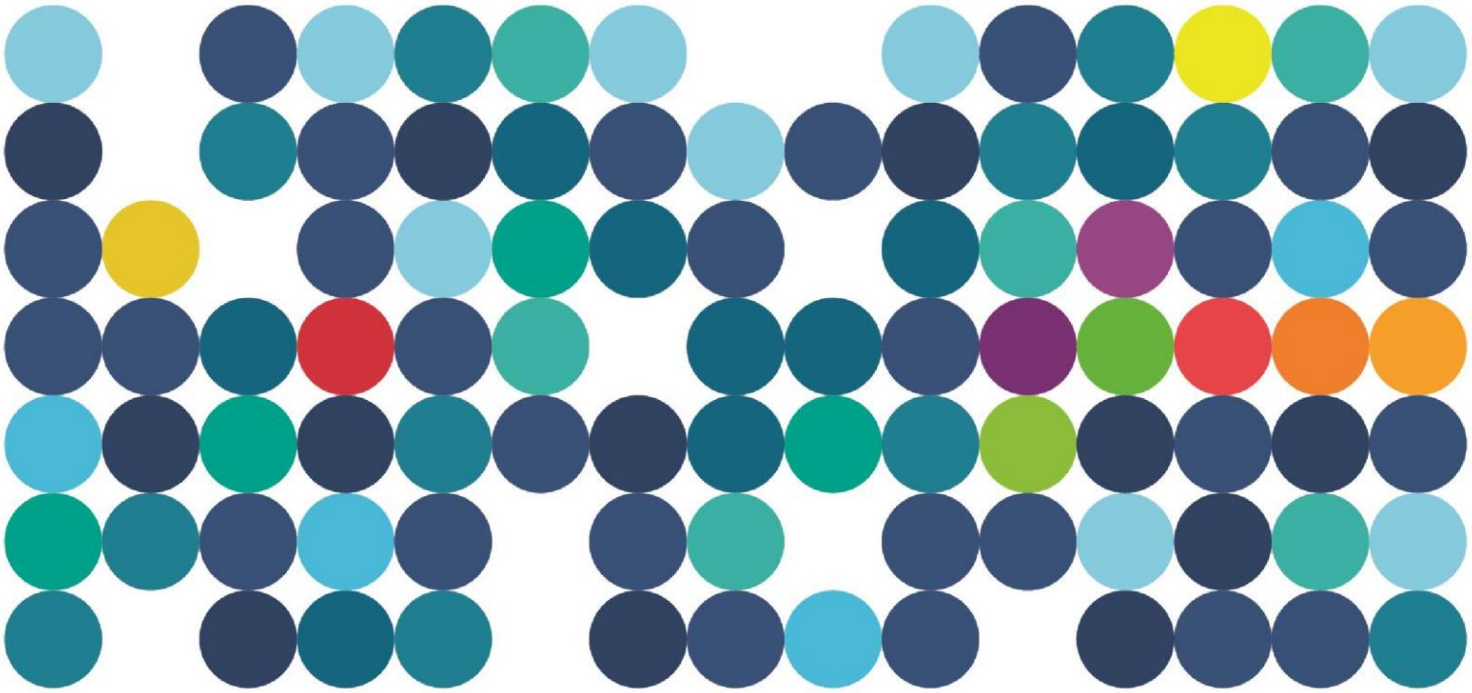
Beenyup Ocean Outlets

Monitoring and Management Plan

October 2023



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Quality Assurance

BMT Commercial Australia Pty Ltd has prepared this report in accordance with our Integrated Management System, certified to OHSAS18001, ISO14001 and ISO9001

Status

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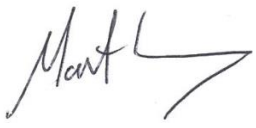
Approved for final release:



Director (or delegate)

Date: 9/10/23

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Corporate endorsement

I hereby certify that to the best of my knowledge, the Condition Environmental Management Plan (EMP) provisions within this Beenyup Ocean Outlets Monitoring and Management Plan are true and correct and address the legal requirements of conditions in Ministerial Statement No. 382 & 569.

Name:	Signed:
Designation:	Date:

Contents

Acronyms 10

Summary 1

1. Introduction 3

1.1 Proposal 3

1.2 Key environmental factors 4

1.3 Condition requirements 5

1.4 Rationale and approach 5

1.4.1 Results of scientific investigations conducted to date 5

1.4.2 Key assumptions and uncertainties 7

1.4.3 Management approach 7

1.4.4 Management zones 8

1.4.5 Rationale for choice of environmental criteria 8

1.4.6 Rationale for choice of EQG level actions and EQS contingency actions 8

2. Outcome based Environmental Management Plan 8

2.1 Maintenance of ecosystem integrity 8

2.1.1 Bioaccumulating toxicants in treated wastewater 8

2.1.2 Toxicants in treated wastewater 11

2.1.3 Whole of effluent toxicity (WET) testing 14

2.1.4 Receiving waters – physical and chemical measures 15

2.1.5 Receiving waters – phytoplankton blooms 16

2.1.6 Sediments 17

2.2 Maintenance of Seafood for Human Consumption 20

2.2.1 Microbial contaminants 20

2.2.2 Algal biotoxins 25

2.3 Maintenance of Primary and Secondary Recreation Values 27

2.3.1 Faecal streptococci 27

2.3.3 Toxic chemicals 32

2.4 Maintenance of Aesthetic Values 33

2.4.1 Aesthetic appearance 33

2.4.2 Fish tainting substances 33

2.5 Diffuser performance 34

3. Reporting 35

3.1 Annual reporting 35

3.2 Reporting on exceedance of an EQG and EQS 35

4. Adaptive Management 36

5. Stakeholder consultation 36

6. Review 36
7. Outcomes based EMP for Beenyup Water Resource Recovery Facility 37
8. References 50

List of tables

Table 1-1 Key environmental factors relevant to this EMP 4
Table 2-1 Concentration based guidelines for the treated wastewater stream toxicants 12
Table 2-2 Protocols for analysis of archived phytoplankton samples 27
Table 2-3 Field sheet for demonstrating compliance with Environmental Quality Guidelines for aesthetics 35
Table 2-4 Sensitivity of the two dilution approaches.....36
Table 7-1 Outcome based provisions 38

List of figures

Figure 1-1 Location of the Beenyup WWTP and ocean outlets 4
Figure 2-1 Management response framework in the event of an exceedance of Environmental Quality Criteria for bioaccumulating toxicants 9
Figure 2-2 Location of sentinel mussel sampling sites 10
Figure 2-3 Management response framework in the event of an exceedance of Environmental Quality Criteria for toxicants..... 14
Figure 2-4 Management response framework in the event of an exceedance of Environmental Quality Criteria for the 1-hour sea urchin test..... 15
Figure 2-5 Management response framework in the event of an exceedance of physico-chemical parameters and nutrient enrichment in receiving waters 17
Figure 2-6 Management response framework in the event of an exceedance of Environmental Quality Criteria for phytoplankton blooms in receiving waters..18
Figure 2-7 Management response framework in the event of an exceedance of the Environmental Quality Criteria for contaminants in sediments 20
Figure 2-8 Boundaries of Observed Zone of Effect and Seafood Management Zone around the Beenyup Ocean Outlet 23
Figure 2-9 Fixed sites around the Beenyup Ocean Outlet sampled for thermotolerant coliforms and phytoplankton during periods with southerly, south-westerly, north-westerly and westerly currents 24
Figure 2-10 Fixed sites around the Beenyup Ocean Outlet sampled for thermotolerant coliforms and phytoplankton during periods with northerly, north-easterly, easterly and south-easterly currents 25
Figure 2-11 Management response framework in the event of an exceedance of the Environmental Quality Criteria for thermotolerant coliforms 26
Figure 2-12 Management response framework in the event of an exceedance of the Environmental Quality Criteria for algal biotoxins in water 27
Figure 2-13 Boundaries of Primary Contact Management Zone around the Beenyup Ocean Outlet 29
Figure 2-14 Fixed sites around the Beenyup Ocean Outlet sampled for *Enterococci* spp. and phytoplankton during periods with northerly, easterly, westerly and southerly currents 30
Figure 2-15 Fixed sites around the Beenyup Ocean Outlet sampled for *Enterococci* spp. and phytoplankton during periods with north-easterly, south-easterly, north-westerly and south-westerly currents 31

Figure 2-16 Management response framework in the event of an exceedance of the Environmental Quality Criteria for faecal pathogens for the EQOs of Maintenance of Primary Contact Recreation 32
Figure 2-17 Management response framework in the event of an exceedance of the EQC for algal biotoxins for the EQOs of Maintenance of Primary and Secondary Contact Recreation 33

Acronyms

Abbreviation	Definition
AWRP	Advanced Water Recycling Plant
CTD	Conductivity-Temperature-Depth
DWER	Department of Water and Environmental Regulation
DoH	Department of Health
EP ACT	*Environmental Protection Act 1986*
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
EMP	Environmental management plan
NOEC	No observed effect concentration
PLOOM	Perth Long-term Ocean Outlet Monitoring
TTC	Thermotolerant coliforms
WRRF	Water Resource Recovery Facility

Summary

This document, the Environmental Quality Management Plan (hereafter, 'the Plan'), is submitted in support of the application for a change to conditions (Ministerial Statements No.382 & 569) for the Beenyup Ocean Outlets by Water Corporation pursuant to the provisions of Section 46 of the Environmental Protection Act 1986 (EP Act 1986). The Plan serves as the Condition Environmental Management Plan, and has been prepared following the guidance in EPA (2016 and 2017).

When implemented, this Plan is intended to protect the EPA's Environmental Factor Guideline for '*Marine Environmental Quality*' and ensure that the Environmental Objective, '*to maintain the quality of water, sediment and biota so that the environmental values, both ecological and social, are protected*', is met for the life of the project.

To maintain consistency with the management approach adopted at other metropolitan ocean outfalls, this Plan has also been developed with reference to EPA (2000) and EPA (2016) which set out the Environmental Quality Management Framework, Environmental Values (EVs) and Environmental Quality Objectives (EQOs) for Perth metropolitan and Western Australian coastal waters, respectively.

The table below presents the Environmental Quality Objectives that must be met through implementation of this Plan. The Table uses terminology consistent with EPA (2000) and EPA (2016).

Item	Description	
Proposal name	Section 46 application for change to Ministerial Conditions for the Beenyup Water Resource Recovery Facility	
Proponent name	Water Corporation	
Ministerial Statement number/s (if applicable)	382 & 569	
Purpose of the EMP (e.g. Environmental Scoping Document requirement or implementation condition/s requirement)	The Plan is submitted in support of an application to change the conditions in Ministerial Statement No.382 & 569 pursuant to the provisions of Section 46 of the EP Act 1986.	
Key environmental factor/s, outcome/s and/or objective/s	Environmental Values	Environmental Quality Objectives
	• Ecosystem Health • Fishing and Aquaculture • Recreation and Aesthetics • Cultural and Spiritual	• Maintenance of ecosystem integrity • Maintenance of seafood for human consumption • Maintenance of primary contact recreation values (waters safe for swimming), • Maintenance of secondary contact recreation values (waters safe for boating) • Maintenance of aesthetic quality • Maintenance of cultural/spiritual values
Condition clauses (if applicable)	NA	
Key components or legal requirements of the plan*		
Proposed construction and operation dates (MM/YYYY)	In operation	
EMP required pre-construction? Yes/No	No	

Note:

1. N/A = not applicable, EMP = environmental management plan

1. Introduction

1.1 Proposal

Water Corporation operates the Beenyup Water Resource Recovery Facility (WRRF) treating predominantly domestic wastewater from Perth's northern suburbs. The secondary treated wastewater (TWW) is discharged to the ocean through two existing ocean outlets at Ocean Reef (1.65 km (Outlet A) and 1.85 km (Outlet B) offshore) (Figure 1-1). Water Corporation's Perth Groundwater Replenishment Scheme (GWRS) has successfully demonstrated capacity for further treating the wastewater within the Advanced Water Recycling Plant (AWRP) (via ultrafiltration (UF), reverse osmosis (RO) and ultraviolet (UV) disinfection processes) to drinking water standard to recharge the confined aquifers, and reduce the environmental impact of potable water extraction.

The initial stage of the GWRS consisted of a Trial (1.5 GL/year capacity plant) which was completed in December 2012 followed by Stage 1 (14 GL/year capacity plant) which commenced production in 2017. The proposed expansion (Stage 2 of the GWRS) will increase the capacity of the AWRP to treat a larger proportion of the secondary TWW from the Beenyup WRRF for groundwater recharge. It will result in a greater proportion of the secondary TWW from the Beenyup WRRF being diverted into the AWRP and a reduction in the volume and change to the composition of the TWW being discharged to the marine environment through the Beenyup Ocean Outlets.

A request for a Change to Conditions under Section 46 of the Environmental Protection Act 1986 (EP Act) seeks to allow for a change in discharge characteristics and seeks to bring the approval and management framework into line with contemporary Environmental Protection Authority (EPA) policy and guidance, through the establishment of an Environmental Quality Plan (EQP) for the area surrounding the discharge location (Marmion Marine Park).

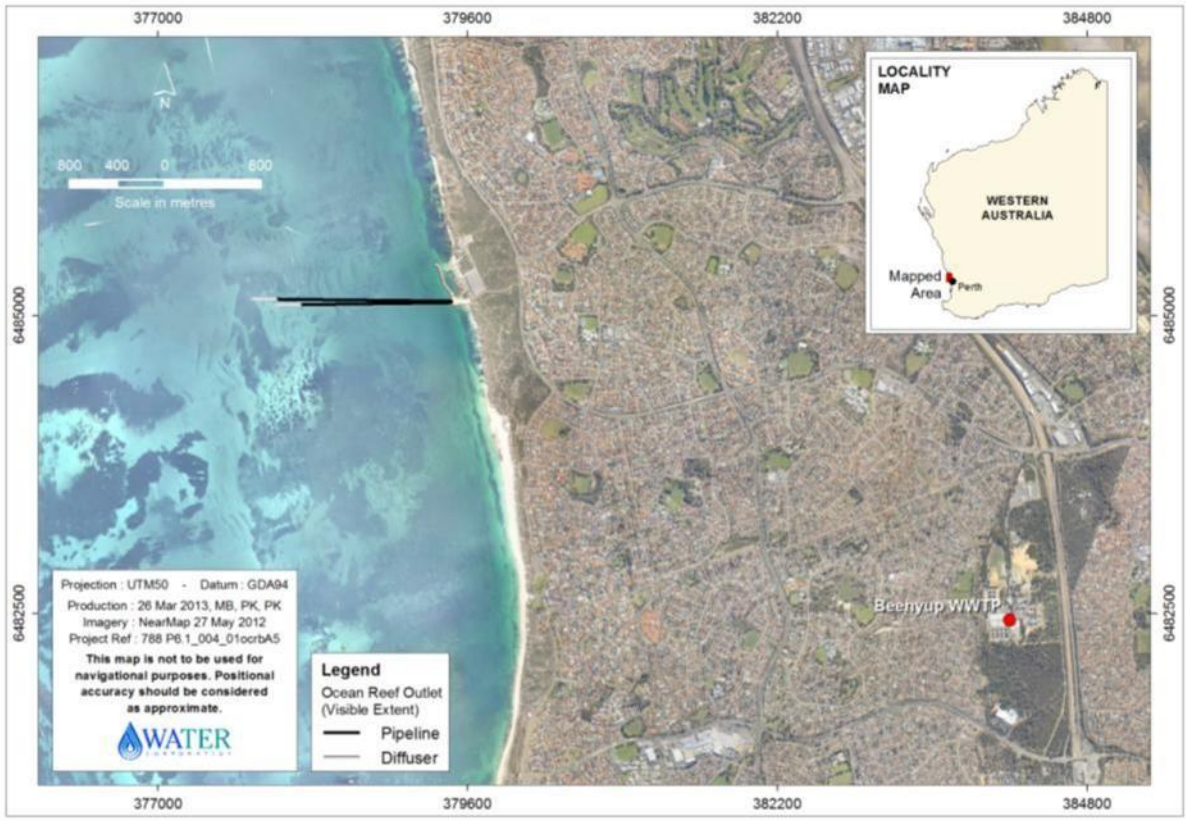


Figure 1-1 Location of the Beenyup Water Resource Recovery Facility and ocean outlets

1.2 Key environmental factors

Key environmental factors are identified in 'Statement of Environmental Principles, Factors and Objectives' (EPA 2016). Those relevant to this EMP are summarised in Table 1-1.

