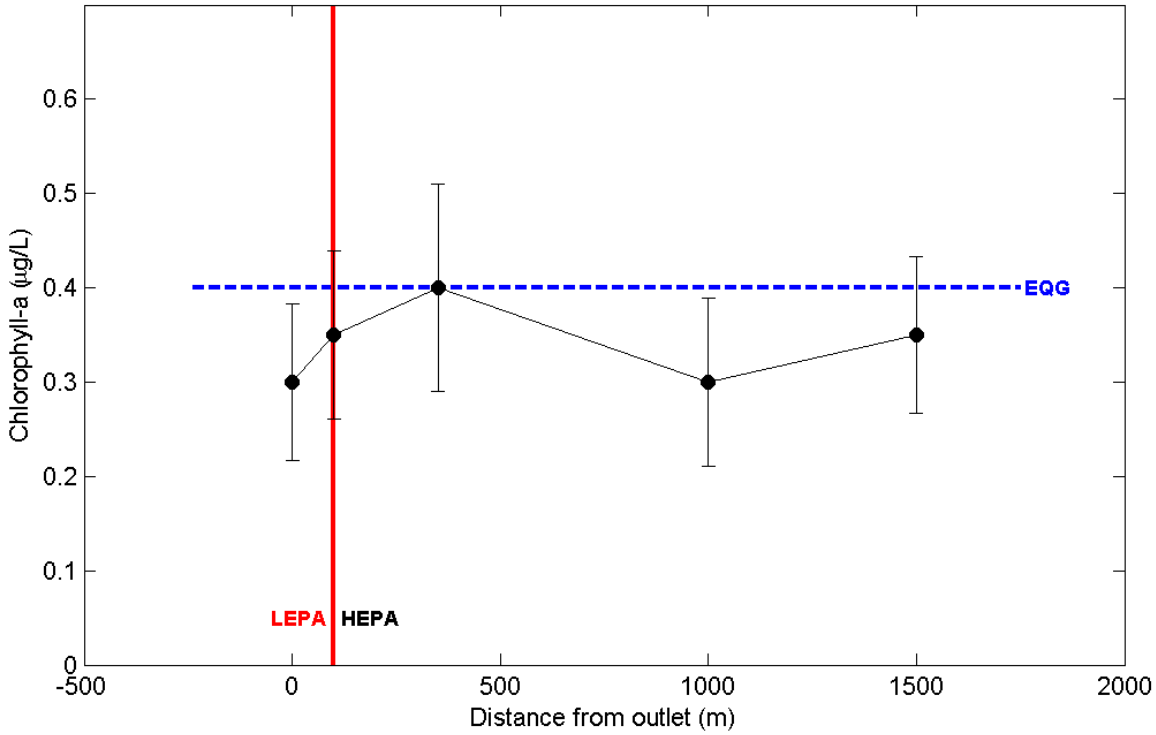
Nutrients, phytoplankton biomass and physical and chemical stressors were monitored along a down-current gradient approximately fortnightly from the beginning of December 2017 to the end of March 2018 (Table 2.5), coinciding with the summer non-river flow period. Refer to Appendix F for detailed methods.

Table 2.5 Water quality monitoring dates near the Ocean Reef ocean outlets between December 2017 and March 2018

Sampling day	Date
1	6/12/2017
2	19/12/2017
3	9/01/2018
4	17/01/2018
5	1/02/2018
6	23/02/2018
7	15/03/2018
8	28/03/2018

2.3.1 Nutrient enrichment

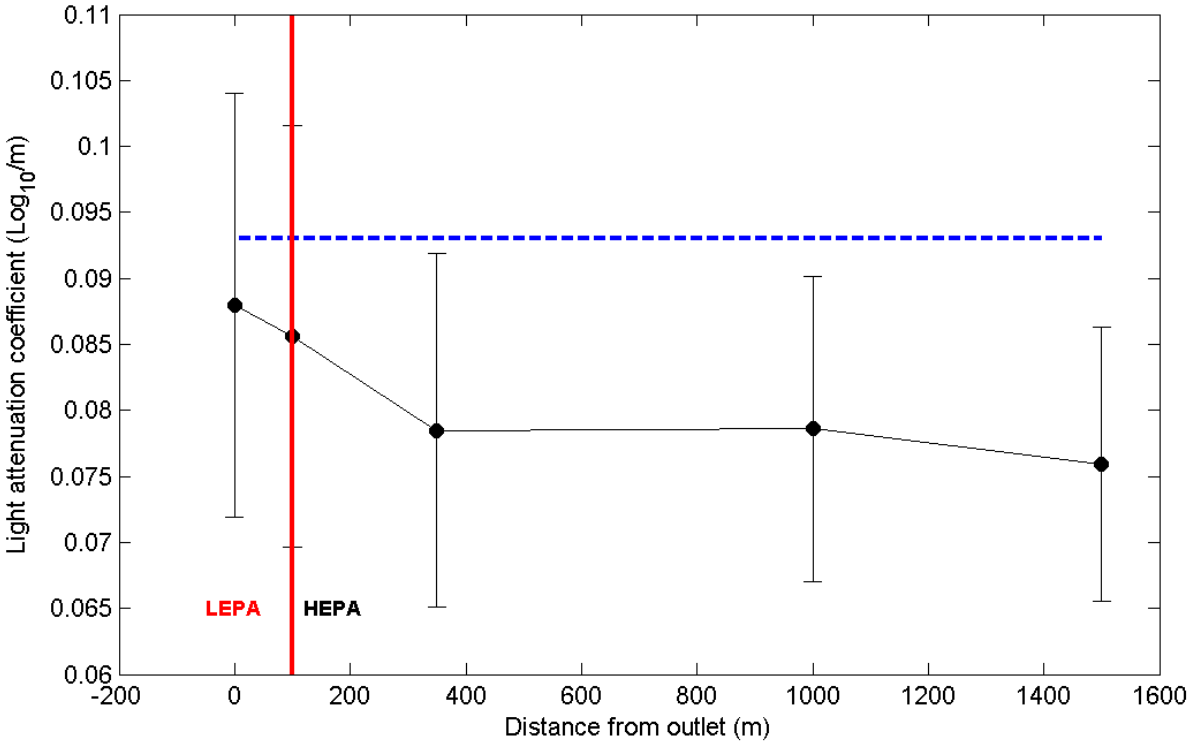
The overall median chlorophyll-a concentration in the Ocean Reef HEPA (100 m plus) was 0.35 µg/L and was therefore below the 80th percentile of historical reference site data (0.4 µg/L; Figure 2.2), thus meeting the EQG.



Notes:
1. Error bars represent ±95%confidence intervals.
2. Dark blue dashed line = Environmental Quality Guideline (EQG) is the 80th percentile of historical reference site data (0.4 µg/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 2017–March 2018.

Figure 2.2 Median chlorophyll-a concentrations obtained at fixed monitoring sites above and down-current of the Ocean Reef outlets during the summer monitoring period

The overall median light attenuation in the Ocean Reef HEPA (100 m plus) was 0.0802 Log_{10}/m and was therefore lower than the 80th percentile of historical reference site data (0.093 Log_{10}/m, Figure 2.3), thus meeting the EQG.



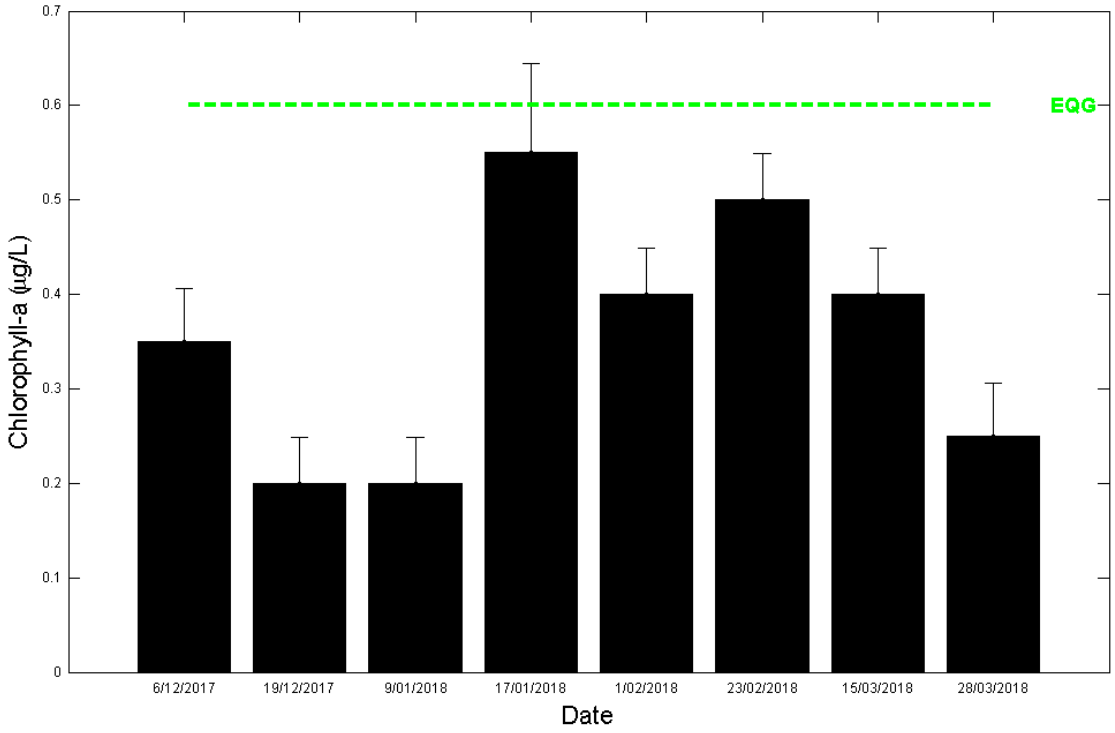
Notes:
1. Error bars represent ±95% confidence intervals
2. Dark blue dashed line = Environmental Quality Guideline (EQG) is the 80th percentile of historical reference site data (0.093Log$_{10}$/m).
3. LEPA = nominal low ecological protection area; HEPA = high ecological protection area.
4. Data for each distance were pooled across eight sampling days over December 2017–March 2018.

Figure 2.3 Median light attenuation coefficient obtained at fixed distances down-current of the Ocean Reef outlets during the summer monitoring period

2.3.2 Phytoplankton blooms

Median chlorophyll-a concentration within the HEPA did not exceed three times the median of reference sites (0.6 µg/L) on any sampling occasion during the summer monitoring period (Figure 2.4), therefore EQG1 was met.

Phytoplankton biomass measured as median chlorophyll-a concentration at any site did not exceed three times the median of reference sites during the summer monitoring period, thus meeting the requirements of EQG (<25% of occasions).



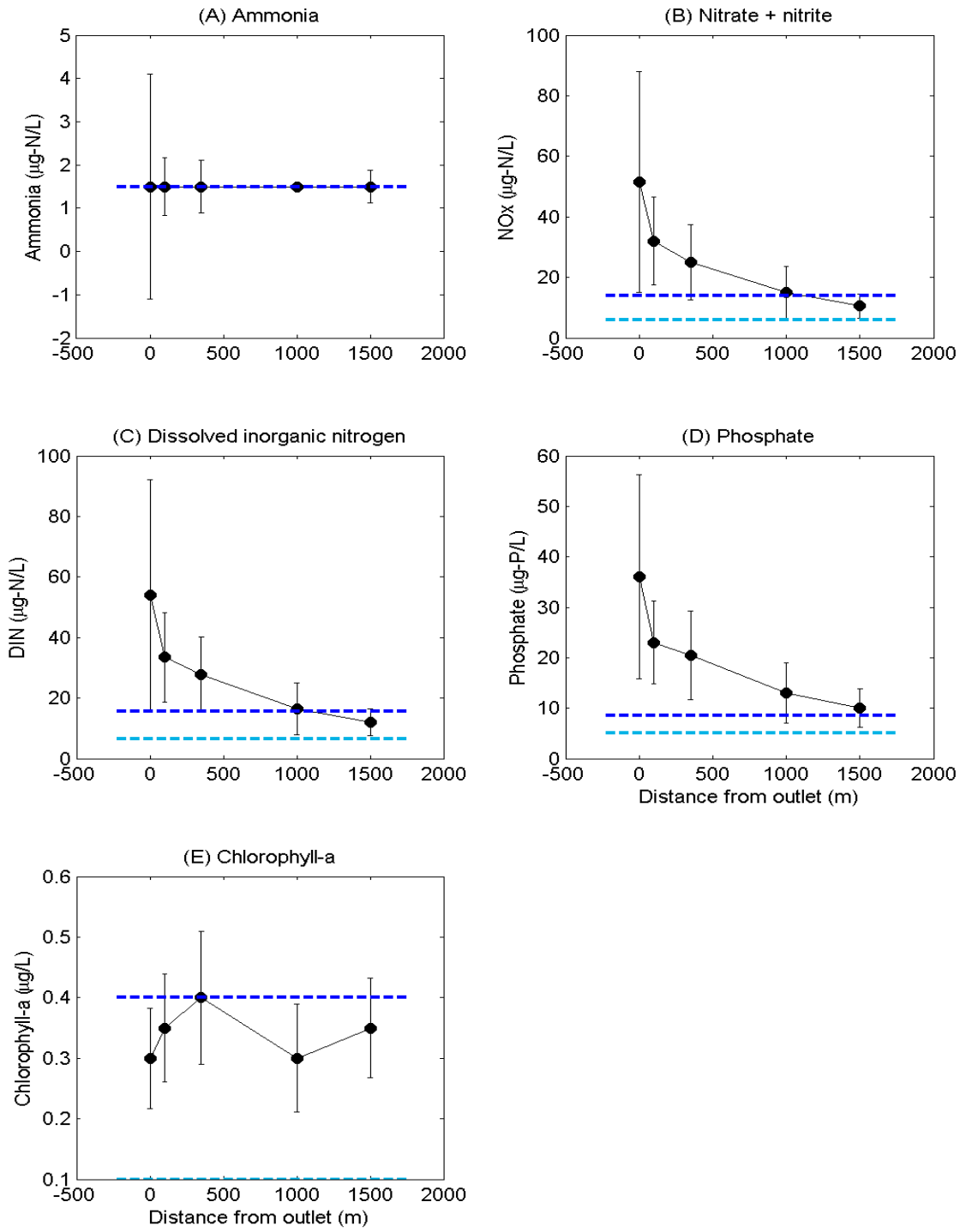
Notes:
1. Error bars represent ±95% confidence intervals.
2. Green dashed line = Environmental Quality Guidelines (EQG) is 3 times the median chlorophyll-a concentration of reference site data.
3. Values measured at 0 m are not included in the figure or EQG assessment, as the 0 m site is situated directly above the outlets within the notional low ecological protection area.
4. Data were pooled across four sites within the high ecological protection area.

Figure 2.4 Median phytoplankton biomass during the summer monitoring period, pooling data from fixed sites ≥100 m down-current of the Ocean Reef outlets

Additional data – nutrient gradients

Examination of nutrient gradients is useful for measuring the environmental footprint of the plume. Median concentrations at fixed distances down-current of the outlet are compared against background concentrations. Background concentrations are considered to be between the 20th and 80th percentile of historical reference site data (light blue and dark blue broken lines, respectively in Figure 2.5).

Median concentrations of ammonia at each site down current of the diffuser and the 20th and 80th percentiles of reference site data were all equal to half the limit of reporting (Figure 2.5A). Concentrations of nitrate+nitrite (NO_x) and dissolved inorganic nitrogen were greater than background at a distance of up to ~1000 m down-current of the outlet (Figure 2.5B, C). Concentrations of phosphate were greater than background at all distances, but decreased towards background, with increasing distance from the diffuser (Figure 2.5D). Median chlorophyll-a concentrations were typically below the 80th percentile of historical reference data (Figure 2.5E).



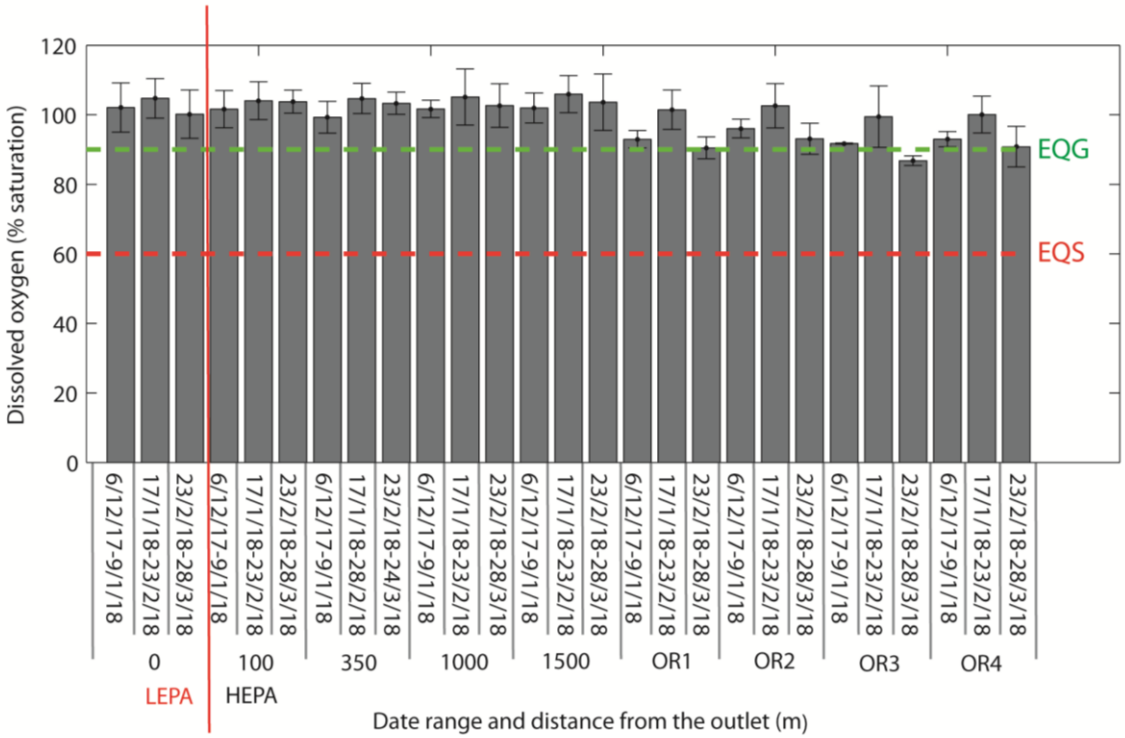
Notes:
1. Error bars represent ±95% confidence intervals.
2. Dark blue line = 80th percentile of historical reference sites; light blue line = 20th percentile of historical reference sites.
3. NOx = nitrate+nitrite; DIN = dissolved inorganic nitrogen.
4. Data for each distance were pooled across eight sampling days over December 2017–March 2018.

Figure 2.5 Median nutrient and chlorophyll-a concentrations obtained at fixed monitoring sites above and down-current of the Ocean Reef ocean outlets during the summer monitoring period

2.3.3 Physical-chemical stressors

Dissolved oxygen (DO)

Bottom (0–0.5 m) DO concentrations measured at monitoring sites on eight occasions between December 2017 and March 2018 remained >90% saturation at all times (Figure 2.6). Bottom DO saturation at the reference sites (OR1-OR4) was <90% on one occasion (Figure 2.6). Median DO in bottom waters at the monitoring sites was >90% saturation over defined periods of ≤6 weeks, the EQG for organic enrichment was met.

