Perth Long Term Ocean Outlet Monitoring (PLOOM) Program

2015 Summer Water Quality Survey

Ocean Reef: 3 February 2015
Swanbourne: 20 January 2015
Sepia Depression: 17 February 2015

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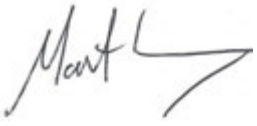

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Executive Summary

Background

Water Corporation operates three major wastewater treatment plants (WWTP) in metropolitan Perth: Beenyup, Subiaco and Woodman Point. The bulk of the treated wastewater processed by the WWTPs is discharged to the sea through three ocean outlets at Ocean Reef, Swanbourne and Sepia Depression, respectively. The discharge of treated wastewater to the marine environment is undertaken according to licence conditions set by the Department of Environment Regulation (formerly, the Department of Environment and Conservation). The licence conditions include a requirement to undertake annual summer surveys of ocean water quality at Ocean Reef and Sepia Depression. For consistency, Water Corporation undertakes an identical survey at Swanbourne.

The objective of the annual summer water quality surveys is to measure the effects of treated wastewater on the marine environment, based on a one-day survey of water quality at each of the ocean outlets. This report presents the results of the summer water quality surveys at Ocean Reef (3 February 2015), Swanbourne (20 January 2015) and Sepia Depression (17 February 2015).

Field survey

Water samples were collected from 35 offshore sites (34 sites at Sepia Depression) within a rectangular sampling grid selected for the prevailing current conditions at each outlet on the day of the survey. At each site, samples were collected from the surface (~1 m depth) and the bottom (~2 m above the seafloor) of the water column. Nine shoreline sites located along the coast adjacent to each of the ocean outlets were also sampled. As per licence conditions, water samples were analysed for nutrients (total nitrogen, total ammonia nitrogen, nitrate+nitrite, total phosphorus and ortho-phosphate), chlorophyll-a (as a measure of phytoplankton biomass) and microbiological indicators (thermotolerant coliforms and *Enterococci* spp.).

Water quality criteria

To provide context for the results, the values for each of the measured nutrient and primary production water quality parameters were compared with (1) ANZECC/ARMCANZ (2000) default low-risk water quality guideline trigger values for south-west Australian inshore marine waters, and/or (2) 'reference values' calculated as the 80th percentile of values from reference sites, collected over the last 16 years. The results of the offshore sampling program are summarised in the Report Cards (Table ES.1 to Table ES.6).

Thermotolerant coliform concentrations were compared with the Environmental Quality Criteria (EQC) for maintenance of seafood safe for human consumption (based on those developed for Cockburn Sound [EPA 2005]). Concentrations of *Enterococci* spp. were compared with the water quality guidelines developed by ANZECC/ARMCANZ (2000). Results for these microbial indicators are summarised in the Report Cards (Table ES.2, Table ES.4 and Table ES.6). The Report Cards compare the median concentrations of thermotolerant coliforms and *Enterococci* spp. with the relevant guidelines using different approaches. For each of the outlets, concentrations of thermotolerant coliforms are compared against the guidelines based on concentrations recorded in surface and bottom waters at distances <250 m and >250 m from the outlet. The same approach is used at Swanbourne and Ocean Reef for *Enterococci* spp., whereby concentrations are compared against the guidelines based on concentrations determined for surface and bottom waters at distances <250 m and >250 m from the outlet. At Sepia Depression, however, *Enterococci* spp. concentrations are compared with the guidelines based on

concentrations recorded in surface and bottom waters at distances 'inside' and 'outside' the post-upgrade boundary.

Key results from the 2015 summer water quality surveys are presented below.

Ocean Reef

The flow rate of the treated wastewater discharge on 3 February 2015 at Ocean Reef was 129 ML/day. The average initial dilution of the plume, calculated using the VPLUMES UM3 numerical model set up to match the conditions at the time of sampling, was 1:157 for Outlet A and 1:136 for Outlet B. Median nutrient concentrations in surface water within 250 m of the diffuser were: total ammonia nitrogen 10 µg/L; ortho-phosphate 43 µg/L, nitrate+nitrite 45 µg/L, total phosphorus 58 µg/L and total nitrogen 170 µg/L. Median nutrient concentrations in surface waters greater than 250 m from the outlet were: total ammonia nitrogen <3 µg/L; ortho-phosphate 16.5 µg/L, nitrate+nitrite 13 µg/L, total phosphorus 28 µg/L and total nitrogen 115 µg/L. Median surface and bottom chlorophyll-a concentrations were 0.6 and 0.55 µg/L, respectively, within the 250 m boundary compared to 0.5 and 0.6 µg/L for surface and bottom concentrations outside the 250 m boundary. Microbial indicators in surface and bottom waters were slightly elevated in the immediate vicinity of the diffuser with a decline in concentrations away from the outlet (supporting rapid die-off of microbes).

Median concentrations of nutrients and chlorophyll-a were compared against the 80th percentile of values from reference sites. In summary, surface water nutrients and chlorophyll-a exceeded the 80th percentile of the reference values at sites within 250 m of the outlets. With the exception of ortho-phosphate, bottom water nutrients within 250 m of the outlets were less than the 80th percentile of the reference values (Table ES.1). Outside of the mixing zone, ortho-phosphate, nitrate+nitrite and chlorophyll-a exceeded the 80th percentile of reference values in surface waters and orthophosphate and chlorophyll-a exceeded the 80th percentile of reference values in bottom waters.

At shoreline sites, median concentrations of all nutrients exceeded the ANZECC/ARMCANZ (2000) guideline values (Table ES.1).

At Ocean Reef, thermotolerant coliform concentrations exceeded the EQG in surface and bottom waters (Table ES.2) less than 250 m from the diffuser. The EQG was met in surface and bottom waters at distances greater than 250 m from the diffuser. Median concentrations of *Enterococci* spp. were below the ANZECC/ARMCANZ (2000) primary contact recreation criteria in all cases. Shoreline sites at Ocean Reef met the EQG for seafood consumption and the ANZECC/ARMCANZ (2000) criteria for primary contact recreation.

Microbiological indicators typically do not meet the relevant guidelines in the immediate vicinity of the ocean outlet diffusers. Results presented here show that the exceedance of the EQG for thermotolerant coliforms during the 2015 sampling event was restricted to sites less than 250 m from the outlets. It is noted that are presently few, if any, suitable habitats for filter feeding shellfish near the ocean outlets. The risk to human consumers of seafood is therefore considered very low.

Table ES.1 Ocean Reef summer water quality survey 2015 Report Card: Nutrients and chlorophyll-a

Parameter	Inside the mixing zone (sites <250 m from diffuser)		Outside the mixing zone (sites >250 m from diffuser)		Shoreline
	Surface	Bottom	Surface	Bottom	
Total ammonia nitrogen					
Ortho-phosphate					
Nitrate+nitrite					
Total phosphorus					
Total nitrogen					
Chlorophyll-a					

Notes:
Assessment criteria for surface and bottom sites:

1. Green = Nutrient median values ≤80th percentile reference values
2. Red = Nutrient median values >80th percentile reference values
1. Assessment criteria for shoreline sites:
3. Green = Nutrient median values ≤ ANZECC/ARMCANZ (2000) guideline values
4. Red = Nutrient median values > ANZECC/ARMCANZ (2000) guideline values

Table ES.2 Ocean Reef summer water quality survey 2015 Report Card: Thermotolerant coliforms (TTC) and *Enterococci* spp.

Parameter	Inside the mixing zone (sites <250 m from diffuser)		Outside the mixing zone (sites >250 m from diffuser)		Shoreline
	Surface	Bottom	Surface	Bottom	
TTC					
Enterococci spp.					

Notes:
Assessment criteria:

1. Green = TTC: ≤14 coliforms/100 mL (seafood safe for human consumption). *Enterococci* spp.: ≤35 *Enterococci* spp./100 mL (primary contact recreation)
2. Red = TTC: >14 coliforms/100 mL (seafood safe for human consumption). *Enterococci* spp.: >35 *Enterococci* spp./100 mL (primary contact recreation)

Swanbourne

The flow rate of the treated wastewater discharge on 20 January 2015 at Swanbourne was 65 ML/day. The average initial dilution of the plume, calculated using the VPLUMES UM3 numerical model set up to match the conditions at the time of sampling, was 1:81. Median concentrations of surface water quality parameters within 250 m from the diffuser were: total ammonia nitrogen 110 µg/L, ortho-phosphate 50 µg/L, nitrate+nitrite 5 µg/L, total phosphorus 62 µg/L and total nitrogen 240 µg/L. Median concentrations in the surface waters greater than 250 m from the outlet were: total ammonia nitrogen 49 µg/L, ortho-phosphate 8 µg/L, nitrate+nitrite 3 µg/L, total phosphorus 18.5 µg/L and total nitrogen 160µg/L. Median surface and bottom chlorophyll-a concentrations were 0.2 and 0.25 µg/L, respectively, within the 250 m boundary compared to 0.2 µg/L for both surface and bottom chlorophyll-a concentrations outside the 250 m boundary. Concentrations of microbiological indicators in surface and bottom waters generally showed elevated concentrations near the diffuser and a decline in concentrations away from the outlet, indicating rapid die-off of microbes.

The median concentrations of nutrients were compared against the 80th percentile of reference values. Median surface water ammonia, ortho-phosphate total phosphorus and total nitrogen, less than 250 m from the outlets at Swanbourne were greater than 80th percentile of reference values for nutrients and chlorophyll-a, whereas all bottom water nutrients inside the mixing zone were less than the 80th percentile of reference site values (Table ES.3).

At shoreline sites, median nutrient concentrations were within ANZECC/ARMCANZ (2000) guideline values for all nutrients except nitrate + nitrite (Table ES.3). The median chlorophyll-a concentrations for surface and bottom sites <250 m and >250 m from the diffuser were below or equal to the 80th percentile of reference values. The median chlorophyll-a concentration at shoreline sites was also below the ANZECC/ARMCANZ (2000) guideline (Table ES.3).

The EQG for thermotolerant coliforms was exceeded at the surface within 250 m but met at bottom <250 m from the diffuser and at the surface and bottom >250 m from the diffuser (Table ES.4). Median concentrations of *Enterococci* spp. were below the ANZECC/ARMCANZ (2000) primary contact recreation criteria in all cases except the surface waters with 250 m from the diffuser at Swanbourne. Thermotolerant coliform and *Enterococci* spp. concentrations at shoreline sites met their respective EQG and ANZECC/ARMCANZ (2000) guidelines.

Table ES.3 Swanbourne summer water quality survey 2015 Report Card: Nutrients

Parameter	Inside the mixing zone (sites <250 m from diffuser)		Outside the mixing zone (sites >250 m from diffuser)		Shoreline
	Surface	Bottom	Surface	Bottom	
Total ammonia nitrogen					
Ortho-phosphate					
Nitrate+nitrite					
Total phosphorus					
Total nitrogen					
Chlorophyll-a					

Notes:
Assessment Criteria for surface and bottom sites:
1. Green = Nutrient median values ≤80th percentile reference values
2. Red = Nutrient median values >80th percentile reference values

Assessment criteria for shoreline sites:
3. Green = Nutrient median values ≤ ANZECC/ARMCANZ (2000) guideline values
4. Red = Nutrient median values > ANZECC/ARMCANZ (2000) guideline values

Table ES.4 Swanbourne summer water quality survey 2015 Report Card: Thermotolerant coliforms (TTC) and *Enterococci* spp.

Parameter	Inside the mixing zone (sites <250 m from diffuser)		Outside the mixing zone (sites >250 m from diffuser)		Shoreline
	Surface	Bottom	Surface	Bottom	
TTC					
Enterococci spp.					