Table 1-1 Key environmental factors relevant to this EMP

EPA Theme	EPA Factor	Objective
Sea	Marine Environmental Quality	To maintain the quality of water, sediment and biota so that environmental values are protected

Note:

1. EPA = Environmental Protection Authority.

Aspects of the proposal which could affect the key environmental factor are:

- Dissolved inorganic forms make up the majority of nitrogen and phosphorus discharged from the outlets. These nutrients can enhance the growth of aquatic plants in the water column (i.e. phytoplankton) and on the seabed (e.g. reef algae, seagrass epiphytes). Enhanced plant growth may lead to changes in the abundance and species composition of aquatic plant communities if some species are favoured more than others by the increased nutrient supply. Particulate organic material can also accumulate in sediments, where it may provide 'food' to marine organisms. The resultant increased

food supply may cause alterations to benthic fauna abundance and species composition, and may reduce sediment oxygen supply.

- Metals and persistent organic compounds may accumulate in biota at concentrations sufficient to pose a risk to humans when wild-caught seafood is consumed. The Beenyup WRRF does not receive stormwater runoff and does not include significant industrial chemicals such as polychlorinated biphenyls (PCBs) or petroleum hydrocarbons. The toxicant of primary concern is copper which is elevated in the waste stream due to the extensive use of copper piping in domestic plumbing. Monitoring has typically not found detectable concentrations of herbicides and pesticides in the waste stream.
- Pathogenic organisms from faecal material are a potential threat to human health via accidental swallowing of contaminated waters during recreational activities or via consumption of uncooked seafood (noting that cooking destroys enteric bacteria). Chloramination is required in order to maintain the effectiveness of the RO membranes. The AWRP will significantly reduce bacterial counts and provide a net benefit with regard to pathogen concentrations.

The representation, diversity, viability and/or ecological function for site-specific species, populations or communities, which could be affected are:

- The benthic habitat around the outlets is predominantly sand, with areas of seagrass and low relief limestone reef.
- Perth's submerged offshore reefs support extensive stands of macroalgae, predominantly larger brown algae (*Ecklonia radiata*, Scytothalia dorycarpa and Sargassum spp.) but also smaller red, green and brown algae. A diverse assemblage of invertebrates also inhabits the reefs.
- The fish populations in the nutrient-poor nearshore waters of Perth depend largely on benthic-based food chains in the seagrass meadows, macroalgal-dominated reef systems and detritus-enriched basins.

1.3 Condition requirements

This plan is submitted in support of an application for changes to conditions in Ministerial Statements 382 & 569 pursuant to the provisions of Section 46 of the EP Act 1986.

1.4 Rationale and approach

1.4.1 Results of scientific investigations conducted to date

PLOOM

Water Corporation has monitored the environmental effects of TWW discharge into Perth's coastal waters since the construction of the ocean outlets at Swanbourne in 1963, Sepia Depression in 1984, Ocean Reef in 1978 (Outlet A) and 1992 (Outlet B), and Alkimos in 2010. Monitoring in its present form commenced after the Perth Coastal Waters Study (Lord & Hillman 1995), which in turn led to the present-day PLOOM program that formally commenced in 1996. In 2003 the PLOOM program was revised to comply with the Environmental Quality Management Framework (EQMF). As part of this, there was a shift in emphasis from investigative studies to a program of Trial Compliance Monitoring (TCM). The results of the PLOOM program have been reported annually since inception.

The discharge

The TWW is primarily fresh and maintains a density lower than seawater. As a result, the

TWW plume is buoyant – rising through the water column and mixing as it ascends. The effects of the TWW plume are therefore observed primarily at the surface of the water column in the immediate vicinity of the ocean outlets.

Hydrodynamics and circulation

The offshore wave climate of Perth is dominated by a persistent low- to moderate-energy wave regime and is generally more variable in winter than in summer. The summer swell is predominantly west to south-westerly in direction and typically 1–2 m in height. The direction of the winter swell is predominantly westerly and typically 1–3 m in height. During summer, the afternoon sea breeze results in the development of local seas (typical wave heights are 0.5–1.5 m) that are superimposed upon the swell regime. Local seas are also generated by the passage of winter storms: wave height and direction varies considerably from storm to storm, but the wave heights often exceed 4 m (7 m or more in severe storms).

Wind is the main factor influencing coastal circulation in the inshore waters, particularly in summer when up to 60% of the variation in the ocean currents can be explained by the wind field (Pattiaratchi & Knock 1995). The prevailing summer winds drive northward-flowing littoral currents, although periods of current reversal can occur under northerly winds, particularly in winter. Currents are strongly influenced by the inshore bathymetry, with water tending to move along reef line channels parallel to the shore. An offshore chain of reef to the west and south-west of the outlets dissipates some wave energy received inshore.

Surface currents at Ocean Reef recorded over one year (1993) ranged between 0 and 5 cm s^{-1} (0 and 0.05 m s^{-1}) for 9% of the time, between 5 and 15 cm s^{-1} (0.05 and 0.15 m s^{-1}) for approximately 75% of the time, and greater than 15 cm s-1 (>0.15 m s^{-1}) for 15% of the time. Calm (i.e. zero current) conditions were rare (Pattiaratchi et al. 1995). Thus, although calm (i.e. zero current) conditions were modelled for the purposes of this report (to investigate ‘absolute worst-case’ conditions), such events are seldom observed.

Habitat

Over time, the TWW outlets have become encrusted with an array of marine life, including ascidians, sponges and complex macroalgal communities. In turn, these communities attract and support a variety of marine life comprising demersal fin-fish, molluscs, crustaceans and echinoderms (BMT Oceanica, unpublished historical data).

The benthic (or seafloor) habitat around the outlets is predominantly sand, with areas of seagrass and low relief limestone reef. Surveys undertaken in February 2002 classified three types of seagrass habitat: dense seagrass cover (>70%), medium seagrass cover (30–70%) and sparse seagrass cover (<30%; DALSE 2003). A more recent benthic communities and habitat survey within the broader Marmion Marine Park found the most common benthic habitat type is ‘mobile sand’ (50%) with ‘macroalgae’ (38%) and ‘seagrass’ being less prevalent (12%) (Strategen 2016). Sandy habitats located close to the outlets contained sparse communities of the seagrass *Posidonia coriacea* (DALSE 2003). Dense seagrass (>70%) cover was restricted to the inshore regions of Whitfords Lagoon, south of the outlets. The Whitfords Lagoon habitats were dominated by *Posidonia sinuosa* and *Amphibolis griffithii* (DALSE 2003). The seagrass covered areas are consistently changing due to transient sediment movement.

The most significant habitat within the Marmion Marine Park is the near-shore macroalgae habitat (intertidal and subtidal high-relief) as this supports a proportion of the Roe’s abalone (Haliotis roei) fishery.

1.4.2 Key assumptions and uncertainties

This plan has been developed assuming the final effluent composition is accurately reflected by the existing discharge concentrate based on the expected plant recovery. Monitoring is conducted in the summer under the assumption that low river flow minimises the degree of natural variability in some of the indicators, summer represents a period of relatively low dilution (i.e. calm weather) and maximum recreational utilisation (i.e. swimming and boating).

1.4.3 Management approach

The EPA (now DWER) has prepared an Environmental Quality Management Framework (EQMF) for Western Australia's coastal waters (EPA 2016). This EQMF is based on:

- identifying Environmental Values (EVs)
    - Ecosystem Health
    - Fishing and Aquaculture
    - Recreation and Aesthetics
    - Cultural and Spiritual
- establishing and spatially defining Environmental Quality Objectives (EQOs) that need to be maintained to ensure the associated Environmental Values are protected
    - maintenance of ecosystem integrity
    - maintenance of seafood for human consumption
    - maintenance of primary contact recreation values (waters safe for swimming)
    - maintenance of secondary contact recreation values (waters safe for boating)
    - maintenance of aesthetic quality
    - maintenance of cultural/spiritual values
- 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 against which monitoring results can be compared.

There are two levels of EQC:

Environmental Quality Guidelines (EQGs) are quantitative, investigative guidelines which signify low risk of an environmental effect if they are met, and trigger further investigations if an exceedance occurs; and

Environmental Quality Standards (EQSs) are management guidelines based on multiple lines of evidence, which if exceeded signify that the Environmental Quality Objective is not being met and that a management response is required.

For the purposes of this plan, EQG are adopted as trigger levels and EQS as thresholds. If monitored values are below the EQG then the EQO are considered to have been met and the Environmental Values protected. If an EQG is exceeded, there is an increased risk that the associated EQO may not be achieved and assessment against the EQS is triggered. If an EQS is exceeded, it is considered there is a significant risk that the associated EQO has not been achieved and a management response is required to ensure the EQO is achieved.

The EQO to protect cultural and spiritual values applies to Aboriginal cultural and spiritual values. In the absence of any specific environmental quality requirements for protection of this value it is assumed that if water quality is managed to protect ecosystem integrity, protect primary contact recreation, protect the quality seafood for eating and maintain aesthetic values, then this may go some way toward maintaining cultural values.

1.4.4 Management zones

In 2017, a Section 45C application established an EQP for Marmion Marine Park waters around the Beenyup Ocean Outlets. The 2017 EQP spatially defined the first formal Low Ecological Protection Area, Seafood Management Zone and Primary Contact Management Zone around the outfalls. Between approval of the management zones in 2017 and issue of the final revised MS382 it became apparent that assumptions about the plant operational performance were over-optimistic and the size of the Seafood Management Zone was incorrect. Application of the 2017 Seafood Management Zone boundary would result in criteria exceedances (despite a real improvement in environmental outcomes relative to the original proposal (MS 382)). Because any exceedances of criteria would be an artifact of incorrect definition of management zones, rather than an indication that the environmental quality objective was at risk of not being achieved, further modelling to determine an appropriate Seafood Management Zone was commissioned. A Section 45C application under the *Environmental Protection Act 1986* (EP Act) seeks to apply the revised Seafood Management Zone. DWER expressed a preference for reduced management areas to assist in showing regard to the principle of waste minimisation. However, it is not possible to determine the proportion of time that the plant will be in shut down and it is not clear in advance that criteria can be reasonably achieved during these periods of shut down if the Seafood Management Zone boundary is smaller than necessary. DWER proposed a hybrid approach which is described in section 2.2.

1.4.5 Rationale for choice of environmental criteria

The EQC are based on those in the Environmental Quality Criteria Reference Document for Cockburn Sound (EPA 2017). These EQC have been adopted in formal monitoring programs at other metropolitan outlets (Sepia Depression Ocean Outlet Landline, Alkimos and Bunbury) and have been applied informally at Beenyup (and Swanbourne) via the long running PLOOM program.

1.4.6 Rationale for choice of EQG level actions and EQS contingency actions

Actions are based on those contained in EPA (2016). If an EQG is exceeded, assessment against the EQS is triggered. If an EQS is exceeded, a management response is required to ensure the EQO is achieved. These responses are specific to maintaining the EQO at risk of not being met. They are consistent with those adopted previously in other formal monitoring programs (Sepia Depression Ocean Outlet Landline, Alkimos and Bunbury) and those applied informally at Beenyup (and Swanbourne) via the long running PLOOM program. The response after triggering an EQS typically requires reporting to the relevant agency (DWER or DoH). Responses include further investigations to determine the extent and source of the environmental impact and/or application of management options to reduce the impact.

2. Outcome based Environmental Management Plan

2.1 Maintenance of ecosystem integrity

2.1.1 Bioaccumulating toxicants in treated wastewater

Background

The treated wastewater (TWW) stream will be monitored by Water Corporation to characterise the concentration of bioaccumulating metals.

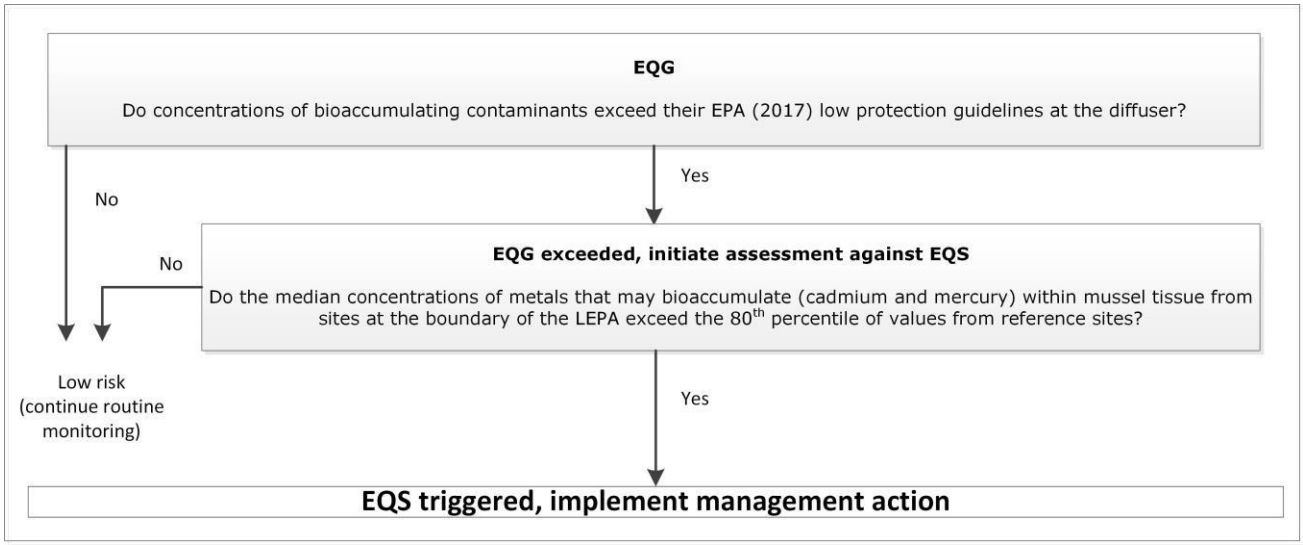
Monitoring

Assessment of bioaccumulating metals (mercury and cadmium) in TWW stream will be conducted biannually. The TWW characterisation sample will be an average of the final TWW discharge for the 24-hour period prior to the sample collection (i.e. a one litre sample

is collected every hour over 24hours, which provides a composite sample of 24 L from which sub-samples are analysed).

The bulk sample will be homogenised (agitated) and divided into appropriate sample containers. Samples will be collected, stored and transported according to the relevant parts of Australian Standard AS/NZS 5667.1:1998 and all analyses will be undertaken by NATA accredited laboratories. Samples for bioavailable metals will be passed through a 0.45 µm filter prior to analysis.

Contaminant concentrations are compared directly to the EPA (2017) Low Environmental Protection guidelines (Table7-1 and Figure 2-1).



Note:

1. EQG = Environmental Quality Guideline; EQS = Environmental Quality Standard; LEPA = Low Ecological Protection Area

Figure 2-1 Management response framework in the event of an exceedance of Environmental Quality Criteria for bioaccumulating toxicants

Sentinel mussels EQS

Sentinel mussels will be deployed at three sites (150 m west (150W), 150 m north (150N) and 150 m south (150S) on the boundary of the Low Ecological Protection Area (150 m radius from the diffuser) (Figure 2-2). Sentinel mussels will also be deployed at a reference site 3 km south of the outlets (ORR4), away from the influence of the TWW discharge, which has a prevailing northerly current in the region.