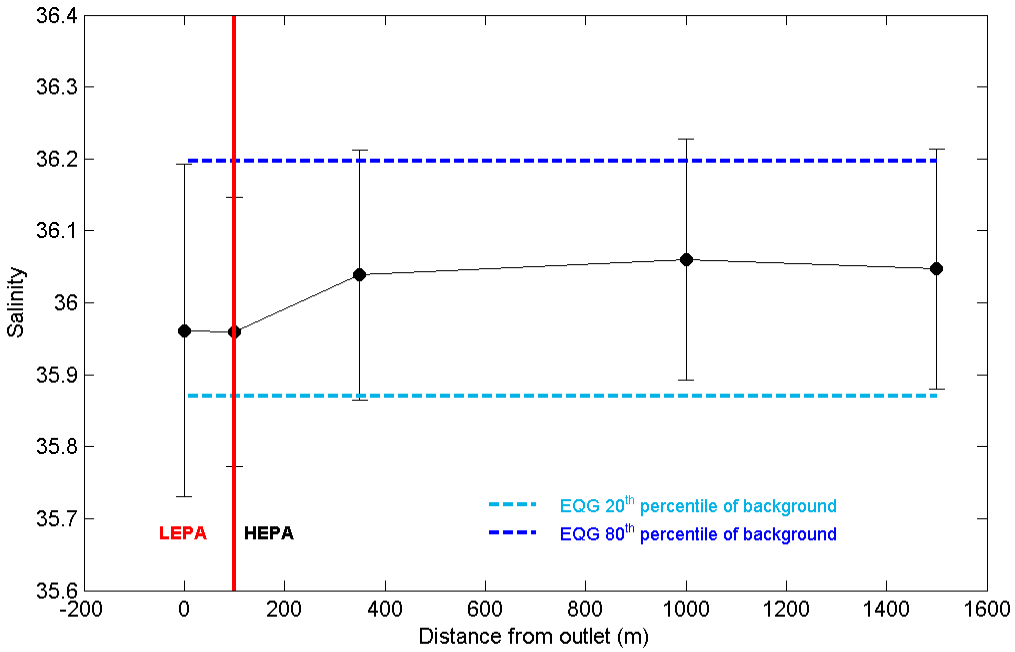


Notes:
1. Error bars represent ±95% confidence intervals.
2. Dissolved oxygen (DO) measured 0–0.5 m above the seabed.
3. Green dashed line = Environmental Quality Guideline (EQG) = 90% saturation.
4. Red dashed line = Environmental Quality Standard (EQS) = 60% DO saturation.
5. LEPA = notional low ecological protection area; HEPA = high ecological protection area.
6. Reference site data (OR1–OR4) are compared against EQG and EQC for contextual purposes only.

Figure 2.6 Median dissolved oxygen for defined periods of ≤6 weeks during the summer monitoring period

Salinity

Median salinity was lowest directly above the outlets within the notional LEPA but was between the 20th and 80th percentile of the natural salinity at all sites within the notional HEPA (at 100, 350, 1000 and 1500 m from the outlets; Figure 2.7). The EQG requires the median salinity not to deviate outside the 20th and 80th percentile of the natural salinity range at any individual site within the notional HEPA over the summer monitoring period, thus the EQG was met.



Notes:
1. Error bars represent ±95% confidence intervals.
2. Salinity measured 0–0.5 m below the sea surface.
3. Dark blue line = 80th percentile of historical reference sites; light blue line = 20th percentile of historical reference sites.
4. LEPA = notional low ecological protection area; HEPA = high ecological protection area.
5. Data for each distance were pooled across eight sampling occasions over December 2017–March 2018.

Figure 2.7 Median salinity compared to the 20th and 80th percentile of reference site data during the summer monitoring period

2.4 Monitoring summary

Results of the 2017–2018 monitoring program reveals no EQG exceedances for the EQO 'Maintenance of Ecosystem Integrity'. These results are summarised in Table 2.6.

Table 2.6 Compliance against EQC relevant to the EQO 'Maintenance of Ecosystem Integrity' (EQO1)

Environmental quality indicator		EQC	Comments	Compliance
Toxicants in treated wastewater (TWW)	Bioaccumulating toxicants	EQG	Concentrations of cadmium and mercury in the undiluted TWW stream were below the ANZECC/ARMCANZ (2000) values for 80% species protection	■
	Non-bioaccumulating toxicants and initial dilution		The rate of initial dilution on 13 February 2018 (1:351) was sufficient to reduce non bioaccumulating contaminant concentrations to below their ANZECC/ARMCANZ (2000) values for 99% species protection	■
	Total toxicity of the mixture (TTM)		The TTM for the additive effect of ammonia, copper and zinc after initial dilution (0.42) was below the ANZECC/ARMCANZ (2000) guideline value of 1.0	■
	Whole of effluent toxicity testing		The lowest NOEC during the reporting period was 100%. No dilution of the TWW was required to achieve this NOEC.	■
Nutrient enrichment	Chlorophyll-a	EQG	Median chlorophyll-a concentration within the high ecological protection area (HEPA) was lower than the 80th percentile of historical reference site data.	■
	Light attenuation coefficient (LAC)		Median LAC within the HEPA was lower than the 80t^{h} percentile of historical reference site data.	■
Phytoplankton blooms	Phytoplankton biomass (measured as chlorophyll-a)	EQG	1. Median chlorophyll-a concentrations in the HEPA did not exceed 3-times the median of reference sites on any occasion.	■
			2. Chlorophyll-a did not exceed 3 times the median chlorophyll-a concentration of reference sites at any site.	■
Physical-chemistry	Organic enrichment	EQG	Dissolved oxygen saturation remained above 90% saturation at all times.	■
	Salinity	EQG	Within the HEPA, median salinity was within the 20th and 80th percentile of reference site data.	■

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. NOEC = no observed effect concentration; the highest concentration of TWW at which there is no statistically significant observed effect on gamete fertilisation.
3. EQO = Environmental Quality Objective.

3. Maintenance of Seafood for Human Consumption

3.1 Environmental Quality Objective

The EQO for the EV 'Fishing and Aquaculture' is aimed at ensuring seafood is safe for human consumption. The EQC for the EQO 'Maintenance of Seafood for Human Consumption' are outlined in Table 3.1.

Table 3.1 Environmental Quality Criteria for the EQO 'Maintenance of Seafood Safe for Human Consumption' (EQO2)

Environmental quality indicator	Environmental Quality Criteria	
	Environmental Quality Guideline	Environmental Quality Standard
Thermotolerant coliforms (TTC)	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 90th percentile must not exceed 21 CFU/100 mL measured using the membrane filtration method.	Median TTC concentrations at sites at the boundary of the OZI not to exceed 70 CFU/100 mL as measured using the membrane filtration method and the estimated 90th percentile must not exceed 85 CFU/100 mL measured using the membrane filtration method.
Algal biotoxins	Cell counts of potentially toxic algae at sites at the boundary of the OZI not to exceed the WASQAP[1] trigger concentrations for any of the following: • *Alexandrium* spp. (200 cells/L) • *Gymnodinium* spp. (1000 cells/L) • *Karenia brevis* (1000 cells/L) • Karenia/Karlodinium/Gymnodinium group (250 000 cells/L) • *Dinophysis* spp. (1000 cells/L) • *Prorocentrum lima* (500 cells/L) • *Pseudo-nitzchia* delicatissima (500 000 cells/L) • *Pseudo-nitzchia* seriata (50 000 cell/L) If this EQO is exceeded, assessment will proceed against the EQS for sentinel mussel tissues.	Toxin concentrations in seafood not to exceed EQS in any sample at the boundary of the OZI1: • paralytic shellfish poison (0.8 mg saxitoxin eq./kg) • diarrhoetic shellfish poison (0.2 mg/kg) • neurotoxic shellfish poison 200 mouse units/kg) • amnesic shellfish poison (domoic acid; 20 mg/kg).

Source: EPA 2017

Note:

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

3.2 Microbiological contaminants and algal biotoxins

3.2.1 Thermotolerant coliforms

TTC were sampled eight times during the 2017–2018 summer monitoring period (yielding a total of 40 samples; Appendix J). NHMRC (2008) guidelines and EPA (2005b) suggest that a minimum of 100 samples over the monitoring period are needed 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 (since summer 2015–16) were pooled to yield an adequate sample size (n=120).

The median concentration of TTC derived from the 3 years of pooled samples was equal to the limit of detection (<10 CFU/100 mL); Table 3.2). The 90th percentile was 10 CFU/100mL and less than 21 CFU/100mL so the EQG was met.

Table 3.2 Median and 90th percentile of thermotolerant coliform concentration at the fixed monitoring sites for the Ocean Reef outlets for 2015–2018 and comparison to the EQC

Sampling period	Environmental Quality Guideline	Result (CFU/100 mL)	Compliance (EQG)
Dec 2015–Mar 2016 Dec 2016–Mar 2017 Dec 2017–Mar 2018 (n=120)	Median TTC ≤14 CFU/100 mL	<10	■
	90th percentile ≤ 21 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. Fore site locations and GPS waypoints, see Appendix I.
3. 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.
4. Environmental Quality Criteria are based on EPA (2017).

3.2.2 Toxic phytoplankton species

Cell densities of toxic phytoplankton species were below relevant Western Australian Shellfish Quality Assurance Program (WASQAP; DoH 2016) guidelines (Table 3.3; Appendix K).

Table 3.3 Estimated cell densities of phytoplankton species known to produce biotoxins

Date	Site[1]	Species	Estimated density (cells/L)	WASQAP guideline[2]	Compliance[3]
6/12/2017	OR22	*Pseudo-nitzschia* delicatissima group	15438	500 000	■
		Alexandrium spp.	186	200	■
	ORR2	*Pseudo-nitzschia* delicatissima group	2046	500 000	■
19/12/2017	OR22	Pseudo-nitzschia delicatissima group	1674	500 000	■
	ORR4	Pseudo-nitzschia delicatissima group	2418	500 000	■
9/01/2018	OR26	*Pseudo-nitzschia* delicatissima group	11 718	500 000	■
	ORR4	*Pseudo-nitzschia* delicatissima group	19 158	500 000	■
		Pseudo-nitzschia seriata group	930	50 000	■
17/01/2018	OR32	*Pseudo-nitzschia* delicatissima group	11 718	500 000	■
		Pseudo-nitzschia seriata group	3906	50 000	■
	ORR3	*Pseudo-nitzschia* delicatissima group	13 206	500 000	■
		Pseudo-nitzschia seriata group	3906	50 000	■
1/02/2018	OR30	*Pseudo-nitzschia* delicatissima group	4278	500 000	■
	ORR3	*Pseudo-nitzschia* delicatissima group	1302	500 000	■
23/02/2018	OR22	No toxic species detected	–	–	NA
	ORR2	No toxic species detected	–	–	NA
15/03/2018	OR19	*Pseudo-nitzschia* delicatissima group	2418	500 000	■
	ORR2	No toxic species detected	–	–	NA
28/03/2018	OR30	*Pseudo-nitzschia* delicatissima group	1302	500 000	■
	ORR3	*Pseudo-nitzschia* delicatissima group	930	500 000	■

Notes:
1. Samples were analysed for one monitoring site and one reference site per sampling occasion.
2. Marine Biotoxin 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; amber (■) and red (■) symbols represent an exceedance of the Environmental Quality Guideline (EQG) or Environmental Quality Standard (EQS), respectively.
4. – = no toxic species detected, NA = not applicable.

3.3 Monitoring summary

Results of the 2017–2018 monitoring programs revealed no exceedances of EQGs for the EQO 'Maintenance of Seafood for Human Consumption' (Table 3.4).

Table 3.4 Compliance against EQC relevant to the EQO 'Maintenance of Seafood for Human Consumption'

Environmental quality indicator		EQC	Comments	Compliance[1]
Microbiological contaminants	Thermotolerant coliforms (TTC)	EQG	The median value for TTC concentrations derived from 120 samples collected over the 2015–2016, 2016–2017 and 2017–2018 sampling seasons was at the limit of detection (<10 CFU/100 mL)[2]	■
		EQG	The 90th percentile was 10 CFU/100 mL and less than 21 CFU/100 mL thus meeting the EQG	■
Algal biotoxins	Toxic phytoplankton species	EQG	Toxic phytoplankton species were not recorded in excess of WASQAP (DoH 2016) guidelines values during 2017–2018 monitoring	■ Hlk306706488

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 values.

4. Maintenance of Primary and Secondary Contact Recreation

4.1 Environmental Quality Objective

EQO for the EV 'Recreation and Aesthetics' are aimed at ensuring Perth's coastal waters are safe for primary and secondary contact recreation activities such as swimming and boating. The EQC for the EQO 'Maintenance of Primary and Secondary Contact Recreation' are outlined in Table 4.1.

Table 4.1 Environmental Quality Criteria for the EQOs of 'Maintenance of Primary and Secondary Contact Recreation' (EQO4 and EQO5)

Environmental quality indicators	Environmental Quality Criteria	
	Environmental Quality Guideline	Environmental Quality Standard
Faecal pathogens	Primary contact: The 95th percentile concentration of *Enterococci* over the bathing season not to exceed 200 MPN/100 mL at the observed zone of influence (OZI) boundary. Secondary contact: The 95th percentile concentration of *Enterococci* over the bathing season not to exceed 2000 MPN/100 mL at the OZI boundary.	Primary contact: The 95th percentile concentration of *Enterococci* over the bathing season not to exceed 500 MPN/100 mL at the OZI boundary. Secondary contact: The 95th percentile concentration of *Enterococci* over the bathing season not to exceed 5000 MPN/100 mL at the OZI boundary.
Algal biotoxins	The phytoplankton cell count from a single site should not exceed 10 000 cells/mL; or detect DoH watch list species or exceed their trigger levels or There should be no reports of skin, eye or respiratory irritation or potential algal poisoning in swimmers considered by a medical practitioner as potentially resulting from toxic algae when less than 10 000 cells/mL are present in the water column.	The phytoplankton cell count from a single site should not exceed 50 000 cells/mL; or detect or exceed DOHWA watch list action levels. There should be no visual presence of algal scums or relatively widespread visible presence of *Lyngbya majuscula* filaments (NHMRC 2008). There should be no confirmed incidences (by the Department of Health) of skin or eye irritation caused by toxic algae, or of algal poisoning in recreational users.

Source: EPA (2017)

4.2 Microbiological contaminants and algal biotoxins

4.2.1 Faecal streptococci (*Enterococci* spp.)

Samples were collected eight times over the 2017–2018 summer monitoring period (yielding a total of 40 samples). NHMRC (2008) guidelines and EPA (2005b) suggest that a minimum of 100 samples over the monitoring period are needed 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 an adequate samples size (n=120).

Over the past three summers, the 95th percentile of *Enterococci* spp. concentrations at the boundary of the observed zone of influence for the Ocean Reef ocean outlet was 10 MPN/100 mL (Table 4.2), and therefore both the primary (<200 MPN/100 mL) and secondary (<2000 MPN/100 mL) contact recreation EQG were met for faecal pathogens in water.

Table 4.2 The 95th percentile of *Enterococci* spp. concentrations at the boundary of the observed zone of influence for the Ocean Reef ocean outlets

Sampling period	95th percentile[1] (MPN/100 mL)	Compliance[2]	
		Primary contact	Secondary contact
Dec 2015–Mar 2016 Dec 2016–Mar 2017 Dec 2017–Mar 2018 (n=120)	10	■	■

Notes:
1. *Enterococci* spp. values below the analytical detection limit (<10 MPN/100 mL) were halved (= 5 MPN/100 mL) to calculate the 95th percentile.
2. 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.
3. For site locations and GPS waypoints, see Appendix I.
4. Environmental Quality Criteria (EQC) based on EPA (2017) water quality guidelines for recreation waters.

4.2.2 Phytoplankton cell concentrations

Phytoplankton densities at individual sites monitored during 2017-2018 were below the 10 000 cells/mL guideline (Table 4.3, Appendix K); meeting the EQG. .

Table 4.3 Estimated phytoplankton cell density at fixed monitoring sites for contact recreation down-current of the Ocean Reef outlets

Date	Site	Total density (cells/mL)	Compliance
6/12/2017	OR7	160	■
19/12/2017	OR7	46	
9/01/2018	OR9	195	
17/01/2018	OR15	178	
1/02/2018	OR13	35	
23/02/2018	OR7	17	
15/03/2018	OR5	54	
28/03/2018	OR13	31	

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.

4.3 Monitoring summary

Results of the 2017–2018 monitoring programs revealed no exceedances of EQGs for the EQO 'Maintenance of Primary and Secondary Contact Recreation' (Table 4.4).

Table 4.4 Compliance against EQC relevant to the EQO 'Maintenance of Primary and Secondary Contact Recreation'

Environmental Quality Indicator		Comments	EQC	Compliance
Faecal streptococci	*Enterococci* spp.	The 95th percentile of *Enterococci* spp. concentrations was 10 MPN/100 mL	EQG (primary contact)	■
			EQG (secondary contact)	■
Algal biotoxins	Phytoplankton (cell concentration)	Estimated total phytoplankton cell count at individual sites were <10 000 cells/mL at each site and sampling occasion during 2017–2018 monitoring	EQG	■

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.

References

ANZECC/ARMCANZ (2000) National Water Quality Management Strategy: Paper No 4 – Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Volume 1 – The Guidelines (Chapters 1–7). Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, Australian Capital Territory, October 2000

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

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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

Appendix A – Beenyup wastewater treatment plant Licence conditions and Ministerial Statement

Government of **Western Australia**
Department of **Environment and Conservation**

Your ref: L7882/1991/14
Our ref: DEC625-02
Enquiries: Bhabesh Das
Phone: 9333 7521
Fax: 9333 7550
Email: bhabesh.das@dec.wa.gov.au

The Manager
Water Corporation
PO Box 100
LEEDERVILLE WA 6902

Dear Sir/Madam

Environmental Protection Act 1986
Licence L7882/1991/14
Occupier: Water Corporation
Premises: Beenyup Wastewater Treatment Plant, Lot8278 on Plan 30778
Ocean Reef Road, CRAIGIE WA6025

You are hereby advised that a licence under the *Environmental Protection Act 1986* (the Act) has been granted for the above premises. The Department of Environment and Conservation will advertise the issuing of this licence in the public notices section of The West Australian newspaper.

The licence is subject to the attached conditions. Under section 58 of the Act, it is an offence to contravene a licence condition. This offence carries a penalty of up to $125,000, with a daily penalty of up to $25,000.

In accordance with section 102(1)(c) of the Act, you are afforded 21 days to appeal the conditions of the licence. Under section 102(3)(a) of the Act, any other person may also appeal the conditions of the licence.

To make an appeal or check if any appeals have been made, contact the Office of the Appeals Convenor on 6467 5190. Please direct all other inquiries to the Licensing Officer above.

Yours faithfully,

Carissa Aitken
A/Manager, Works Approval & Emissions Licensing Section

Thursday, 29 September 2011

enc: Environmental Protection Act 1986 Licence 7882/1991/14
copy to: Local Government Authority: City of Joondalup

Government of **Western Australia**
Department of **Environment and Conservation**

LICENCE FOR PRESCRIBED PREMISES
Environmental Protection Act 1986

LICENCE NUMBER: L7882/1992/14 **FILE NUMBER** DEC625 - 02

LICENSEE
Water Corporation
629 New Castle Street
LEEDERVILLE WA 6007
ABN: 28 003 434 917

PREMISES
Beenyup Wastewater Treatment Plant
Lot 8278 on Plan 30778, Ocean Reef Road
CRAIGIE WESTERN AUSTRALIA 6025
(as depicted in Attachment 1)

PRESCRIBED PREMISES CATEGORY
Schedule 1 of the *Environmental Protection Regulations 1987*

CATEGORY NUMBER	CATEGORY DESCRIPTION	CATEGORY PRODUCTION OR DESIGN CAPACITY	PREMISES PRODUCTION OR DESIGN CAPACITY
54	Sewage facility: premises – (a) On which sewage is treated (excluding septic tanks); or (b) From which treated sewage is discharged onto land or into waters.	100 cubic metres or more per day	135,000 cubic metres per day
61	Liquid waste facility: premises on which liquid waste produced on other premises (other than sewage waste) is stored, reprocessed, treated or irrigated.	100 tonnes or more per year	50,000 tonnes per year

CONDITIONS OF LICENCE
Subject to the conditions of licence set out in the attached pages.