Notes:
Assessment criteria:
1. Green = TTC: ≤14 coliforms/100 mL (seafood safe for human consumption). *Enterococci* spp.: ≤35 *Enterococci* spp./100 mL (primary contact recreation)
2. Red = TTC: >14 coliforms/100 mL (seafood safe for human consumption). *Enterococci* spp.: >35 *Enterococci* spp./100 mL (primary contact recreation

Sepia Depression

The rate of the treated wastewater discharge from the SDOOL was 145 ML/day on 17 February 2015. The average initial dilution of the plume, calculated using the VPLUMES UM3 numerical model set up to match the conditions at the time of sampling, was 1:338.

Median concentrations of surface water quality parameters at sites <250 m from the outlet were: total ammonia nitrogen 81 µg/L, ortho-phosphate 24 µg/L, nitrate+nitrite 9 µg/L, total phosphorus 35 µg/L and total nitrogen 190 µg/L. Median concentrations in the surface waters at sites >250 m from the outlet were: total ammonia nitrogen 13 µg/L, ortho-phosphate 6 µg/L, nitrate+nitrite 3 µg/L, total phosphorus 16 µg/L and total nitrogen 110 µg/L. Median surface and bottom chlorophyll-a concentrations were both 0.4 µg/L at sites <250 m from the outlet compared to 0.3 and 0.4 µg/L for surface and bottom, respectively at sites >250 m from the outlet. Microbiological indicators in surface and bottom waters showed elevated concentrations in the immediate vicinity of the diffuser and a general decline in concentrations away from the outlet, indicating rapid die-off of microbes.

All median surface nutrient concentrations at sites <250 m from the outlet exceeded the 80th percentile of reference values (Table ES.5). Bottom nutrient concentrations at sites <250 m from the outlet were below the 80th percentile of reference values. All median nutrient concentrations except ammonia, from surface sites >250 m from the outlet were below or equal to 80th percentile of reference values. Median nutrient concentrations for shoreline locations were below the ANZECC/ARMCANZ (2000) guideline value against which they were compared (Table ES.5), except for median total ammonia nitrogen concentrations which exceeded the guideline value.

Median chlorophyll-a concentrations for all surface and bottom sites <250 m and >250 m from the outlet were less than the 80th percentile of reference values. The median chlorophyll-a concentration of shoreline sites also met the relevant ANZECC/ARMCANZ (2000) criteria for inshore coastal waters.

Thermotolerant coliforms and *Enterococci* spp. concentrations (Table ES.6) at Sepia Depression met their respective EQG and ANZECC/ARMCANZ (2000) guidelines at sites >250 m from the outlet. Thermotolerant coliforms exceeded the EQG in surface and bottom waters <250 m from the outlet. Median concentrations of *Enterococci* spp. exceeded the ANZECC/ARMCANZ (2000) guideline in surface waters at sites <250 m from the outlet, but were below the guideline at bottom water sites. Concentrations of thermotolerant coliforms and *Enterococci* spp. at shoreline sites met their respective EQG and ANZECC/ARMCANZ (2000) criteria.

Microbiological indicators typically do not meet the relevant guidelines in the immediate vicinity of the ocean outlet diffuser. Results presented here show that the exceedance of the criteria for thermotolerant coliforms during the 2015 sampling event was restricted to sites <250 m from the outlets, and inside the post-upgrade boundary. It is noted there are presently few, if any, suitable habitats for filter feeding shellfish near the ocean outlets. The risk to human consumers of seafood is therefore considered very low.

Table ES.5 Sepia Depression summer water quality survey 2015 Report Card: Nutrients

Parameter	Inside the mixing zone (sites <250 m from diffuser)		Outside the mixing zone (sites >250 m from diffuser)		Shoreline
	Surface	Bottom	Surface	Bottom	
Total ammonia nitrogen					
Ortho-phosphate					
Nitrate+nitrite					
Total phosphorus					
Total nitrogen					
Chlorophyll-a					

Notes:
Assessment criteria for surface and bottom sites:
1. Green = Nutrient median values ≤80th percentile reference values
2. Red = Nutrient median values >80th percentile reference values

Assessment criteria for shoreline sites:
3. Green = Nutrient median values ≤ ANZECC/ARMCANZ (2000) guideline values
4. Red = Nutrient median values > ANZECC/ARMCANZ (2000) guideline values

Table ES.6 Sepia Depression summer water quality survey 2015 Report Card: Thermotolerant coliforms and *Enterococci* spp.

Parameter	Inside the mixing zone (sites <250 m from diffuser)		Inside the mixing zone (sites >250 m from diffuser)		Shoreline
	Surface	Bottom	Surface	Bottom	
TCC					
Enterococci spp.	Sites inside post-upgrade boundary		Sites outside post-upgrade boundary		Shoreline
	Surface	Bottom	Surface	Bottom	

Notes:
Assessment criteria:
1. Green= TTC: ≤14 coliforms/100 mL (seafood safe for human consumption). *Enterococci* spp.: ≤35 *Enterococci* spp./100 mL (primary contact recreation)
2. Red= TTC: >14 coliforms/100 mL (seafood safe for human consumption). *Enterococci* spp.: >35 *Enterococci* spp./100 mL (primary contact recreation)

Conclusions

The 2015 summer water quality surveys provide a snapshot of marine water quality conditions, on individual sampling days during summer, near three ocean outlets. Results indicated that the treated wastewater plumes dissipated away from the diffusers and that the region of influence was localised within the immediate vicinity (<250 m) of each outlet. The results of this report, in conjunction with other PLOOM components (i.e. trial compliance monitoring [reported separately]), found no evidence that the treated wastewater from any of the three outlets is having detectable adverse effects on water quality conditions in the surrounding area.

1. Introduction

1.2 Background

Water Corporation operates three major wastewater treatment plants (WWTPs) within the Perth metropolitan area, at Beenyup, Subiaco and Woodman Point (Figure 1.1). The WWTPs employ an activated sludge treatment process with high nitrogen removal capacity. Most of the treated wastewater is discharged to the sea through three ocean outlets located at Ocean Reef, Swanbourne and Sepia Depression, respectively (Figure 1.1).

The Beenyup WWTP discharges advanced secondary treated wastewater via two outlets at Ocean Reef. The two outlets are located in ~10 m of water, have overall lengths of 1.6 km (outlet A) and 1.8 km (outlet B), and diffuser lengths of 195 m each. The Subiaco WWTP discharges secondary treated wastewater via an outlet at Swanbourne, which is located in ~11 m of water, has an overall length of 1.1 km, and a diffuser length of 91 m. The Sepia Depression Ocean Outlet Landline (SDOOL) discharges secondary treated domestic wastewater (~85% of the total), a smaller volume of primary treated wastewater (~10% of the total discharge flow) and wastewater from industry, the Jervoise Bay Groundwater Recovery Scheme and the Kwinana Wastewater Reclamation Plant (5% of discharge). The Sepia Depression ocean outlet is located in ~20 m of water, has an overall (offshore) length of 4.2 km and a diffuser length of 324 m.

The operation of each of the WWTPs in Perth's metropolitan region and the discharge of treated wastewater to the marine environment is conducted under licence conditions set by the Department of Environment Regulation (Appendix A). Licence conditions include a requirement to undertake annual summer surveys of ocean water quality at Ocean Reef and Sepia Depression. For consistency, Water Corporation implements an identical survey at Swanbourne. The objective of the annual water quality surveys is to measure the effects of treated wastewater on the marine environment.

Water quality parameters (Table 1.1) are measured annually at a rectangular sampling grid of 35 offshore sites (34 sites at Sepia Depression) appropriate for the prevailing currents on the day of the survey (Appendix B). Nine shoreline sites along the coast adjacent to each of the outlets are also sampled.

Table 1.1 Water quality parameters for the summer survey of ocean outlets

Nutrients	Phytoplankton biomass	Microbial indicators
Total ammonia nitrogen Ortho-phosphate Nitrate+nitrite Total phosphorus Total nitrogen	Chlorophyll-a Phaeophytin	Thermotolerant coliforms *Enterococci* spp.

The purpose of the annual summer water quality surveys is to:

- provide data on water quality in the vicinity of the outlets
- assess the performance of each outlet by determining the dilution and dispersion characteristics of the treated wastewater
- examine the extent of influence of the plumes
- allow for the ongoing assessment of the environmental impact of the wastewater discharge in relation to the marine water quality and beneficial uses of the area
- allow for the ongoing assessment of the level of public health risk associated with ocean disposal of treated wastewater.

Water Corporation has undertaken the annual water quality surveys in the vicinity of the outlets since their construction and they have been a component of the Perth Long Term Ocean Outlet Monitoring (PLOOM) program since it was implemented in 1996. The PLOOM Program was developed to determine the impacts of treated wastewater discharges on the marine environment in terms of nutrients, bacteria, metals and organic contaminants, and to assess whether environmental and public health values are being maintained (DALSE 2004a).

This report presents the results of the 2015 summer water quality surveys of the marine environment near the three ocean outlets: Ocean Reef (3 February 2015), Swanbourne (20 January 2015) and Sepia Depression (17 February 2015).