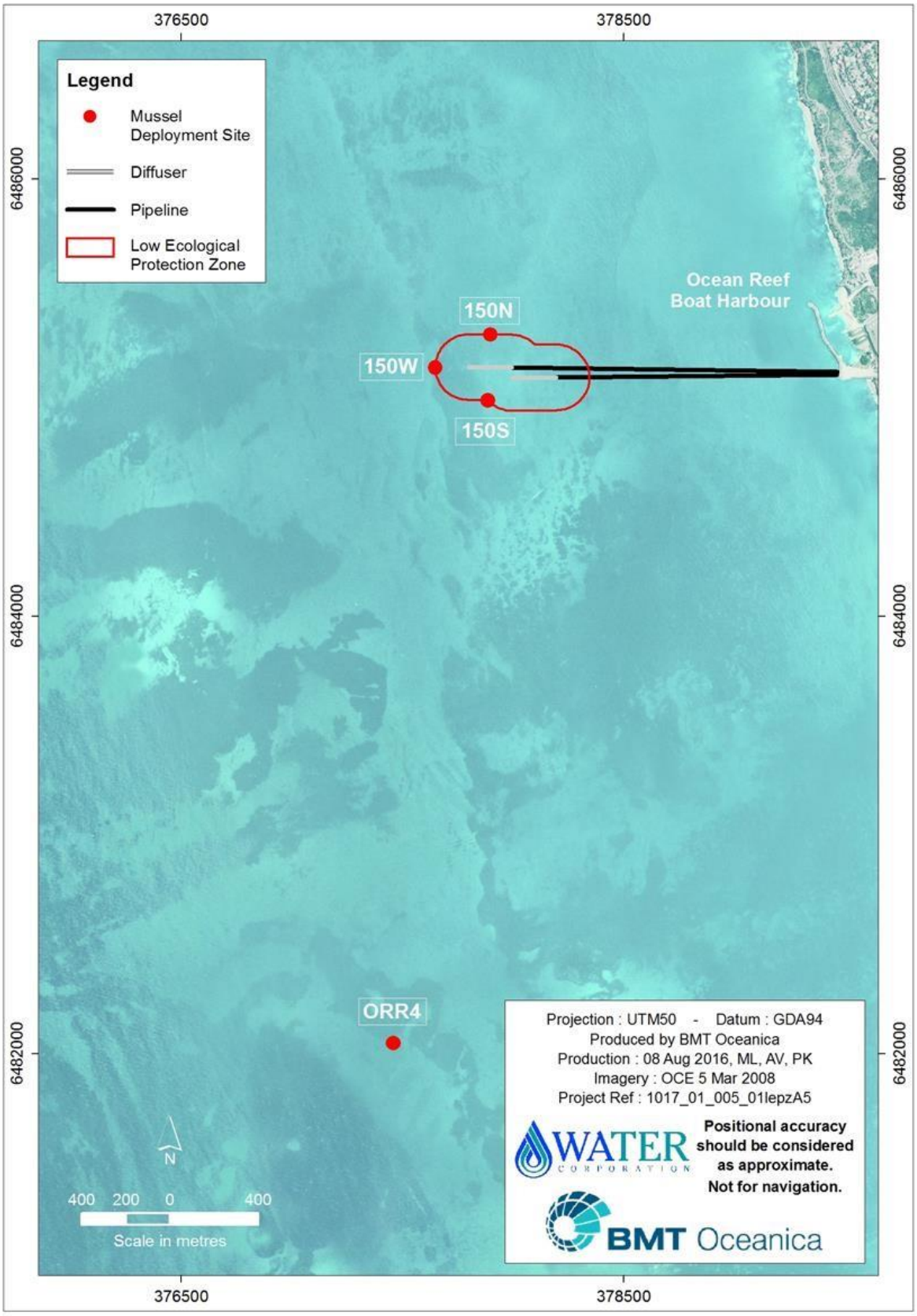


Figure 2-2 Location of sentinel mussel sampling sites

Five replicate mussel lines will be deployed at each site, with mussels suspended in plastic mesh baskets approximately 2 m below the surface and 2 m above the seafloor. Approximately 30 mussels (55–65 mm shell length) will be deployed in each bag. To prevent the accumulation of algal growth (a cause of mussel mortality), the mesh baskets will be cleaned after 3 weeks. Mussels equilibrate with environmental conditions after a period of 4 weeks. To ensure equilibrium is reached, the mussels will be deployed for a 6week period (Regoli & Orlando 1994). After that, the live mussels will be retrieved and placed into sterile bags and stored frozen until analysis.

Prior to analysis, mussel samples will be thawed, the shells shucked, the soft tissue homogenised, and the samples freeze-dried and ground. In line with the Western Australian Shellfish Quality Assurance Program (DoF 2007), the tissue from the mussels deployed at Ocean Reef will be analysed for the relevant contaminant/s of concern.

Standard laboratory analytical procedures will be employed throughout and laboratories with NATA-accredited methods or appropriate QA/QC standards in place will undertake the analyses.

2.1.2 Toxicants in treated wastewater

Background

Comprehensive TWW characterisation will be conducted annually for the suite of contaminants in Table 2-1.

Monitoring

The TWW characterisation sample will be an average of the final TWW discharge for the 24-hour period prior to the sample collection (i.e. a one litre sample is collected every hour over 24hours, which provides a composite sample of 24 L from which sub-samples are analysed).

The bulk sample will be homogenised (agitated) and divided into separate sample containers. Samples will be collected, stored and transported according to the requirements of the NATA-accredited laboratories that will be undertaking the analyses. Samples for bioavailable metals will be passed through a 0.45 µm filter prior to analysis. A separate grab sample for microbiological parameters will be collected as 24-hour composites are not suitable for microbiological parameters.

The concentrations of toxicants in the TWW will be assessed against guidelines derived from the relevant EPA (2017) guidelines for marine waters based on the 5th percentile dilution expected to be achieved at the LEPA boundary down-current of the outlets, under low energy summer and autumn conditions (Table 2-1). The worst-case dilution at the LEPA boundary was determined using a validated 3-dimensional hydrodynamic model (Delft3D) in combination with background concentrations as per the formula):

TWW guideline = (Dilution x [Existing Guideline - Background]) + Background

The modelled 5th percentile dilution (1:483) was derived on the basis that the high protection guidelines for toxicants must be met at the LEPA boundary 95% of the time. All, including worst-case, toxicant concentrations are expected to meet the guidelines (Table 2-1, Figure 2-3 and Table7-1). The guidelines will be reviewed if the EPA (2017) values are revised.

Table 2-1 Concentration based guidelines for the treated wastewater stream toxicants

Parameter	Background	High protection guideline (µg/L)	TWW guideline (µg/L)
Nutrients (µg/L)			
Ammonia-N	1.5[1]	500	240528
Dissolved metals (0.45 µm filtered) (µg/L)			
Chromium III (Cr III)	0.2[3]	7.7	3619
Chromium III (Cr VI)	0[4]	0.14	68
Copper (Cu)	0.08[2]	0.3	106
Lead (Pb)	0.01[5]	2.2	1057
Nickel (Ni)	0.5[6]	7	3137
Silver (Ag)	0.0007[2]	0.8	386
Zinc (Zn)	0.15[2]	7	3305
Organophosphate pesticides (µg/L)			
Chlorpyrifos	0[7]	0.0005	0.24
Organochlorine pesticides (µg/L)			
Endrin	0[7]	0.004	1.93
Endosulfan sulfate	0[7]	0.005	2.41
Phenol (µg/L)			
Phenol	0.05[8]	270	130251
Pentachlorophenol (PCP)	0.1[8]	11	5259
Chlorinated hydrocarbons (µg/L)			
1,2,4-Trichlorobenzene	0.5[8]	20	9409
BTEX (µg/L)			
Benzene	0.5[8]	500	241009
Poly aromatic hydrocarbons (PAHs) (µg/L)			
Naphthalene	0.05[8]	50	24101
Benzo(g,h,i)perylene	0.05[9]	50	24101
Chlorination by products (µg/L)			
Residual chlorine			3000

Notes:

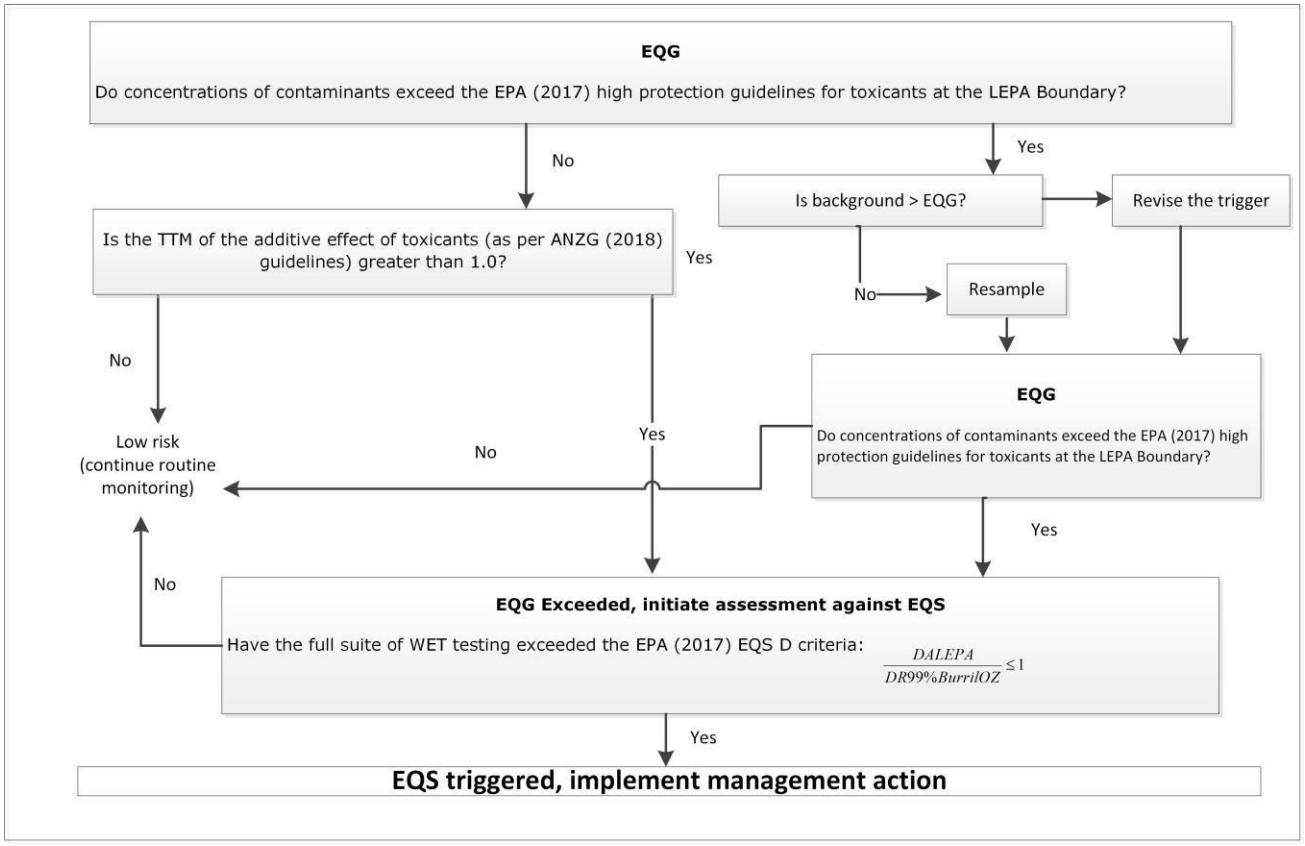
1. Median of Perth Long-term Ocean Outlet Monitoring Program Ocean Reef reference site
2. From Table 13 of McAlpine et al. (2005)
3. From Table 13 of McAlpine et al. (2005) (value is for total chromium)
4. No background available, assumed to be zero
5. Half the limit of detection from Table 13 of McAlpine et al. (2005)
6. Half the limit of reporting from National Measurement Institute
7. Half the limit of reporting from Table 9 of McAlpine et al. (2005) is greater than the guideline, assumed to be zero
8. Half the limit of reporting from Table 9 of McAlpine et al. (2005)
9. Half the limit of reporting for PAHs from Table 9 of McAlpine et al. (2005)

Calculation of the total toxicity of the mixture (TTM) is an additional interpretative tool used for estimating the potential toxicity where the effects of the toxicants may be 'additive'. The potential toxicity of the TWW to marine biota at the LEPA boundary (i.e. after 1:483 dilutions of the TWW with background seawater) is assessed as per the ANZG (2018) guidelines, based on the effects of ammonia, copper and zinc; the three contaminants identified as most likely to cause toxicity effects based on the degree to which they exceed EPA (2017) guidelines in undiluted TWW. It is important to note, however, that the formula is only meant to be used for simple mixtures where the interactions are simple and predictable. The approach does not account for synergistic and/or antagonistic effects, or complex mixtures. The effects of ammonia, copper and zinc (or other metals) in combination is assumed to be additive. If the mixture is complex (i.e. >5 components and/or has uncertain mixture effects), ANZG (2018) recommends proceeding to direct toxicity assessment (i.e. WET testing).

The formula used to calculate the TTM is:

$$TTM = \frac{[ammonia]}{ammonia\ guideline} + \frac{[copper]}{copper\ guideline} + \frac{[zinc]}{zinc\ guideline}$$

The TTM needs to be less than 1 in order to meet the total toxicity criteria, in accordance with ANZG (2018) guidelines (Table7-1).



Note:

1. EQG = Environmental Quality Guideline; EQS = Environmental Quality Standard; LEPA = Low Ecological Protection Area; TTM = total toxicity of the mixture; DALEPA = Dilutions achieved at the boundary of the LEPA; DR99%BurrliOZ = Number dilutions required to achieve the 99% species protection guideline

Figure 2-3 Management response framework in the event of an exceedance of Environmental Quality Criteria for toxicants

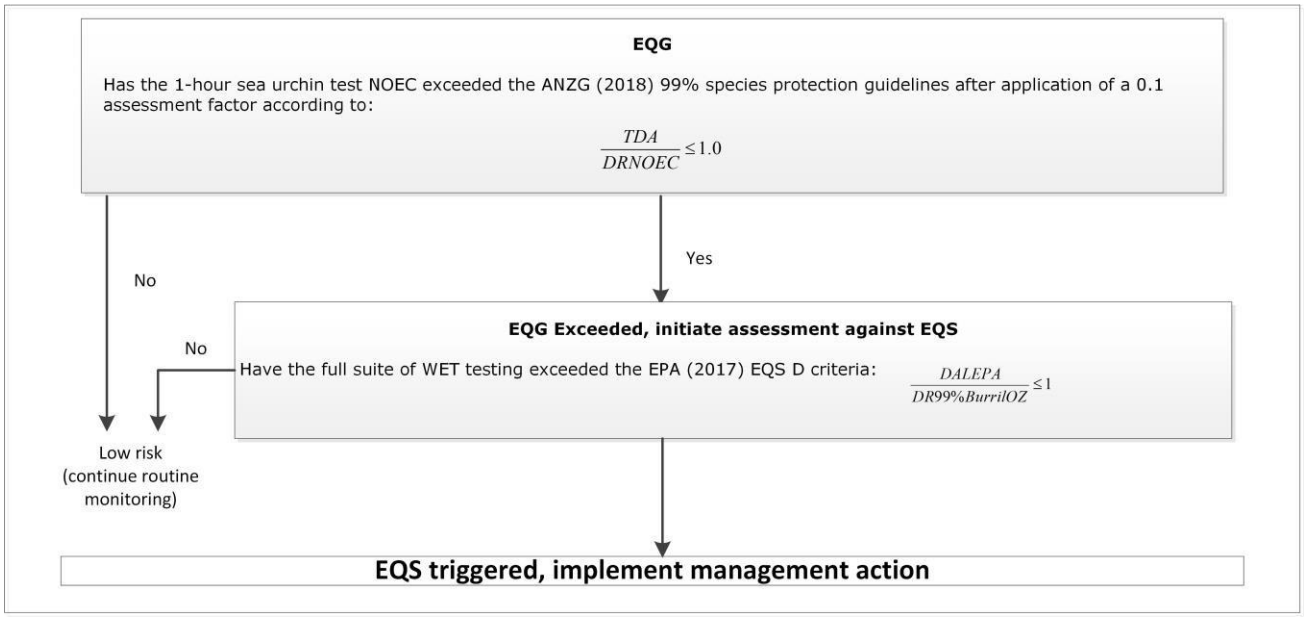
2.1.3 Whole of effluent toxicity (WET) testing

1-hour urchin fertilisation

The 1-hour sea urchin fertilisation WET tests will be conducted biannually. The sample will be a composite of the final TWW discharge for the 24-hour period prior to the sample collection (i.e. a one litre sample is collected every hour over 24-hours, which provides a mixed composite sample of 24 L from which sub-samples are analysed). The sample will be collected in clean sterile jars, packaged chilled and sent to the relevant laboratory for analysis. Seawater (for use as the dilution water in the WET tests) will be provided by the laboratory undertaking the WET test (QA/QC of seawater is routinely undertaken under controlled conditions, as part of this process).

The 1-hour sea urchin fertilisation test will measure the rate of sea urchin sperm and egg fertilisation when exposed to a range of TWW solutions. The dilutions of TWW used will be appropriate for the expected dilutions, unless revised during subsequent reporting, a typical dilution series may be: 1%, 3.1%, 6.25%, 12.5%, 25%, 50% and 100%. All test dilutions for TWW will be salt-adjusted (using artificial sea salts) to achieve marine salinities, so that only the toxicity due to the presence of contaminants is examined and not the toxic effect of freshwater on the marine organism. Testing will also be undertaken on a seawater control, and an artificial sea salt (brine) control.

The 1-hour urchin fertilisation test is a short-term chronic test with a sub-lethal end point. A variety of test statistics, including NOEC, LOEC, EC/IC10 and EC/IC50 values, will be generated from the test. The NOEC after application of a 0.1 assessment factor (as per ANZG (2018) protocols where there are fewer than 5 test results) is required for assessment against the EQG (Figure 2-4 and Table7-1). The typical dilutions achieved (TDA) is conservative and based on modelling which suggests actual dilutions at the LEPA boundary are 483-fold 95% of the time during the low energy summer to autumn period.