Officer delegated under Section 20
of the *Environmental Protection Act 1986*

ISSUE DATE Friday, 30 September 2011
COMMENCEMENT DATE: Tuesday, 1 November 2011
EXPIRY DATE: Monday, 31 October 2016

DEFINITIONS

"APHA-AWWA-WEF" means American Public Health Association; American Water Works Association; Water Environment Federation;

"Biological wastes category 1.02 and 1.05" means biological wastes under category 1.02 and 1.05 within Appendix A – Controlled Waste Categories and Descriptions of the *Environmental Protection (Controlled Waste) Regulations 2004;*

"Director" means Director, Environmental Regulation Division of the Department of Environment and Conservation for and on behalf of the Chief Executive Officer as delegated under Section 20 of the *Environmental Protection Act 1986*;

"Director" for the purpose of correspondence means-

Regional Leader, Industry Regulation
Booragoon Office, Swan Region
Department of Environment and Conservation
Locked Bad 104 Telephone: (08) 9333 7510
Bentley Delivery Centre WA 6983 Facsimile: (08) 9333 7550;

"chemical scrubbing system" means a chemical scrubbing system for the removal of odorous compounds;

"continuous monitor" means a monitor that measures the instantaneous concentration of exit gas every fifteen minute;

"covers" means metallic or non-metallic covers used to cover the pre-treatment, primary treatment and secondary aeration areas of the treatment plant;

"histogram" means a chart, graph or table showing the results of specified monitoring over a specified interval;

"Inspector" means person appointed to be an inspector under section 88 of the *Environmental Protection Act 1986;*

"licensed" means licensed or registered under the *Environmental Protection Act 1986* unless otherwise specified;

"monitoring period" means 1 July to 30 June;

"NATA" means National Association of Testing Authorities;

"plant" means the Beenyup WWTP;

"sewage treatment" means the activity under which the premises is prescribed, and includes the treatment of sewage and the discharge of treated wastewater onto land or into waters;

"sensitive receptor' means any land or building that is used as a residence, guest house, hotel, motel, caravan park, school, church, hospital, or as an office or consulting rooms, where such office or consulting rooms are not located in an industrial area;

"STP, dry" means standard temperature and pressure (0°C and 101.325 kilopascals);

"scrubber stack 1" means the stack from the chemical scrubbing system;

"scrubber stack 2" means the stack from the carbon scrubbing system;

"Ocean Reef Outlet" means Ocean Reef Outlet extending 1.8 kilometres off the shore; and

"USEPA" means United States Environmental Protection Agency.

ANNUAL ENVIRONMENTAL REPORT

1 The licensee shall submit to the Director, by **1 September** each year, an Annual Environmental Report providing the following information obtained during the monitoring period from 1 July to 30 June:

(i) A histogram showing the monthly recorded average flow rate, temperature and concentration of hydrogen sulphide being emitted through the scrubber stack, measured in accordance with condition 4;

(ii) A histogram showing the daily maximum and daily average concentrations of hydrogen sulphide emitted through the scrubber stack, as measured in accordance with condition 5;

(iii) A histogram showing the reliability of the continuous monitor against the bench marks of 90% of the time in a calendar month and 95% of the time over monitoring period of a year;

(iv) A histogram showing the volumes of treated wastewater discharged each month through the Beenyup Ocean Outlet;

(v) A histogram showing the monthly average loadings for total phosphorus and total nitrogen in treated wastewater discharged to the ocean from BeenyupWWTP through the Beenyup Ocean Outlets in kg/day;

(vi) A histogram showing the results of treated wastewater monitoring as per condition 10(b) including duplicate NATA accredited laboratory results;

(vii) A histogram showing the number of complaints received by the licensee over the reporting period.

ANNUAL AUDIT COMPLIANCE REPORT

2 The licensee shall by 1 September in each year, provide to the Director an Annual Audit Compliance Report in the form in Attachment 2 to this licence, signed and certified in the manner required by Section C of the form, indicating the extent to which the licensee has complied with the conditions of this licence, and any previous licence issued under Part V of the Act for the premises, during the period beginning 1 July the previous year and ending on 30 June in that year.

COMPLAINTS

3 The licensee shall keep a written record of all complaints received at the premises. The record must be dated and provide the following information (if known):

(i) date and time of complaint;
(ii) location about which the complaint was made;
(iii) general description of the nature of complaint;
(iv) wind direction, wind speed and temperature at the time of the complaint;
(v) likely source of the reported problem; and
(vi) action taken in response to the complaint.

This record, or copies thereof, shall be made available to the inspector on request.

OPERATIONAL ODOUR EMISSION MONITORING

4 The licensee shall operate and maintain a continuous hydrogen sulphide monitor in accordance with the manufacturer's instructions to measure and record the concentration of hydrogen sulphide emitted from the scrubber located within the premises.

ODOUR CONTROL STACK - MANUAL MONITORING

5 The licensee shall monitor each of the parameters stated in column 1 of Table 1, at the locations stated in column 2 of Table 1, at the frequency stated in column 3 of Table 1 using the methods specified in column 4 of Table 1, and record the results in the units specified in column 5 of Table 1.

Table 1: Odour control stack – manual monitoring

Column 1	Column 2	Column 3	Column 4	Column 5
Parameters	**Measurement and sampling locations**	**Monitoring frequency**	**Sampling method**	**Units**
Hydrogen sulphide	Scrubber stack 1 and scrubber stack 2	March, June, September and December	NATA accredited method for the measurement and analysis of hydrogen sulphide emissions from stationary sources	mg/ m^3 at STP, dry
Volumetric flow rate			USEPA method 2	m^3/s at STP, dry and at STP, wet
Stack exit temperature			n/a	°C

ODOUR CONTROL STACK- TARGET

6 The licensee shall operate the plant to achieve a hydrogen sulphide emission target of less than 1.5 ppm at the stack outlet as monitored in accordance with the condition 4 of this licence.

ODOUR CONTROL STACK– LIMITS

7 The licensee shall ensure that the emission of the parameter specified in Column 1 of Table 2, from the locations stated in column 2 of Table 2, do not exceed the concentration limits specified in column 3 and 4 of Table 2.

Table 2: Odour Control stack emission limits

Column 1	Column 2	Column 3	Column 4
Parameter	**Location**	**Concentration limit**	**Mass emission rate limit**
Hydrogen sulphide	Scrubber stack 1	5mg/m³ at STP, dry	0.20g/s at STP, dry
	Scrubber Stack 2		0.19g/s at STP, dry

8 The licensee shall notify the Director, in writing, before 5pm on the next usual business day after becoming aware of any confirmed measurement which indicates that an emission target as specified in condition 6 or an emission limit as specified in condition 7 has been exceeded and the notification shall include:

(i) the date and time of the exceedance;
(ii) production rate at time of exceedance;
(iii) the cause of the exceedance;
(iv) an estimate of the period over which the limit was exceeded;
(v) an indication of known or potential environmental impacts;
(vi) corrective actions taken or planned to mitigate environmental consequences resulting from the exceedance; and
(vii) corrective action taken or planned to prevent a recurrence of the exceedance.

ODOUR CONTROL CONDITIONS

9 The licensee shall ensure that odour emitted from the premises does not unreasonably interfere with the health, welfare, convenience, comfort or amenity of any person at a sensitive receptor.

DISCHARGE TO WATER

MONITORING OF DISCHARGED TREATED WASTEWATER

10(a) The licensee shall monitor and record the cumulative monthly volumes of treated wastewater being discharged to the ocean via Ocean Reef ocean outlet.

10(b) The licensee shall monitor the concentration of the parameters stated in column 1 of Table 3, at the monitoring frequency stated in column 2 of Table 3, within treated wastewater being discharged from the Beenyup WWTP to the ocean through the Ocean Reef Ocean Outlet at the treated wastewater sampling point and the results shall be recorded in the units stated in column 3 of Table 3.

Table 3: Monitoring of discharged treated wastewater

Column 1 **Parameters**	Column 2 **Monitoring frequency**	Column 3 **Units**
Total Nitrogen, Total Phosphorus	Monthly	Kilograms per day (monthly average)
pH	Six monthly	pH unit
E.Coli		Most probable number per 100 ml
Total dissolved soilds, Total suspended solids, 5-Day Biochemical Oxygen Demand (filtered), Oil and Grease, Arsenic, Cadmium, Copper, Chromium, Lead, Mercury, Nickel and Zinc		mg/l

10(c) The licensee shall ensure that all water samples are collected, handled and preserved in accordance with the relevant parts of the Australian Standard 5667.

10(d) The licensee shall ensure that all water samples are analysed in accordance with the current "Standard Methods for Examination of Water and Wastewater," APHA-AWWA-WEF.

10(e) The licensee shall analyse all water samples, required to be monitored by any condition of this licence, in its own laboratory, or ensure that samples are analysed in a laboratory holding NATA accreditation for the analyses specified. If the licensee uses its own laboratory, then at least one set of samples per year shall also be submitted to a laboratory holding NATA accreditation for the analysis specified.

TOTAL PHOSPHORUS AND NITROGEN LOAD LIMIT

11(a) The licensee shall ensure that the load for total phosphorus in treated wastewater discharged from the Beenyup WWTP to the ocean through the Ocean Reef ocean outlet does not exceed an annual average of 1500 kilograms per day recorded over the financial year.

11(b) The licensee shall ensure that the load for total nitrogen in treated wastewater discharged from the Beenyup WWTP to the ocean through the Ocean Reef ocean outlet does not exceed an annual average of 3600 kilograms per day recorded over the financial year.

TANKERED WASTE

12 The licensee may accept biological wastes category 1.02 and 1.05 (from other Water Corporation assets) tankered into the premises at the pre-treatment works of the sewage treatment plant. The waste shall be delivered to the plant via an enclosed pipeline.

DISCHARGE TO LAND

MANAGEMENT OF PROCESS SOLID WASTES

13(a) The licensee shall dispose of all collected grit and screenings from the pre-treatment area to a licensed or registered landfill.

13(b) The licensee shall dispose of sludge and biosolids in accordance with the document *Western Australian Guidelines for Direct Land Application of Biosolids and Biosolids Products*, Department of Environmental Protection, Water and Rivers Commission and Department of Health (February, 2002) (as amended).

ATTACHMENT 1

LICENCE NUMBER: L7882/1992/14 **FILE NUMBER:** DEC625-02

PLAN OF PREMISES

BeenyupWWTP

LICENCE NUMBER: L7882/1992/14 **FILE NUMBER:** DEC625-02

ANNUAL AUDIT COMPLIANCE REPORT

SECTION A

LICENCE DETAILS

Licence Number:	Licence File Number:
Company Name: Trading as:	ABN:
Reporting period: _____ to _____	

STATEMENT OF COMPLIANCE WITH LICENCE CONDITIONS

1. Were all conditions of licence complied with within the reporting period? (please tick the appropriate box)

Yes □ Please proceed to Section C
No □ Please proceed to Section B

Each page must be initialed by the person(s) who signs Section C of this annual audit compliance report

INITIAL:_____

LICENCE NUMBER: L7882/1992/14 **FILE NUMBER:** DEC625-02

SECTION B - DETAILS OF NON-COMPLIANCE WITH LICENCE CONDITION.

Please use a separate page for each licence condition that was not complied with.

a) Licence condition not complied with?
b) Date(s) when the non compliance occurred, if applicable?
c) Was this non compliance reported to DEC?
☐ Yes ☐ Reported to DEC verbally Date _____ ☐ No ☐ Reported to DEC in writing Date _____
d) Has DEC taken, or finalised any action in relation to the non compliance?
e) Summary of particulars of non compliance, and what was the environmental impact?
f) If relevant, the precise location where the non compliance occurred (attach map or diagram)
g) Cause of non compliance
h) Action taken or that will be taken to mitigate any adverse effects of the non compliance
i) Action taken or that will be taken to prevent recurrence of the non compliance

Each page must be initialed by the person(s) who signs Section C of this annual audit compliance report

INITIAL:_____

LICENCE NUMBER: L7882/1992/14 **FILE NUMBER:** DEC625-02

SECTION C - SIGNATURE AND CERTIFICATION

This Annual Audit Compliance Report may only be signed by a person(s) with legal authority to sign it. The ways in which the Annual Audit Compliance Report must be signed and certified, and the people who may sign the statement, are set out below.
Please tick the box next to the category that describes how this Annual Audit Compliance Report is being signed. If you are uncertain about who is entitled to sign or which category to tick, please contact the licensing officer for your premises.

If the licence holder is		The Annual Audit Compliance Report must be signed and certified:
an individual	☐	by the individual licence holder, or
	☐	by a person approved in writing by the Chief Executive Officer of the Department of Environment and Conservation to sign on the licensee's behalf.
A firm or other unincorporated company	☐	by the principal executive officer of the licensee; or
	☐	by a person with authority to sign on the licensee's behalf who is approved in writing by the Chief Executive Officer of the Department of Environment and Conservation.
A corporation	☐	by affixing the common seal of the licensee in accordance with the Corporations Act 2001; or
	☐	by two directors of the licensee; or
	☐	by a director and a company secretary of the licensee, or
	☐	if the licensee is a proprietary company that has a sole director who is also the sole company secretary – by that director, or
	☐	by the principal executive officer of the licensee; or
	☐	by a person with authority to sign on the licensee's behalf who is approved in writing by the Chief Executive Officer of the Department of Environment and Conservation.
A public authority (other than a local government)	☐	by the principal executive officer of the licensee; or
	☐	by a person with authority to sign on the licensee's behalf who is approved in writing by the Chief Executive Officer of the Department of Environment and Conservation.
a local government	☐	by the chief executive officer of the licensee; or
	☐	by affixing the seal of the local government.

It is an offence under section 112 of the *Environmental Protection Act 1986* for a person to give information on this form that to their knowledge is false or misleading in a material particular. There is a maximum penalty of $50,000 for an individual or body corporate.

I/We declare that the information in this annual audit compliance report is correct and not false or misleading in a material particular.

SIGNATURE: _____ SIGNATURE: _____

NAME: (printed) _____ NAME: (printed) _____

POSITION: _____ POSITION: _____

DATE: ____/____/____ DATE: ____/____/____

SEAL (if signing under seal)

Government of Western Australia
Department of Environment and Conservation

ENVIRONMENTAL ASSESSMENT REPORT

LICENCE NUMBER:L7882/1991/14
LICENCE FILE NUMBER: DEC625-02
APPLICATION DATE: 31/08/2011
EXPIRY DATE: 31 October 2016

PREMISES DETAILS

LICENSEE AND OCCUPIER
Water Corporation
629 New Castle Street
LEEDERVILLE WA 6007
ABN: 28 003 434 917

PREMISES
Beenyup Wastewater Treatment Plant (WWTP)
Lot 8278 on Plan 30778
Ocean Reef Road
CRAIGIE WA 6025

PRESCRIBED PREMISES SUMMARY

Table 1: Prescribed premises summary

Category number*	Category Description*	Category Production or Design Capacity*	Premises Production or Design Capacity#	Premises Fee Component**
54	Sewage facility: premises – a) on which sewage is treated (excluding septic tanks); or b) from which treated sewage is discharged onto land or into waters.	100 cubic metres or more per day	135,000 cubic metres per day	More than 2000 cubic metres per day
61	Liquid waste facility: premises on which liquid waste produced on other premises (other than sewerage waste) is stored, reprocessed, treated or irrigated	100 tonnes or more per year	50,000 tonnes per year	More than 10,000 but not more than 100,000 tonnes per year

* From Schedule 1 of the Environmental Protection Regulations 1987
# From application
** From Schedule 4 of the Environmental Protection Regulations 1987

This Environmental Assessment Report (EAR) has been drafted for the purposes of detailing information on the management and mitigation of emissions and discharges from the prescribed premises. The objective of the EAR is to provide a risk assessment of emissions and discharges, and information on the management of other activities occurring onsite which are not related to the control of emissions and discharges from the prescribed premises activity. This does not restrict the Department of Environment and Conservation (DEC) to assessing only those emissions and discharges generated from the activities that cause the premises to become prescribed premises.

Basis of Assessment
Beenyup WWTP, which has been assessed as a "prescribed premises" under category numbers 54 and 61, within Schedule 1 of the *Environmental Protection Regulations 1987*.

- Category 54: sewage facility: premises – (a) on which sewage is treated (excluding septic tanks); or (b) from which treated sewage is discharged onto land or into waters; and
- Category 61: liquid waste facility: premises on which liquid waste produced on other premises (other than sewerage waste) is stored, reprocessed, treated or irrigated.

The Beenyup WWTP serve's Perth's rapidly developing northern suburbs from Quinns Rock through to Scarborough and inland through Dianella and Bayswater to the foothills east of Midland. Sewage enters the WWTP via pipelines by gravity. The current throughput of the facility is about 122 ML (Mega litres) per day. At present, the facility is licensed to accept 135 ML per day. With the recent upgrade of the plant, the annual throughput may go up to 150 ML.

1.0 BACKGROUND

1.1 GENERAL COMPANY DESCRIPTION

The Water Corporation (WC) provides water and wastewater services to Perth and hundreds of towns and communities spread over 2.5 million square kilometres of Western Australia. They also provide drainage and irrigation services to thousands of households, businesses and farms across the state. WC holds many licences for WWTP's with DEC.

WC has an environmental policy available on its website and operates to an environmental management system which enables the systematic identification of environmental risks, setting of targets and development of environment improvement plans to reduce risks and ensure its activities are sustainable. WC is heavily involved with a diverse range of environmental programs and ongoing sponsorship programs.

1.2 LOCATION OF PREMISES

Beenyup WWTP is located at Lot 8278 on Plan 30778 Ocean Reef Road, Craigie, Western Australia. The plant has been operating at this premises since 1972. A major upgrade of the plant in terms of odour control has been completed recently. The site is bounded by the Mitchell Freeway to the east, Ocean Reef Road to the north, the residential suburb of Craigie to the west and Craigie Open Space, an area of regionally significant bushland, to the south. The site has a number of land uses, including its primary function, wastewater treatment.

1.3 EXISTING ENVIRONMENT

1.3.1 Adjacent land use

Beenyup WWTP is located directly south of the Groundwater Replenishment Trial facility. Other land uses on site include areas of Radiata Pine, Bush Forever Site 303 and bushland areas outside of the Bush Forever site. These bushland areas consist of a mixture of vegetation communities varying in condition from quite good to highly degraded. Commercial land at the northern boundary of the Beenyup site occupies 5 ha and includes a depot site with workshops and a bitumen lay-down storage area. Additionally, WC's Construction Branch occupies 0.6ha south of the commercial area, which consists of a bitumen lay-down hardstand area for the storage of pipes and equipment used in water and sewer reticulation mains repairs.

1.3.2 Bush Forever Site 303

The Beenyup site contains 24.5ha of land designated Bush Forever (site 303). This area occurs as a number of remnant bush islands that accompany a greater area of bushland along the eastern boundary of the site. The surrounding bushland varies in quality from quite good to highly degraded. Currently the Beenyup Site Management Plan provides management planning and actions to manage the potential effect of WC activities on the Bush Forever land.

1.3.3 Geology

The sub-surface geology of the site is generally made up of Quaternary Age sands of the Bassendean sand unit (Bennett Environmental Consulting, 2006). The sands are typically pale to darker olive yellow in colour and are medium to course with evidence of sub-rounded quartz and trace quantities of moderately sorted residual feldspar. They are derived from local weathering of the underlying Tamala Limestone.

A large stretch of the Quindalup dune system occurs along the western margin of Beenyup site and the Craigie Open Space, commencing at the southern boundary of Warrandyte Reserve to the north through to Whitfords Avenue to the south. WC has acquired 2.7ha of the dune, from Warrandyte Reserve southwards to the pine log steps. The remaining section of the dune, in addition to Craigie Open Space, is vested to the City of Joondalup for management. Remnant vegetation covers the dune, but it is relatively disturbed by human impacts such as rubbish dumping, weed invasion and localised erosion.

1.3.4 Flora, Vegetation and Fauna

The Beenyup site is included in the Karrakatta Vegetation Complex – Central and South. The vegetation of the Karrakatta Complex – Central and South is described as predominantly an Open Forest of *Eucalyptus gomphocephala*, *Eucalyptus marginate* subsp. *marginate* and *Corymbia calphylla* and a Woodland of *Eucalyptus marginate* subsp. *marginate* – Banksia species (Bennett Environmental Consulting, 2005).

A flora, vegetation and fauna survey was conducted for the general Beenyup site (including the Bush Forever Site) for the Beenyup Site Management Plan (Bennett Environmental Consulting, 2006). No Declared Rare or Priority Flora was recorded in the survey area and there is no known *Phytophthora* dieback at the site.

1.3.5 Contaminated Sites

A site approximately 150m to the north of the Beenyup site was reported to DEC in May 2007 as a 'suspected site', the assessment is still ongoing. The proposed construction works for the upgrade does not disturb the suspected contamination to the north.

1.3.6 Groundwater

The Perth Groundwater Atlas indicates the historical maximum water table level at the site is at 4.0m AHD, corresponding to 17-19m below current ground level. A dissipation test at the site indicated that the water table was present at 18.1m below ground level (3.6m AHD) (Worley Parsons, 2007); therefore, interference of plant structural and civil elements by groundwater is not expected.

The Beenyup site is located in a Priority 3 Perth Coastal Underground Water Pollution Control Area.

1.4 PROCESS DESCRIPTION

Sewage entering the plant passes through bar screens that remove materials such as paper, rags and other large objects from the flow and mechanically rake the material into a screw conveyor. The material is then pressed and disposed of in a DEC licensed landfill.