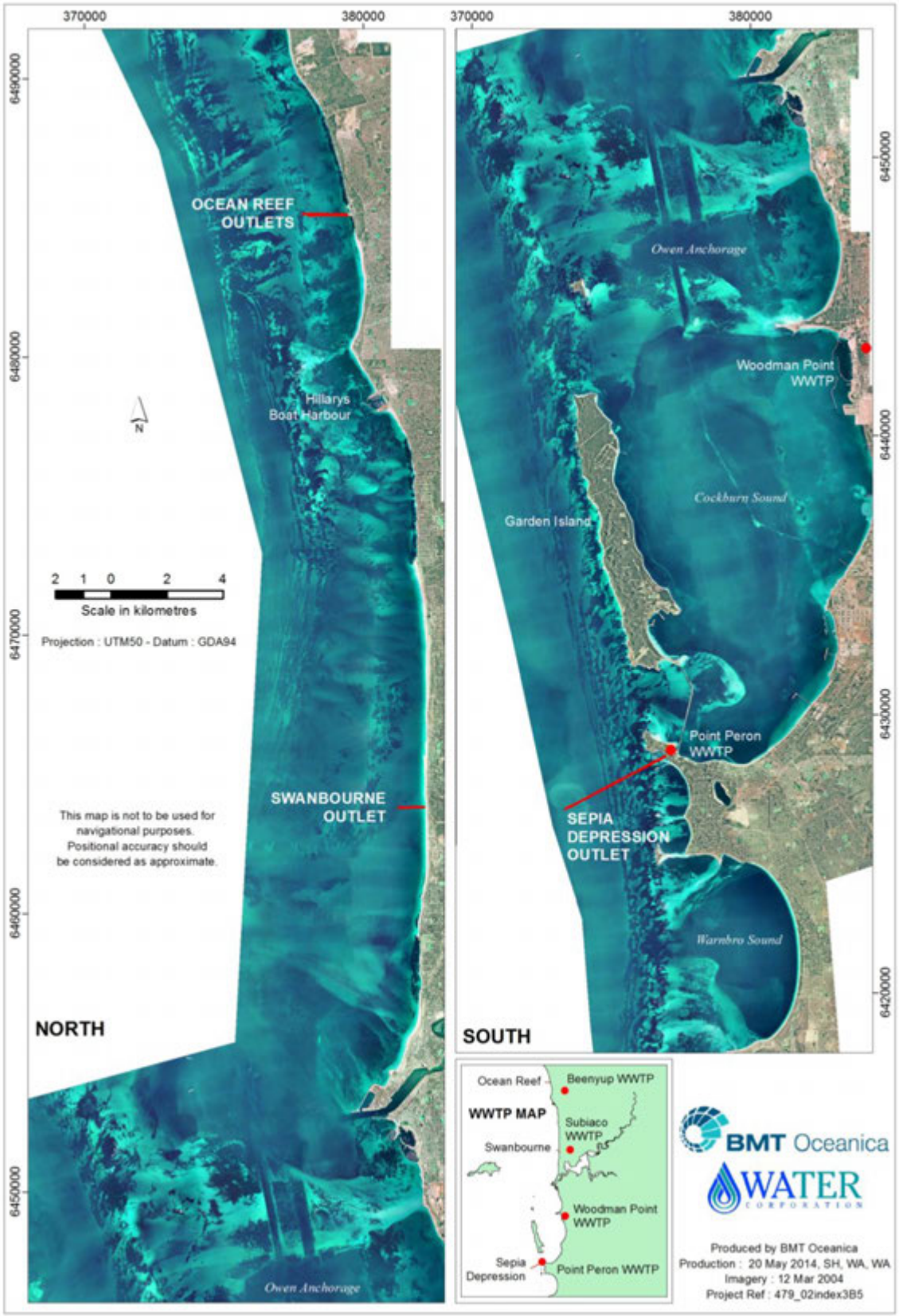


Figure 1.1 Treated wastewater ocean outlet locations, Perth

1.3 Water quality criteria for Perth coastal waters

1.3.1 An environmental quality management framework for Perth's coastal waters

In 2000, the Environmental Protection Authority (EPA) published *Perth's Coastal Waters – Environmental Values and Objectives*, a working document aimed at establishing an Environmental Quality Management Framework (EQMF) for Perth's coastal waters. In 2015, the *Environmental Assessment Guideline for Protecting the Quality of Western Australia's Marine Environment*, expanded the Environmental Quality Management Framework (EQMF) to all the state's coastal waters. The document identified Environmental Values and Objectives relevant to coastal waters, and outlined the process for developing Environmental Quality Criteria (EPA 2000). Four Environmental Values are relevant to this report: Ecosystem Health (an ecological value), Fishing and Aquaculture (a social value), Recreation and Aesthetics (a social value) and Industrial Water Supply (a social value). Seven Environmental Quality Objectives (EQOs) were developed to protect these Environmental Values. The relevant EQOs are:

EQO1: Maintenance of ecosystem integrity

The objective of EQO1 is to maintain a healthy and diverse ecosystem. Over 99% of Perth's coastal waters have been designated as having a high level of protection (E2) with less than 1% designated as moderate (E3) or low (E4) levels of protection. The areas designated with a moderate (E3) level of protection, where moderate changes from natural variation are identified as the limit of acceptable change, include those areas around the discharge points of the Ocean Reef and Swanbourne metropolitan ocean outlets (EPA 2000). EPA (2000) includes appendices showing notional levels of ecological protection around each of the metropolitan ocean outlets (see Figure 3, Map 2, Map 3 and Map 4; EPA 2000). Although the framework published in this document still applies at Ocean Reef and Swanbourne, it was superseded at Sepia Depression through the publication of Ministerial Statement 665 (28 October 2004). The levels of ecological protection were updated in this document such that area within 100 m of the Sepia Depression outlet is a low ecological protection area, whereas the area outside 100 m is a high ecological protection area.

EQO2: Maintenance of seafood for human consumption, EQO3: Maintenance of aquaculture, EQO4: Maintenance of primary contact recreation values and EQO5: Maintenance of secondary contact recreation values

The objectives of EQO2–5 are to support social uses such as fishing, swimming and boating. These EQOs will be enforced throughout Perth's coastal waters with the exception of small areas surrounding the three metropolitan ocean outlets. The EPA has appended maps to *Perth's Coastal Waters – Environmental Values and Objectives* to provide an indication for each of the metropolitan ocean outlets of the boundaries identified by the EPA as S2 areas where EQO2 will not apply (i.e. seafood collected from these waters may be unsafe to eat) and S3 areas where EQO4 will not apply (i.e. water quality may not be suitable for swimming) (see Figure 4, Map 2, Map 3 and Map 4; EPA 2000).

EQO6: Maintenance of aesthetic values and EQO7: Maintenance of industrial water supply values

The objectives of EQO6–7 are to maintain the attractiveness of the environment and maintain industrial water supplies. These EQOs will apply throughout Perth's coastal waters.

In 2003, a Memorandum of Understanding (MOU) was developed between five relevant stakeholders, each with an interest in the management of treated wastewater discharges to the Marmion Marine Park. According to the MOU (Anon 2003), the next phase in the establishment of an EQMF was to develop a Schedule outlining the Environmental Quality Criteria (EQC)[1], their associated measurement and interpretation protocols, and the boundaries of the areas where the different EQOs will apply. A guideline for the establishment of Environmental Quality Criteria for use near Perth's existing ocean outlets was released in March 2015.

1.3.2 ANZECC/ARMCANZ guidelines for fresh and marine water quality

Physical and chemical stressors

In the absence of formal Environmental Quality Guidelines (EQGs) or Environmental Quality Standards (EQSs), the ANZECC/ARMCANZ (2000) Guidelines for Fresh and Marine Water Quality include default trigger values, which are low-risk water quality guidelines for physical and chemical stressors. These guidelines are applicable to south-west Australian 'inshore marine waters', which includes the coastal waters off metropolitan Perth. To provide some context for the results from the annual summer water quality surveys, it is useful to compare the values for each of the measured water quality parameters with the default water quality guidelines identified in ANZECC/ARMCANZ (2000). According to the guidelines, an exceedance of a trigger value should be regarded as an 'early warning' mechanism; trigger values are not intended as a means of assessing 'compliance'.

The default water quality guidelines for 'slightly disturbed' marine inshore waters in the south-west Australia region are shown in Table 1.2. The ANZECC/ARMCANZ (2000) guidelines define 'slightly-to-moderately disturbed systems' as "ecosystems in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity" and where the "biological communities remain in a healthy condition and ecosystem integrity is largely retained". The ANZECC/ARMCANZ (2000) guidelines identify marine ecosystems lying immediately adjacent to metropolitan areas as potential examples of slightly-to-moderately disturbed systems. Inshore waters are defined in the ANZECC/ARMCANZ (2000) guidelines as "coastal lagoons (excluding estuaries) and embayments and waters less than 20 m depth". The marine environments of the three metropolitan ocean outlets can be classed as 'inshore marine'. The Ocean Reef and Swanbourne outlets discharge to waters of ~10 m depth and the Sepia Depression outlet discharges into a natural channel ~20 m deep, bounded offshore by a shallower reef (~15 m deep).

[1] *Environmental Quality Criteria are benchmarks for monitoring used to guide and assess the results of monitoring programs, specifically to identify when and where Environmental Quality Objectives are being met or not met. There are two types of Environmental Quality Criteria: Environmental Quality Guidelines and Environmental Quality Standards.*

Table 1.2 Summary of default water quality guidelines (trigger values) applicable to south-west Australian coastal waters

Parameter	Inshore marine waters trigger value[1]
Total ammonia nitrogen (µg/L)	5
Ortho-phosphate (µg/L)	5
Nitrate+nitrite (µg/L)	5
Total phosphorus (µg/L)	20
Total nitrogen (µg/L)	230
Chlorophyll-a (µg/L)	0.7

Notes:
1. From ANZECC/ARMCANZ (2000)
2. The ANZECC/ARMCANZ (2000) guidelines shown are recommended for summer (low rainfall) periods.

Previous summer surveys (DALSE 2002, 2003, 2004a, 2004b, Oceanica 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, BMT Oceanica 2014) have indicated that levels of some of the measured 'background' water quality parameters are naturally higher than the ANZECC/ARMCANZ (2000) default guidelines. For example, it has been the general trend for concentrations of ortho-phosphate, measured at sites located away from the influence of the outlets, to be above the guideline values. Conversely, in the case of the chlorophyll-a, it is likely that the ANZECC/ARMCANZ (2000) guideline is relatively high compared to the background levels in Perth's coastal waters.

The ANZECC/ARMCANZ (2000) guidelines recommend, for naturally occurring stressors, that data from appropriate local reference systems should be used to determine the low-risk trigger values for each key water quality parameter. Data collected over two years of monthly sampling are generally regarded as sufficient to indicate ecosystem variability and can be used to derive trigger values. Where few data are available (e.g. few reference sites or sampling times) the guidelines recommend that a single trigger value should be derived from the available data as an interim measure. The guidelines recommend defining trigger values for physical and chemical stressors for slightly-to-moderately disturbed ecosystems in terms of the 80th and/or 20th percentile values[2] obtained from an appropriate reference system. For stressors that cause problems at high concentrations (e.g. nutrients), the 80th percentile of the reference distribution represents the low-risk trigger value.

Reference values

In this report 'reference values' for each nutrient and primary production water quality parameter have been derived as a measure of the background conditions for each outlet (Table 1.3). Separate reference values have been derived for surface and bottom waters of the marine environment. These reference values were calculated as the 80th percentile of the 'background concentrations' collated from the summer water quality surveys undertaken over the last 17 years (1999–2015).[3] Background concentrations are the surface and bottom concentrations measured at sampling sites located upstream of the outlet at the time of each summer water quality survey. Note that the 80th percentile of reference values has not been calculated for the shoreline sites.

[2] *A percentile is a value on a scale of one hundred that indicates the percent of a distribution that is equal to or below it. For example, the 80th percentile is greater than or equal to 80% of all values – conversely, 80% of all values are less than or equal to the 80th percentile.*

[3] *These years were selected on the basis that the same laboratory (Marine and Freshwater Research Laboratory) has been responsible for undertaking water quality analysis over this period, thereby minimising the potential for between-laboratory differences within the dataset (see DALSE 2004a).*

Table 1.3 Median and 80th percentile values for the nutrient and primary production water quality parameters in the marine environment for each ocean outlet

	Total ammonium nitrogen (µg/L)	Ortho-phosphate (µg/L)	Nitrate+ nitrite (µg/L)	Total phosphorus (µg/L)	Total nitrogen (µg/L)	Chlorophyll-a (µg/L)
Ocean Reef – surface waters						
median	<3	7	8	18	110	0.3
80th percentile	4	8	12	35	140	0.5
Ocean Reef – bottom Waters						
median	<3	7	7	17	112	0.3
80th percentile	3	8	12	33	130	0.5
Swanbourne – surface waters						
median	<3	4	<2	14	110	0.3
80th percentile	4	8	11	35	140	0.5
Swanbourne – bottom waters						
median	<3	4	<2	14	120	0.3
80th percentile	3	8	11	33	130	0.5
Sepia Depression – surface waters						
median	<3	4	3	15	110	0.4
80th percentile	6	6	5	31	146	0.6
Sepia Depression – bottom waters						
median	<3	3	3	14	110	0.4
80th percentile	4	5	4	31	150	0.7

Note:
1. Values in this table are rounded.

In ANZECC/ARMCANZ (2000), the recommended approach for physical and chemical stressors is that the median concentration of independent samples taken at a test site should be compared with the relevant guideline values. Where suitable reference site data are available, the comparison should be against the 80th (or 20th) percentile of the reference site data. The summer water quality surveys have not been specifically designed to provide information suitable for these types of comparisons. In this report, the water quality parameters measured for each of the individual sites within the sampling grid are compared with the ANZECC/ARMCANZ (2000) guidelines and the 80th percentile of reference values for contextual purposes only. In addition, the median concentrations of each water quality parameter were calculated for sites located within 250 m of the diffuser and greater than 250 m from the diffuser. This distance nominally represents the region encapsulating the initial stages of treated wastewater mixing, as indicated by historical initial dilution modelling.

Water quality guidelines for recreational waters

The ANZECC/ARMCANZ (2000) water quality guidelines for microbiological characteristics for primary and secondary contact recreation in marine waters are listed in Table 1.4. The guidelines are exceeded if the median of the impact sites exceeds 35 and 230 MPN/100mL for primary and secondary contact, respectively.