Note:
1. EQG = Environmental Quality Guideline; EQS = Environmental Quality Standard; LEPA = Low Ecological Protection Area; TDA = Typical Dilutions Achieved; DRNOEC = Number of dilutions required to achieve the No Observed Effects Concentration; DALEPA = Dilutions achieved at the boundary of the LEPA; DR99%BurrliOZ = Number dilutions required to achieve the 99% species protection guideline

Figure 2-4 Management response framework in the event of an exceedance of Environmental Quality Criteria for the 1-hour sea urchin test

Full suite of WET tests EQS

The full suite of WET testing is a more comprehensive assessment of TWW toxicity and measures the responses of a number of biota (from a number of trophic levels) to a range of salt-adjusted TWW solutions. Data generated are used to calculate the dilutions of TWW required to protect 99% of species, using the BurrliOZ software. The full suite of WET testing will use a selection of five chronic tests as per ANZG (2018).

2.1.4 Receiving waters – physical and chemical measures

Background

Ocean monitoring will be undertaken to measure the environmental impacts of the TWW on the receiving environment through regular and intensive water quality analysis capable of measuring environmental quality against the Environmental Quality Objectives. EQC employ indicators for nutrient enrichment (chlorophyll-a and light attenuation coefficient [LAC]), phytoplankton blooms (chlorophyll-a), organic enrichment (dissolved oxygen) and osmotic stress (salinity). Monitoring is based on the existing PLOOM Program and is consistent with the monitoring regime already practiced at Ocean Reef and other metropolitan outlets.

Monitoring

Fortnightly sampling will be conducted over a 4-month period between December and March (i.e. eight occasions per year). Sampling will be conducted during the summer to avoid potential confounding effects of riverine and groundwater discharge.

On each sampling occasion, a surface drogue will be deployed over the centre of the operational diffuser and retrieved approximately 30 min later. The time and location of the drogue at deployment and retrieval will be recorded using an on-board GPS. This information will be used to derive a directional vector along which sampling will be undertaken. These data will also provide an accurate estimate of surface current speed at the time of sampling. On each sampling occasion, samples will be collected at four reference sites and five compliance sites located at intervals of 0, 150, 350, 1000 and 1500 m down-current of the outlets.

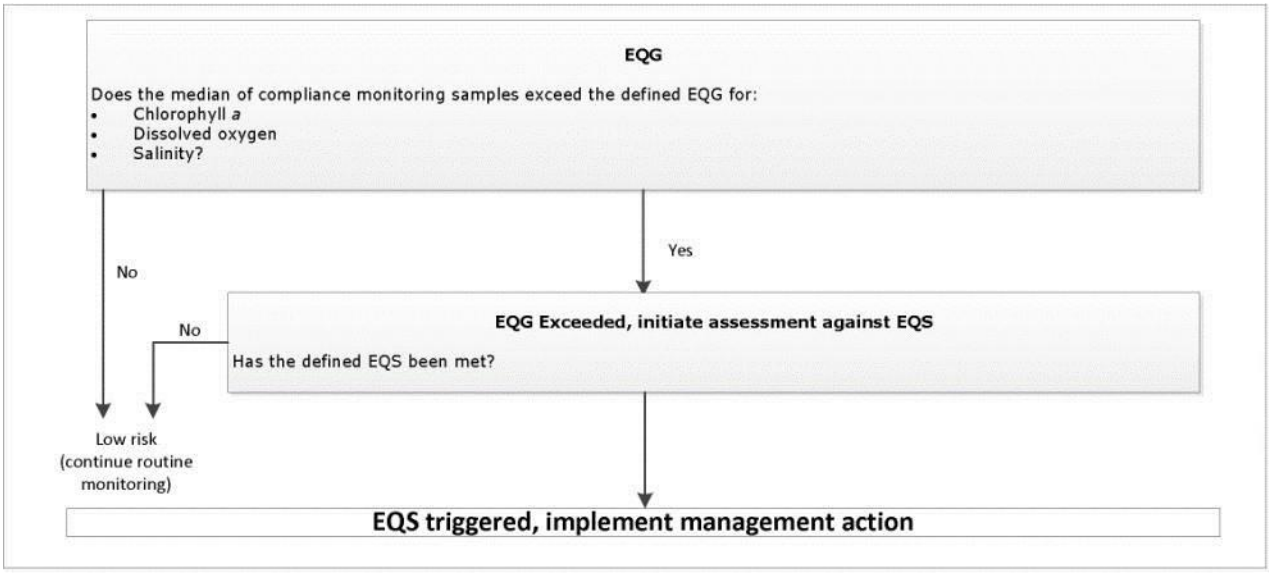
The physico-chemical parameters to be measured at each of the compliance and reference sites are:

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

Irradiance measurements will be undertaken with one sensor positioned 1 m below the surface and a second sensor 7 m below the surface and the LAC calculated as follows:

$$Light\ Attenuation\ Coefficient\ (LAC) = \frac{\log_{10} 1\ m\ Irradiance - \log_{10} 7\ m\ Irradiance}{6}$$

A composite sample representative of the top half of the water column will be collected from each of the sites for analysis of chlorophyll-a and nutrients. Two 10 mL filtered (on-site through a 45 µm filter) samples will be collected in polypropylene tubes for ortho-phosphate, ammonia and nitrate+nitrite analysis. An additional 4–10 L of water will be filtered (on-site through a Grade GF/C filter) and the filter retained for chlorophyll-a analysis. Concentrations are compared to the defined EQG and EQS in Table 7-1 (Figure 2-5).



Note:

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

Figure 2-5 Management response framework in the event of an exceedance of Environmental Quality Criteria for physico-chemical parameters and nutrient enrichment in receiving waters

Osmotic stress EQS

Sampling will be undertaken along 3 transects extending away from the LEPA boundary in the direction of the prevailing current as predicted by modelling. The central transect will be in the direction of the prevailing current with two transects radiating out either side of the central transect at 30 degrees. Sampling will involve towed video surveys of the sea floor (analysed to identify deceased fauna) and continuous surface observations from the vessel. Sampling will extend from the edge of the LEPA boundary to a maximum distance 500 m.

Organic enrichment EQS

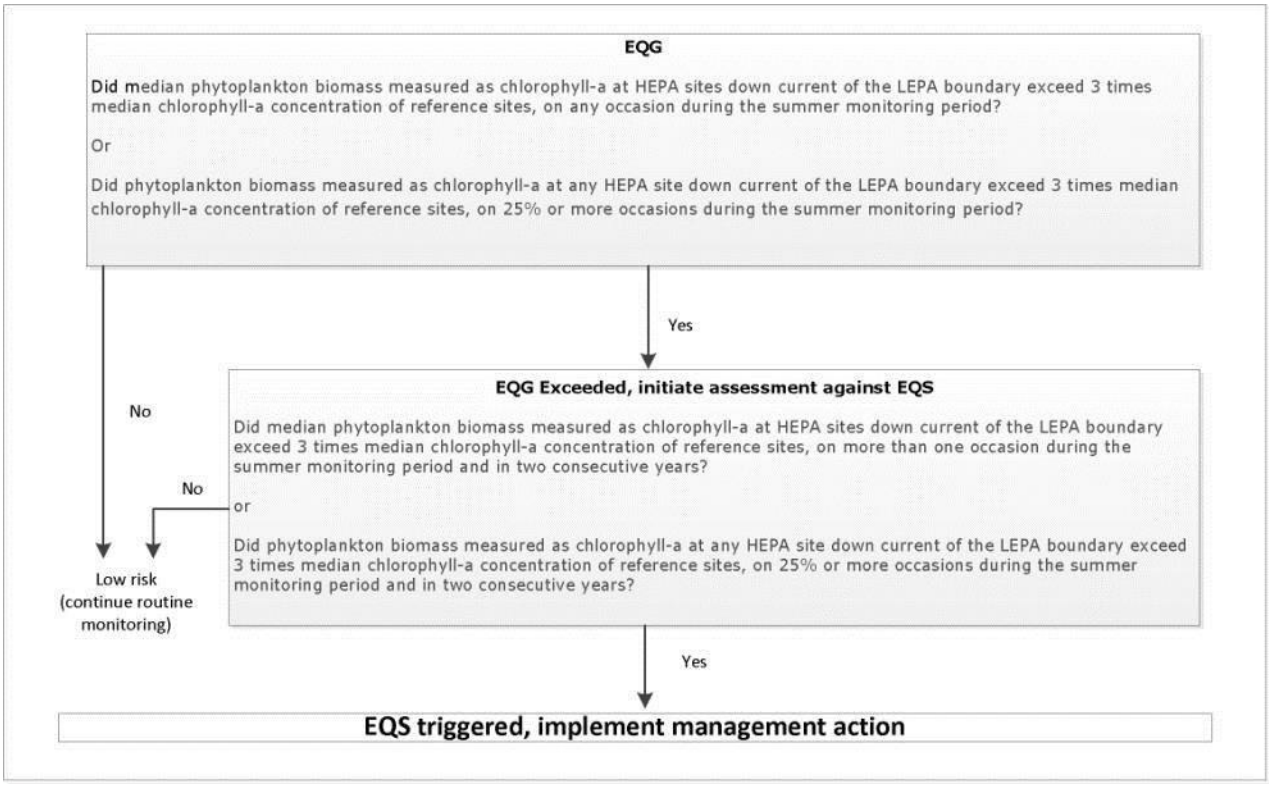
Exceedance of the dissolved oxygen EQG triggers an EQS assessment using the same data. Faunal deaths will be determined as described above (for Osmotic stress).

Nutrient enrichment EQS

An EQS based on light attenuation was developed according to the risk-based approach defined in EPA (2017).

2.1.5 Receiving waters – phytoplankton blooms

Analysis against the EQG for phytoplankton blooms is based on chlorophyll-a data, a proxy for phytoplankton biomass (Table 7-1 and Figure 2-6).



Note:

1. EQG = Environmental Quality Guideline; EQS = Environmental Quality Standard; LEPA = Low Ecological Protection Area; HEPA = High Ecological Protection Area

Figure 2-6 Management response framework in the event of an exceedance of Environmental Quality Criteria for phytoplankton blooms in receiving waters

2.1.6 Sediments

Background

Sediments provide a potential indicator of the distribution and accumulation of any toxicants and may provide an indication of the toxic effects of contaminants on benthic organisms. The objective of the sediment surveys is to determine the spatial variability in concentrations of potential TWW contaminants in sediments at sites in the vicinity of the outlets.

Monitoring

Sediments will be collected at the sentinel mussel deployment sites (Figure 2-7). At each site, five replicate surface sediment samples will be collected by divers using 9.5 cm diameter polycarbonate corers (according to the procedures set out in Australian Standard AS/NZS 5667.12:1999). Corers will be pre-rinsed with dilute acid, deionised water and a suitable solvent. The corers will be washed between sampling sites with site water before re-sampling.

Each replicate sample will comprise a composite from five subsamples of the top 2 cm of sediment obtained from the four corners and the centre of a 1 m2 quadrat, in accordance with the Manual of Standard Operating Procedures for Cockburn Sound (EPA 2005). Although five replicate samples will be taken at each site, only three samples from each site are to be analysed initially, in accordance with the minimum replicates for analysis (EPA 2005).

Sediment samples will be kept on ice and then frozen prior to analysis. Analyses will be undertaken by analytical laboratories with NATA-accredited methods. Sample analysis will report against the lowest practical analytical limits from a NATA commercial laboratory, and where possible analytical limits will achieve the EPA (2017) sediment quality guidelines. Where concentrations are reported as less than this limit, the limits of reporting will be used in the calculations.

Sediment samples will be analysed for:

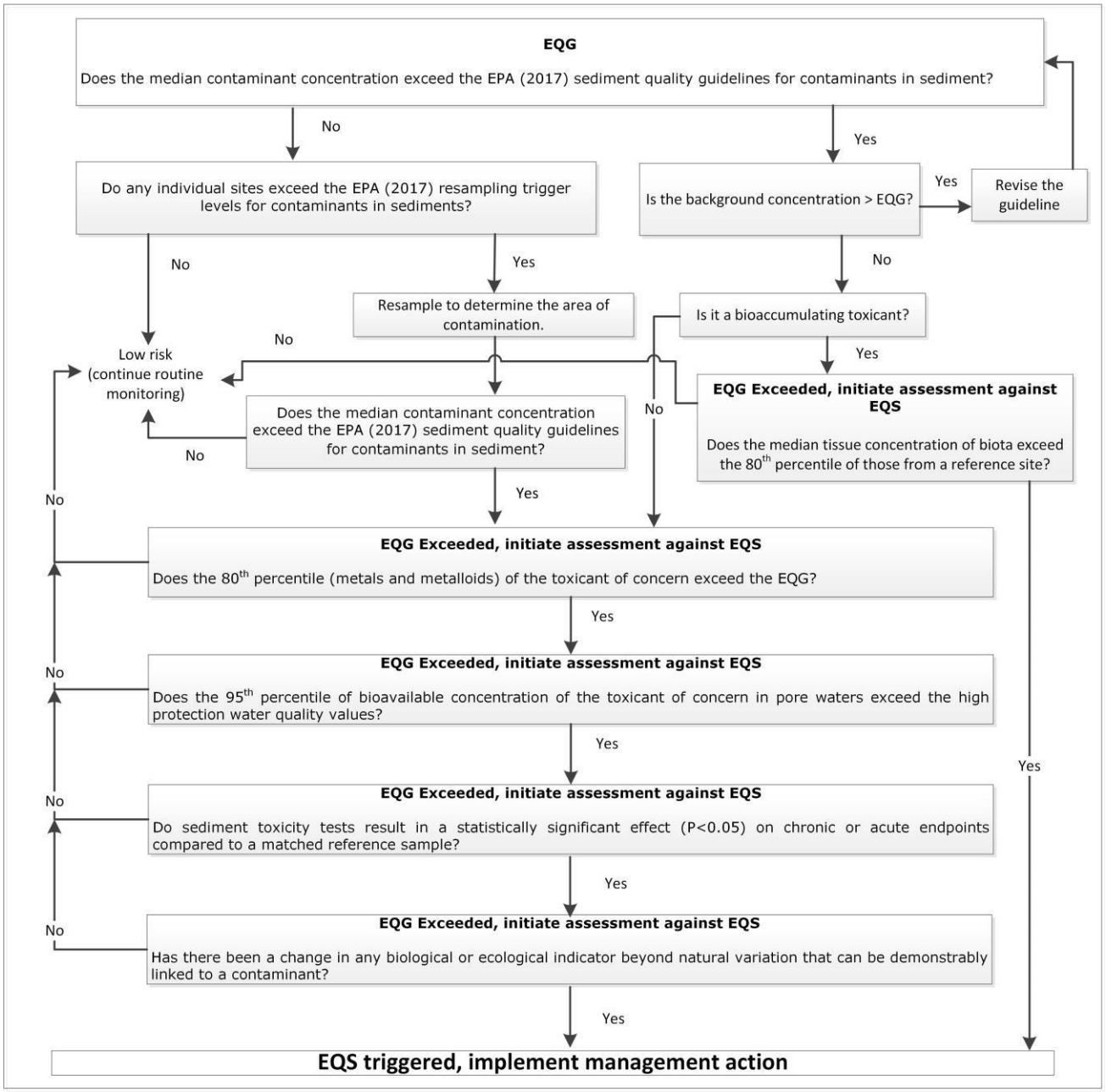
- grain size distribution (laser diffraction and sieving)
- organic matter content (loss on ignition at 550°C)
- carbonate content (loss on ignition at 1000°C)

- nutrients (TKN, TP)
- metals (Al, As, Cd, Co, Cu, Pb, Hg, Ni, Se, Ag and Zn).

Previous sediment sampling in the vicinity of the outlets has consistently found pesticide and herbicide levels to be below detection (Oceanica 2007, 2010). Pesticide and herbicide levels are also consistently below detection in the TWW based on annual comprehensive TWW characterisation. Because the risks are considered low, pesticides and herbicides in the sediments will be measured only if TWW characterisation indicates concentrations of pesticides and herbicides have increased in the TWW stream under the following conditions:

- for pesticides/herbicides with guidelines >LOR: If concentrations exceed the EPA (2017) guidelines following dilution equivalent to that expected at the LEPA boundary
- for pesticides/herbicides with guidelines <LOR: If concentrations exceed the LOR following dilution equivalent to that expected at the LEPA boundary.

For contaminant concentrations in marine sediments the median concentration at the impact sites are compared with the EQG (Table 7-1 and Figure 2-7). The EQS are adapted from the risk-based approaches recommended in ANZG (2018) (Table 7-1 and Figure 2-7).