After screening, the wastewater flows into circular grit removal tanks, aerated to allow the inorganic material to settle and the organic material to pass through very slowly to large rectangular primary sedimentation tanks allowing about 50 per cent of the suspended solids to settle out as sludge. Sludge is collected by scraper mechanism and pumped to the solids handling area for thickening and digestion.

The treated wastewater leaving the primary tanks called primary treated wastewater passes to secondary treatment tanks. Secondary treatment is achieved in aeration tanks by the activated sludge process where ideal conditions are provided for microbiological life to grow rapidly and consume the organic material in the wastewater. Microorganisms require oxygen to survive and this is provided by blowers which inject air through fine bubble dome diffusers on the floor of the tanks.

Following aeration, the treated wastewater passes slowly through circular clarifiers in which the activated sludge settles leaving a high quality secondary effluent.

The settled sludge containing micro-organisms is rapidly removed using scrapers and is returned to the aeration tanks.

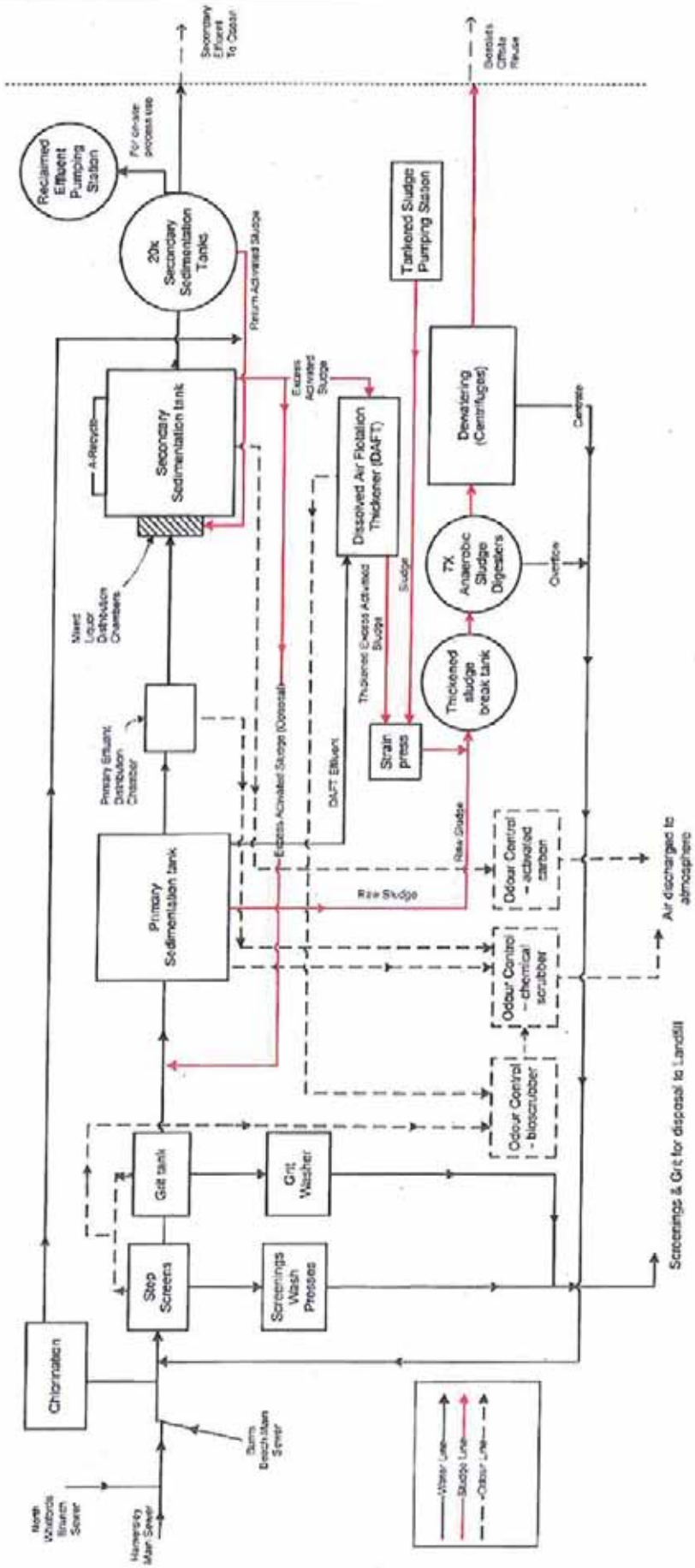
Solids removed from the primary sedimentation tanks and excess solids produced by the activated sludge process are thickened and fed to the anaerobic digesters. Following digestion, the sludge is mechanically dewatered to produce a biosolid suitable for use as a soil conditioner.

Secondary treated wastewater flows by gravity to the Indian Ocean in the vicinity of the Marmion Marine Park and is discharged into 10 metres of water via two outlets, one 1850 metres and the other one 1650 metres offshore where it is rapidly diluted and dispersed.

The throughput of the plant may increase to 135 mega litres per day with the recent upgrade of the plant (W4090/1991/1). The upgrade to the plant includes the following:

1. Construction of four secondary sedimentation tanks;
2. building three sludge thickeners;
3. construction of three sludge digesters;
4. installation of sludge dewatering centrifuge;
5. building additional grit washer;
6. construction of an odour scrubber system;
7. installation of an enclosed sludge load out facility;
8. installation of additional covers and duct work

Beenyup WWTP flow chart is shown below in Figure 1.



Beenyup WWTP_Basic Plant Flow Diagram

Odour Control
The Beenyup WWTP has the potential for causing odour emissions which can affect health, welfare, amenity of people if not properly managed.

The facility services northern suburbs, thus wastewater will travel in the sewers for hours before it reaches the treatment plant. Biological activity in sewers decomposes some of the organic material present in sewage and the wastewater arriving at the WWTP is odourous. Hydrogen sulphide and other sulphur-containing compounds will cause most of the odour from the inlet sewer and primary treatment tanks.

The plant odour control incorporates mechanical, chemical and biological treatment approaches. Mechanical odour control is to be through coverings and ventilation ducts. The inlet sewer, screening, primary treatment tanks, secondary treatment tanks are covered and ventilated in order to prevent fugitive emissions of odorous gases. Covers on the tanks and connecting channels have access hatches for operations and monitoring purposes. The covers are designed to minimise odour leakage and ensure negative pressure under the covers during normal operation. Odourous air will be extracted from beneath the covers and conveyed to scrubbers in fibreglass reinforced plastic ducts. A system of dampers at each extraction point will control the amount of air extracted. In addition key mechanical equipment such as extraction fans, odour scrubbers, chemical pumps are installed with stand-by capacity.

The odour treatment system incorporates biological and chemical air treatment to remove odour causing compounds. The odourous air from the odour sources will be ducted to the odour treatment system for the removal of odourous compounds. Odourous air from the secondary tanks will be treated with carbon column prior to its discharge to the environment via 50 m tall stack.

Overall, the odour treatment system will significantly remove hydrogen sulphide and reduce the odour level of the air before it is discharged to the environment through a nominal 50 metre tall emission stack.

Sludge Out-loading Facility:
The WWTP has been upgraded with a new sludge load out facility. The design of the new sludge load out facility allows for the steel lids to be retracted within the odour enclosure, ensuring the system provides full containment of odour. Trucks will remain in the enclosure for 1 complete air-change after the steel lids are closed. The doors are then opened allowing the trucks to exit.

Additional Stack:
A new 50m tall and 2.6m diameter stack has been constructed in addition to the existing 50 m tall and 2m diameter stack which will have a combined capacity of 342,000m3/h air flow and plant capacity to treat 135 ML/day.

Odour model predications suggest the highest predicted ground level concentrations from the two stacks of 2 Odour Units (OU) occurs within a small zone to the west and north-west, and on the south boundary of the treatment plant. There is a zone above 1.5 OU to the west of the plant and a smaller zone above 1.5 OU to the south-east. All predicted concentrations of the contribution from the new larger stack are below 5 OU.

Ocean Outlet
The Beenyup ocean outlet will discharge average flows of treated wastewater of up to 135ML/day in approximately 10m of water via a 200m long diffuser. This will be located at

the end of the discharge pipe. The outlet is designed to maximise the efficient dilution of the treated wastewater by spreading the discharge along the diffuser via 50 individual ports (~125mm diameter) located laterally along the last 200 metres of the pipe. As the effluent rises to the surface from each port, it mixes with surrounding seawater. The initial dilution is about 50 times and further dilution is achieved by dispersion by wind driven currents. Under the Ministerial statement 569, July 2001, the nutrients load discharged to the ocean shall not be more than 3600 kg per day for nitrogen and 1700 kg per day for phosphorus.

1.5 REGULATORY CONTEXT

1.5.1 Part IV Environmental Protection Act 1986, Environmental Impact Assessment

Beenyup WWTP has been assessed under Part IV of the *Environmental Protection Act 1986.* The Office of the Environmental Protection Authority (OEPA) assessed two proposals from WC relating to Beenyup WWTP. They are as follows:

- Beenyup wastewater Ocean Outlet Duplication into Marmion Marine Park. OEPA assessment Bulletin 393, Statement 101, January 1990;
- Change of Environmental Conditions – Beenyup Ocean Outfall Duplication into Marmion Marine Park. OEPA assessment Bulletin 762, Statement No. 382, March 1995; and
- Change of Environmental Conditions - Beenyup Ocean Outfall Duplication into Marmion Marine Park, Statement No. 569, July 2001.

This premises is bound by Ministerial Conditions for its operation, which should be considered in conjunction with this licence. The Ministerial Conditions were amended in July 2001 to allow the load of phosphorus discharged at the ocean outlet to be greater. The increase was approved because it has been demonstrated that nitrogen is the limiting factor in algal growth in the particular body of water subject to the discharge.

1.5.2 Part V Environmental Protection Act 1986, Environmental Management

The Beenyup WWTP has been assessed as a "prescribed premises" under Category 54 within Schedule 1 of the *Environmental Protection Regulations 1987* and requires a licence for the operation of the WWTP.

DEC will also administer the following regulations to regulate various activities associated with the WWTP:

- *Environmental Protection (Controlled Waste) Regulations 2004*
- *Environmental Protection (Clearing of Native Vegetation) Regulations 2004*
- *Environmental Protection (Noise) Regulations 1997*
- *Environmental Protection (Unauthorised Discharges)Regulations 2004*

The guidelines that also apply to this premises include:

- *Limits and Targets for Prescribed Premises Policy,* Department of Environment and Conservation (April, 2006).
- *Regulatory Monitoring Requirements for Prescribed Premises,* Department of Environment and Conservation (April, 2006).
- *A Guide to Clearing Permits under the Environmental Protection Act 1986*, Department of Environment and Conservation, June 2005.
- *A Guide to the Exemptions and Regulations for Clearing Native Vegetation under the Environmental Protection Act 1986*, Department of Environment and Conservation, June 2005.

- *Land development sites and impacts on air quality - A Guideline for the Prevention of Dust and Smoke Pollution from Land Development Sites in Western Australia* (Department of Environment and Conservational Protection, 1996)
- *Australian Guidelines for Sewerage Systems – Effluent Management* (ANZECC 1997).
- *EPA Guidance Statement No. 3 – Separation Distances between Industrial and Sensitive Land Uses*
- *EPA Draft Guidance Statement No. 8 – Environmental Noise*
- *EPA Draft Guidance Statement No. 47 – Interim guidance on odour as a relevant environmental Factor*
- *EPA Guide – Interim industry consultation guide to community consultation*
- *Western Australian Guidelines for Direct Land Application of Biosolids and Biosolids Products*, Department of Environmental Protection, Water and Rivers Commission and Department of Health (February, 2002)

1.5.3 Other Decision Making Authorities' Legislation which applies

Department of Mines and Petroleum (DMP) for the storage of chemicals;
Local Government Act 1995; and
Health Act 1911.

1.5.4 Local Government Authority

Beenyup WWTP is located within the City of Joondalup.

2.0 STAKEHOLDER AND COMMUNITY CONSULTATION

SUBMISSIONS RECEIVED DURING 21 DAY PUBLIC COMMENT PERIOD

The Application for licence for this facility was advertised in the West Australian newspaper on 19/09/2011 as a means of advising stakeholders and to seek public comments. No submissions were received.

3.0 EMISSIONS AND DISCHARGES RISK ASSESSMENT

DEC considers that conditions should focus on regulating emissions and discharges of significance. Where appropriate, emissions and discharges which are not significant should be managed and regulated by other legislative tools or management mechanisms.

The following section assesses the environmental risk of potential emissions from the Beenyup WWTP facility. In order to determine the site's appropriate environmental regulation, an emissions and discharges risk assessment was conducted of the Beenyup WWTP facility using the environmental risk matrix outlined in Appendix B. The results of this are summarised in Table 2.

Table 2: Risk assessment and regulatory response summary table.

Risk factor	Significance of emissions	Socio-Political Context of Each Regulated Emission	Risk Assessment	DEC Regulation (EP Act - Part V)	EAR Reference	Other management (legislation,tools,agencies)
Dust emissions	1. Dust emission from the plant is insignificant	No interest	E – No regulation	LIC – no condition	N/A	General provisions of the *Environmental Protection Act 1986* relating to pollution and environmental harm.
Odour emissions	5 –Significant. Odours will primarily be in the form of hydrogen sulfide and volatile organic compounds. Odourous air will be extracted from the inlet works, primary tanks, secondary treatment tanks, and sludge storage facilities, sludge loading and unloading area, passed through a biological scrubber and chemical scrubber and vented to a nominal 50 metre tall stack. Odour control is managed by covering and sealing inlet , primary treatment tanks, secondary treatment tanks, sludge storage, biosolids loading and unloading raeas and directing odourous gas from these odour sources to biological and chemical odour scrubbing system. Most of the odourous compounds (hydrogen sulphide and volatile organic compounds) are removed from the exiting gas by the scrubbers before the gas exits through a 50m tall stack.	High. Community concern is strong. Distance to interested parties is approximately 200m	B – condition (LIC – limits condition) (setting targets) (emission management condition)	LIC– require condition	Apendix A Section 1.1	General provisions of the Environmental Protection Act 1986.
Noise emissions	1. Not significant	No community interest	E – No regulation	LIC– No condition is required	N/A	EP Noise Regulations, Code of Practice, EMP or EMS
Light emissions	1. Not significant	No community concern	E – No regulation	LIC– No licence condition is required	N/A	DEC, EMP or EMS, General provisions of the EP Act

Discharges to water	3 – Somewhat significant. Secondary treated wastewater will be discharged via two ocean outlets (1850m & 1650 m) offshore into the marine environment of the Indian Ocean at a depth of 10m into deep water and open ocean conditions. Under the Ministerial Statement No. 569, nitrogen and phosphorus load discharged into the ocean shall not be more than 3600 kg and 1700 kg per day respectively . WC is also required to monitor heavy metals, BOD and coliform	There is some community interest	B – condition (Limits for nitrogen and phosphorus), monitoring of heavy metals and bacteria.	LIC – require conditions	Appendix A Section 1.2	Ministerial Condition for nutrients (nitrogen and Phosphorus) load discharged to the ocean via ocean outlet. UD Regulations, Code of Practice EMP or EMS
Discharges to land	1. Not significant. WC irrigates its plantation areas within the premises	No community concern	E - No regulation	LIC – No condition is required	N/A	UD Regulations, Code of Practice EMP or EMS
Solid / liquid wastes	1. Not significant. Disposal of biosolids will be in accordance with *WA Guidelines for Direct Land Application of Biosolids and Biosolids Products 2002.*	No community concern	E – no regulation	LIC – No condition is required.		Controlled Waste Regs, EMS
Hydrocarbon/ chemical storage	1. Chemical storages have been constructed in accordance with the dangerous goods regulations.	No community concern	D – regulation is required	LIC – require conditions	N/A	Dangerous Goods storage licence and relevant legislation (DOCEP), EMS
Native vegetation clearing	N/A	N/A	N/A	LIC – No conditions	N/A	Clearing permit pending (DMP), EMS
Contaminated site identification	NA	N/A	N/A	LIC – No conditions	N/A	Contaminated Sites Branch (DEC), Tenement Conditions and Closure Plan (DOIR), EMS

4.0 GENERAL SUMMARY AND COMMENTS

Beenup WWTP is an existing sewage facility servicing northern suburbs since 1972. The WWTP has been recently upgraded to increase the daily throughput from 120 ML to 135 ML per day. The plant has been substantially upgraded in terms of odour emission control which includes among others:

- a biological odour scrubber system coupled with the existing chemical scrubber;
- a carbon column odour scrubbing system dedicated to the secondary tanks;
- two new digesters in addition to five existing digesters;
- enclosed biosolid storage and loading area; and
- a 50m tall and 2.6m diameter stack.

The existing licence for Beenyup WWTP has been reviewed and a new licence drafted for the premises. However, the WWTP has the potential to cause odour emission and it requires regulation. Licence conditions have been set to minimise odour emissions from the premises. DEC considers that WC is required to adhere to its odour management plan to ensure odour does not does not unreasonably interfere with the health, welfare, convenience, comfort or amenity of any person at a sensitive receptor.

Secondary treated water will be discharged to the ocean via Beenyup ocean outlet. As per Ministerial statement 569, July 2001, the nutrients load discharged to the ocean shall not be more than 3600 kg per day for nitrogen and 1700 kg per day for phosphorus. Licence conditions have been set to reflect the nutrient limits.

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APPENDIX A: EMISSIONS AND DISCHARGES OF SIGNIFICANCE

1.1 ODOUR EMISSIONS

Beenyup WWTP has the potential to generate odour emissions from the site. Unless an adequate odour management system is in place, odour may impact the amenity of land users surrounding the plant.

The sources of odour at the plant include but not limited to the following:

- inlet;
- screening;
- primary tanks;
- secondary tanks;
- sludge loading and unloading area;
- digesters and bio gas; and
- fugitives from leaks, opening of covers.

The main constituent of odour from the WWTP is hydrogen sulphide with minor percent of sulphur containing compounds. Majority of hydrogen sulphide will be removed from odourous air by biological and acid scrubber system before exiting through 50m tall stack.

At Beenyup WC's environmental objective for odour reduction at the WWTP is to ensure that the 5 OU contour (99.9th percentile, 1-hour average, Australian Standard threshold certainty Odour Unit), predicted using the specific odour model developed to simulate conditions at the Beenyup WWTP, falls within 600m buffer distance. At Beenyup residential development has been encroached within just over 200 metres from the premises boundary.

Odour model predications suggest the highest predicted ground level concentrations from the two stacks of 2 Odour Units (OU) occurs within a small zone to the west and north-west, and on the south boundary of the treatment plant. There is a zone above 1.5 OU to the west of the plant and a smaller zone above 1.5 OU to the south-east. All predicted concentrations of the contribution from the new larger stack are below 5 OU.

ODOUR EMISSIONS RISK ASSESSMENT

The environmental risk of odour emission is set at medium high considering community concern about odour from the premises and in accordance with Appendix B: Emissions and Discharges risk assessment matrix.

RECOMMENDED STRATEGY FOR MANAGING ODOUR EMISSIONS

The issue of odour emissions require regulation. Accordingly, licence conditions have been set requiring continuous monitoring of hydrogen sulphide on the exiting air from the scrubber system before discharging through 50m tall stack, stack monitoring to meet licence criteria. WC is required to adhere to its Odour Management Plan.

1.2 DISCHARGES TO WATER

Secondary treated water is discharged to the ocean via Beenyup ocean outlet. Secondary treated wastewater is also directed to WC's groundwater replenishment plant.

DISCHARGES TO WATER RISK ASSESSMENT

WC has been monitoring marine environment surrounding the discharge point and provides the report to the Marine Branch of DEC. The impact on the marine environment appears to be insignificant.

RECOMMENDED STRATEGY FOR MANAGING DISCHARGES TO WATER

The issue of water discharges require regulation. Under the Ministerial statement 569, July 2001, the nutrients load discharged to the ocean shall not be more than 3600 kg per day for nitrogen and 1700 kg per day for phosphorus. Licence conditions have been set to reflect the nutrient limits.