Table 1.4 ANZECC/ARMCANZ water quality guidelines for microbial characteristics for primary and secondary contact recreation in marine waters

Enterococci spp.[1]	Marine waters primary contact recreation guidelines from ANZECC/ARMCANZ (2000)
Primary contact recreation	35 MPN/100 mL
Secondary contact recreation	230 MPN/100 mL

Notes:
1. ANZECC/ARMCANZ (2000) guidelines for *Enterococci* spp. are provided for primary and secondary contact recreation and are based on median values and maximum number in any one sample of 60–100 organisms/100 mL (primary) or 450–700 organisms/100 mL (secondary). *Enterococci* spp. are the major component of the faecal streptococci group.
2. Concentrations of *Enterococci* spp. are shown as Most Probable Number (MPN)/100 mL

Source: ANZECC/ARMCANZ (2000)

In this report, the median concentrations of *Enterococci* spp. were calculated for sites located within 250 m of the diffuser and greater than 250 m from the diffuser at Ocean Reef and Swanbourne. At Sepia Depression, the median concentrations of *Enterococci* spp. were calculated for those sites inside and outside the post-upgrade boundary.

It should be noted that the microbiological water quality guidelines are not intended to be used as the basis for establishing conditions for the discharge of treated wastewaters. Public health concerns relating to primary (whole-body) contact recreation are not considered to be an issue because there is no recreational use of the waters within the vicinity of the ocean outlets. The NHMRC (2005) *Guidelines for Managing Risks in Recreational Water* identify that the first step in the framework for microbial quality assessment of recreational waters is the question "Is the water body used for contact recreation?" If the response is 'No', the water body should remain unclassified, to be reassessed if use changes.

1.3.3 Environmental Quality Criteria for the maintenance of seafood safe for human consumption

The EPA (2005) Environmental Quality Criteria for maintenance of seafood safe for human consumption are listed in Table 1.5. The Environmental Quality Guidelines (EQGs) are a measure of the potential threat to human health. The Environmental Quality Standards (EQSs) are intended to "confidently predict whether there is a significant risk to the health of human consumers" (EPA 2005). The important subtext is that these criteria were developed for Cockburn Sound where aquaculture or commercial and amateur harvesting of wild seafood species occurs. They were not intended to be used as the basis for establishing conditions for the discharge of treated wastewaters to Perth's coastal waters. In addition, the EQO Seafood Safe for Human Consumption is primarily concerned with the harvesting and consumption of raw shellfish (meaning filter feeding bivalve molluscs, e.g. oysters, mussels, clams, pipis, scallops, cockles, and razor clams), and not other forms of seafood (e.g. fin fish, abalone, crayfish, etc.). Human health concerns relating to consumption of shellfish are not considered an issue at the outfalls as there is no aquaculture within 250 m of the diffusers and no known harvesting of shellfish in the waters 1–2 km offshore. In addition, any exceedance of the EQC for thermotolerant coliforms (TTC) is to be viewed conservatively. The Department of Health (DoH) discourages the public from taking wild shellfish, recommending instead that shellfish are only consumed if harvested commercially and under strict monitoring programs. The DoH has further indicated that "It is impossible to guarantee the safety of eating wild shellfish without having a comprehensive monitoring program that tests the waterway concerned for harmful microorganisms and toxins" and has formally advised DEC that, in the absence of a full monitoring program, the application of the TTC criteria (EPA 2005) is insufficient to protect those who wish to collect and eat wild shellfish.

Table 1.5 Environmental Quality Criteria for the maintenance of seafood safe for human consumption

Thermotolerant coliforms	Environmental Quality Criteria from EPA (2005)
EQG[1]	14 CFU/100 mL
EQS[2]	70 CFU/100 mL

Notes:
1. The EQG is based on median values with no more than 10% of the samples exceeding 21 CFU/100 mL.
3. The EQS is based on median values with no more than 10% of the samples exceeding 85 CFU/100 mL.
4. Concentrations of thermotolerant coliforms are shown as Colony Forming Units (CFU)/100 mL.

Source: EPA (2005)

2. Survey Methods

2.1 Wind, wave and tide conditions

Information on the prevailing wind conditions (wind speed and direction) at Ocean Reef[4], Swanbourne[5] and Sepia Depression[6] immediately prior to and over the duration of each summer water quality survey was provided by the Bureau of Meteorology.

Significant wave height and wave period was provided by the Department of Transport (DoT) from a wave rider buoy located south-west of Rottnest Island in a water depth of 48 m. Attenuation of the wave energy, due to refraction and diffraction processes around the offshore reefs, will cause the wave height near the outlets to be considerably lower than that observed offshore of Rottnest Island. Water surface elevations were provided by the DoT from their gauge in Fremantle Fishing Boat Harbour.

This information was used to describe the prevailing wind, wave and tide conditions at each location immediately prior to and during the summer water quality surveys. The prevailing flow conditions determine which sampling grid was used for the summer water quality survey at each outlet (Section 2.5; DAL 2001).

2.2 Discharge from the outlets

Flow-proportionate composite samples of treated wastewater were collected from each of the WWTPs over the 24-hour period prior to and during the annual summer water quality survey at each outlet and the characteristics of the treated wastewater samples determined.

2.3 Surface drogue movement

At the commencement of the summer water quality survey at each outlet, a drogue was released over the centre of the operational outlet diffuser (Outlet B for Ocean Reef). The location of the drogue was recorded at intervals throughout the survey using an on-board global positioning system (GPS). Drogue tracking provides an estimate of mean surface current and this information is used in the initial dilution modelling (Section 2.4).

2.4 Initial dilution modelling

2.4.1 Model

VPLUMES is an initial dilution model developed by the United States Environmental Protection Agency. Initial dilution occurs from the point of discharge to a point of maximum rise or fall (e.g. reaching the surface of the water body) of the plume.

These numerical models are designed to model the near-field behaviour of plumes; that is, the behaviour in the region where the plume first jets into the surrounding waters and then (in the case of positively buoyant plumes) rises and mixes with the surrounding waters. These models capture simple features of the surrounding environment such as depth at point of discharge, net current and wind speed. However, because the models do not take into account broader scale bathymetry and hydrodynamics, they generally do not accurately predict the far-field behaviour; that is, the behaviour after the plume has reached the surface or is fully mixed in the water column. Three-dimensional baroclinic or barotropic hydrodynamic models are required to better estimate far-field behaviour.

[4] *Bureau of Meteorology Site Number 009214.*
[5] *Bureau of Meteorology Site Number 009215.*
[6] *Bureau of Meteorology Site Number 009256 (Garden Island).*

The UM3 initial dilution model, which is part of the Visual Plumes (VPLUMES) suite of dilution models (Frick et al. 2001), was applied to the discharges from each outlet under ambient conditions and treated wastewater flows at the time of the surveys.

2.4.2 Model set-up

Model set-up parameters were selected to represent the outlet diffuser, flows and ambient conditions at Ocean Reef, Swanbourne and Sepia Depression, respectively, at the time of the surveys (Table 2.1).

Table 2.1 Initial dilution model set-up parameters for ocean outlets at Ocean Reef, Swanbourne and Sepia Depression

Diffuser characteristics	Ocean Reef (outlet A) 3/02/2015	Ocean Reef (outlet B) 3/02/2015	Swanbourne 20/01/2015	Sepia Depression 17/02/2015
Port diameter (m)[1]	0.125	0.16	0.17	0.135
Port elevation (m)	0.76	0.84	1	0.75
Number of open ports	50	48	20	68
Port spacing (m)[2]	4	4	5	4.65
Port orientation	Alternating horizontal	Alternating horizontal	Tee discharge horizontal, aligned N-S	Alternating horizontal
Water depth (m)	9.8	9.8	11	20
Ambient conditions at the time of sampling				
Temperature (°C)[3]	22.81	22.81	24.10	23.19
Salinity[3]	35.97	35.97	36.09	36.04
Surface current (m/s)(based on drogue movement)	0.07	0.07	0.07	0.14
Discharge characteristics				
Flow (ML/day)	59.09	59.17	65.00	145.26
Temperature (°C)	25.0	25.0	24.0	29.7
Salinity (psu)	0.6	0.6	0.70	0.47

Notes:
1. Equivalent diameter for a 0.15 x 0.15 m square section.
2. In the case of alternate ports, they are all assumed to be on one side of the diffuser and 'port spacing' is the distance between each port irrelevant of the actual position on either side of the diffuser. For T-shaped risers, it is assumed that all ports are on the one side of the diffuser with the spacing equal to half of the spacing between the risers.
3. Ambient conditions have been taken from sites 64 for Ocean Reef and Sepia depression and site 48 for Swanbourne.

The surface drogue tracking at each location provides an accurate estimate of mean surface current with good agreement among velocities calculated from the four, four and six observations taken at Ocean Reef, Swanbourne and Sepia Depression, respectively, on each day of the water quality surveys. The mean direction[7] of the surface current was also estimated from the surface drogue tracking locations. The mean surface currents were used to synthesise vertical velocity profiles based on the findings of Pattiaratchi et al. (1995), who installed current meters at 3 m and 7 m above the seabed at the Ocean Reef outlet and at 3 m and 13 m above the seabed near the Sepia Depression outlet. The difference between the mean currents at these depths was used as an indication of a likely linear decrease in current speeds from the surface to the seabed[8]. At Ocean Reef it was estimated that the current speed dropped by ~1.2% per

[7] *The current direction was assumed to remain constant throughout the water column.*

[8] *Two sets of ambient conditions are set in the model, one at the surface (0 m) and one at ~1 m above the seabed. The current speed is set to linearly decrease to zero from this depth to the seabed.*

metre depth and at Sepia Depression it was estimated that the current speed dropped by ~3.8% per metre depth. There were no current measurements from the Swanbourne outlet, so the currents at Ocean Reef were also used to determine the likely linear decrease in current speeds at Swanbourne.

2.5 Water quality sampling

2.5.1 Sampling locations

Water samples were collected from 35 offshore sites (34 at Sepia Depression) within a rectangular sampling grid appropriate for the prevailing flow conditions at each outlet on the day of the survey (Appendix B; DAL 2001). The sampling grid was chosen after 4–6 drogue readings to determine the predominant flow direction. The actual position of each sampling site was recorded using an on-board GPS. In addition, nine shoreline sites located along the coast adjacent to each ocean outlet were sampled.

2.5.2 Sample collection

At each offshore site, water samples were collected from the surface (1 m depth) and the bottom (~2 m above the seafloor) of the water column. The samples were collected with two electric bilge pumps (one for the surface and one for the bottom samples). Prior to collecting a sample at each site, the pumps were operated for ~30 s to flush the delivery hose. Single shoreline samples were obtained by filling the sample containers directly in waist-deep water.

At the surface and the bottom of each of the offshore sites and at each shoreline site, the following samples were collected:

- two 125 mL unfiltered samples for total phosphorus and total nitrogen analysis
- two 10 mL filtered samples (onsite through a 45 µm filter) for ortho-phosphate, ammonia and nitrate+nitrite analysis
- one 10 mL sample for fluorometric chlorophyll-a analysis
- one 250 mL sample for thermotolerant coliforms and faecal streptococci analysis.

Prior to collecting a sample at each site, the sample containers (with the exception of pre-sterilised sample bottles used for the microbiological analysis) were flushed with seawater. Immediately after collection all the samples were placed on ice and in the dark.

2.5.3 Replicate samples

During each survey, three replicate samples for nutrients were obtained from surface waters at a single offshore site in the sampling grid. The samples were compared to identify variance from small-scale spatial variability in the water column or by variability associated with laboratory analyses.

2.5.4 Water column structure

A multi-parameter water quality sensor was lowered through the water column at seven or eight of the offshore sites in the sampling grid at each of the outlets to provide information on the physical structure of the water column, i.e. vertical profiles of temperature, salinity and dissolved oxygen. The selected sites were located along a north–south transect through the middle of each sampling grid, with additional sites measured around the diffuser.

2.5.5 Laboratory analysis

The nutrient and primary production analyses were undertaken using the analytical methods identified in Table 2.2.