Note:

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

Figure 2-7 Management response framework in the event of an exceedance of the Environmental Quality Criteria for contaminants in sediments

If an individual site exceeds the EPA (2017) GV-High for contaminants in sediments, repeat sampling will be conducted to define the spatial extent of the contamination which will be assessed against the ISQG-Low guidelines.

Further sampling for the relevant component of the EQS (i.e. toxicity testing) will be developed and completed as required.

2.2 Maintenance of Seafood for Human Consumption

2.2.1 Microbial contaminants

Background

Many disease-causing organisms are transferred from human and animal faeces to water via wastewater from where they can be ingested by marine fauna, which may adversely affect their suitability for human consumption. Thermotolerant coliforms (TTC) are one such bacteria that primarily originate in the intestines of warm-blooded animals. By testing marine waters for TTC, it can be determined whether there is potential for contamination of shellfish near the outlets. Fortnightly sampling will be conducted over a 4-month period between December and March.

To adequately assess the risk to human health based on ingestion of infected shellfish and to determine whether the EQC for maintenance of seafood for human consumption have been met, numbers of TTC will be monitored at the boundary of the pre-designated Seafood Management Zone (Figure 2-8). The first formal Seafood Management Zone around the outlets was established in 2017. After approval of the Seafood Management Zone in 2017 it became apparent that assumptions about the plant operational performance were overoptimistic and the size of the Seafood Management Zone determined as per EPA (2016) were incorrect. Application of the 2017 Seafood Management Zone would result in criteria exceedances despite a real improvement in environmental outcomes relative to the original proposal (MS 382). Because any exceedances of criteria would be an artifact of incorrect definition of the Seafood Management Zone, rather than an indication that the environmental quality objective was at risk of not being achieved, the Seafood Management Zone is not fit for purpose. Recognising this, Water Corporation commissioned further modelling to determine an appropriate Seafood Management Zone that is representative of actual operating conditions and submitted a Section 45C application under the *Environmental Protection Act 1986* (EP Act) seeking to apply a correctly-defined Seafood Management Zone.

The AWRP has two operating scenarios:

- Where only the Water Resource Recovery Facility is operating (i.e. during shutdown and maintenance of the AWRP) and there is no water recycling or chloramination (equivalent to the original proposal in MS382 and the existing discharge footprint) or where the AWRP plant is in partial operation and over 59 ML/d unchlorinated treated wastewater is directed to the outfall.
- Where the AWRP plant is in operation and up to 59 ML/d unchlorinated treated wastewater (combined with 30 ML/d chloraminated treated wastewater) is directed to the outfall (61 ML/d of water recycled for groundwater replenishment).

At present, TTC is monitored at the boundary of Observed Zone of Effect (OZE) developed based on Long-term monitoring data (15 years) compiled using Inverse Distance Weighted Interpolation to calculate long-term medians for each sampling site. OZE were based on the distance from the outlets where the environmental quality criteria (EQC) for thermotolerant coliforms (TTC) would be met 50% of the time based on the historical worst-case scenario. The TTC footprint from the scenario where the AWRP is operating normally is up to about 75% of the size of the existing (original proposal) discharge footprint (OZE).

The proportion of time that the AWRP will be in production or at partial production/offline cannot be determined in advance and while it is possible that the criteria will be met at the

smaller Seafood Management Zone boundary the uncertainty surrounding operations makes committing to such a boundary difficult.

Monitoring

Monitoring will be conducted at both the boundary of the OZE and the boundary of a smaller Seafood Management Zone that reflects the expected discharge footprint during AWRP operation (Figure 2-8) regardless of the operational status of the AWRP. Initially, compliance will be determined based on samples collected at the boundary of the OZE. Monitoring will be reviewed annually after 8 years to determine if compliance can be maintained at the boundary of the smaller zone. The 8 year duration prior to review is arbitrary. The assessment requires at least 100 pooled samples (3 years of data) and eight years of sampling allows for 6 rolling median assessments. If it can be demonstrated that compliance will be maintained at the smaller Seafood Management Zone boundary, those sites will be adopted for ongoing assessment. If it cannot be demonstrated that compliance will be maintained at the smaller Seafood Management Zone boundary a revised area reflecting the improved water quality outcomes expected from the AWRP will be developed.

Samples will be collected 0.5 m above the benthos. Samples will be collected on eight occasions during the non-river flow period at five fixed sites at the Seafood Management Zone boundary (Figure 2-9 and Figure 2-10). Monitoring sites will be selected on the day of sampling based on the current direction as indicated by the drogue release during compliance monitoring. Near bottom (i.e. approximately 0.5 m from the seabed) water samples for microbiological contaminants will be collected in pre-sterilised bottles before being chilled in the dark to 4°C. Samples will be subsequently transferred to a laboratory (e.g. Pathwest) and analyses for TTC undertaken according to NATA-accredited methods. Median thermotolerant coliform (TTC) counts (rolling median consisting of 100 samples) are compared to the EQG/EQS (Table 7-1 and Figure 2-11).

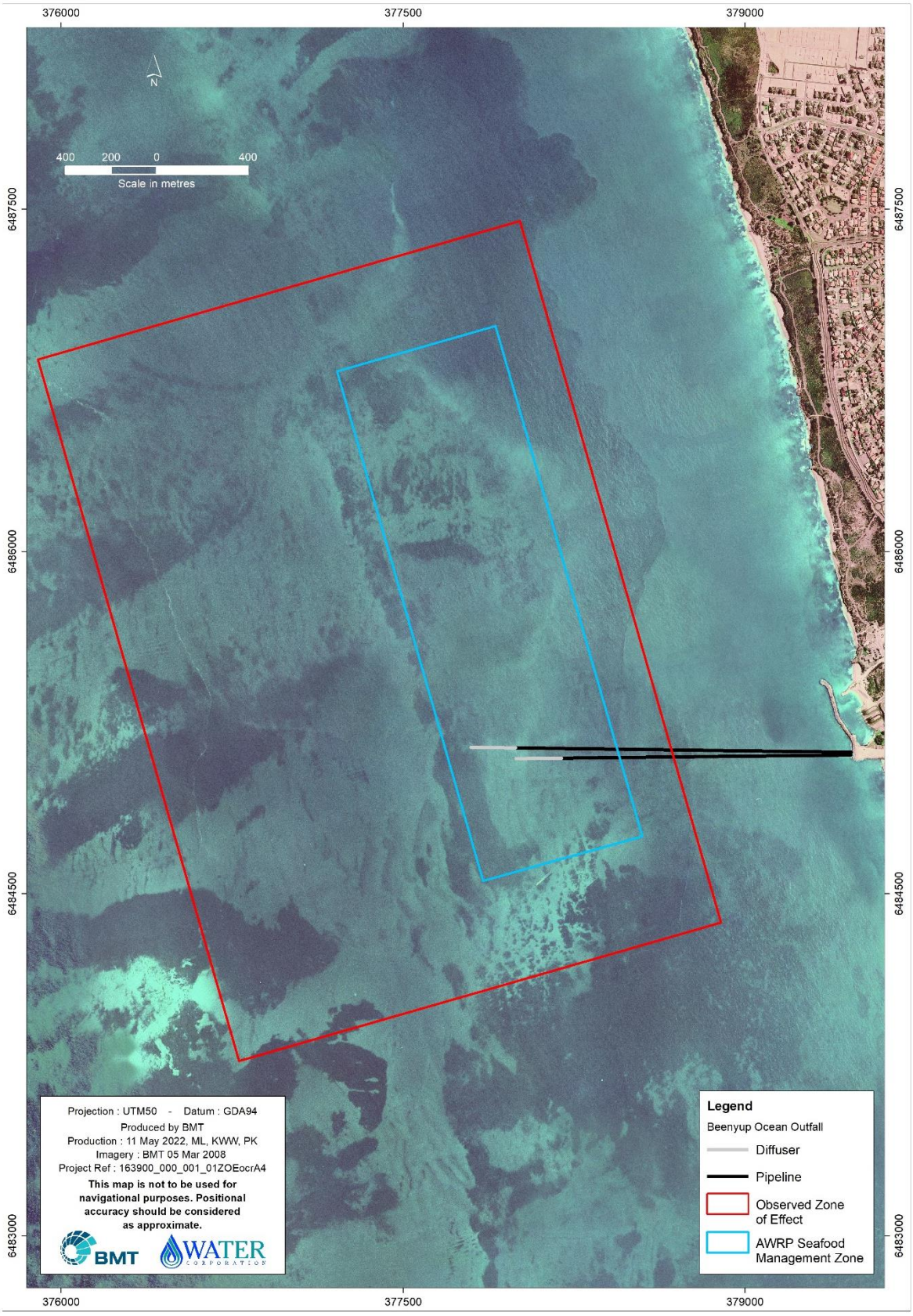


Figure 2-8 Boundaries of Observed Zone of Effect and Seafood Management Zone around the Beenyup Ocean Outlet

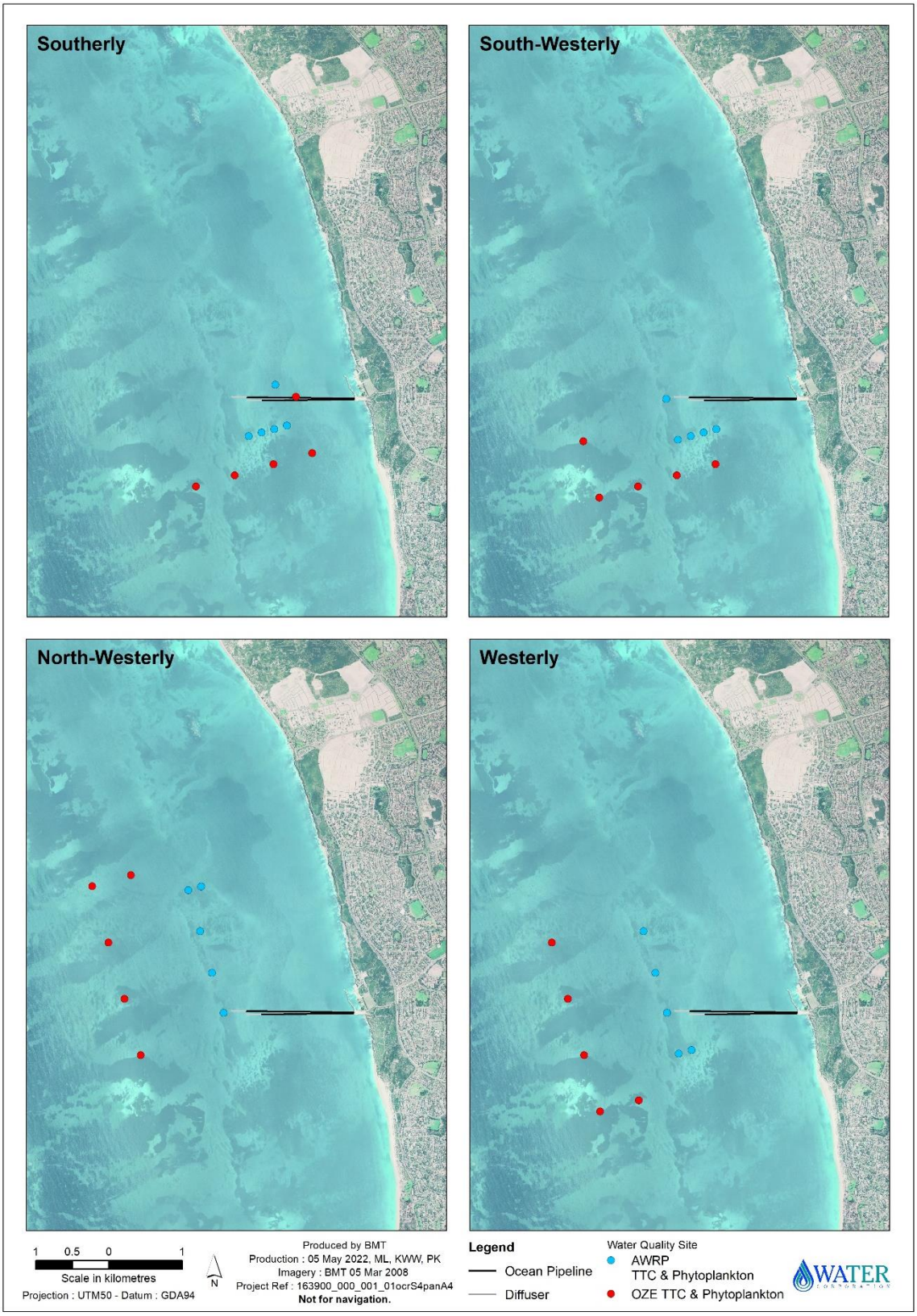


Figure 2-9 Fixed sites around the Beenyup Ocean Outlet sampled for thermotolerant coliforms and phytoplankton during periods with southerly, south-westerly, north-westerly and westerly currents

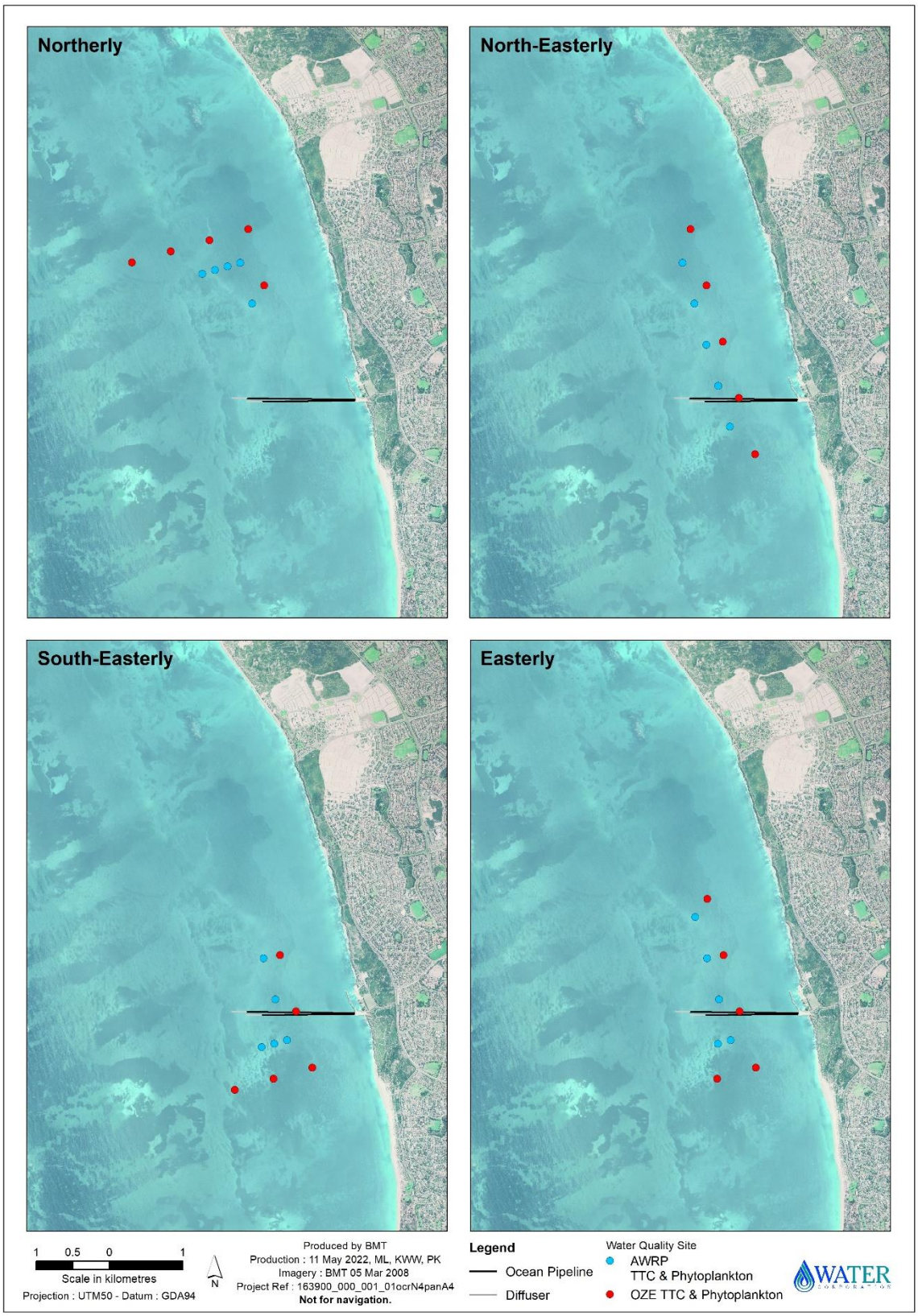


Figure 2-10 Fixed sites around the Beenyup Ocean Outlet sampled for thermotolerant coliforms and phytoplankton during periods with northerly, north-easterly, south-easterly and easterly currents