APPENDIX B: EMISSIONS AND DISCHARGES RISK ASSESSMENT MATRIX

Table 3: Measures of Significance of Emissions

Emissions as a percentage of the relevant emission or ambient standard		Worst Case Operating Conditions (95th Percentile)			
		>100%	50 – 100%	20 – 50%	<20%*
Normal Operating Conditions (50th Percentile)	>100%	5	N/A	N/A	N/A
	50 – 100%	4	3	N/A	N/A
	20 – 50%	4	3	2	N/A
	<20%*	3	3	2	1

*For reliable technology, this figure could increase to 30%

Table 4: Socio-Political Context of Each Regulated Emission

		Relative proximity of the interested party with regards to the emission				
		Immediately Adjacent	Adjacent	Nearby	Distant	Isolated
Level of Community Interest or Concern*	5	High	High	Medium High	Medium	Low
	4	High	High	Medium High	Medium	Low
	3	Medium High	Medium High	Medium	Low	No
	2	Low	Low	Low	Low	No
	1	No	No	No	No	No

Note: These examples are not exclusive and professional judgement is needed to evaluate each specific case

*This is determined by DEC using the DEC "Officer's Guide to Emissions and Discharges Risk Assessment" May 2006.

Table 5: Emissions Risk Reduction Matrix

		Significance of Emissions				
		5	4	3	2	1
Socio-Political Context	High	A	A	B	C	D
	Medium High	A	A	B	C	D
	Medium	A	B	B	D	E
	Low	A	B	C	D	E
	No	B	C	D	E	E

PRIORITY MATRIX ACTION DESCRIPTORS
A = Do not allow (fix)
B = licence condition (setting limits + EMPs - short timeframes)(setting targets optional)
C = licence condition (setting targets + EMPs - longer timeframes)
D= EIPs, other management mechanisms/licence conditions (monitoring/reporting)/other regulatory tools
E = No regulation, other management mechanisms

Note: The above matrix is taken from the DEC Officer's Guide to Emissions and Discharges Risk Assessment May 2006.

Ass # 912
Bull # 762
State # 382

WESTERN AUSTRALIA

MINISTER FOR THE ENVIRONMENT

STATEMENT TO AMEND CONDITIONS APPLYING TO A PROPOSAL (PURSUANT TO THE PROVISIONS OF SECTION 46 OF THE ENVIRONMENTAL PROTECTION ACT 1986)

PROPOSAL:	BEENYUP WASTEWATER OCEAN OUTLET DUPLICATION INTO MARMION MARINE PARK (079 / 912)
CURRENT PROPONENT:	WATER AUTHORITY OF WESTERN AUSTRALIA
CONDITIONS SET ON:	13 JULY 1990

The implementation of this proposal is now subject to the following conditions which replace all previous conditions:

1 Implementation

The proponent must adhere in substance to the proposal as assessed. However, changes to the proposal which are not substantial may be carried out with the approval of the Minister for the Environment.

1-1 Subject to these conditions, the manner of detailed implementation of the proposal shall conform in substance with that set out in any designs, specifications, plans or other technical material submitted by the proponent to the Environmental Protection Authority with the proposal. Where, in the course of that detailed implementation, the proponent seeks to change those designs, specifications, plans or other technical material in any way that the Minister for the Environment determines on the advice of the Environmental Protection Authority, is not substantial, those changes may be effected.

2 Target Loads for Nitrogen and Phosphorus

2-1 The proponent shall not permit the combined mean monthly nutrient loadings within both the original and second pipelines from the Beenyup Wastewater Treatment Plant to exceed the maximum loads set for total phosphorus (plus 10 per cent) and total nitrogen for the original single outfall.

The maximum load set for total phosphorus is 913 kg per day and for total nitrogen 3.6 tonnes per day.

2-2 The proponent shall refer to the Environmental Protection Authority any proposal to increase the levels of nutrients discharged beyond the levels referred to in condition 2-1 .

2-3 Prior to 31 August each year, the proponent shall submit monitoring reports to the Department of Environmental Protection, giving details of the plant performance, in relation to the mean monthly nutrient concentrations and loads in the wastewater.

Published on

1 3 MAR 1995

12th FLOOR, DUMAS HOUSE, 2 HAVELOCK STREET, WEST PERTH, 6005 TELEPHONE (09) 321 2222 FAX (09) 322 5149

3 Nutrient Impact Studies

The proponent should undertake studies to determine the impacts of nutrients from the Beenyup outfalls.

3-1 Prior to 31 July 1990, the proponent shall commence a study to examine water circulation in the region of the outlets of both pipelines in order to determine the flushing characteristics of the receiving waterbody, in consultation with and to the requirements of the Department of Environmental Protection on advice of the Department of Conservation and Land Management. A complete range of conditions shall be sampled to enable calibration of an appropriate numerical model.

3-2 Prior to 31 July 1990, the proponent shall commence a study to examine the effects of nutrient loadings on the local marine communities, in consultation with and to the requirements of the Department of Environmental Protection on advice of the Department of Conservation and Land Management. This study shall involve at least three years of intensive effort (Phase 1) and two years of reduced effort (Phase 2).

3-3 Prior to commencement of the studies required by conditions 3-1 and 3-2, the proponent shall establish a Technical Advisory Group, which includes representatives from the Water Authority of Western Australia, the Department of Environmental Protection, the Fisheries Department and the Department of Conservation and Land Management, to co-ordinate the studies.

3-4 In the event that, due to excessive nutrient loading, the effluent causes an unacceptable environmental impact in the opinion of the Minister for the Environment on advice of the Department of Environmental Protection, the proponent shall undertake additional treatment of the effluent to further remove nutrients to a level acceptable to the Minister for the Environment.

4 Monitoring Programme

4-1 The proponent shall continue with the existing monitoring programme as described in the Public Environmental Report, to the requirements of the Department of Environmental Protection in consultation with the Department of Conservation and Land Management and the Fisheries Department.

4-2 The proponent shall submit reports on the monitoring programme referred to in condition 4-1 to the Department of Environmental Protection as outlined in the Public Environmental Report.

5 Water Quality

Condition deleted. (Matter addressed by Procedures 3 and 4).

6 Bacterial Concentrations

6-1 In the event that water quality criteria for bacteria in the prescribed beneficial use zones are exceeded, the proponent shall further treat the effluent to reduce bacterial concentrations.

7 Effects on Marine Biota

7-1 In the event that concentrations of bacteria or other contaminants introduced into the receiving water by the proponent are unacceptable, in the opinion of the Minister for the Environment, because of demonstrable effects on marine biota (especially mammals), the proponent shall take action to ensure that concentrations of contaminants are reduced to levels which are acceptable to the Minister for the Environment on advice of the Departments of Environmental Protection and Conservation and Land Management.

8 Surveys of Biota Contamination

8-1 The proponent shall undertake surveys, to the requirements of the Department of Environmental Protection in consultation with the Department of Conservation and Land Management and the Fisheries Department, to investigate contamination of biota (particularly the harvestable fish species of the area) by heavy metals, pesticides and by-products of the chlorination process.

These surveys shall:

1 incorporate an initial survey, commencing as soon as possible and to be completed before the second pipeline becomes operational, to establish current levels of contamination in a range of species; and

2 include follow-up surveys, to take place every three years, with a major review after 12 years.

The proponent shall forward results to the Department of Environmental Protection within six months of completion of sampling.

8-2 In the event that levels of contamination of biota are found to be unacceptable in the opinion of the Minister for the Environment, the proponent shall reduce concentrations of contaminants to levels which are acceptable to the Minister for the Environment on advice of the Department of Environmental Protection.

9 Approval of Pipeline Alignment

Condition deleted. (Alignment now approved and pipeline constructed).

10 Alternative to Underwater Blasting for Rock Removal

Condition deleted. (Alternative approved and rock removed).

11 Rehabilitation of On-shore Site

11-1 Following the completion of construction and launching of the pipeline, the proponent shall rehabilitate the onshore site to the requirements of the Department of Environmental Protection on advice of the Ministry for Planning.

12 Studies to Predict Loads and Impacts by 2040

12-1 Prior to 31 March 1995, the proponent shall undertake and complete studies to the requirements of the Environmental Protection Authority which:

1 predict the wastewater discharges and characteristics likely to occur by the year 2040 from Metropolitan Perth (including discharges from the area between Mandurah and Yanchep, inclusive); and

2 determine whether the waters off Metropolitan Perth have the assimilative capacity for the combined wastewater discharges predicted to occur by 2040.

13 Studies of Alternatives to Ocean Disposal

13-1 Prior to 31 March 1995, the proponent shall undertake and complete a study to the requirements of the Environmental Protection Authority which investigates alternatives to ocean disposal of wastewater.

14 Decommissioning

14-1 The proponent shall achieve satisfactory decommissioning, and if necessary, removal of the pipeline and rehabilitation of the site and its environs.

14-2 At least six months prior to decommissioning, the proponent shall prepare a decommissioning and rehabilitation plan.

14-3 The proponent shall implement the plan required by condition 14-2.

Procedure

1 The Department of Environmental Protection is responsible for verifying compliance with the conditions contained in this statement, with the exception of conditions stating that the proponent shall meet the requirements of either the Minister for the Environment or any other public authority.

2 If the Department of Environmental Protection, other public authority or proponent is in dispute concerning compliance with the conditions contained in this statement, that dispute will be determined by the Minister for the Environment.

3 Prior to commencing operations, the Department of Environmental Protection, on advice of the Water Authority of Western Australia, the Departments of Conservation and Land Management and Health and the Fisheries Department will identify beneficial uses and beneficial use zones for the waters in the locality of the outlets and determine a mixing zone, to the requirements of the Minister for the Environment. The water quality criteria for the beneficial use zones will be those published in Environmental Protection Authority Bulletin No 103, Water Quality Criteria for Marine and Estuarine Waters of Western Australia, April 1981, or as revised from time to time.

4 The allocation of beneficial uses and beneficial use zones and the mixing zone will be periodically reviewed in the light of monitoring data, to the requirements of the Minister for the Environment on advice of the Department of Environmental Protection.

Peter Foss, MLC
MINISTER FOR THE ENVIRONMENT

13 MAR 1995

Appendix B – Analytical laboratories and methods

Analytical Laboratories

Analytes determined and analytical laboratories used for treated wastewater characterisation

Analytes	Analytical Laboratory	Analytical Method	Reporting Limit	Unit
Microbiological				
E.coli	PathWest Laboratory Medicine WA	Membrane filtration	Dilution dependent(1)	CFU 100 mL^{-1}
Enterococci	PathWest Laboratory Medicine WA	Membrane filtration	Dilution dependent(1)	MPN 100 mL^{-1}
Nutrients				
Ortho-phosphate	Murdoch University Marine and Freshwater Research Laboratory (MAFRL) and/or National Measurement Institute (NMI)	Lachat-Automated Flow Injection Analyser (4100)	2(2)	µg P L^{-1}
Ammonia		Lachat-Automated Flow Injection Analyser (2000)	3(2)	µg N L^{-1}
Nitrate + Nitrite		Lachat-Automated Flow Injection Analyser (2100)	2(2)	µg N L^{-1}
Total Nitrogen		Lachat-Automated Flow Injection Analyser (2700)	50(2)	µg N L^{-1}
Total Phosphorus		Lachat-Automated Flow Injection Analyser (4700)	5(2)	µg P L^{-1}
Metals and Metalloids				
Arsenic filtered	National Measurement Institute (NMI)	Inductively coupled plasma mass spectrometry and inductively coupled plasma atomic emission spectrometry (NT2.47.251)	1	µg L^{-1}
Arsenic total		NT2.47.251	1	µg L^{-1}
Cadmium filtered		Inductively coupled plasma mass spectrometry and inductively coupled plasma atomic emission spectrometry (NT2.47)	0.1	µg L^{-1}
Cadmium total		NT2.47	0.1	µg L^{-1}
Chromium filtered		NT2.47	2	µg L^{-1}
Chromium total		NT2.47	2	µg L^{-1}
Copper filtered		NT2.47	1	µg L^{-1}
Copper total		NT2.47	1	µg L^{-1}
Lead filtered		NT2.47	1	µg L^{-1}
Lead total		NT2.47	1	µg L^{-1}
Mercury filtered		Inductively coupled plasma mass spectrometry and inductively coupled plasma atomic emission spectrometry (NT2.47.244)	0.1	µg L^{-1}
Mercury total		NT2.47.244	0.1	µg L^{-1}
Nickel filtered		NT2.47	2	µg L^{-1}
Nickel total		NT2.47	2	µg L^{-1}
Selenium filtered		NT2.47.251	1	µg L^{-1}
Selenium total		NT2.47	1	µg L^{-1}
Silver filtered		NT2.47	0.8	µg L^{-1}
Silver total		NT2.47	0.8	µg L^{-1}
Zinc filtered		NT2.47	2	µg L^{-1}
Zinc total		NT2.47	2	µg L^{-1}

Analytes	Analytical Laboratory	Analytical Method	Reporting Limit	Unit
Phenoxy Acid Herbicides				
Dicamba	National Measurement Institute (NMI)	Electron Impact Full Scan or Selected Ion Monitoring (NGCMS_1117)	1	$\mu g\ L^{-1}$
MCPA		NGCMS_1117	1	$\mu g\ L^{-1}$
Dichlorprop		NGCMS_1117	1	$\mu g\ L^{-1}$
2,4-D		NGCMS_1117	1	$\mu g\ L^{-1}$
2, 4, 5-T		NGCMS_1117	1	$\mu g\ L^{-1}$
2 4, 5 –TP		NGCMS_1117	1	$\mu g\ L^{-1}$
2, 4-DB		NGCMS_1117	1	$\mu g\ L^{-1}$
MCPP		NGCMS_1117	1	$\mu g\ L^{-1}$
Trichlopyr		NGCMS_1117	1	$\mu g\ L^{-1}$
Triazine Herbicides				
Atrazine	National Measurement Institute (NMI)	Extraction, Cleanup and Analysis (NR_19)	0.1	$\mu g\ L^{-1}$
Hexazinone		NR_19	0.1	$\mu g\ L^{-1}$
Metribuzine		NR_19	0.1	$\mu g\ L^{-1}$
Prometryne		NR_19	0.1	$\mu g\ L^{-1}$
Simazine		NR_19	0.1	$\mu g\ L^{-1}$
Organophosphate Pesticides				
Azinphos-Methyl	National Measurement Institute (NMI)	NR_19	0.1	$\mu g\ L^{-1}$
Azinphos-Ethyl		NR_19	0.1	$\mu g\ L^{-1}$
Chlorpyrifos		NR_19	0.1	$\mu g\ L^{-1}$
Chlorpyrifos Methyl		NR_19	0.1	$\mu g\ L^{-1}$
Chlorfenvinophos (E)		NR_19	0.1	$\mu g\ L^{-1}$
Chlorfenvinphos (Z)		NR_19	0.1	$\mu g\ L^{-1}$
Demeton-S-Methyl		NR_19	0.1	$\mu g\ L^{-1}$
Dichlorvos		NR_19	0.1	$\mu g\ L^{-1}$
Diazinon		NR_19	0.1	$\mu g\ L^{-1}$
Dimethoate		NR_19	0.1	$\mu g\ L^{-1}$
Ethion		NR_19	0.1	$\mu g\ L^{-1}$
Fenthion		NR_19	0.1	$\mu g\ L^{-1}$
Fenitrothion		NR_19	0.1	$\mu g\ L^{-1}$
Malathion		NR_19	0.1	$\mu g\ L^{-1}$
Parathion (Ethyl)		NR_19	0.1	$\mu g\ L^{-1}$
Parathion Methyl		NR_19	0.1	$\mu g\ L^{-1}$
Pirimiphos-Ethyl		NR_19	0.1	$\mu g\ L^{-1}$
Pirimiphos-Methyl		NR_19	0.1	$\mu g\ L^{-1}$
Organochlorine Pesticides				
Aldrin	National Measurement Institute (NMI)	NR_19	0.01	$\mu g\ L^{-1}$
trans-Chlordane		NR_19	0.01	$\mu g\ L^{-1}$
cis-Chlordane		NR_19	0.01	$\mu g\ L^{-1}$
Oxychlordane		NR_19	0.01	$\mu g\ L^{-1}$
BHC (other than lindane)		NR_19	0.01	$\mu g\ L^{-1}$
DDD		NR_19	0.01	$\mu g\ L^{-1}$
DDE		NR_19	0.01	$\mu g\ L^{-1}$
DDT		NR_19	0.01	$\mu g\ L^{-1}$
Dieldrin		NR_19	0.01	$\mu g\ L^{-1}$
Endrin		NR_19	0.01	$\mu g\ L^{-1}$
Endrin Aldehyde		NR_19	0.01	$\mu g\ L^{-1}$
Endrin Ketone		NR_19	0.01	$\mu g\ L^{-1}$
alpha-Endosulfan		NR_19	0.01	$\mu g\ L^{-1}$
beta-Endosulfan		NR_19	0.01	$\mu g\ L^{-1}$
Endosulfan Sulfate		NR_19	0.01	$\mu g\ L^{-1}$
HCB		NR_19	0.01	$\mu g\ L^{-1}$

Analytes	Analytical Laboratory	Analytical Method	Reporting Limit	Unit
Heptachlor		NR_19	0.01	μg L^{-1}
Heptachlor epoxide		NR_19	0.01	μg L^{-1}
Lindane		NR_19	0.01	μg L^{-1}
Methoxychlor		NR_19	0.01	μg L^{-1}
Phthalates				
Dimethyl phthalate	National Measurement Institute (NMI)	Electron Impact or Selected Ion Monitoring (NGCMS_1111)	10	μg L^{-1}
Diethyl phthalate		NGCMS_1111	10	μg L^{-1}
Di-n-butyl phthalate		NGCMS_1111	10	μg L^{-1}
Benzyl butyl phthalate		NGCMS_1111	10	μg L^{-1}
Bis(2-ethylhexyl)phthalate		NGCMS_1111	20	μg L^{-1}
Di-n-octyl phthalate		NGCMS_1111	10	μg L^{-1}
PCB Aroclors				
Aroclor 1016	National Measurement Institute (NMI)	NR_19	0.1	μg L^{-1}
Aroclor 1221		NR_19	0.1	μg L^{-1}
Aroclor 1232		NR_19	0.1	μg L^{-1}
Aroclor 1242		NR_19	0.1	μg L^{-1}
Aroclor 1248		NR_19	0.1	μg L^{-1}
Aroclor 1254		NR_19	0.1	μg L^{-1}
Aroclor 1260		NR_19	0.1	μg L^{-1}
Total PCBs (as above)		NR_19	0.1	μg L^{-1}
Chlorinated Hydrocarbons				
2-Chloronaphthalene	National Measurement Institute (NMI)	Extraction, Filtration and Analysis using a modified USEPA 8270 method (NGCMS_1122)	20	μg L^{-1}
1,4-Dichlorobenzene		NGCMS_1122	20	μg L^{-1}
1,2-Dichlorobenzene		NGCMS_1122	20	μg L^{-1}
1,3-Dichlorobenzene		NGCMS_1122	20	μg L^{-1}
Hexachlorobenzene		NGCMS_1122	20	μg L^{-1}
1,2,4-Trichlorobenzene		NGCMS_1122	20	μg L^{-1}
Hexachloroethane		NGCMS_1122	20	μg L^{-1}
Hexachlorocyclopentadiene		NGCMS_1122	20	μg L^{-1}
Hexachloro-1,3-butadiene		NGCMS_1122	20	μg L^{-1}
Ethers				
4-Bromophenyl phenyl ether	National Measurement Institute (NMI)	NGCMS_1122	20	μg L^{-1}
4-Chlorophenyl phenyl ether		NGCMS_1122	20	μg L^{-1}
Bis(2-chloroethyl)ether		NGCMS_1122	20	μg L^{-1}
Bis(2-chloroethoxy)methane		NGCMS_1122	20	μg L^{-1}
Bis(2-chloroisopropyl)ether		NGCMS_1122	20	μg L^{-1}
Amines, Nitroaromatics & Nitrosamines				
Azobenzene	National Measurement Institute (NMI)	NGCMS_1122	20	μg L^{-1}
2,4-Dinitrotoluene		NGCMS_1122	20	μg L^{-1}
2,6-Dinitrotoluene		NGCMS_1122	20	μg L^{-1}
Nitrobenzene		NGCMS_1122	20	μg L^{-1}
NNitrosodimethylamine		NGCMS_1122	20	μg L^{-1}
N-Nitrosodiphenylamine		NGCMS_1122	20	μg L^{-1}
N-Nitrosodi-n-		NGCMS_1122	20	μg L^{-1}