The measurement of chlorophyll-a by fluorescence was performed on unfiltered water samples. The sample fluorescence was measured the same day using a Turner Designs Trilogy Benchtop Fluorometer (Model 7200-042). The fluorometer was calibrated against acetone-extracted chlorophyll-a samples that were collected from a number of corresponding sites. Water samples collected for the measurement of chlorophyll-a and phaeophytin (acetone extraction method) were filtered in the field onto Whatman 47 mm GF/C glass fibre filter papers, placed on ice and kept in the dark for transport. In the laboratory, filter papers were ground with 90% acetone and extraction occurred over 24 hours. Chlorophyll-a and phaeophytin were measured using a spectrophotometer following extraction.

Ortho-phosphate was analysed by the ascorbic acid method (Johnson & Petty 1982), nitrate+nitrite by copper-cadmium reduction (Johnson & Petty 1983) and ammonia using the alkaline phenate method (Switala 1993). Total nitrogen and total phosphorus were determined from autoclave digests with potassium persulfate (Valderrama 1981). All nutrient analyses were carried out on a Lachat Quick Chem 8500 Automated Flow Injection Analyser in accordance with NATA accreditation requirements.

Occasionally the concentration of a particular parameter in a sample was below the reporting limits. The lower reporting limit for thermotolerant coliforms and *Enterococci* spp. is dependent on the maximum sample volume that can be processed. For the purposes of calculating statistics and data presentation, nutrient, chlorophyll a and microbial concentrations below the reporting limit were assumed to be half the reporting limit (e.g. <3 µg/L becomes 1.5 µg/L).

Table 2.2 Analytical methods and reporting limits

Parameter	Analytical method	Reporting limit	Unit
Nutrient			
Total phosphorus	Lachat automated flow injection analyser (Valderrama 1981)	5[1]	µg P/L
Ortho-phosphate	Lachat automated flow injection analyser (Johnson & Petty 1982)	2[1]	µg P/L
Total nitrogen	Lachat automated flow injection analyser (Valderrama 1981)	50[1]	µg N/L
Total ammonia nitrogen	Lachat automated flow injection analyser (Switala 1993)	3[1]	µg N/L
Nitrate+nitrite	Lachat automated flow injection analyser (Johnson & Petty 1983)	2[1]	µg N/L
Primary production			
Chlorophyll-a	Fluorometric	0.1[2]	µg/L
Chlorophyll-a	Acetone extraction	0.1[1]	µg/L
Phaeophytin	Acetone extraction	0.1[1]	µg/L
Microbiological indicators			
Thermotolerant coliforms	Membrane filtration	Dilution dependent[3]	CFU/100 mL
Faecal streptococci (as *Enterococci* spp.)	Enterolert Defined Substrate Technology	Dilution dependent[3]	MPN/100 mL

Notes:
1. The reporting limit is calculated as the constituent concentration that produces a signal ten standard deviations above the reagent water blank.
2. Instrument reporting limit.
3. The lower assay limit for thermotolerant coliforms and faecal streptococci are dependent on the dilution of the original sample.

Data analysis and presentation

The water quality data for each sampling site are presented as bar plots. Dot distribution plots are presented to illustrate the spatial variation in water quality parameters within the sampling grid. It should be emphasised that although individual sites may exceed ANZECC/ARMCANZ (2000) guidelines or the 80th percentile of reference values, this does not imply that an EQG or EQS has been exceeded. EQG and EQS exceedance criteria are based on median values of samples taken from many sites.

Summer Water Quality Survey

Ocean Reef

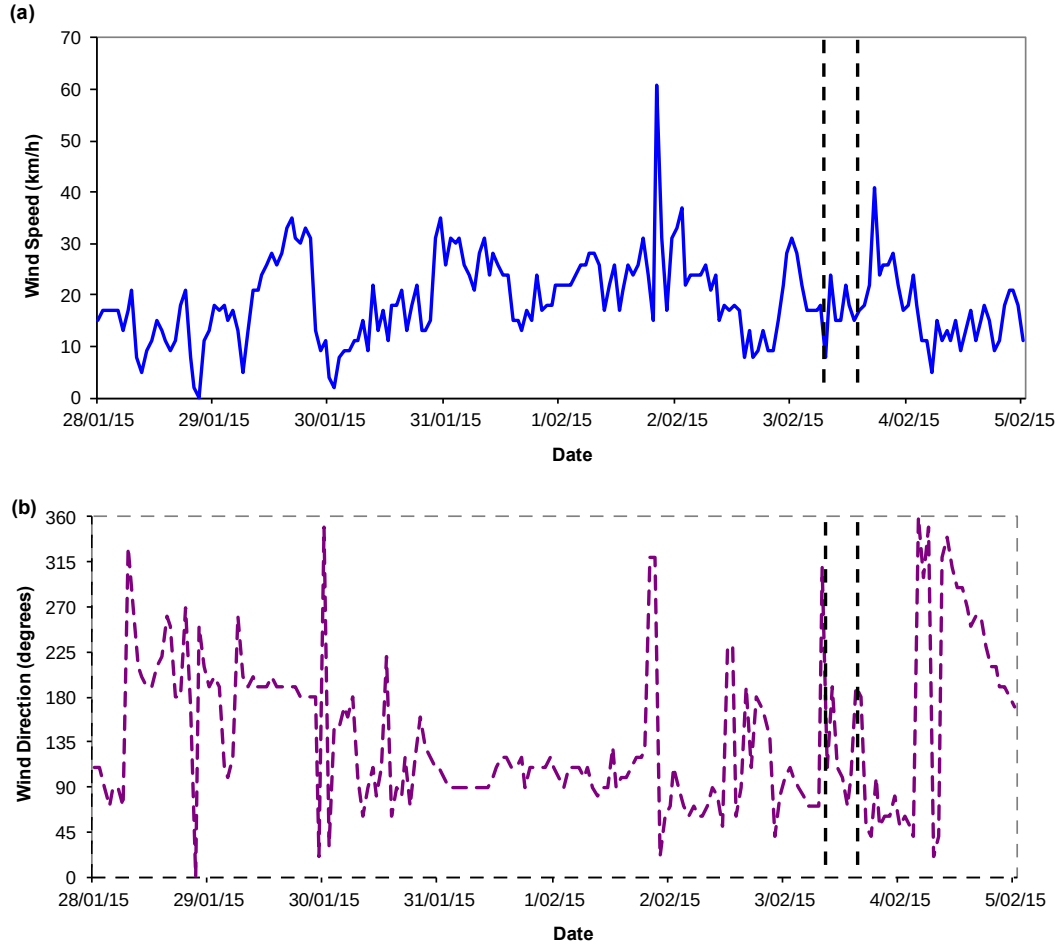
3 February 2015

WATER CORPORATION

3. Ocean Reef Summer Water Quality Survey – Results and Interpretation

3.1 Wind, wave and tide conditions

The survey at Ocean Reef was undertaken on 3 February 2015. For 24 hours prior to the survey, winds at Ocean Reef ranged from 10.5 to 22.2 km/h (Figure 3.1a) and were from the east and south (Figure 3.1b). During the survey, gentle easterlies prevailed with an average wind speed of 16.8 km/h.



Note:
1. a = wind speed
2. b = wind direction
3. Dashed lines (- -) show approximate timing of the summer water quality survey.

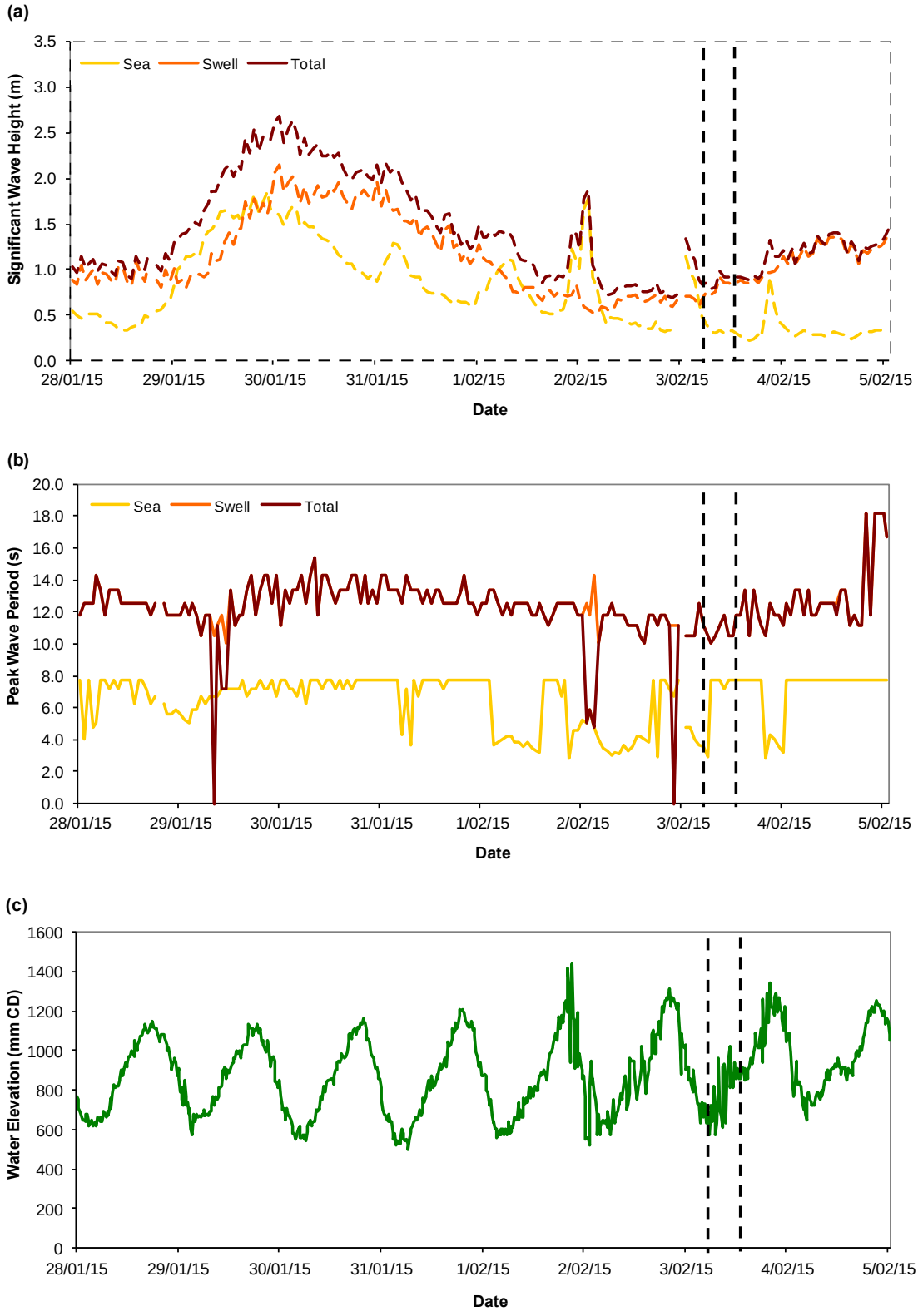
Figure 3.1 Wind speed and wind direction at Ocean Reef

For 24 hours prior to the survey, the average significant wave height[9] offshore from Rottnest Island was 0.84 m[10], with an average peak wave period[11] of 10.77 s[10] (Figure 3.2a and b). During the survey the average significant wave height was 0.89 m and the average peak wave period increased to 11.00 s. The survey was conducted during a low tide (Figure 3.2c).

[9] *The significant wave height (in metres) is defined as the average height of the highest one-third of waves recorded (source: http//www.dpi.wa.gov.au/).*

[10] *Values presented are for the 'total' wave conditions, that is, the combined sea and swell conditions.*

[11] *The wave period (in seconds) is the time between consecutive wave crests. The peak wave period is the wave period of those waves that are producing the most energy in a wave record.*



Note:
1. a = significant wave height
2. b = peak wave period
3. c = water level elevation
4. Dashed lines (- -) show approximate timing of the summer water quality survey.