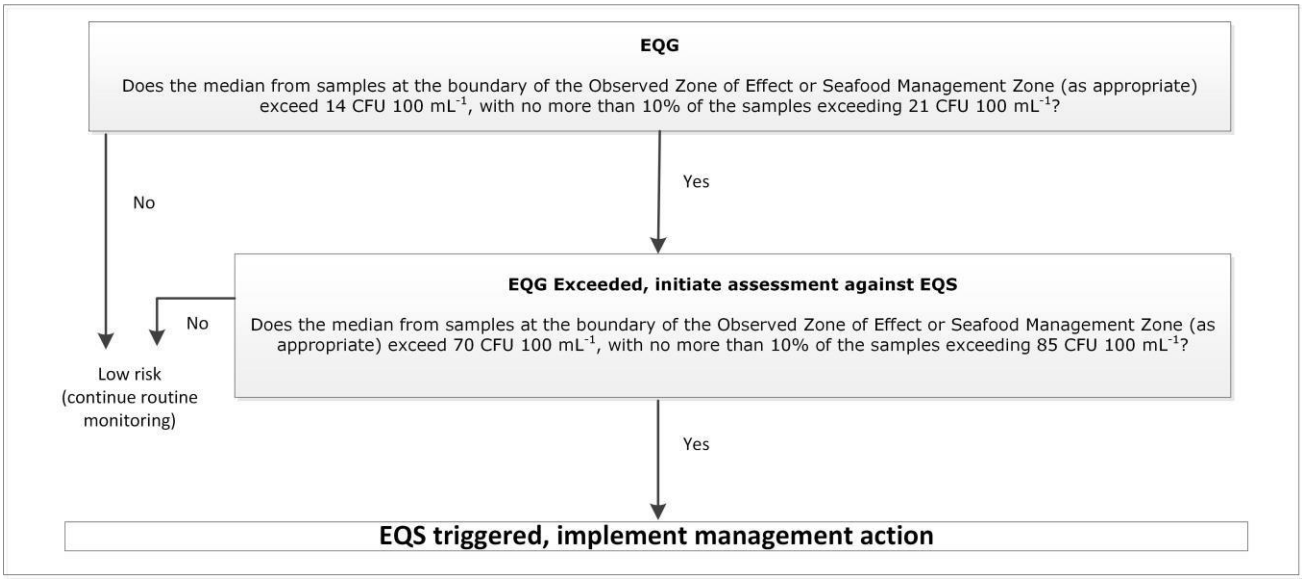


Figure 2-11 Management response framework in the event of an exceedance of the Environmental Quality Criteria for thermotolerant coliforms

2.2.2 Algal biotoxins

Background

Blooms of planktonic algae, or 'red tides', are naturally-occurring events. Most blooms comprise algal species that are considered harmless and result only in water discolouration. Other algal species can, however, produce toxins that may impact on marine life. Some algae are capable of secreting compounds into the water that are toxic to filter-feeders and planktivorous fish that may uptake the toxic algal cells directly from the water column and retain the toxins in their viscera (internal organs). Monitoring of algal biotoxins aims to target concentrations of species most likely to occur in local waters and involves a staged process, whereby water quality is assessed in the first instance (i.e. the EQG), and if this does not meet the required quality standards, a secondary assessment is required to assess toxin concentrations within sentinel mussels (i.e. EQS).

Monitoring

Fortnightly sampling will be conducted over a 4-month period between December and March. Sampling is conducted during the summer to avoid potential confounding effects of riverine and groundwater discharge.

Phytoplankton samples are collected at the same sites and same occasions as TTC (Figure 2-9 and Figure 2-10). Composite water samples representative of the top half of the water column will be preserved in Lugol's iodine solution and transported to a laboratory for phytoplankton identification using the Utermöhl method. Phytoplankton will be identified to the lowest taxonomic level possible. On each sampling occasion only one sample (i.e. in the direct path of the drogue) will initially be analysed with the remaining four samples archived. In the event that toxic phytoplankton species are present in the sample analysed at concentrations that exceeded the recommended WASQAP guideline concentrations (DoF 2007), the archived phytoplankton samples collected on that sampling occasion will also be analysed (Table 2-2). A management framework has also been adopted (Table 7-1 and Figure 2-12).

Table 2-2 Protocols for analysis of archived phytoplankton samples

Outcome of initial analysis	Further action
No exceedance of Western Australian Shellfish Quality Assurance Program guideline concentrations	No analysis of archived samples
Exceedance of Western Australian Shellfish Quality Assurance Program guideline concentrations at both the reference site and the Trial Compliance Monitoring site	No analysis of archived samples
Exceedance of Western Australian Shellfish Quality Assurance Program guideline concentrations at the reference site, but not at the Trial Compliance Monitoring site	No analysis of archived samples
Exceedance of Western Australian Shellfish Quality Assurance Program guideline concentrations at the Trial Compliance Monitoring site but not at the reference site	Additional samples analysed

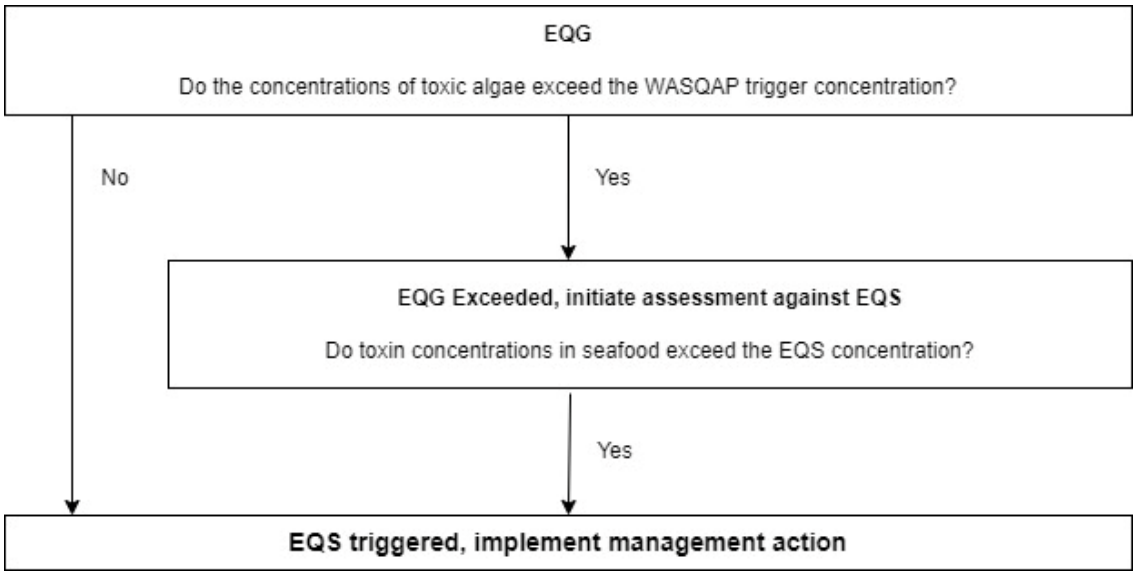


Figure 2-12 Management response framework in the event of an exceedance of the Environmental Quality Criteria for algal biotoxins in water

Mussel deployment will be implemented as soon as practicable after exceedance of the EQG. The mussels will be deployed in the manner described in section 2.1.6 except the sites will be arranged at equivalent locations on the Seafood Management Zone boundary rather than the LEPA boundary. Samples will be analysed for the relevant biotoxins using standard laboratory analytical procedures by NATA-accredited laboratories or laboratories with appropriate QA/QC standards in place).

2.3 Maintenance of Primary and Secondary Recreation Values

2.3.1 Faecal streptococci

Background

Disease-causing microorganisms (pathogens) associated with bathing areas include salmonellae, shigellae, enteropathogenic Escherichia coli, cysts of Entamoeba histolytica, parasite ova, enteroviruses and infectious hepatitis. Generally, the most common types of diseases that have been associated with swimming areas are eye, ear, nose and throat infections, skin diseases and gastrointestinal disorders. Direct detection of pathogens is not a feasible option for routine assessment, since they occur intermittently and are difficult to recover from water. For this reason, indicator microorganisms are generally used to assess the health risks associated with pathogens in recreational waters (Elliot & Colwell 1985). While a number of organisms have been considered as indicators of health risks for swimming areas (Daly 1991), *Enterococci* spp. is the preferred indicator organism (EPA 2017, NHMRC 2008).

Monitoring

Fortnightly sampling will be conducted over a 4-month period between December and March. Sampling is conducted during the summer as the period of highest recreational use and to avoid potential confounding effects of riverine and groundwater discharge.

The first formal Primary Contact Management Zone around the outlets was established in 2017 (Figure 2-13). To determine whether the EQC for primary and secondary contact recreation have been met faecal streptococci (*Enterococci* spp.) samples will be collected on eight occasions at the boundary of the Primary Contact Management Zone (Figure 2-13). Depth-integrated samples for analysis of *Enterococci* spp. will be collected from the top half of the water column at five sites selected based on the current direction indicated by a drogue (Figure 2-14 and Figure 2-15). *Enterococci* spp. samples will be collected in presterilised bottles before being chilled to 4°C and placed in the dark. On completion of sampling, the samples will be transferred to a laboratory (e.g. Pathwest) and analysed according to NATA-accredited methods. The 95th percentile of Enterococci spp. counts (rolling median consisting of 100 samples) are compared to the EQG/EQS (Table 7-1 and Figure 2-16).

Figure 2-13 Boundaries of Primary Contact Management Zone around the Beenyup Ocean Outlet

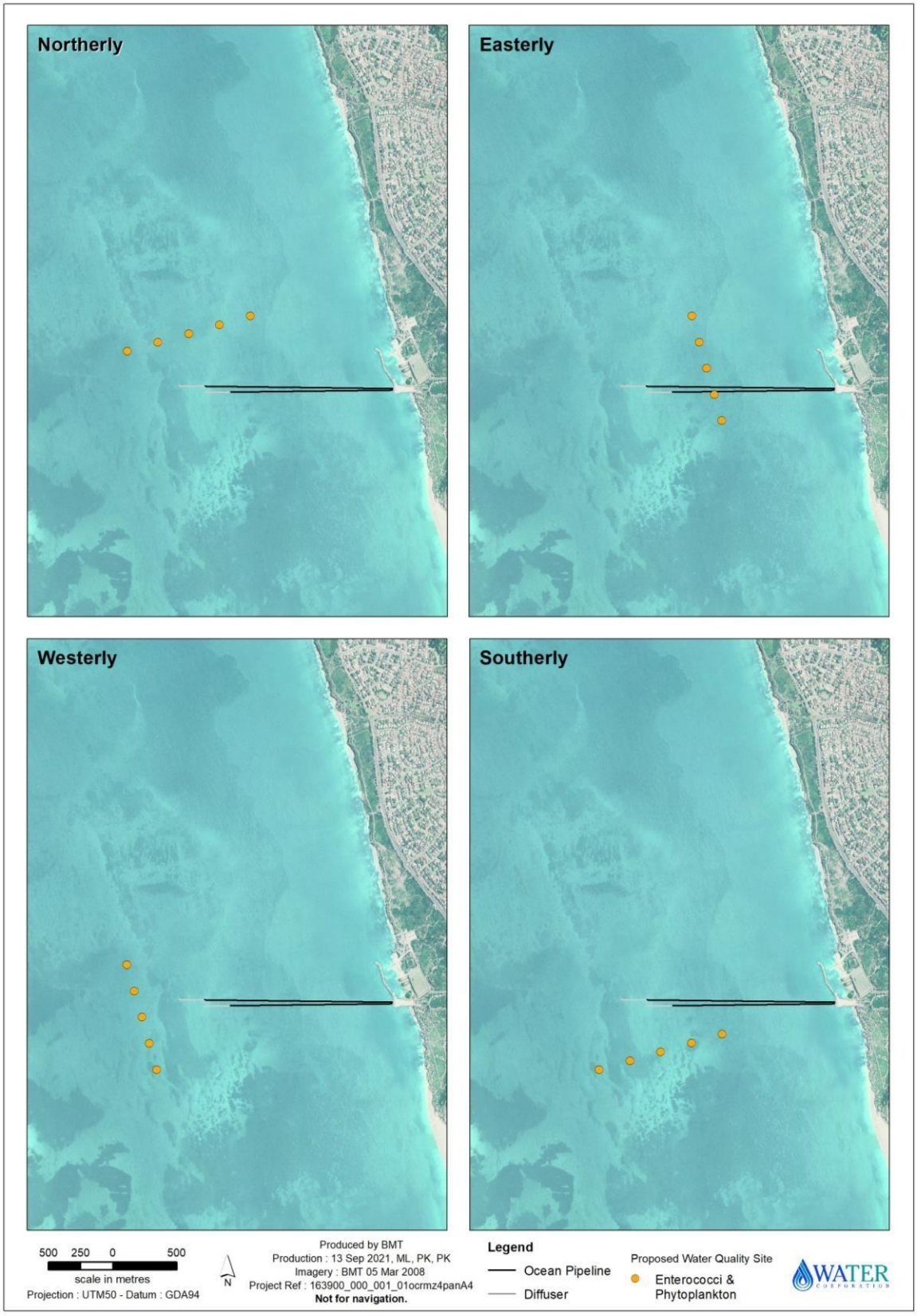


Figure 2-14 Fixed sites around the Beenyup Ocean Outlet sampled for *Enterococci* spp. and phytoplankton during periods with northerly, easterly, westerly and southerly currents

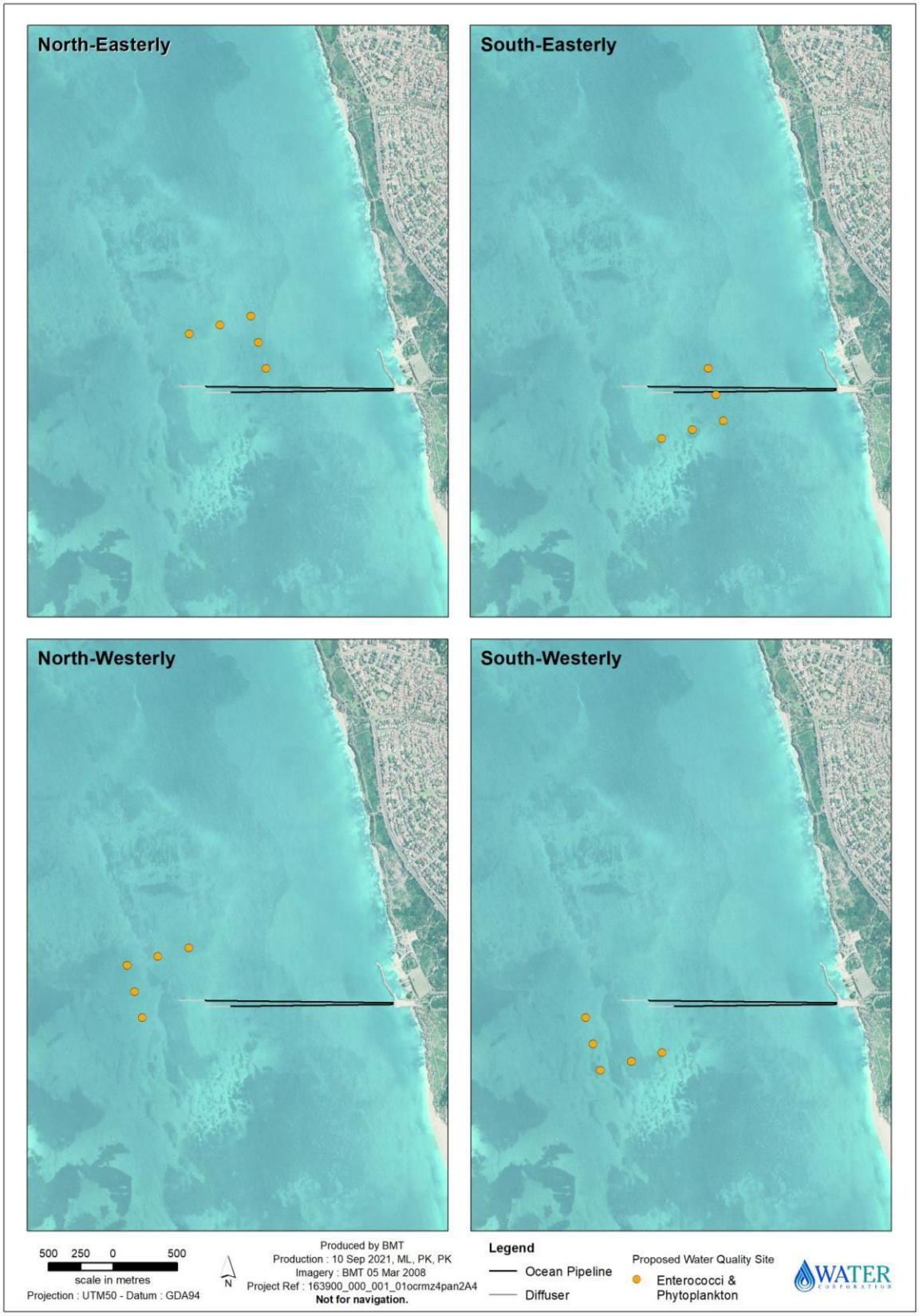


Figure 2-15 Fixed sites around the Beenyup Ocean Outlet sampled for *Enterococci* spp. and phytoplankton during periods with north-easterly, south-easterly, north-westerly and south-westerly currents