Analytes	Analytical Laboratory	Analytical Method	Reporting Limit	Unit
propylamine				
Aniline		NGCMS_1122	20	μg L^{-1}
4-Chloroaniline		NGCMS_1122	20	μg L^{-1}
2-Nitroaniline		NGCMS_1122	20	μg L^{-1}
3-Nitroaniline		NGCMS_1122	20	μg L^{-1}
4-Nitroaniline		NGCMS_1122	20	μg L^{-1}
Other Organics				
Dichlorobenzidine	National Measurement Institute (NMI)	NGCMS_1122	20	μg L^{-1}
2-Methylnaphthalene		NGCMS_1122	10	μg L^{-1}
Isophorone		NGCMS_1122	20	μg L^{-1}
Benzyl alcohol		NGCMS_1122	20	μg L^{-1}
Carbazole		NGCMS_1122	20	μg L^{-1}
Dibenzofuran		NGCMS_1122	20	μg L^{-1}
BTEX				
Benzene	National Measurement Institute (NMI)	Purge and trap technique with GC/FID (WL244)	1	μg L^{-1}
Toluene		WL244	1	μg L^{-1}
Ethylbenzene		WL244	1	μg L^{-1}
Xylene		WL244	2	μg L^{-1}
Total BTEX		WL244	5	μg L^{-1}
TPH				
TPH C6-C9	National Measurement Institute (NMI)	WL244	25	μg L^{-1}
TPH C10-C14		Gas chromatography with flame ionisation detection (WL203)	25	μg L^{-1}
TPH C15-C28		WL203	100	μg L^{-1}
TPH C29-C36		WL203	100	μg L^{-1}
Total Petroleum Hydrocarbons (TPH)		WL203	250	μg L^{-1}
PAHs				
Naphthalene	National Measurement Institute (NMI)	NGCMS_1111	0.1	μg L^{-1}
Acenaphthylene		NGCMS_1111	0.1	μg L^{-1}
Acenaphthene		NGCMS_1111	0.1	μg L^{-1}
Fluorene		NGCMS_1111	0.1	μg L^{-1}
Phenanthrene		NGCMS_1111	0.1	μg L^{-1}
Anthracene		NGCMS_1111	0.1	μg L^{-1}
Fluoranthene		NGCMS_1111	0.1	μg L^{-1}
Pyrene		NGCMS_1111	0.1	μg L^{-1}
Benzo(a)anthracene		NGCMS_1111	0.1	μg L^{-1}
Chrysene		NGCMS_1111	0.1	μg L^{-1}
Benzo(b)&(k)fluoranthene		NGCMS_1111	0.1	μg L^{-1}
Benzo(a)pyrene		NGCMS_1111	0.1	μg L^{-1}
Indeno(1,2,3-cd)pyrene		NGCMS_1111	0.1	μg L^{-1}
Dibenz(ah)anthracene		NGCMS_1111	0.1	μg L^{-1}
Benzon(ghi)perylene		NGCMS_1111	0.1	μg L^{-1}
Surfactants				
methylene blue active substances (MBAS) *	SGS Australia	Methylene dye added, extraction and colorimetrically measured based on test APHA 5540C	n/a	n/a
Miscellaneous Other				
Chlorine-Free	National Measurement Institute (NMI)	Colour test by comparision with coloured disc (WL146)	0.02	mg/L
Chlorine-Total		WL146	0.02	mg/L
Dissolved Organic		Split Sample and Compare	n/a	mg/L

Analytes	Analytical Laboratory	Analytical Method	Reporting Limit	Unit
Carbon (after filtering)		Total Carbon and Inorganic Carbon measured with Infrared Detector – Based on Method APHA 5310B (WL240)		
Total Organic Carbon		WL240	n/a	mg/L
Total Suspended Solids		Gravimetric Procedure – Based on APHA Methods 2540D and E (WL126)	5	mg/L
5-day Biological Oxygen Demand		5 Day Incubation of Neutralised, Chlorine Free Sample – Based on APHA Method 5210B (WL189)	5	mg/L
pH		Measured Potentiometrically Using a Combination Electrode (WL120)	0.1	pH unit

Notes:

1. The upper and lower detection limits for microbiological indicators are dependent on the dilution of the original sample.
2. Method detection limit determined from 3.2 x standard deviation of 10 standard samples.
   n/a = information not available

Analytical methods and reporting limits for water quality parameters

Parameter	Analytical Method(1)	Reporting Limit	Unit
Nutrients			
Ortho-phosphate	Lachat-Automated Flow Injection Analyser (4100)	2(2)	µg P L^{-1}
Ammonia	Lachat-Automated Flow Injection Analyser (4100)	3(2)	µg P L^{-1}
Nitrate + Nitrite	Lachat-Automated Flow Injection Analyser (4100)	2(2)	µg P L^{-1}
Primary Production			
Chlorophyll-a	Acetone extraction (3000)	0.1(2)	µg P L^{-1}
Phaeophytin	Acetone extraction (3000)	0.1(2)	µg P L^{-1}
Microbiological Indicators			
E.coli	Membrane filtration	Dilution dependent(3)	CFU 100 ml^{-1}
Enterococci	Membrane filtration	Dilution dependent(3)	CFU 100 ml^{-1}

Notes:

1. Numbers in brackets refer to the MAFRL analysis method number.
2. Method detection limit determined from 3.2 x standard deviation of 10 standard samples.
3. The upper and lower detection limits for microbiological indicators are dependent on the dilution of the original sample.

Appendix C – Comprehensive treated wastewater characterisation results

PLOOM 7.3 - 2017-2018						
Date sampled: 13 Feb 2018						
Parameter	**OCEAN REEF TWW**	**ANZECC/ARMCANZ (2000) Guidelines (µg/L)[1]**				
		Level of protection				**Low Reliability Value (LRV)**
		99%	**95%**	**90%**	**80%**	
Microbiological (cfu/100ML)						
Confirmed *Enterococci*[2]	650	n/a[3]	n/a	n/a	n/a	n/a
Presumptive Thermo-tolerant Coliforms (TTC)[4]	28,000	n/a	n/a	n/a	n/a	n/a
Confirmed Thermo-tolerant Coliforms (TTC)[4]	28,000	n/a	n/a	n/a	n/a	n/a
Escherichia coli	28,000	n/a	n/a	n/a	n/a	n/a
Nutrients (µg/L)						
Ammonia-N	**740**	**500**	910	1,200	1,700	-
Nitrate-N+Nitrite-N	16,000	ID[5]	ID	ID	ID	13,000
Nitrogen-Total N	18,000	n/a	n/a	n/a	n/a	n/a
Phosphate-Ortho as P	10,000	n/a	n/a	n/a	n/a	n/a
Phosphorous-Total P	23,000	n/a	n/a	n/a	n/a	n/a
"Dissolved" Metals (0.45 µm filtered) (µg/L)						
Arsenic (As)	<1	ID	ID	ID	ID	2.3 (As III) 4.5 (As V)
Cadmium (Cd)	<0.1	0.7	5.5	14	36	-
Chromium (Cr)	**1.4**	7.7 (Cr III) **0.14** (Cr VI)	27.4 (Cr III) 4.4 (Cr VI)	48.6 (Cr III) 20 (Cr VI)	90.6 (Cr III) 85 (Cr VI)	-
Copper (Cu)	**9.8**	**0.3**	1.3	3	8	-
Lead (Pb)	<1	2.2	4.4	6.6	12	-
Mercury (Hg)	<0.1	0.1	0.4	0.7	1.4	-
Nickel (Ni)	5.9	7	70	200	560	-
Selenium (Se)	<1	ID	ID	ID	ID	3

Silver (Ag)	<1	0.8	1.4	1.8	2.6	-
Zinc (Zn)	52	7	15	23	43	-
Total Metals (Acid extractable; unfiltered) (µg/L)[22]						
Arsenic (As)	<1	ID	ID	ID	ID	2.3 (As III) 4.5 (AsV)
Cadmium (Cd)	<0.1	0.7	5.5	14	36	-
Chromium (Cr)	2.7	7.7 (Cr III) 0.14 (Cr VI)	27.4 (Cr III) 4.4 (Cr VI)	48.6 (Cr III) 20 (Cr VI)	90.6 (Cr III) 85 (Cr VI)	-
Copper (Cu)	23	0.3	1.3	3	8	-
Lead (Pb)	<1	2.2	4.4	6.6	12	-
Mercury (Hg)	<0.1	0.1	0.4	0.7	1.4	-
Nickel (Ni)	6.3	7	70	200	560	-
Selenium (Se)	<1	ID	ID	ID	ID	3
Silver (Ag)	<1	0.8	1.4	1.8	2.6	-
Zinc (Zn)	81	7	15	23	43	-
Triazine Herbicides (µg/L)						
Atrazine	<0.1	ID	ID	ID	ID	13
Hexazinone	0.37	ID	ID	ID	ID	75
Metribuzine	<0.1	n/a	n/a	n/a	n/a	n/a
Prometryne	<0.1	n/a	n/a	n/a	n/a	n/a
Simazine	0.78	ID	ID	ID	ID	3.2
Phenoxy Acid Herbicides (µg/L)						
Dicamba[6]	<1	n/a	n/a	n/a	n/a	n/a
MCPA	<1	ID	ID	ID	ID	1.4
Dichlorprop	<1	n/a	n/a	n/a	n/a	n/a
2,4-D	<1	ID	ID	ID	ID	280
2,4,5-T	<1	n/a	n/a	n/a	n/a	n/a
2,4,5-TP	<1	n/a	n/a	n/a	n/a	n/a

2,4-DB	<1	n/a	n/a	n/a	n/a	n/a
MCPP	<1	n/a	n/a	n/a	n/a	n/a
Triclopyr[7]	<1	n/a	n/a	n/a	n/a	n/a
Organophosphate Pesticides (µg/L)						
Azinphos-Methyl	<0.1	ID	ID	ID	ID	0.01
Azinphos-Ethyl	<0.1	n/a	n/a	n/a	n/a	n/a
Chlorpyrifos	<0.1	0.0005	0.009	0.04	0.3	-
Chlorfenvinphos (E)	<0.1	n/a	n/a	n/a	n/a	n/a
Chlorfenvinphos (Z)	<0.1	n/a	n/a	n/a	n/a	n/a
Demeton-S-Methyl	<0.1	ID	ID	ID	ID	4
Dichlorvos	<0.1	n/a	n/a	n/a	n/a	n/a
Diazinon	<0.1	ID	ID	ID	ID	0.01
Dimethoate	<0.1	ID	ID	ID	ID	0.15
Ethion	<0.1	n/a	n/a	n/a	n/a	n/a
Fenthion	<0.1	n/a	n/a	n/a	n/a	n/a
Fenitrothion	<0.1	ID	ID	ID	ID	0.001
Malathion	<0.1	ID	ID	ID	ID	0.05
Parathion (Ethyl)	<0.1	ID	ID	ID	ID	0.004
Parathion Methyl	<0.1	n/a	n/a	n/a	n/a	n/a
Pirimiphos-Ethyl[8]	<0.1	n/a	n/a	n/a	n/a	n/a
Pirimiphos-Methyl[9]	<0.1	n/a	n/a	n/a	n/a	n/a
Organochlorine Pesticides (µg/L)						
Aldrin	<0.001	ID	ID	ID	ID	0.003
Trans-Chlordane[10]	<0.001	ID	ID	ID	ID	0.001
Cis-Chlordane[10]	<0.001	ID	ID	ID	ID	0.001
Oxychlordane[10]	<0.001	ID	ID	ID	ID	0.001
Gamma-BHC (Lindane)	<0.001	ID	ID	ID	ID	0.007

alpha-BHC	<0.001	n/a	n/a	n/a	n/a	n/a
beta-BHC	<0.001	n/a	n/a	n/a	n/a	n/a
delta-BHC	<0.001	n/a	n/a	n/a	n/a	n/a
p,p-DDD	<0.001	n/a	n/a	n/a	n/a	n/a
p,p-DDE	<0.001	ID	ID	ID	ID	0.0005
p,p-DDT	<0.001	ID	ID	ID	ID	0.0004
Dieldrin	<0.001	ID	ID	ID	ID	0.01
Endrin	<0.001	0.004	0.008	0.01	0.02	-
Endrin Aldehyde	<0.001	n/a	n/a	n/a	n/a	n/a
Endrin ketone	<0.001	n/a	n/a	n/a	n/a	n/a
alpha-Endosulfan	<0.001	ID	ID	ID	ID	0.0002
beta-Endosulfan	<0.001	ID	ID	ID	ID	0.007
Endosulfan Sulfate[12]	<0.001	0.005	0.01	0.02	0.05	-
HCB (Hexachlorobenzene)	<0.001	ID	ID	ID	ID	0.05
Heptachlor	<0.001	ID	ID	ID	ID	0.0004
Heptachlor epoxide	<0.001	n/a	n/a	n/a	n/a	n/a
Methoxychlor	<0.001	ID	ID	ID	ID	0.004
Phthalates (µg/L)						
Dimethyl phthalate	<10	ID	ID	ID	ID	3700
Diethyl phthalate	<10	ID	ID	ID	ID	900
Di-n-butyl phthalate	<10	ID	ID	ID	ID	25
Butyl benzyl phthalate	<10	n/a	n/a	n/a	n/a	n/a
Bis(2-ethylhexyl) phthalate	<20	ID	ID	ID	ID	1
PCB Aroclors (µg/L)						
Aroclor 1016	<0.1	ID	ID	ID	ID	0.009
Aroclor 1221	<0.1	ID	ID	ID	ID	1
Aroclor 1232	<0.1	ID	ID	ID	ID	0.3

Aroclor 1242	<0.1	ID	ID	ID	ID	0.3
Aroclor 1248	<0.1	ID	ID	ID	ID	0.03
Aroclor 1254	<0.1	ID	ID	ID	ID	0.01
Aroclor 1260	<0.1	ID	ID	ID	ID	n/a
Total PCB's (as above)[13]	<0.1	ID	ID	ID	ID	n/a
BTEX (µg/L)						
Benzene	<1.0	500	700	900	1300	500
Toluene	<1.0	ID	ID	ID	ID	180
Ethylbenzene	<1.0	ID	ID	ID	ID	5
Xylene[16]	<2.0	ID	ID	ID	ID	75
Total BTEX[12]	<5.0	n/a	n/a	n/a	n/a	n/a
Total Petroleum Hydrocarbons (TPH) (µg/L)						
TPH C6 - C9[17]	<25	ID	ID	ID	ID	n/a
TPH C10 - C14[17]	<25	ID	ID	ID	ID	n/a
TPH C15 - C28[17]	<100	ID	ID	ID	ID	n/a
TPH C29 - C36[17]	<100	ID	ID	ID	ID	n/a
Total TPH[17,18]	<250	ID	ID	ID	ID	n/a
Poly Aromatic Hydrocarbons (PAHs) (µg/L)						
Naphthalene	<0.01	50	70	90	120	-
Acenaphthylene	<0.01	n/a	n/a	n/a	n/a	n/a
Acenaphthene	<0.01	n/a	n/a	n/a	n/a	n/a
Fluorene	<0.01	n/a	n/a	n/a	n/a	n/a
Phenanthrene	<0.01	ID	ID	ID	ID	2
Anthracene	<0.01	ID	ID	ID	ID	0.4
Fluoranthene	<0.01	ID	ID	ID	ID	1.4
Pyrene	<0.01	n/a	n/a	n/a	n/a	n/a
Benz(a)anthracene	<0.01	n/a	n/a	n/a	n/a	n/a

Chrysene	<0.01	n/a	n/a	n/a	n/a	n/a
Benzo(b,k)fluoranthene	<0.02	n/a	n/a	n/a	n/a	n/a
Benzo(a)pyrene	<0.01	n/a	n/a	n/a	n/a	n/a
Indeno(1,2,3-cd)pyrene	<0.01	n/a	n/a	n/a	n/a	n/a
Dibenz(a,h)anthracene	<0.01	n/a	n/a	n/a	n/a	n/a
Benzo(g,h,i)perylene	<0.01	50	70	90	120	-
Surfactants (mg/L)						
Methylene Blue Active Substances (MBAS)[19]	0.11	n/a	n/a	n/a	n/a	n/a
Miscellaneous other (mg/L unless indicated)						
Chlorine-Free	<0.01	ID	ID	ID	ID	3
Chlorine-Total	<0.01	ID	ID	ID	ID	3
Dissolved Organic Carbon (DOC)	16	n/a	n/a	n/a	n/a	n/a
Total Organic Carbon (TOC)	19	n/a	n/a	n/a	n/a	n/a
Total Suspended Solids (TSS)[20]	25	n/a	n/a	n/a	n/a	n/a
Biological Oxygen Demand (BOD)	10	n/a	n/a	n/a	n/a	n/a
pH[21]	7.6	n/a	n/a	n/a	n/a	n/a
Notes:						
1. 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, that the 99% species protection levels should be used, with the exception of cobalt, where the 95% species protection levels is used.						
2. Primary and secondary contact guideline for recreational marine waters are 35 and 230 *Enterococci* organisms 100 mL^{-1}, respectively (ANZECC/ARMCANZ 2000).						
3. n/a = ANZECC/ARMCANZ (2000) Guideline or Low Reliability Value not available for this parameter.						
4. Primary and secondary contact guidelines for recreational marine waters 150 and 1,000 faecal coliforms 100 mL^{-1} (ANZECC/ARMCANZ 2000), respectively.						
5. ID = insufficient data to derive a reliable national trigger value.						
6. Recreational guideline for Dicamba = 300 µg L^{-1} (Table 5.2.4; ANZECC/ARMCANZ 2000).						
7. Recreational guideline for Triclopyr = 20 µg L^{-1} (Table 5.2.4; ANZECC/ARMCANZ 2000).						

8. Recreational guideline for Pirimiphos-ethyl = 1 µg L^{-1} (Table 5.2.4; ANZECC/ARMCANZ 2000).			
9. Recreational guideline for Pirimiphos-methy = 60 µg L^{-1} (Table 5.2.4; ANZECC/ARMCANZ 2000).			
10. Guideline values are for total chlordane though cis-chlordane is around 7 times more toxic than transchlordane (ANZECC/ARMCANZ 2000).			
11. Values for Endosulphan, not Endosulphan sulfate (Table 3.4.1; ANZECC/ARMCANZ 2000).			
12. ANZECC/ARMCANZ (2000) recommends using a formula to calculate total toxicity of the mixture if using total PCBs and BTEX (page 8.3-65; ANZECC/ARMCANZ 2000).			
13. Environmental Concern Level (ECL) for Hexachloro-1,3-butadiene (not LRV) (definition of ECL on page 8.3-35; page 8.3-231; ANZECC/ARMCANZ 2000).			
14. Recommended ECL for 4-Bromophenyl phenyl ether = 12 µg L^{-1} (page 8.3-232; ANZECC/ARMCANZ 2000).			
15. ECL for Dichlorobenzidine (not LRV) (page 8.3-187; ANZECC/ARMCANZ 2000).			
16. Guideline for o-Xylene = 350 µg/L, for m-xylene = 75 µg/L and for p-xylene = 200 µg L^{-1} (ANZECC/ARMZANC 2000).			
17. Guideline values are for generic oils and petroleum hydrocarbons (Table 3.4.1; ANZECC/ARMCANZ 2000).			
18. A generic estimate of 7 µg L^{-1} for a total petroleum hydrocarbon chronic value has been estimated using USEPA methods (page 8.3-297; ANZECC/ARMCANZ 2000).			
19. Recreational guideline for MBAS = 200 µg L-1 (ANZECC/ARMCANZ 2000).			
20. Suspended solids guidelines for the protection of saltwater aquaculture species = <10,000 µg L^{-1} (Table 4.4.2; ANZECC/ARMCANZ 2000).			
21. pH guideline range for slightly disturbed inshore marine ecosystems in south-west Australia = 8.0 to 8.4 (Table 3.3.6; ANZECC/ARMCANZ 2000).			