Figure 3.2 Significant wave heights (offshore Rottnest Island), peak wave periods (offshore Rottnest Island) and water level elevation (Fremantle Fishing Boat Harbour)

3.2 Discharge from outlets

The characteristics of the treated wastewater from Beenyup WWTP measured from a 24-hour composite sample collected prior to and during the survey at Ocean Reef on 3 February 2015 are presented in Table 3.1. At the time of the survey, 50 ports were operational on Outlet A and 48 ports were operational on Outlet B.

Table 3.1 Characteristics of Beenyup WWTP treated wastewater on 3 February 2015

Parameter	Concentration
Total phosphorus	6.6 mg/L
Total nitrogen	11 mg/L
Total ammonia nitrogen	2.4 mg/L
Nitrate+nitrite	8 mg/L
Thermotolerant coliforms	460 000 CFU/100 mL
Enterococci spp.	16 000 MPN/100 mL
Total suspended solids	11 mg/L
Biological oxygen demand	6 mg/L
Total flow (outlet A)	129.00 ML/d
Total flow (outlet B)	129.00 ML/d

3.3 Surface drogue movement

The surface drogue, released above the centre of the Outlet B diffuser at the beginning of the survey, initially drifted in an easterly direction before veering north-east, with an average velocity of 0.07 m/s (Figure 3.3). At the time of the survey it was expected that the discharged treated wastewater would advect north-east and inshore of the diffuser.

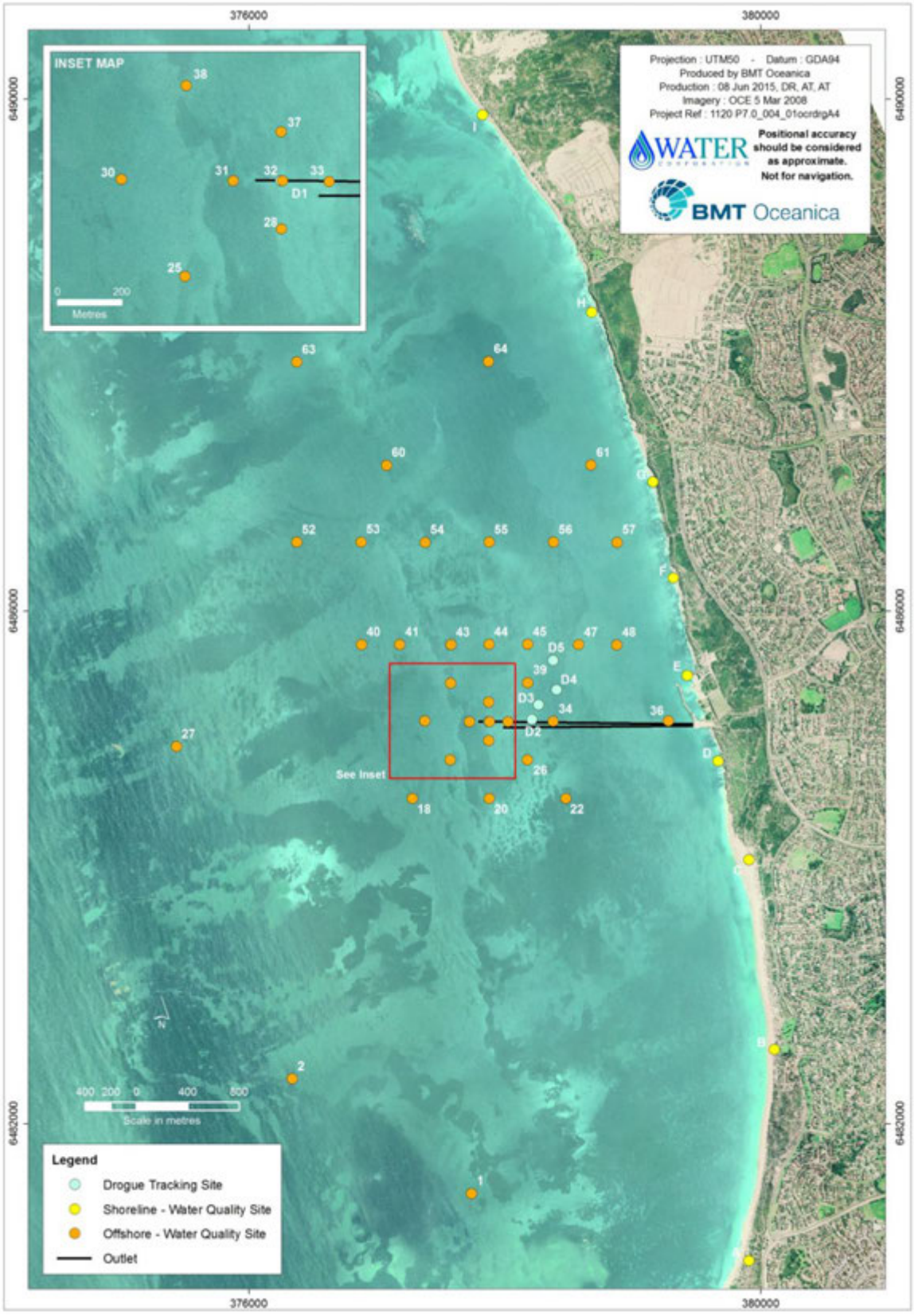
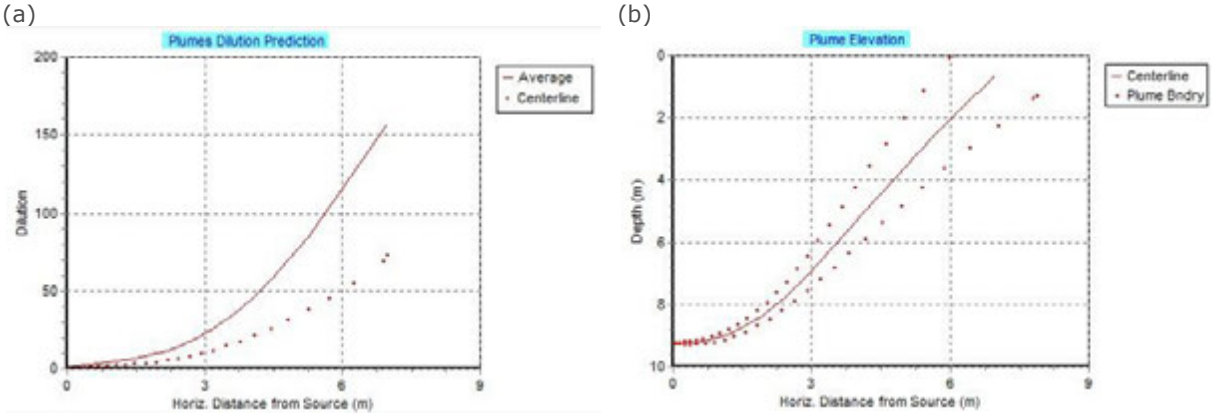


Figure 3.3 Ocean Reef ocean outlets summer water quality survey and drogue tracking sites

3.4 Initial dilution modelling

For ambient conditions at the time of the summer water quality survey on 3 February 2015, the modelling predicted average initial dilutions of 1:157 for Outlet A and 1:136 for Outlet B with centreline dilutions of 1:73 for Outlet A and 1:62 for Outlet B (Figure 3.4a and Figure 3.5a). The plume was predicted to first reach the surface within ~5–8 m (horizontal distance) from the discharge point (see the ambient boundary[12] of the plume in Figure 3.4b and Figure 3.5b). The full model output is included in Appendix C.

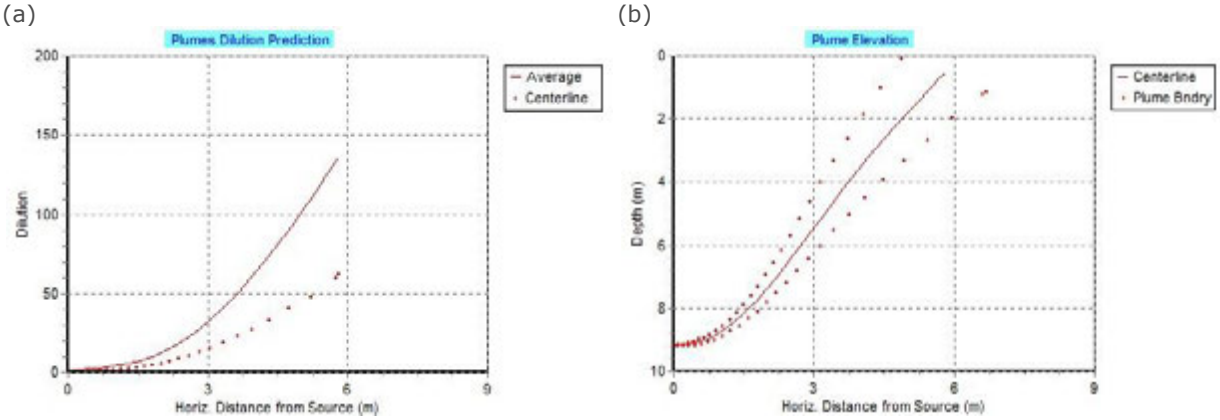
(a) (b)



Notes:
1. a = predicted average and centreline dilution
2. b = predicted plume elevation

Figure 3.4 Predicted average and centreline dilutions and predicted plume elevation trajectory for Outlet A at Ocean Reef

(a) (b)



Notes:
1. a = predicted average and centreline dilution
2. b = predicted plume elevation

Figure 3.5 Predicted average and centreline dilutions and predicted plume elevation trajectory for Outlet B at Ocean Reef

3.5 Water quality

The grid for northerly flow conditions at Ocean Reef was sampled during the survey on 3 February 2015 (Section 3.3). Water samples were collected from the surface and bottom waters of the 35 offshore sites and from nine shoreline sites (Figure 3.3). The concentrations of all water quality parameters measured during the summer water quality survey are included in Appendix D.

[12] *The ambient boundary corresponds to the plume boundary at which concentrations are estimated to be equal to ambient conditions.*

3.5.1 Water column structure

Water column profiles were collected at eight sites (sites 28, 31, 32, 33, 37, 44, 55, 64). Across all sites, water temperature varied between 22.41 and 22.97°C, salinity was 35.72–35.99[13] and dissolved oxygen was 6.59–7.38 mg/L (equivalent to 93.72–105.13% saturation) (Figure 3.6 and Figure 3.7). There was evidence of a thermocline at sites 44, 55 and 64, with temperatures declining by up to 0.5 °C over the first 2–6 m depth. Salinity showed little variation with increasing depth (difference of 0.27 between minimum and maximum values). Salinity was slightly reduced in surface waters at sites 28, 31, 32, 33, 37 and 44; the reduced salinity may indicate the presence of the treated wastewater plume. Dissolved oxygen also showed little variation with increasing depth (difference of 0.79 mg/L between minimum and maximum values). The dissolved oxygen profiles varied among sites and were not indicative of the presence of the treated wastewater plume.