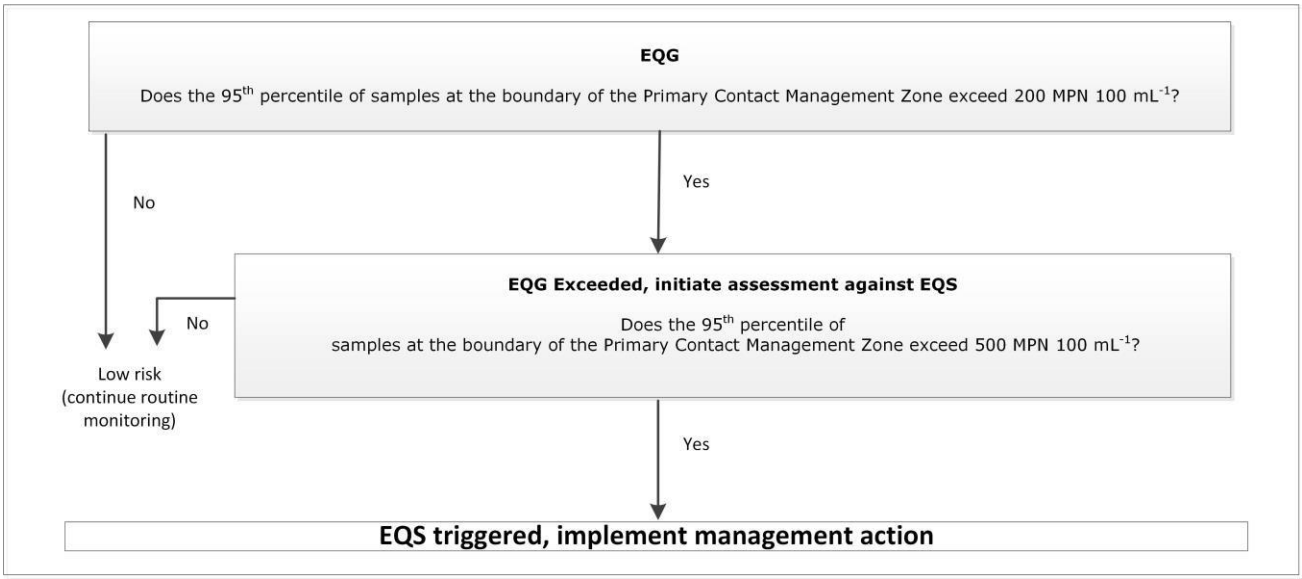


Figure 2-16 Management response framework in the event of an exceedance of the Environmental Quality Criteria for faecal pathogens for the EQOs of Maintenance of Primary Contact Recreation

2.3.2 Algal biotoxins

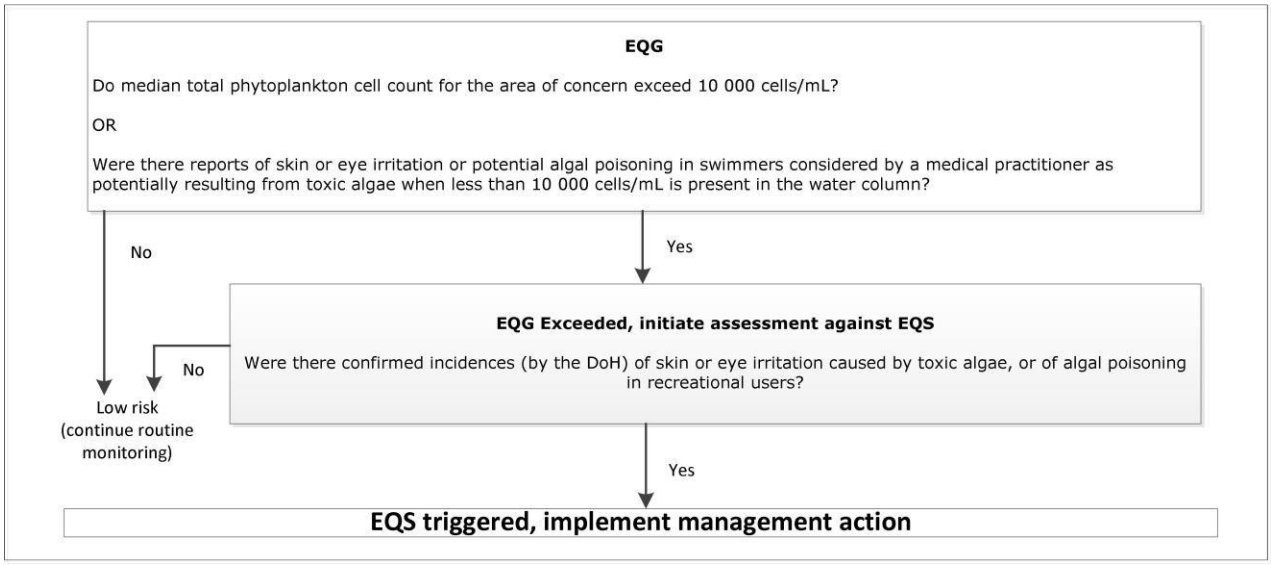
Background

Algal blooms can be harmful to human/animal health if encountered via ingestion or skin contact.

Monitoring

Fortnightly sampling will be conducted over a 4-month period between December and March. Sampling is conducted during the summer to avoid potential confounding effects of riverine and groundwater discharge. Phytoplankton samples (as an indicator of algal biotoxins present in certain phytoplankton) will be collected at the contact recreation boundary, preserved and analysed in the manner described in Section 2.2.2.

Sample analysis will be conducted as described in Section 2.2.2. The median total phytoplankton cell count from all the samples should not exceed 10 000 cells/mL or contain DoH watch list species exceeding their trigger levels (Table 7-1 and Figure 2-17). A complaints register has been established and complaints from the public and/or medical practitioners will be investigated to determine if there is evidence of skin, eye or respiratory irritation caused by toxic algae, or of algal poisoning in recreational users.



Note:

1. EQG = Environmental Quality Guideline; EQS = Environmental Quality Standard; DoH = Department of Health

Figure 2-17 Management response framework in the event of an exceedance of the EQC for algal biotoxins for the EQOs of Maintenance of Primary and Secondary Contact Recreation

The EQS for phytoplankton cell counts/DoH watch list species will be assessed using the same data as the EQG (Table 7-1). The EQS for algal scums and *Lyngbya majuscula* filaments will be determined from surface observations from the vessel at each compliance site downstream of the diffuser already collected as part of the EQG for aesthetic appearance (see Section 2.4.1). The DoH will be contacted to determine if reports of skin, eye and/or respiratory irritation have been made and confirmed by the organisation.

2.3.3 Toxic chemicals

Background

The recreational guidelines for toxic chemicals (EPA 2017) are generally high compared to the guidelines for ecosystem protection. An initial assessment for toxic chemicals will be made against the most sensitive guideline (usually the ecological guidelines) in the first instance. If the requirements of the most sensitive guidelines (e.g. ecosystem protection) are met then the subsequent (e.g. human health guidelines) are also met. Further assessment against subsequent guidelines will only be made in the event of an exceedance of the most sensitive guideline.

Monitoring

Sample analysis will be conducted as described in Section 2.1.2.

The concentrations of toxic chemicals in the TWW will be corrected based on minimum dilutions achieved at the LEPA boundary (a conservative proxy for dilution at the Primary Contact Management Zone boundary) to allow direct comparison against the relevant guidelines (EPA 2017) and determine whether they have been met. The formula used to correct chemicals for dilution is:

$$[After\ dilution] = \left(\frac{[undilutted] + (dilution\ factor - 1)\ [background]}{(dilution\ factor)}\right)$$

2.4 Maintenance of Aesthetic Values

2.4.1 Aesthetic appearance

Background

To ensure this EQO is being met, monitoring will routinely assess the quality of surface water appearance.

Monitoring

Aesthetic appearance will be determined on eight occasions during the non-river flow period. On each sampling occasion, the questionnaire (Table 2-3) will be completed at one location on the contact recreation boundary down-current of the diffuser (Figure 2-14 and Figure 2-15). A complaints register has been established and trends in complaints from users of the resource to determine community perception of aesthetic values will serve as an assessment of the EQS.

Table2-3 Field sheet for demonstrating compliance with Environmental Quality Guidelines for aesthetics

Site: Date:	Recorder:	Comments
Environmental Quality Guideline		
Algal/plant material visible on surface?	Yes/No	
Dead marine organisms visible?	Yes/No	
Water clarity (light attenuation)	Metres	
Noticeable colour variation?	Yes/No	
Oil or other films visible on surface?	Yes/No	
Floating debris visible on the surface?	Yes/No	
Noticeable odour associated with water?	Yes/No	

2.4.2 Fish tainting substances

Background

The guidelines for fish tainting substances are high compared to the guidelines for ecosystem protection.

Monitoring

Sample analysis will be conducted as described in Section 2.1.2. Dilution calculations will be conducted as described in Section 2.3.3. An initial assessment for fish tainting substances will be made against the most sensitive guideline (the ecological guidelines) in the first instance. If the requirements for the most sensitive guideline are met then it will be

assumed that the aesthetics guidelines are also met. Further assessment against subsequent guidelines will only be made in the event of an exceedance of the most sensitive guideline.

2.5 Diffuser performance

Near and far field diffuser performance will be evaluated on one occasion once the AWRP reaches full production using two independent methods.

A drogue will be released from above the outlet to establish the current speed and direction. A series of high resolution vertical Conductivity-Temperature-Depth (CTD) profiles will be collected along transects extending out from the outlet in the direction drogue. Profiles will be collected 0 m, 10, 20, 50 and 100 m from the diffuser. The CTD will be lowered to the bottom at each waypoint and slowly retrieved to obtain a vertical profile of the water column. At each site a surface water sample will be collected at each site and analyzed for total nutrients. A wastewater sample will be analyzed to determine nutrient concentrations at the source.

The number of dilutions achieved will be determined based on the formula modified from Zaker et al. (2001):

$$Dilutions = \frac{([TWW] - [Background])}{([Final] - [Background])}$$

Where:

[TWW] = Concentration in TWW
[Background] = Background concentration
[Final] = Final concentration

The difference between the salinity of the effluent and ambient surface waters is large enough to determine dilution in the near field. However, the difference is not large enough to determine dilution in the far field (Table 2-4). In this analysis we also use total phosphorus as a quasi-conservative tracer of mixing and calculate the dilution base on the reduction in concentration relative to its wastewater source. The large total phosphorus gradient between wastewater and background makes it a more sensitive indicator of dilution than salinity for this application (Table 2-4). Phosphorus is not a limiting nutrient in Perth coastal waters (Lourey et al. 2006) and is not in demand by primary producers. It is assumed that over the spatial and timescales of interest here (i.e. dilution at 100 m) phosphorus distribution is dominantly determined by physical rather than chemical or biological processes and as a result serves as a “conservative” tracer of mixing.

Table 2-4 Sensitivity of the two dilution approaches to assessing diffuser performance

Parameter	Discharge Concentration	Background	In situ concentration	Dilution
Salinity	0.6	36	35.8	177
Total phosphorus	23 000	10	11	22 990

3. Reporting

3.1 Annual reporting

The environmental objectives for each financial year will be reported against EQGs and EQSs in an annual report. In the event that EQGs or the EQSs (or both) were exceeded during the reporting period, the annual report will include a description of the effectiveness of EQG level actions, and EQS contingency actions that have been implemented to manage the impact, as well as an analysis of trends. The Annual Report will be submitted to key stakeholders (e.g. DWER) and made publicly available via Water Corporation's website.

3.2 Reporting on exceedance of an EQG and EQS

Exceedance of any EQG will reported in the annual report. In the event of exceedance of any EQS, Water Corporation will notify the relevant authority in writing within five days of the exceedance being identified.

4. Adaptive Management

Water Corporation will implement adaptive management to respond to any issues identified by monitoring and evaluation against the EQC to maintain the EQOs. Water Corporation will generally report an exceedance of an EQS to the DWER, however, any exceedance of a seafood or primary/secondary contact EQS will also be reported to the DoH as the principal authority. The significance of the exceedance, and any required investigation/action will be discussed with the DWER and other relevant regulatory agencies. A management response would generally be initiated in consultation with the DWER and other relevant regulatory agencies. Management response could include wastewater characterisation, WET tests, *in situ* monitoring, detailed risk assessment to indicate potential risk to the environment, management measures to reduce the contaminant(s) of concern and/or ongoing wastewater characterisation to confirm that the required results are being achieved. Water Corporation will report annually to the DWER and other relevant regulatory agencies on any management initiated.

5. Stakeholder consultation

An extensive stakeholder consultation program was undertaken during the 2017 Section 46 assessment process. Ongoing stakeholder management will be undertaken as required to ensure effective management and reporting.

6. Review

Review and revision of this Plan will be undertaken as required to incorporate the results of monitoring and/or further knowledge on effective environmental management. Any significant changes to this Plan will result in it being resubmitted to the DWER for approval.

7. Outcomes based EMP for Beenyup Water Resource Recovery Facility

Table 7-1 Outcome based provisions

Environmental objective	Monitoring target	Monitoring	Trigger criteria (Environmental Quality Guidelines)	Trigger level action(s)/Reporting	Threshold criteria (Environmental Quality Standards)	Threshold contingency action(s)/Reporting
Maintenance of ecosystem integrity	Bioaccumulating toxicants	Annual monitoring of the final discharge for dissolved cadmium and mercury.	Concentrations of bioaccumulating toxicants (cadmium and mercury) will not exceed the EPA (2017) 80% species protection guideline.	Water Corporation will report the EQG exceedance in the annual report. Assessment against the EQS will commence.	Median concentrations of bioaccumulating toxicants (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 concentrations at from reference sites.	Water Corporation will conduct a detailed risk assessment to indicate potential risk to the environment. Water Corporation will undertake a toxicity reduction evaluation (TRE) to identify the contaminant(s) of concern, and inform the management required to reduce them to acceptable levels. This would include a detailed examination of the combined waste stream. Water Corporation will implement management measures to reduce the contaminant(s) of concern and conduct ongoing combined waste stream characterisation to confirm that the required results are being achieved.