Appendix D – Initial dilution output

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

Ocean Reef A

(a) (b)

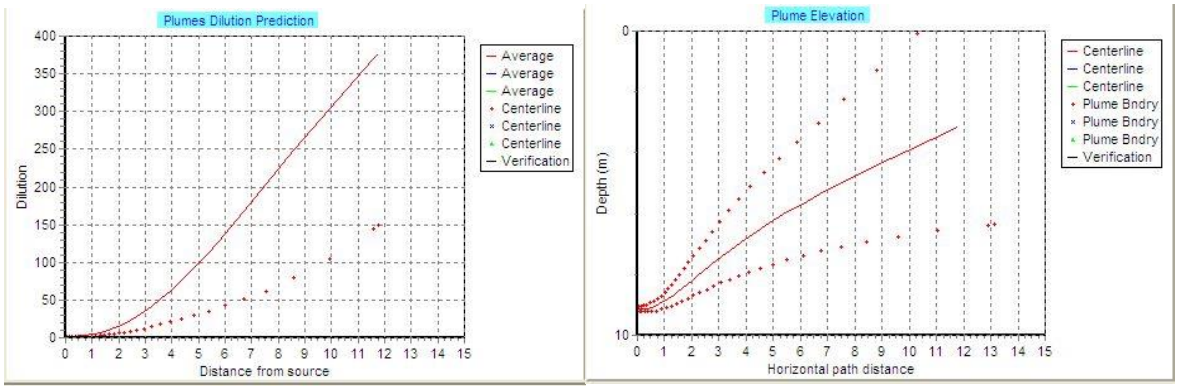


Figure 1 **Initial dilution modelling output showing (left) predicted average and centreline dilutions and (right) predicted centreline dilution and plume elevation trajectory at Ocean Reef Outlet A**

Ocean Reef B

(a) (b)

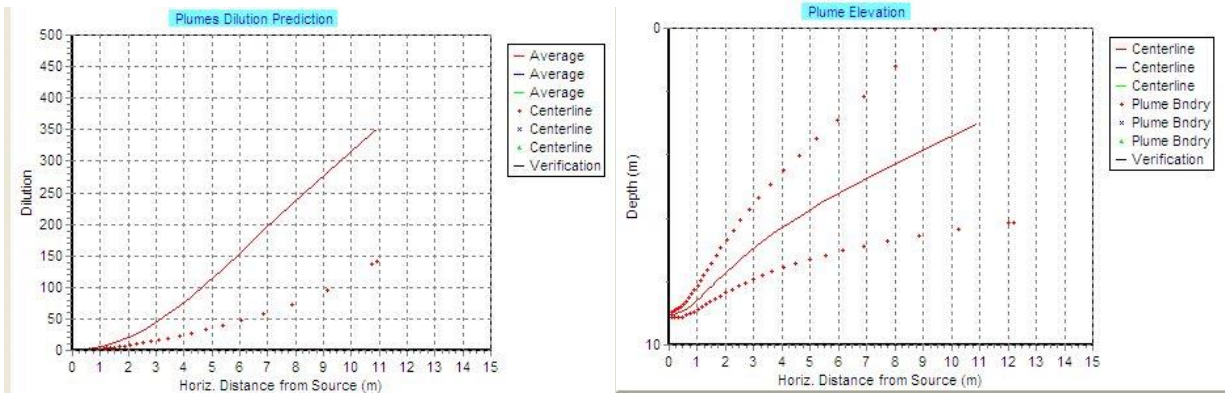


Figure 2 **Initial dilution modelling output showing (left) predicted average and centreline dilutions and (right) predicted centreline dilution and plume elevation trajectory at Ocean Reef Outlet B**

Appendix E – Chem Centre laboratory results

Appendix F – Detailed methodologies

1. Maintenance of Ecosystem Integrity

1.1 Environmental Quality Objective

The EQO for the EV 'Ecosystem Health' is aimed at maintaining ecosystem integrity and biodiversity, thereby ensuring the continued health and productivity of Perth's coastal waters (EPA 2015). There are two areas of ecological protection surrounding the Ocean Reef ocean outlets; a high ecological protection area (HEPA) and a notional low ecological protection area (LEPA). The notional LEPA includes waters within a 100 m radius around the diffuser; waters outside this zone are managed as a HEPA (Figure 1.1).

A comprehensive suite of contaminants are monitored in the TWW prior to discharge (i.e. in the undiluted TWW stream), as well as a subset of contaminants within the receiving environment (i.e. in the diluted TWW plume). Monitoring against trial EQC involves:

- toxicants in TWW
- metals and pesticides in marine biota
- receiving water physical-chemical measures
- receiving water direct biological measures.

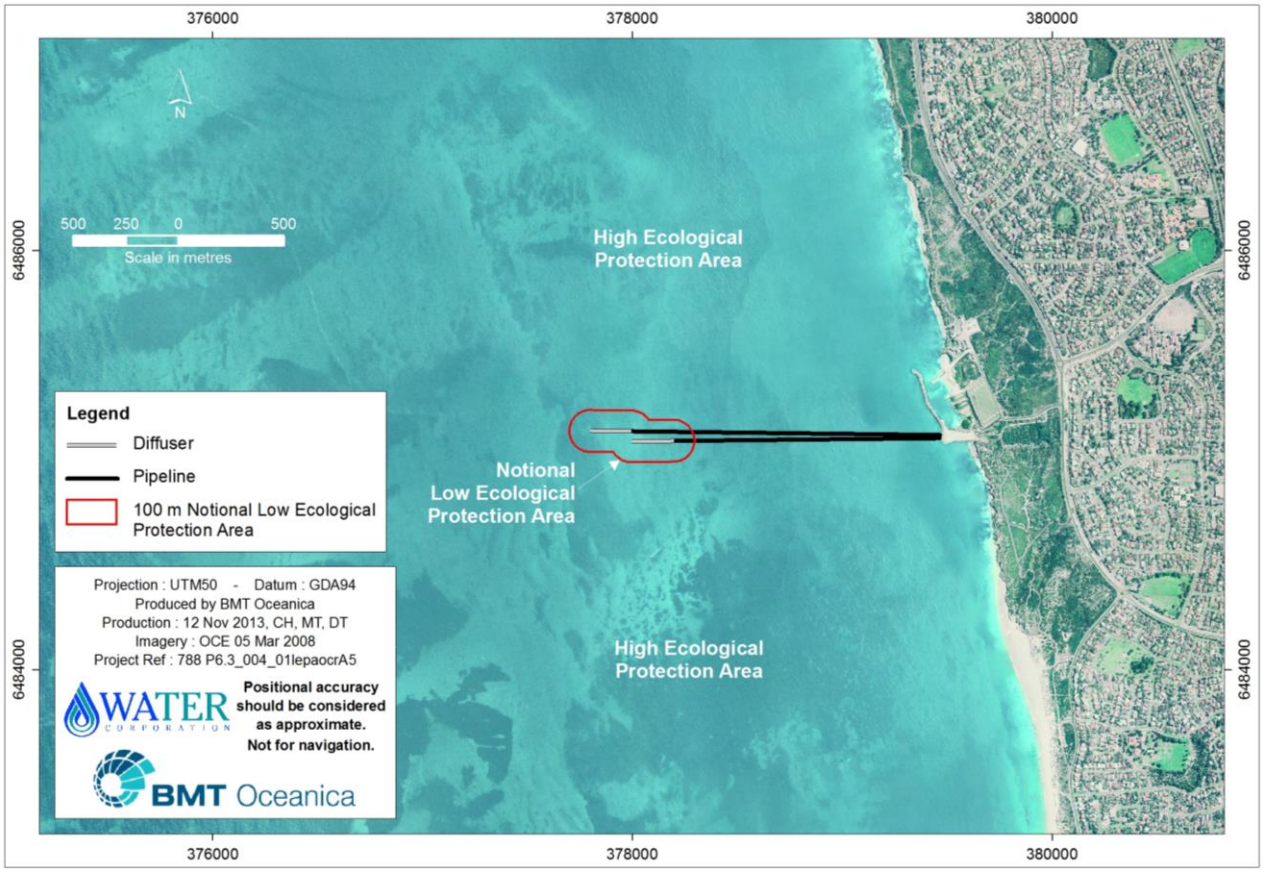


Figure 1.1 Ocean Reef ocean outlets notional ecological protection boundaries

1.2 Toxicants in treated wastewater

Toxicants in TWW are assessed using four trial EQG triggers that are evaluated annually for:

- bioaccumulating toxicants in the undiluted TWW stream (EQG 1)
- non-bioaccumulating toxicants at the notional LEPA boundary (EQG 2)
- total toxicity of the mixture (TTM) for key contaminants (ammonia, copper and zinc) at the notional LEPA boundary (EQG 3)
- WET testing using various dilution levels of the TWW stream (EQG 4).

Every three years, the EQS for bioaccumulating toxicants is also tested via sentinel mussel monitoring, irrespective of whether the EQG has been exceeded.

1.2.1 Comprehensive treated wastewater characterisation

TWW (final effluent) from the Beenyup WWTP is analysed for a suite of parameters comprising the major contaminants of concern for the Ocean Reef ocean outlets:

- nutrients (total nitrogen, ammonia, nitrate+nitrite, total phosphorus, orthophosphate)
- microbiological contaminants
- 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.

A 24-hour flow-weighted composite sample is obtained from the Beenyup WWTP on the same date as the ASWQS. This sample represents an average of the final treated effluent discharged from the Beenyup WWTP for the 24 hours prior to and during the sample collection.

The bulk sample is homogenised (agitated), split into separate sample containers for the various analyte groups and handled according to the National Association of Testing Authorities (NATA)-accredited laboratory requirements for those analytes. Samples for bioavailable metals are passed through a 0.45 µm filter prior to analysis, in accordance with Environmental Protection Authority (EPA) prescribed methods (EPA 2016). Analyses are completed by laboratories with NATA-accredited methods, and the results are compared against ANZECC/ARMCANZ (2000) species protection guideline levels.

Initial dilution modelling

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

Total toxicity of the mixture

The total toxicity of the mixture (TTM) calculation is an additional interpretative tool used for estimating the potential toxicity of TWW, and is used to evaluate EQG 3 for toxicants in TWW. The potential for cumulative toxic effects on marine organisms is assessed as per the ANZECC/ARMCANZ (2000) guidelines based on the effects of ammonia, copper and zinc (after initial dilution of the TWW with seawater), the three contaminants of concern most likely to exceed their respective guidelines.

$$\text{Total Toxicity of Mixture} = \frac{[\text{ammonia}]}{[\text{Trigger Value}]} + \frac{[\text{copper}]}{[\text{Trigger Value}]} + \frac{[\text{zinc}]}{[\text{Trigger Value}]}$$

The TTM must be <1 to meet the total toxicity criteria, in accordance with ANZECC/ARMCANZ (2000) guidelines. The initial mixing zone dilution calculated in the ASWQS (see above) is applied.

1.2.2 Whole of effluent toxicity (WET) testing

To meet the fourth EQG for TWW toxicants, quarterly WET testing is used to establish whether the TWW stream is toxic to marine biota. WET testing is particularly useful in the absence of reliable guidelines for toxicants that occur in low concentrations, or where the toxicity effects of contaminants are poorly understood. For example, the detection limits for pesticide analysis presently attainable by commercial laboratories in Australia are sometimes higher than the ANZECC/ARMCANZ (2000) guidelines.

WET testing involves exposing sea urchins (*Heliocidaris tuberculata*) to different concentrations of TWW effluent for ~1 hour and then measuring fertilisation success. This test has been chosen for its fast analytical turn-around time and the sea urchins' sensitivity to contaminants in TWW. The test results are used to calculate the NOEC (highest concentration where no significant effect is observed), LOEC (lowest concentration where a significant effect is observed) and the EC50 (the concentration of TWW causing 50% inhibition fertilisation rate). In some circumstances, sea urchin WET test results may act as a 'trigger' for a full suite of WET testing. This is an additional series of WET tests incorporating a suite of marine organisms from a variety of trophic levels. To trigger the full suite of WET tests, the NOEC must be ≤1.0% (equivalent to more than a 100-fold dilution).

All WET tests were carried out by NATA-accredited Ecotox Services Australasia Pty Ltd (Ecotox), Sydney, New South Wales. Twenty-four hour flow-weighted composite samples were collected quarterly (July 2017, October 2017, January 2018, April 2018) from the Beenyup WWTP, using containers supplied by Ecotox. The test dilutions of TWW used were 1.0, 1.6, 3.1, 6.3, 12.5, 25, 50 and 100%. All TWW dilutions were salt-adjusted (using artificial sea salts) to achieve marine salinities, so that only the toxicity due to the presence of contaminants was examined, not the toxic effect of freshwater on the marine organism. Testing was also undertaken on a seawater control, and an artificial sea salt (brine) control.

1.3 Water quality monitoring – receiving environment

Water quality was monitored approximately fortnightly from the beginning of December to the end of March, coinciding with the non-river flow period. The program collects data for comparison with the trial EQC for nutrients, phytoplankton biomass and physical and chemical stressors.

On each sampling occasion, a surface drogue was deployed over the centre of the ocean outlet diffuser and retrieved ~30 min later. The drift direction of the drogue was used to provide a directional vector and samples were collected at five compliance sites located at intervals of 0, 100, 350, 1000, and 1500 m along that vector down-current of the outlets (Figure 1.2). Samples were also collected at four reference sites.

A composite sample representative of the top half of the water column, was collected from each site for analysis of chlorophyll-a and nutrients. Chlorophyll-a was measured using material retained on GF/C filters through which 1–5 L of water was passed. Water samples for inorganic nutrient analysis were passed through a 0.45 µm GF/C filter. All samples were immediately placed on ice before being transported to the laboratory for analysis. Samples were analysed at Murdoch University's Marine and Freshwater Laboratory using standard laboratory analytical procedures undertaken according to NATA-accredited methods.

At each of the sites the following physio-chemical parameters were measured in situ using a YSI 6600/YSI 600XL water quality sensor or LiCor Model LI–1000 light meter:

- dissolved oxygen (DO) depth profile
- salinity depth profile
- irradiance
- temperature depth profile (for contextual purposes).

Irradiance measurements are obtained with one sensor positioned 1 m below the surface and a second sensor 7 m below the surface and the light attenuation coefficient (LAC) calculated as follows:

LAC = [$\log_{10}$ (irradiance at depth) – $\log_{10}$ (irradiance at surface)/depth interval (in metres)][1]

The extent to which the EQG were met was assessed using data collected at distances ≥100 m from the ocean outlets. Sites positioned at distances >100 m from the diffuser are considered to lie within the HEPA. Any data collected inside the 100 m radius (notional LEPA) are presented for contextual purposes only.

[1] *Base 10 logs have been specified as they are generally the basis for environmental quality criteria favoured by the Office of the EPA.*

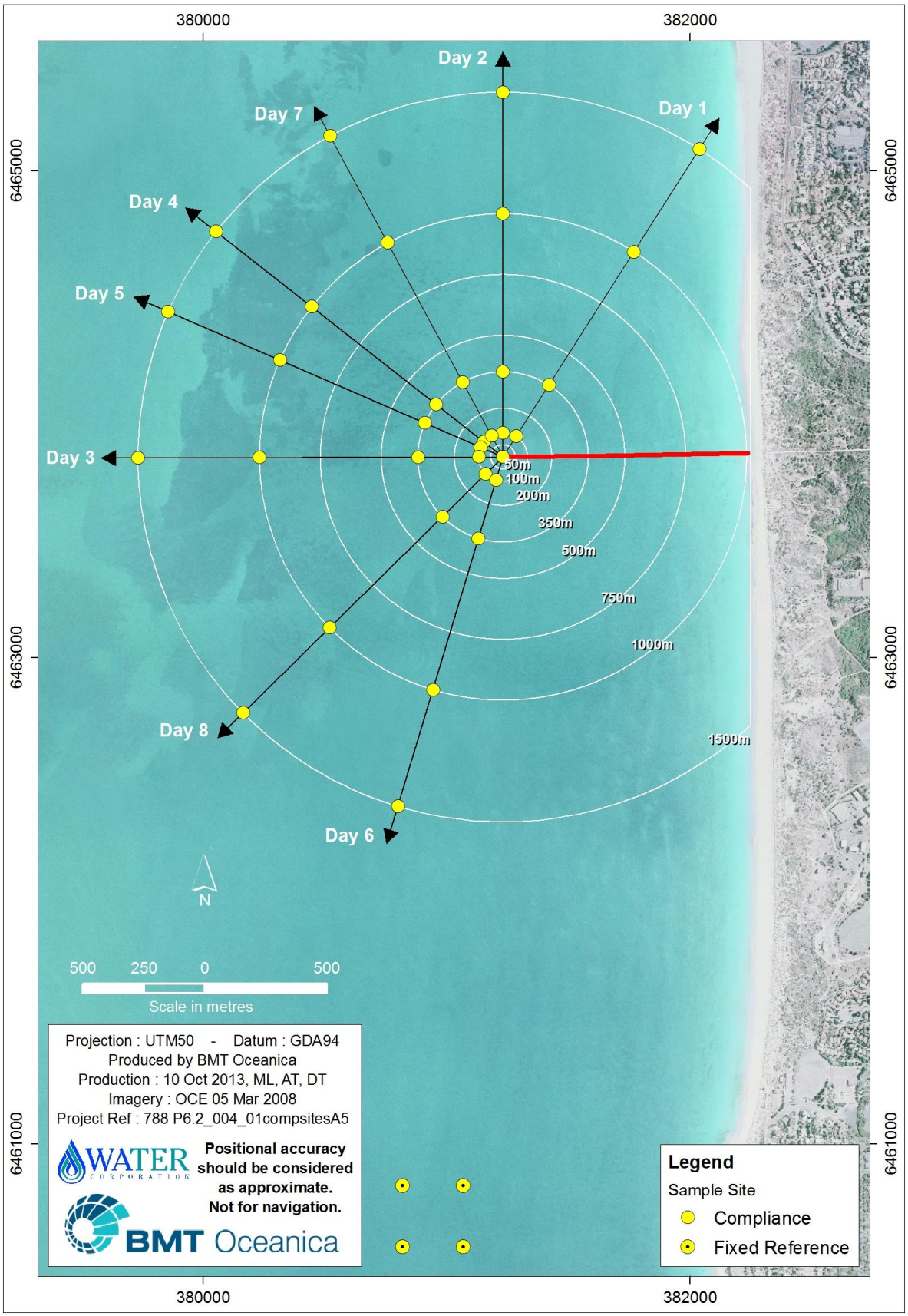


Figure 1.2 **Conceptual diagram of the Trial Compliance Monitoring program showing hypothetical compliance sites and their relative distances from the outlet diffusers**

2. Maintenance of Seafood for Human Consumption

2.1 Environmental Quality Objective

The EQO for the EV 'Fishing and Aquaculture' is aimed at ensuring seafood is safe for human consumption. To ensure the EQO is being met, microbiological contaminants and algal (phytoplankton) biotoxins are monitored as part of the PLOOM TCM program and the PLOOM ASWQS. Ministerial Conditions placed on the operation of the Beenyup WWTP by the EPA also require that a survey of metals and pesticides in marine biota be undertaken every three years (the most recent survey was in summer 2015–2016 and reported in BMT Oceanica (2016)).

The EQO, Maintenance of Seafood Safe for Human Consumption, is primarily concerned with the harvesting and consumption of raw shellfish (i.e. filter-feeding bivalve molluscs such as oysters, mussels, clams, pipis, scallops, cockles, and razor clams) and not other forms of seafood. Human health concerns relating to consumption of shellfish are not considered an issue at Ocean Reef as there is no aquaculture within 250 m of the diffuser and no known harvesting of shellfish in the waters 1–3 km offshore. The Department of Health (DoH) discourages the public from taking wild shellfish, recommending instead that shellfish are only consumed if harvested commercially and under a strict monitoring program. The DoH has further indicated that "it is impossible to guarantee the safety of eating wild shellfish without having a comprehensive monitoring program that tests the waterway concerned for harmful microorganisms and toxins" and has formally advised the Department of Environment and Conservation[2] that, in the absence of a full monitoring program, the application of the TTC criteria (EPA 2017) is insufficient to protect those who wish to collect and eat wild shellfish.

2.2 Microbiological contaminants and algal biotoxins

The accepted method for determining whether the relevant EQC for maintenance of seafood for human consumption have been met is to monitor microbiological contaminants (measured as concentrations of thermotolerant coliforms (TTC)) and algal biotoxins (measured as concentrations of phytoplankton species) at the boundary of a pre-designated management zone.

Many disease-causing organisms are transferred from human and animal faeces to water via sewage effluent, from where they can be ingested by marine fauna and infect them, adversely affecting their suitability for human consumption. TTC are one such bacteria that primarily originate in the intestines of warm-blooded animals. By testing for TTC, it can be determined whether the ocean water around Ocean Reef has potentially been exposed to faecal contamination.

Nutrient enrichment as a result of TWW discharge could result in changes to the naturally occurring planktonic algal community. Although most algal blooms are considered harmless, some may contain species that produce toxins that have a potentially harmful effect on the surrounding marine environment. Species such as *Heterosigma akashiwo* and *Cryptosporidium parvum* are two such algae that cause fish mortalities.