[13] *Salinity throughout this report is referred to without units according to the Practical Salinity Scale. On this scale salinity is defined as the ratio of conductivities and therefore cannot have units. Seawater typically has a salinity in the range of 34–36.*

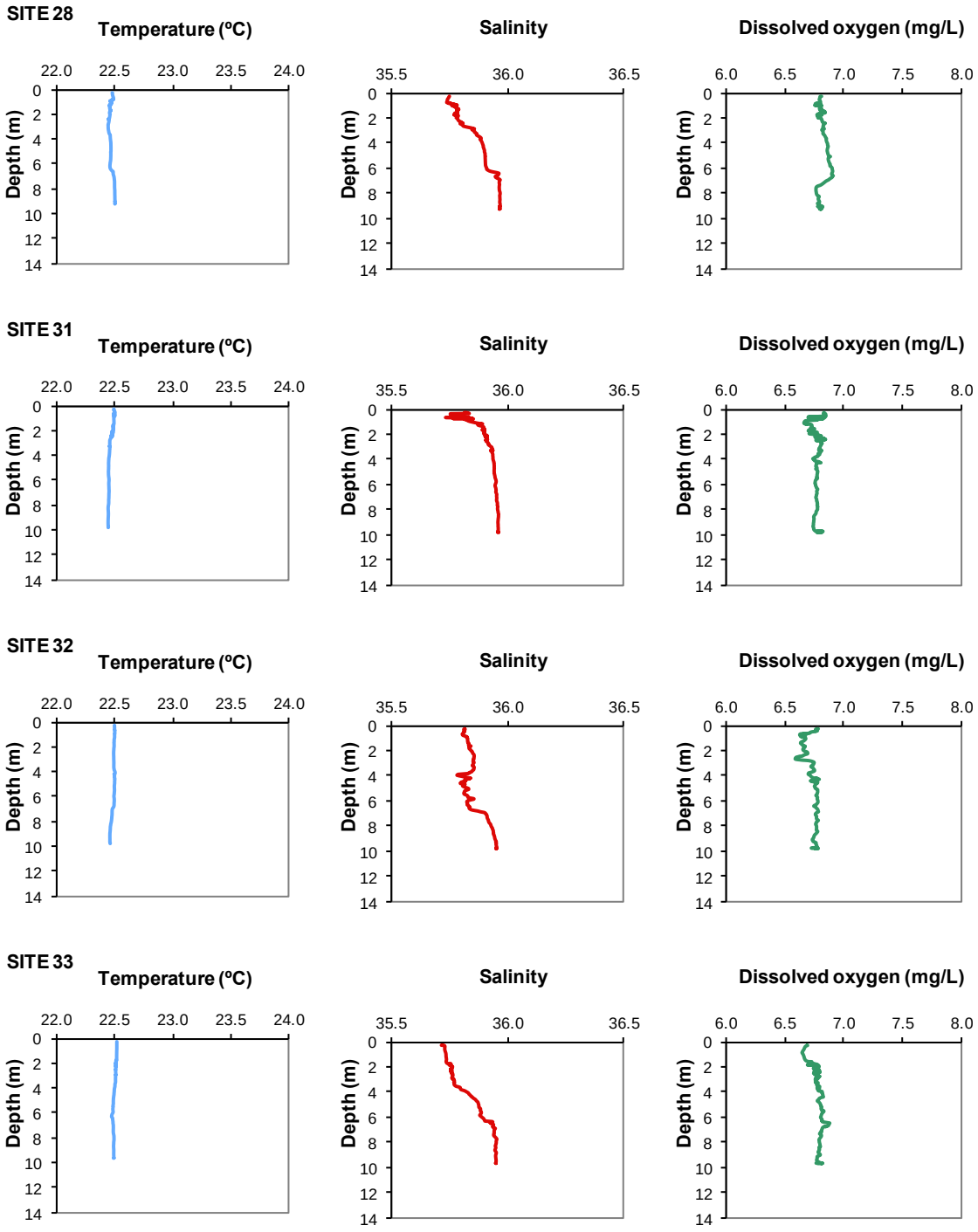


Figure 3.6 Temperature, salinity and dissolved oxygen vertical profiles at Ocean Reef

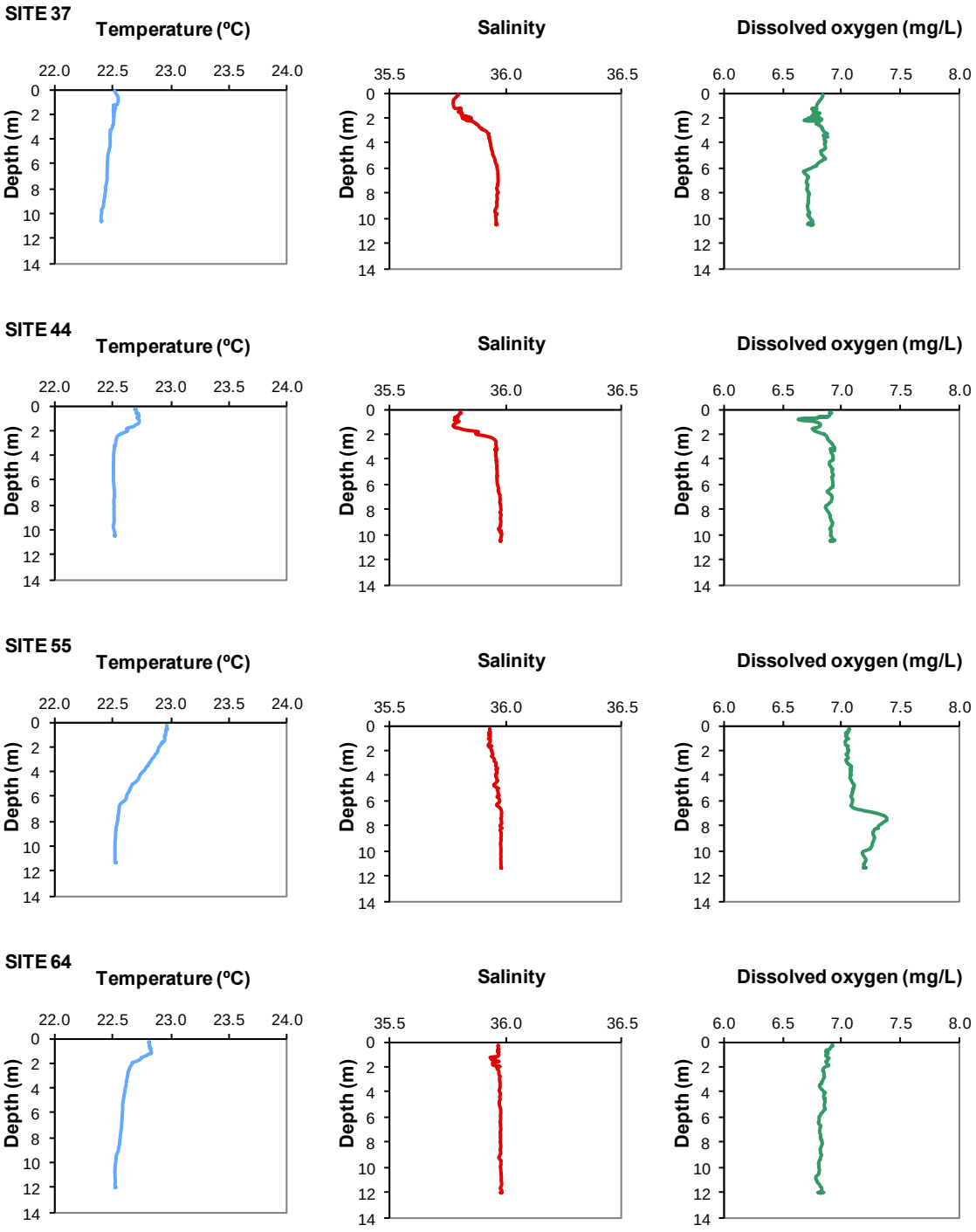
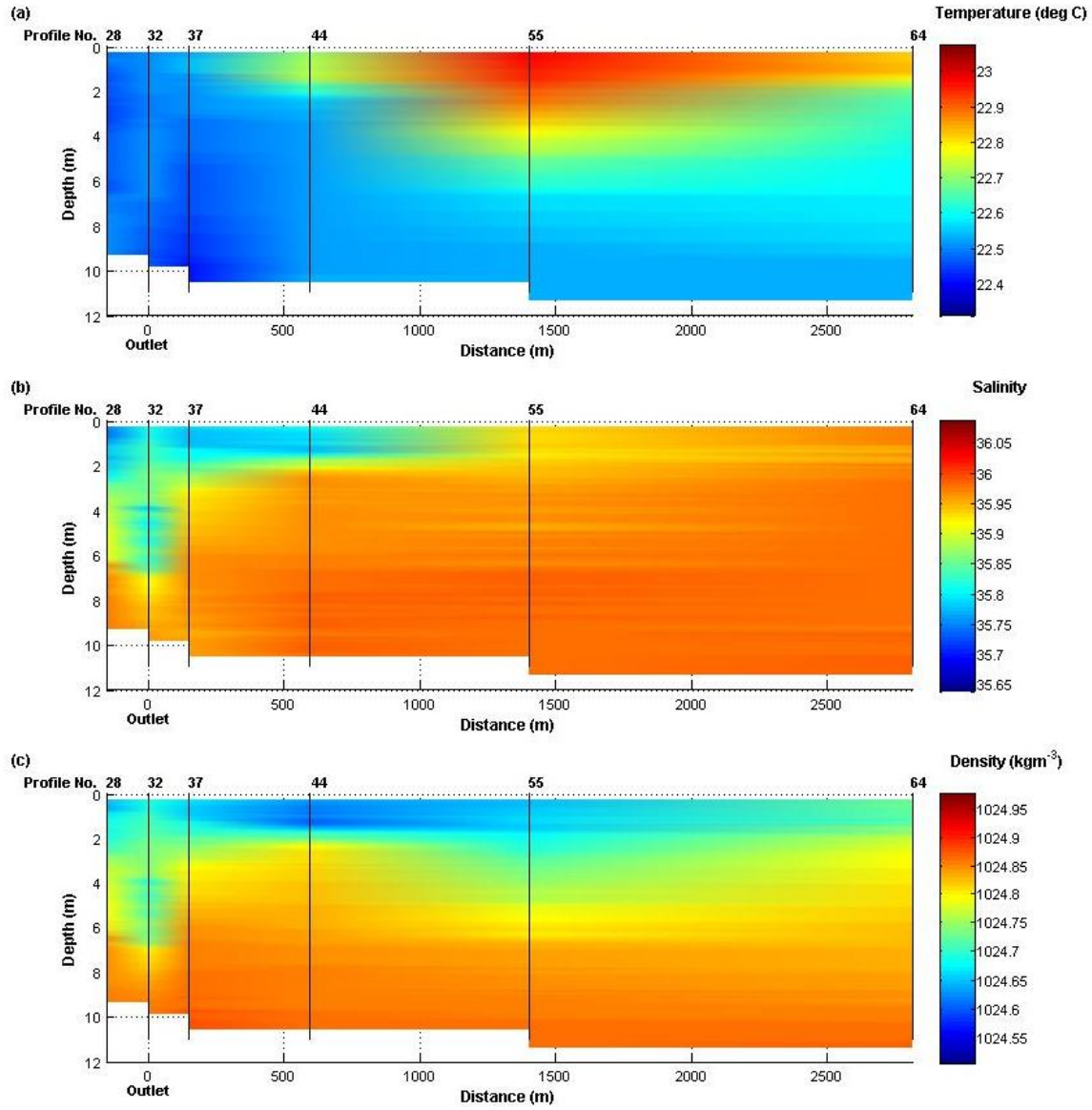


Figure 3.7 Temperature, salinity and dissolved oxygen vertical profiles at Ocean Reef

The effect of the discharged wastewater on the physical structure of the water column is illustrated in Figure 3.8. The colour scales used in Figure 3.8 range from the minimum to the maximum of each parameter, thus exaggerating small differences in measurements. A mass of slightly warmer water was recorded in surface waters from sites 44–64, extending up to 4 m depth (Figure 3.8a). Surface and bottom waters surrounding the diffuser (sites 28, 32, 37) showed little variation in temperature with depth. A body of lower salinity water was recorded directly above the outlet, extending north for ~1.5 km before equalising to background salinities (Figure 3.8b). Similarly, water density was lower in the waters directly above and to the north of the outlet (Figure 3.8c). The temperature, salinity and density profiles were taken in a north–south direction and therefore may not have captured the full extent of the discharged wastewater plume.