Environmental objective	Monitoring target	Monitoring	Trigger criteria (Environmental Quality Guidelines)	Trigger level action(s)/Reporting	Threshold criteria (Environmental Quality Standards)	Threshold contingency action(s)/Reporting
Maintenance of ecosystem integrity	Non-bioaccumulating toxicants	Annual monitoring of the final discharge for ammonia, dissolved metals (As, Cr, Cu, Pb, Ni and Zn), oil and grease, and suspended solids.	Concentrations of contaminants will not exceed the EPA (2017) 99% species protection guideline for toxicants after initial dilution equivalent to that between the discharge point and the boundary of the Low/High Ecological Protection Area.	Water Corporation will report the EQG exceedance in the annual report. Assessment against the EQS will commence.	Dilutions achieved at LEPA boundary will be greater than the number of dilutions required to achieve the 99% species protection derived using a full suite of Whole Effluent Toxicity testing of the waste stream in accordance with ANZG (2018) guidelines.	Water Corporation will undertake a toxicity reduction evaluation (TRE) to identify the contaminant(s) of concern and inform the management required to reduce them to acceptable levels. This would include a detailed examination of the combined waste stream and potentially include a Stage 1 toxicity identification evaluation (TIE). Water Corporation will implement management measures to reduce the contaminant(s) of concern and monitor to confirm that the required results are being achieved. The monitoring could include combined waste stream characterisation, further Whole Effluent Toxicity tests, and in situ monitoring, subject to further consultation with the DWER.
Maintenance of ecosystem integrity	Non-bioaccumulating toxicants	Annual monitoring of the final discharge for ammonia, dissolved copper and zinc.	The total toxicity of the mixture for the additive effect of ammonia, dissolved copper and dissolved zinc (as per ANZG (2018) guidelines) will be less than 1.0.	Water Corporation will report the EQG exceedance in the annual report. Assessment against the EQS will commence.		
Maintenance of ecosystem integrity	Non-bioaccumulating toxicants	Bi-annual WET testing on final discharge.	The typical dilutions achieved at the LEPA boundary will be greater than the number of dilutions required to achieve the No Observed Effects Concentration	Water Corporation will report the EQG exceedance in the annual report. Assessment against		

Environmental objective	Monitoring target	Monitoring	Trigger criteria (Environmental Quality Guidelines)	Trigger level action(s)/Reporting	Threshold criteria (Environmental Quality Standards)	Threshold contingency action(s)/Reporting
			in a 1-hour sea urchin test after application of a 0.1 assessment factor.	the EQS will commence.		
Maintenance of ecosystem integrity	Osmotic stress	Ocean salinity profiles collected on 8 occasions at four reference sites and five compliance sites located at intervals of 0 (for context), 150, 350, 1000 and 1500 m down-current of the outlets.	Median salinity (0.5 m below the water surface) at an individual HEPA site down current of the LEPA boundary over the summer monitoring period not to deviate beyond the 20th and 80th percentile of reference site salinity over the same period.	Water Corporation will report the EQG exceedance in the annual report. Assessment against the EQS will commence.	There will be no deaths of marine organisms resulting from anthropogenically sourced salinity stress.	Water Corporation will report any instances faunal deaths to the DWER within five working days of determining that this has occurred along with the proposed management response to maintain median salinity.
Maintenance of ecosystem integrity	Organic enrichment	Ocean dissolved oxygen profiles collected on 8 occasions at four reference sites and five compliance sites located at intervals of 0 (for context), 150, 350, 1000 and 1500 m down-current of the outlets.	Median dissolved oxygen in bottom waters (0–0.5 m above the sediment surface) greater than 90% saturation at any HEPA site down current of the LEPA boundary for a defined period of not more than one week.	Water Corporation will report the EQG exceedance in the annual report. Assessment against the EQS will commence.	Median dissolved oxygen in bottom waters (0–0.5 m above the sediment surface) will be greater than 60% saturation at any HEPA site down current of the LEPA boundary for a period of not more than one week And There will be no deaths of marine	Water Corporation will report any instances an exceedance of the EQS and/or faunal deaths to the DWER within five working days of determining that this has occurred along with the proposed management response to reduce biochemical oxygen demand of the discharge and/or maintain ocean oxygen concentration as appropriate.

Environmental objective	Monitoring target	Monitoring	Trigger criteria (Environmental Quality Guidelines)	Trigger level action(s)/Reporting	Threshold criteria (Environmental Quality Standards)	Threshold contingency action(s)/Reporting
					organisms resulting from deoxygenation.	
Maintenance of ecosystem integrity	Nutrient enrichment	Chlorophyll a in water samples collected on 8 occasions from four reference sites and five compliance sites located at intervals of 0 (for context), 150, 350, 1000 and 1500 m down-current of the outlets.	Median chlorophyll-a of HEPA sites down current of the LEPA boundary during the summer monitoring period not to exceed the 80th percentile of reference site data.	Water Corporation will report the EQG exceedance in the annual report. Assessment against the EQS will commence.	Median light attenuation derived from pooled HEPA sites down current of the LEPA boundary during the summer monitoring period not to exceed the two-year rolling 80th percentile of the reference site data in two consecutive years.	Water Corporation will report any instances of an exceedance of the EQS to the DWER within five working days of determining that this has occurred, and as soon as practical implement a management response.
Maintenance of ecosystem integrity	Phytoplankton biomass	Chlorophyll a samples collected on 8 occasions from four reference sites and five compliance sites located at intervals of 0 (for context), 150, 350, 1000 and 1500 m down-current of the outlets.	Median phytoplankton biomass measured as chlorophyll-a at the HEPA sites down current of the LEPA boundary not to exceed 3 times median chlorophyll-a concentration of reference sites, on any occasion during the summer monitoring period.	Water Corporation will report the EQG exceedance in the annual report. Assessment against the EQS will commence.	Median phytoplankton biomass measured as chlorophyll-a at HEPA sites down current of the LEPA boundary will not exceed 3 times median chlorophyll-a concentration of reference sites, on more than one occasion during the summer monitoring	Water Corporation will report any instances of an exceedance of the EQS to the DWER within five working days of determining that this has occurred and the proposed management response to reduce nutrients in the discharge and/or median chlorophyll a as appropriate.

Environmental objective	Monitoring target	Monitoring	Trigger criteria (Environmental Quality Guidelines)	Trigger level action(s)/Reporting	Threshold criteria (Environmental Quality Standards)	Threshold contingency action(s)/Reporting
					period and in two consecutive years.	
Maintenance of ecosystem integrity	Phytoplankton biomass	Chlorophyll a samples collected on 8 occasions from four reference sites and five compliance sites located at intervals of 0 (for context), 150, 350, 1000 and 1500 m down-current of the outlets.	Phytoplankton biomass measured as chlorophyll a at any HEPA site down current of the LEPA boundary does not exceed 3 times median chlorophyll-a concentration of reference sites, on 25% or more occasions during the summer monitoring period.	Water Corporation will report the EQG exceedance in the annual report. Assessment against the EQS will commence.	Phytoplankton biomass measured as chlorophyll-a at any HEPA site down current of the LEPA boundary does not exceed 3 times median chlorophyll-a concentration of reference sites, on 25% or more occasions during the summer monitoring period and in two consecutive years.	Water Corporation will report any instances of an exceedance of the EQS to the DWER within five working days of determining that this has occurred and the proposed management response to reduce nutrients in the discharge and/or median chlorophyll a as appropriate.
Maintenance of ecosystem integrity	Sediment contamination	5 yearly monitoring of sediments for metals (Al, As, Cd, Co, Cu, Pb, Hg, Ni, Se, Ag and Zn).	Median bioavailable contaminant concentration at each site not to exceed the EPA (2017) sediment quality guidelines for contaminants in sediments And Concentrations at individual sites not to exceed the EPA (2017) resampling trigger for bioavailable contaminants in sediments.	Water Corporation will report the EQG exceedance in the annual report. Assessment against the EQS will commence.	The 80th percentile of bioavailable metal or metalloid concentrations or the median bioavailable organometallic or organic contaminants concentration will not exceed the EQG. If bioavailable	In the event that the EQS for sediment quality is exceeded, Water Corporation will report the matter to the DWER within five working days of determining that this has occurred. The proposed management response to an exceedance of the EQS is:

Environmental objective	Monitoring target	Monitoring	Trigger criteria (Environmental Quality Guidelines)	Trigger level action(s)/Reporting	Threshold criteria (Environmental Quality Standards)	Threshold contingency action(s)/Reporting
					measures exceed the EQG, sediment toxicity tests will not result in a statistically significant effect ($p<0.05$) on sublethal chronic or lethal acute endpoints for any species, compared to a matched reference sediment.	A toxicity reduction evaluation (TRE) will be undertaken to identify the contaminant(s) of concern and inform the management required to reduce them to acceptable levels. This would include a detailed examination of the combined waste stream and potentially include a Stage 1 toxicity identification evaluation (TIE). Management measures to reduce the contaminant(s) of concern will be implemented by Water Corporation, along with monitoring to confirm that the required results are being achieved. The monitoring could include combined waste stream characterisation, further Whole Effluent Toxicity tests, and in situ monitoring, subject to further consultation with the DWER.

Environmental objective	Monitoring target	Monitoring	Trigger criteria (Environmental Quality Guidelines)	Trigger level action(s)/Reporting	Threshold criteria (Environmental Quality Standards)	Threshold contingency action(s)/Reporting
Maintenance of seafood for human consumption	Microbiological contaminants	Themotolerant coliforms in water samples collected on 8 occasions from 0.5 m above the benthos at 5 sites on the Seafood Management Zone boundary.	Median thermotolerant coliform (TTC) counts (rolling median consisting of 100 samples) at sites at the Observed Zone of Effect or Seafood Management Zone boundary (as appropriate) boundary are not to exceed 14 CFU 100 mL^{-1} and the estimated 90th percentile concentration will not exceed 21 CFU 100mL^{-1} as measured using the membrane filtration method during normal plant operating conditions.	Water Corporation will report the EQG exceedance in the annual report. Assessment against the EQS will commence.	Median thermotolerant coliform counts (rolling median consisting of 100 samples analysed concurrently with the EQG) at sites at the Observed Zone of Effect or Seafood Management Zone (as appropriate) not to exceed 70 CFU 100 mL^{-1} and the estimated 90th percentile concentration will not exceed 85 CFU 100 mL^{-1} as measured using the membrane filtration method during normal plant operating conditions.	Any instances of an exceedance of the EQS will be reported by Water Corporation to the Department of Health and the DWER within five working days of determining that this has occurred. If the EQS is exceeded, Water Corporation will take management action in consultation with DoH and DWER to manage risk.
Maintenance of seafood for human consumption	Algal biotoxins	Phytoplankton in composite water samples representing the top half of the water column, preserved with Lugols solution	Concentrations of potentially toxic algae in any sample at the Seafood Management Zone boundary not to exceed the Western Australian Shellfish Quality Assurance Program guideline concentrations for any of the following during normal plant operating conditions:	Water Corporation will report the EQG exceedance in the annual report. Assessment against the EQS will commence.	Toxin concentrations in shellfish not to exceed EQS in any sample at the Seafood Management Zone boundary during normal plant	Any instances of an exceedance of the EQS will be reported by Water Corporation to the Department of Health and the DWER within five working days of determining that this has occurred.

Environmental objective	Monitoring target	Monitoring	Trigger criteria (Environmental Quality Guidelines)	Trigger level action(s)/Reporting	Threshold criteria (Environmental Quality Standards)	Threshold contingency action(s)/Reporting
		water samples collected on 8 occasions from a single site on the Seafood Management Zone boundary.	• *Alexandrium* spp. (100 cells/L) • *Gymnodinium* spp. (1000 cells/L) • Karenia spp. (1000 cells/L) • *Dinophysis* spp. (500 cells/L) • *Dinophysis acuminta* (3000 cells/L) • *Prorocentrum* spp. (500 cells/L) • *Psuedo-nitzschia* spp. (250 000 cells/L) • *Gonyaulax* cf. *spinifera* (100 cells/L) • *Protoceratium reticulatum* (*Gonyaulax grindleyi*) (500 cells/L)		operating conditions: • 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) • Yessotoxins (1 mg Yessotoxin eq./kg)	Management actions will be taken by Water Corporation to reduce the contamination to a level where the Environmental Quality Objective assigned to the receiving environment is achieved, and may include: • an investigation into the conditions prevailing (nutrient enrichment indicators, metocean conditions and plant operations) during the summer period • development of a management response on advice of the Department of Health and in consultation with the DoH and DWER, considering all relevant information collected.

Environmental objective	Monitoring target	Monitoring	Trigger criteria (Environmental Quality Guidelines)	Trigger level action(s)/Reporting	Threshold criteria (Environmental Quality Standards)	Threshold contingency action(s)/Reporting
Maintenance of primary and secondary contact recreation values	Faecal streptococci	*Enterococci* spp. in depth integrated samples from the top half of the water column collected on 8 occasions from five sites on the Primary Contact Management Zone boundary.	The 95th percentile concentration of *Enterococci* spp. (rolling Hazen 95th percentile consisting of 100 samples) taken over the bathing season not to exceed 200 MPN/100 mL, outside the Primary Contact Management Zone boundary during normal plant operating conditions.	Water Corporation will report the EQG exceedance in the annual report. Assessment against the EQS will commence.	The 95th percentile concentration of *Enterococci* spp. (rolling Hazen 95th percentile consisting of 100 samples analysed concurrently with the EQG) taken over the bathing season not to exceed 500 MPN/100 mL, outside the Primary Contact Management Zone boundary during normal plant operating conditions.	Any instances of an exceedance of the EQS will be reported to by Water Corporation to the Department of Health and the DWER within 48 hours of determining that this has occurred. If the EQS is exceeded, the Department of Health will be contacted and a management response determined based on Department of Health advice in consultation with the DWER.

Environmental objective	Monitoring target	Monitoring	Trigger criteria (Environmental Quality Guidelines)	Trigger level action(s)/Reporting	Threshold criteria (Environmental Quality Standards)	Threshold contingency action(s)/Reporting
Maintenance of primary and secondary contact recreation values	Toxic algae	Phytoplankton in a composite water sample of the top half of the water column collected on 8 occasions from a single site on the Primary Contact Management Zone boundary.	Median total phytoplankton cell count for the area of concern (either from one sampling run or from a single site over agreed period of time) should not exceed 10 000 cells/mL during normal plant operating conditions or detect DoH watch list species exceeding their trigger levels.	Water Corporation will report the EQG exceedance in the annual report. Assessment against the EQS will commence.	The phytoplankton cell count from a single site should not exceed 50 000 cells/mL or exceed DoH watch list action levels And There should be no visual presence of algal scums or relatively widespread visible presence of Lyngbya majuscula filaments (NHMRC 2008).	Any instances of an exceedance of the Environmental Quality Standard will be reported by Water Corporation to the Department of Health and the DWER within 48 hours of determining that this has occurred. If the EQS is exceeded, the Department of Health will be contacted and a management response determined based on Department of Health advice in consultation with the DWER. Re-sampling will occur within 48 hours and then weekly until two all-clear results are achieved.

Environmental objective	Monitoring target	Monitoring	Trigger criteria (Environmental Quality Guidelines)	Trigger level action(s)/Reporting	Threshold criteria (Environmental Quality Standards)	Threshold contingency action(s)/Reporting
Maintenance of primary and secondary contact recreation values	Toxic algae	Any reports to Water Corporations from Department of Heath.	There should be no reports of skin or eye 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 is present in the water column.	Water Corporation will report the EQG exceedance in the annual report. Assessment against the EQS will commence.	There should be no confirmed incidences (by the Department of Health) of skin, eye or respiratory irritation caused by toxic algae, or of algal poisoning in recreational users.	Any instances of an exceedance of the Environmental Quality Standard will be reported by Water Corporation to the Department of Health and the DWER within 48 hours of determining that this has occurred. If the EQS is exceeded, Water Corporation will take management action in consultation with DoH and DWER to manage risk.
Maintenance of primary and secondary contact recreation values	Toxic chemicals	Concentrations in 24 hour composite sample.	Concentrations of contaminants will not exceed the recreational guidelines for toxic chemicals at the boundary of the Primary Contact Management Zone during normal plant operating conditions.	Water Corporation will report the EQG exceedance in the annual report. Department of Health will be contacted by Water Corporation for advice on further investigations/response required to protect recreational users.		
Maintenance of aesthetic values	Nuisance organisms	Questionnaire by field personnel collected on 8	Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae and sewage fungus should not be present in excessive amounts.	Water Corporation will report the EQG exceedance in the annual report.	There should be no overall decrease in the aesthetic water quality values of Ocean Reef waters	Any instances of an exceedance of the EQS will be reported by Water Corporation to

Environmental objective	Monitoring target	Monitoring	Trigger criteria (Environmental Quality Guidelines)	Trigger level action(s)/Reporting	Threshold criteria (Environmental Quality Standards)	Threshold contingency action(s)/Reporting
	Faunal deaths	occasions from a single site on the on the Primary Contact Management Zone boundary.	There should be no reported incidents of large-scale deaths of marine organisms relating from unnatural causes.	Assessment against the EQS will commence.	using direct measures of community perception of aesthetic value.	the DWER. A review will be conducted to ensure the treatment process and discharge infrastructure is functioning properly and plant processes/infrastructure repaired if shown to be malfunctioning.
	Water clarity		The natural visual clarity of the water should not be reduced by more than 20%.			
	Colour		The natural hue of the water should not be changed by more than 10 points on the Munsell scale.			
	Surface films		Oil and petrochemicals should not be noticeable as a visible film on the water or detectable by odour.			
	Surface debris		Water surfaces should be free of floating debris, dust and other objectionable matter, including substances that cause foaming.			
	Odour		There should be no objectionable odours.			

Environmental objective	Monitoring target	Monitoring	Trigger criteria (Environmental Quality Guidelines)	Trigger level action(s)/Reporting	Threshold criteria (Environmental Quality Standards)	Threshold contingency action(s)/Reporting
Maintenance of aesthetic values	Fish tainting substances	Concentrations in a 24-hour composite sample.	Concentrations of contaminants will not exceed the aesthetics guidelines for fish tainting substances at the Primary Contact Management Zone boundary during normal plant operating conditions.	Water Corporation will report the EQG exceedance in the annual report. Assessment against the EQS will commence.	There should be no detectable tainting of edible fish harvested outside the Seafood Management Zone boundary.	Water Corporation will undertake examination users waste streams to identify the source of the contaminant(s) of concern and inform the management required to reduce them to acceptable levels. Water Corporation will implement management measures in consultation of the DoH and DWER to reduce the contaminant(s) of concern, and monitor to confirm that the required results are being achieved.

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