As formal management zones have yet to be established for the Ocean Reef ocean outlets, sampling for the EQO Seafood for Human Consumption was undertaken at a series of fixed monitoring sites located at the boundary of an 'observed zone of influence' (OZI; Figure 2.1). The OZI was derived from ten years of monitoring data collected at Ocean Reef. Data collected at the boundaries of the OZI are used in the assessment of the EQC. The OZI allow direct comparison with outlets where similar zones have been adopted as a requirement (i.e. Alkimos and Sepia Depression).

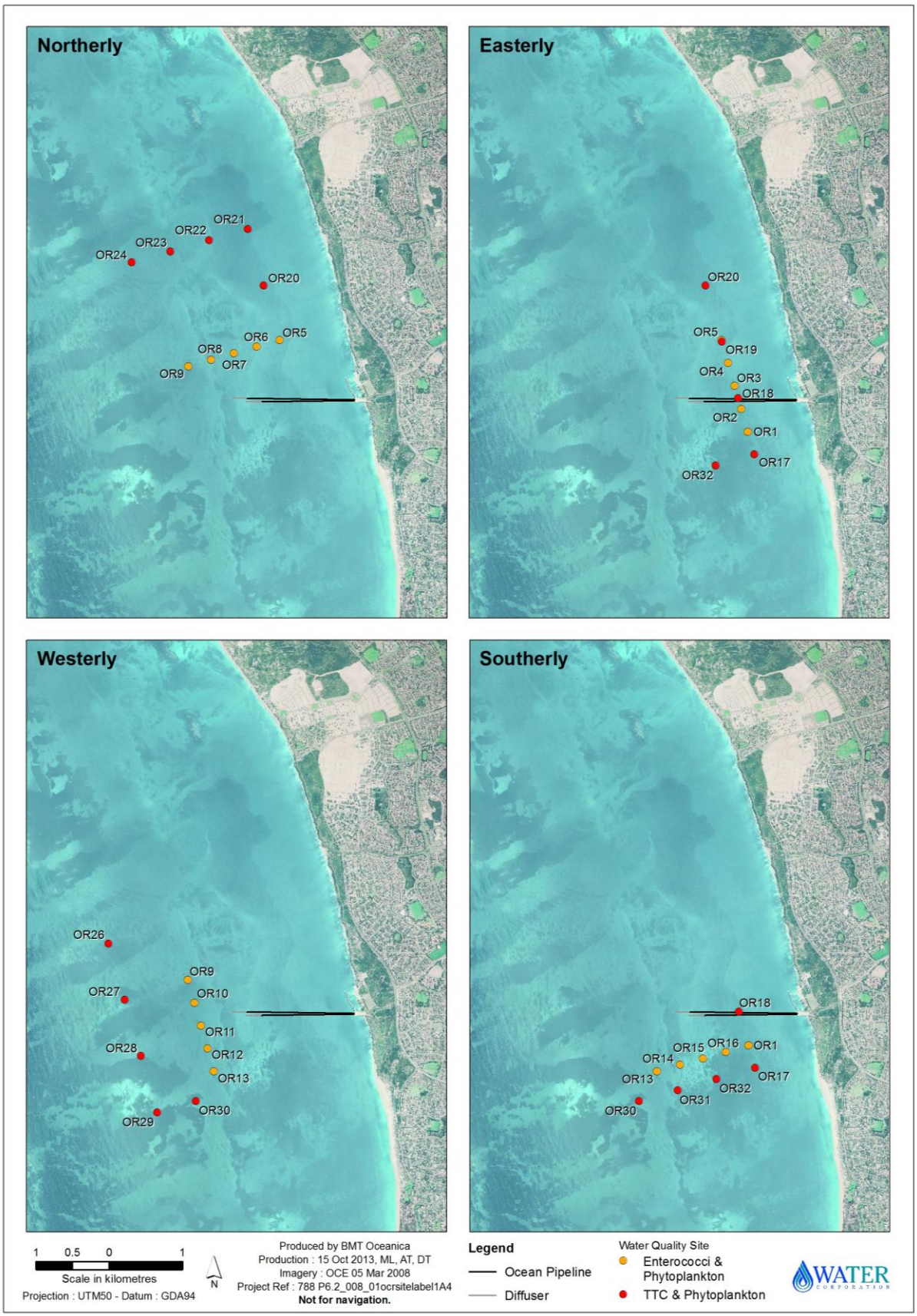
Samples were collected approximately fortnightly during the non-river flow period at five fixed sites located on the boundary of the OZI immediately down-current of the diffusers, with site selection based on the water current direction as indicated by the

[2] *Now known as Department of Water and Environmental Regulation.*

drogue (Figure 2.1, Figure 2.2). Composite water samples representative of the top half of the water column were collected and analysed for TTC and phytoplankton species.

For TTC, samples were collected in pre-sterilised bottles before being chilled in the dark to 4°C. Samples were subsequently transferred to PathWest Laboratories and analysed according to NATA-accredited methods.

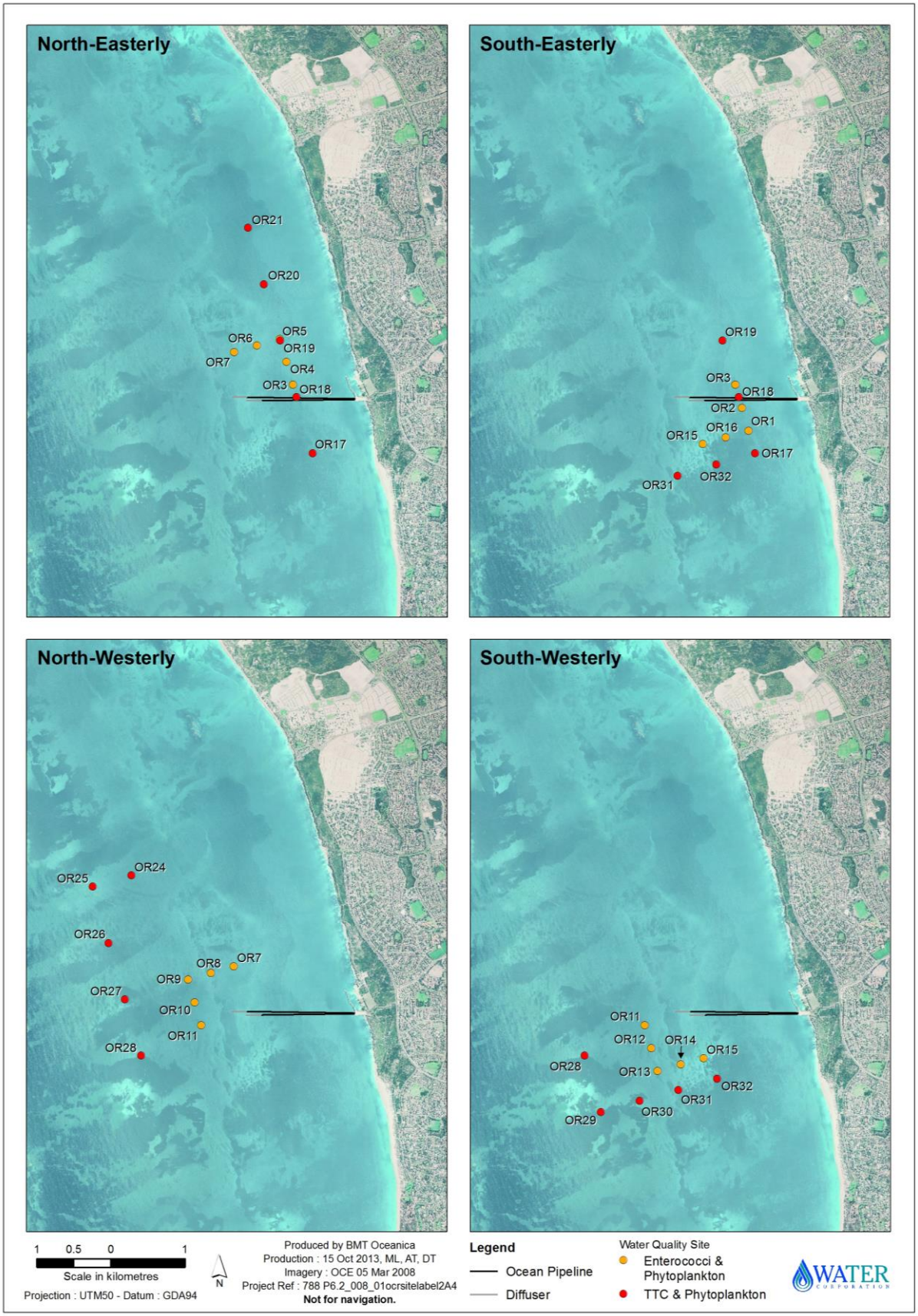
For phytoplankton, samples were preserved in Lugol's iodine solution and transported to Dalcon Environmental Laboratories for phytoplankton identification using the Utermöhl method. Phytoplankton were identified to the lowest taxonomic level possible. On each sampling date only one sample (i.e. in the direct path of the drogue) was analysed and the remaining four samples archived. In the event that toxic phytoplankton species are present at concentrations that exceed the recommended WASQAP guideline concentrations (DoH 2011), the full set of archived samples collected on that sampling occasion are also analysed (Table 2.1).



Notes:

1. Sites are located on the boundary of the observed zone of influence (OZI).

Figure 2.1 Fixed sites around the Ocean Reef outlet sampled for thermotolerant coliforms, *Enterococci* spp. and algal (phytoplankton) toxins during periods with northerly, easterly, westerly and southerly currents



Notes:

1. Sites are located on the boundary of the observed zone of influence (OZI).

Figure 2.2 Fixed sites around the Ocean Reef outlet sampled for thermotolerant coliforms, *Enterococci* spp. and algal (phytoplankton) toxins during periods with north-easterly, south-easterly, north-westerly and south-westerly currents

Table 2.1 Protocols for analysis of archived phytoplankton samples

Outcome of initial analysis	Further action
No exceedance of WASQAP[1] guideline concentrations	No analysis of archived samples
Exceedance of WASQAP guideline concentrations at both the reference site and the TCM[2] site	No analysis of archived samples
Exceedance of WASQAP guideline concentrations at the reference site, but not at the TCM site	No analysis of archived samples
Exceedance of WASQAP guideline concentrations at the TCM site but not at the reference site	Additional samples analysed

Notes:
1. Western Australian Shellfish Quality Assurance Program, DoH (2011).
2. Trial Compliance Monitoring.

3. Maintenance of Primary and Secondary Contact Recreation

3.1 Environmental Quality Objective

The EQOs for the EV 'Recreation and Aesthetics' are aimed at ensuring Perth's coastal waters are safe for primary and secondary contact recreation activities such as swimming and boating. To meet this objective, water quality around the Ocean Reef outlets is to be maintained so that:

- primary contact recreation (e.g. swimming) is safe in all waters except areas designated otherwise
- secondary contact recreation (e.g. boating) is safe in all waters except areas designated otherwise.

A formal area where contact recreation is not recommended has not been established for the area surrounding the Ocean Reef outlets. Sampling for this EQO was therefore undertaken at a series of fixed monitoring sites located at the boundary of the OZI, as described in Section 2.2. As the maintenance of primary contact recreation EQO requires a higher water quality standard to be maintained than secondary contact recreation EQO, by default, it is assumed that if primary contact recreation EQSs are met, secondary contact recreation EQSs will also be achieved.

3.2 Microbiological contaminants and algal biotoxins

The accepted method for determining whether the EQC for primary and secondary contact recreation have been met is to monitor microbiological contaminants (measured as numbers of faecal streptococci) and algal toxins (measured as numbers of phytoplankton cells) at the boundary of a pre-designated management zone. Such an approach has been developed for the ocean outlets at Sepia Depression and Alkimos.

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

Algal blooms can be harmful to human/animal health if encountered via ingestion or skin contact. For this reason, phytoplankton cell concentrations are monitored in the TCM program to ensure concentrations are within acceptable guidelines limits (EPA 2005b).

Microbial contaminants were sampled for approximately fortnightly at a series of fixed monitoring sites on the OZI boundary (refer Section 2.2, Figure 2.1 and Figure 2.2). Samples were collected during the non-river flow period at five fixed sites located immediately down-current of the diffusers, with site selection based on the water current direction as indicated by the drogue. Composite water samples representative of the top half of the water column were collected for faecal streptococci (*Enterococci* spp.) and phytoplankton cell concentrations.

Enterococci spp. samples were collected in pre-sterilised bottles before being chilled to 4°C and placed in the dark. On completion of sampling, the samples were transferred to PathWest laboratories and analysed according to NATA-accredited methods).

For phytoplankton, samples were collected, preserved and analysed in the manner described in Section 2.2.

Appendix G – Ecotox Australasia laboratory results

Appendix H – Marine and Freshwater Laboratory results

Appendix I – Site locations and coordinates

Site Coordinates

Ocean Reef trial compliance monitoring (TCM) reference and seasonal monitoring site location details and water quality parameters measured at the different sites

Site Code	Location with Respect to Outlet	Parameters Measured	Easting	Northing
Intensive Summer Water Quality ('Trial Compliance') Monitoring				
ORR1	Reference Site ≈ 4,000 m south	Nutrients; Phytoplankton; Water column profiles	377208	6482300
ORR2	Reference Site ≈ 4,000 m south	Nutrients; Phytoplankton; Water column profiles	377457	6482294
ORR3	Reference Site ≈ 4,000 m south	Nutrients; Phytoplankton; Water column profiles	377213	6482056
ORR4	Reference Site ≈ 4,000 m south	Nutrients; Phytoplankton; Water column profiles	377460	6482052

Datum: UTM WGS84 Zone 50

Ocean Reef trial compliance monitoring (TCM) sites and their relative distances from the outlet diffuser

Date	Site code - distance from outlet diffuser	Easting	Northing
06/12/2017	ORT-0	377878	6485137
	ORT-100	377825	6485242
	ORT-350	377702	6485464
	ORT-1000	377394	6486027
	ORT-1500	377152	6486468
19/12/2017	ORT-0		
	ORT-100	377821	6485242
	ORT-350	377695	6485456
	ORT-1000	377368	6486017
	ORT-1500	377105	6486440
09/01/2018	ORT-0	377877	6485140
	ORT-100	377777	6485237
	ORT-350	377594	6485409
	ORT-1000	377130	6485862
	ORT-1500	376768	6486212
17/01/2018	ORT-0	377877	6485138
	ORT-100	377977	6484993
	ORT-350	378116	6484782
	ORT-1000	378478	6484247
	ORT-1500	378761	6483832
01/02/2018	ORT-0	377876	6485139
	ORT-100	377827	6485041
	ORT-350	377764	6484914
	ORT-1000	377467	6484338
	ORT-1500	377221	6483895
23/02/2018	ORT-0	377881	6485139
	ORT-100	377865	6485239
	ORT-350	377832	6485486
	ORT-1000	377727	6486128
	ORT-1500	377667	6486625
15/03/2018	ORT-0	377880	6485138
	ORT-100	377894	6485241
	ORT-350	377940	6485488
	ORT-1000	378058	6486123
	ORT-1500	378157	6486612
28/03/2018	ORT-0	377881	6485144
	ORT-100	377710	6485185
	ORT-350	377464	6485252
	ORT-1000	376837	6485426
	ORT-1500	376354	6485554

Datum: UTM WGS84 Zone 50

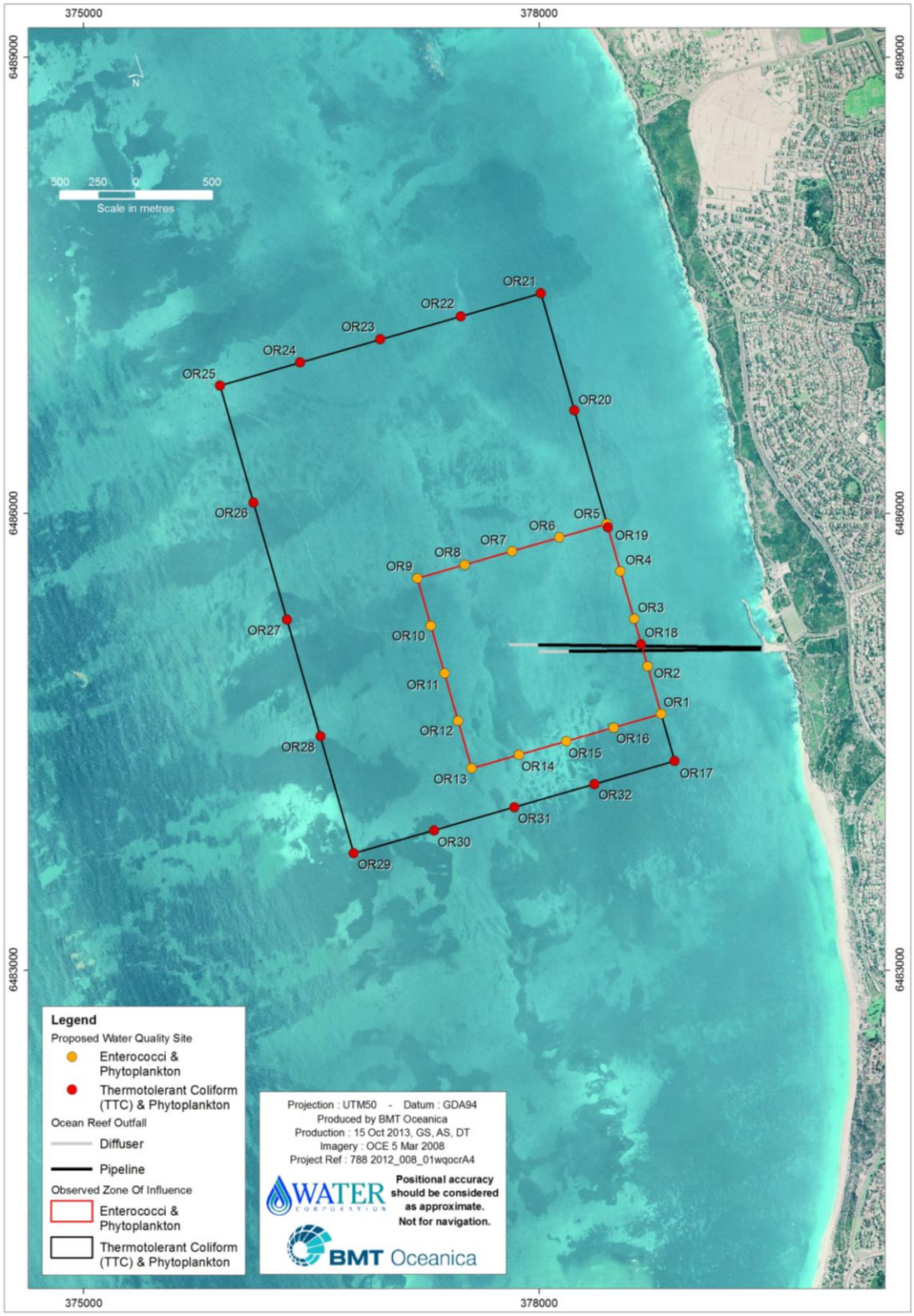
Notes:

1. The location of TCM potential impact sites are determined based on the direction of the surface current on the sampling day

Ocean Reef microbial and phytoplankton monitoring sites at the boundary of the observed zone of influence for contact recreation (1-16) and human consumption (17-32)

Site	Easting	Northing
OR1	378806	6484682
OR2	378717	6484995
OR3	378627	6485307
OR4	378537	6485620
OR5	378448	6485932
OR6	378135	6485842
OR7	377823	6485753
OR8	377511	6485663
OR9	377198	6485574
OR10	377288	6485261
OR11	377378	6484949
OR12	377467	6484637
OR13	377557	6484324
OR14	377869	6484414
OR15	378181	6484503
OR16	378494	6484593
OR17	378895	6484373
OR18	378674	6485142
OR19	378454	6485911
OR20	378233	6486680
OR21	378013	6487449
OR22	377484	6487297
OR23	376956	6487145
OR24	376427	6486994
OR25	375898	6486842
OR26	376119	6486073
OR27	376339	6485304
OR28	376560	6484535
OR29	376780	6483766
OR30	377309	6483918
OR31	377838	6484069
OR32	378366	6484221

Datum: UTM WGS84 Zone 50



Note:

On each sampling occasion, samples are collected down-current of the diffuser at a sub-set of five fixed monitoring sites located at the observed zone of influence boundary. The sites are selected based on the water current direction as indicated by a drogue release.

Fixed sites around the Ocean Reef ocean outlets sampled for thermotolerant coliforms, *Enterococci* spp. and algal (phytoplankton) toxins in relation to the observed zone of influence

Appendix J – PathWest microbiological laboratory results

Appendix K – Dalcon environmental laboratory results

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