Notes:
1. a = temperature
2. b = salinity
3. c = density

Figure 3.8 Temperature, salinity and density transect at Ocean Reef

3.5.2 Replicate samples

Variance in measurements of water quality parameters may be introduced by small-scale spatial variability in the water column or by variability among laboratory analyses. To examine the range of this variance, three surface samples were collected at site 1 (Table 3.2). The results indicated that in general, the variability amongst replicates was small. The mean value of these replicate samples was used as representative of the water quality parameters at site 1.

Table 3.2 Replicate surface samples from site 1, Ocean Reef, 3 February 2015

Parameter	**Total ammonia nitrogen**	**Ortho-phosphate**	**Nitrate+nitrite**	**Total phosphorus**	**Total nitrogen**
Units	µg/L	µg/L	µg/L	µg/L	µg/L
Reporting limit	<3	<2	<2	<5	<50
Surface rep 1	<3	14	12	25	120
Surface rep 2	<3	13	13	24	120
Surface rep 3	<3	13	12	24	120
Mean	*<3*	*13.3*	*12.3*	*24.3*	*120*
Parameter	**Chlorophyll-a** *(Fluorometry)*	**Chlorophyll-a** *(Acetone)*	**Phaeophytin**	**Thermotolerant coliforms**	***Enterococci* spp.**
Units	µg/L	µg/L	µg/L	CFU/100mL	MPN/100mL
Reporting limit	<0.1	<0.1	<0.2	<10	<10
Surface rep 1	0.5	0.6	0.3	<10	<10
Surface rep 2	0.5	0.6	0.3	<10	<10
Surface rep 3	0.4	0.6	0.3	<10	<10
Mean	*0.5*	*0.6*	*0.3*	*<10*	*<10*

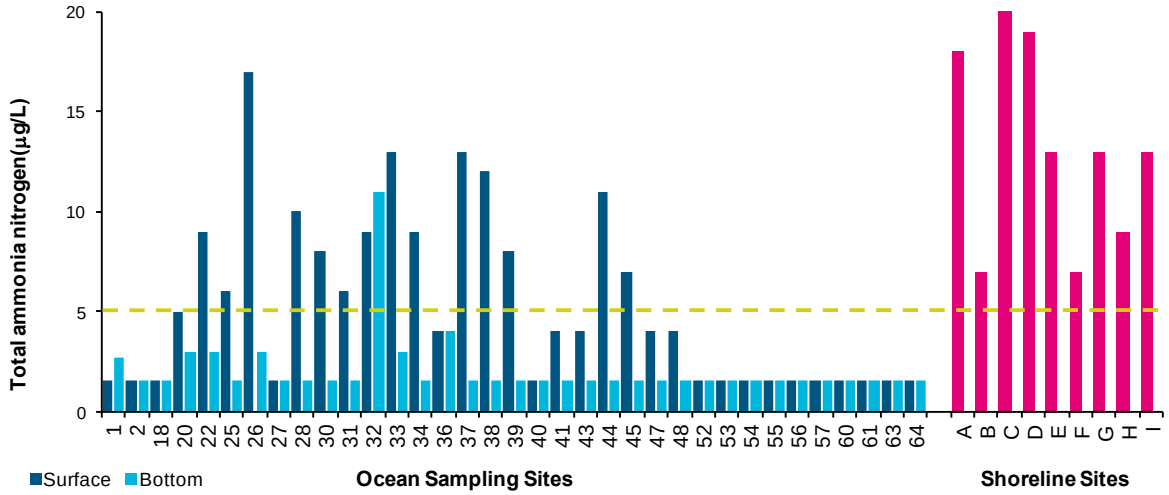
Note:
1. Mean values were calculated by replacing values below the reporting limit as half the reporting limit.

3.5.3 Nutrient concentrations and distributions

Total ammonia nitrogen (NH_4^+)

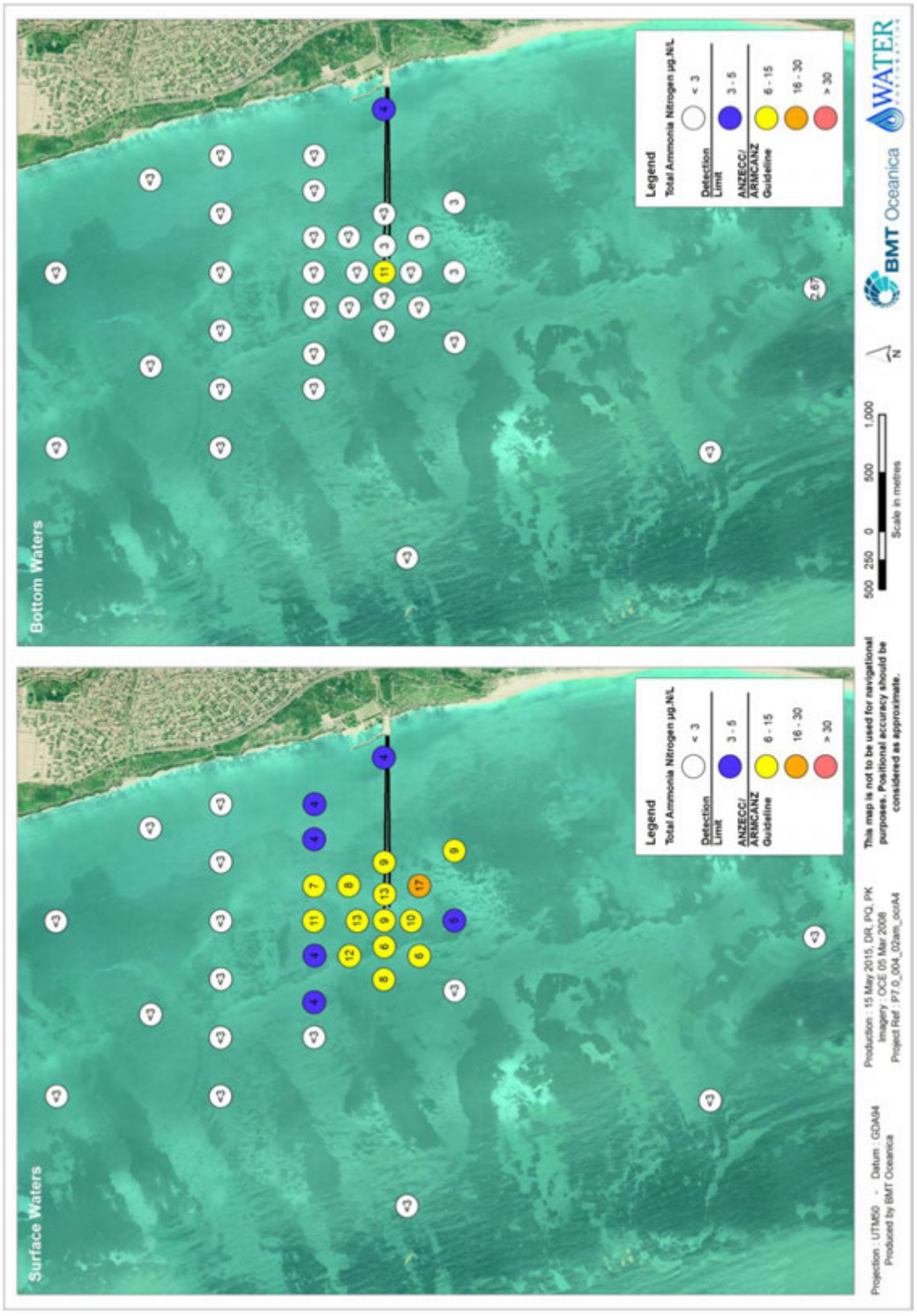
- Offshore surface concentrations of NH_4^+ ranged from <3 to 17 µg/L with 21 (60%) sites below or equal to the ANZECC/ARMCANZ (2000) guideline of 5 µg/L. Bottom concentrations of NH_4^+ ranged from <3 to 11 µg/L with 34 (97%) sites below or equal to the ANZECC/ARMCANZ (2000) guideline.
- NH_4^+ concentrations in surface waters of 20 (57%) sites were below or equal to the 80th percentile reference value of 4 µg/L. Concentrations in bottom waters at 33 (94%) sites were below or equal to the 80th percentile reference value.
- Sites within 250 m from the diffuser had NH_4^+ concentrations ranging between 6 and 13 µg/L (median of 10 µg/L) in surface waters and between <3 and 11 µg/L (median of <3 µg/L) in bottom waters. All surface samples within 250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline of 5 µg/L and the 80th percentile of reference values (4.3 µg/L). Two bottom sites within 250 m of the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline, and one of these (site 32, directly over the diffuser) exceeded the 80th percentile of reference values (3.3 µg/L).
- Sites outside 250 m from the diffuser had NH_4^+ concentrations ranging between <3 and 17 µg/L (median of 2.75 µg/L) in surface waters and between <3 and 4 µg/L (median of <3 µg/L) in bottom waters. Nine out of 30 (30%) surface sites >250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline of 5 µg/L compared to none of the bottom sites. Ten surface and one bottom sites exceeded the 80th percentile of reference values (4.3 µg/L and 3.3 µg/L for surface and bottom waters, respectively).

- NH_4^+ concentrations at shoreline sites ranged from 7 to 23 µg/L. All shoreline sites had concentrations above the ANZECC/ARMCANZ (2000) guideline of 5 µg/L.
- For surface waters, the highest concentrations of NH_4^+ occurred at sites immediately adjacent to and up to ~600 m surrounding the diffuser (Figure 3.10). Surface sites outside ~600 m were below the ANZECC/ARMCANZ (2000) guideline. In bottom waters, NH_4^+ concentrations were consistently below the ANZECC/ARMCANZ (2000) guideline, with the exception of site 32 immediately above the diffuser.



Note:
1. Dashed line indicates ANZECC/ARMCANZ (2000) guideline value.

Figure 3.9 Total ammonia nitrogen concentrations at Ocean Reef

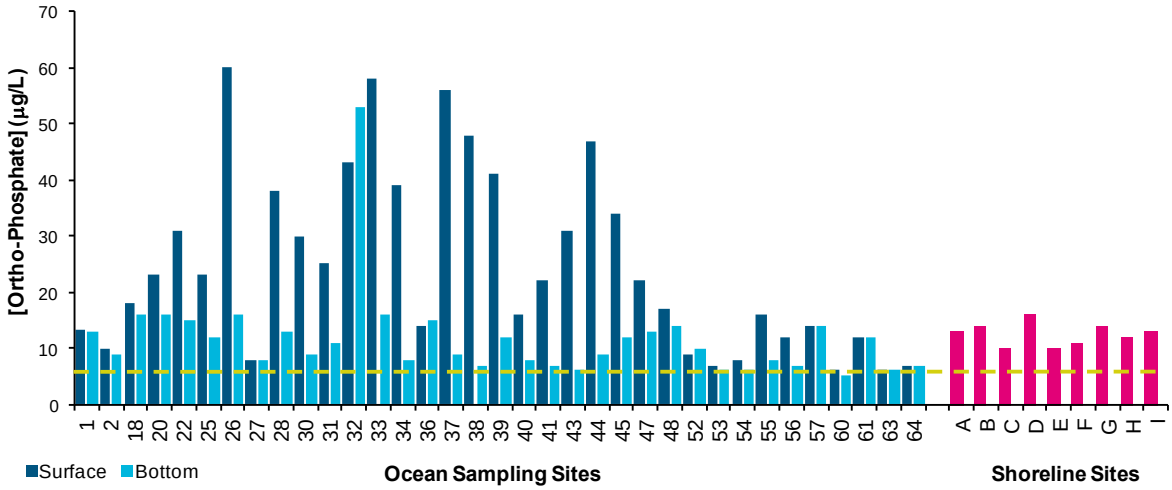


Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 3.3.
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline.

Figure 3.10 Spatial distribution of total ammonia at Ocean Reef

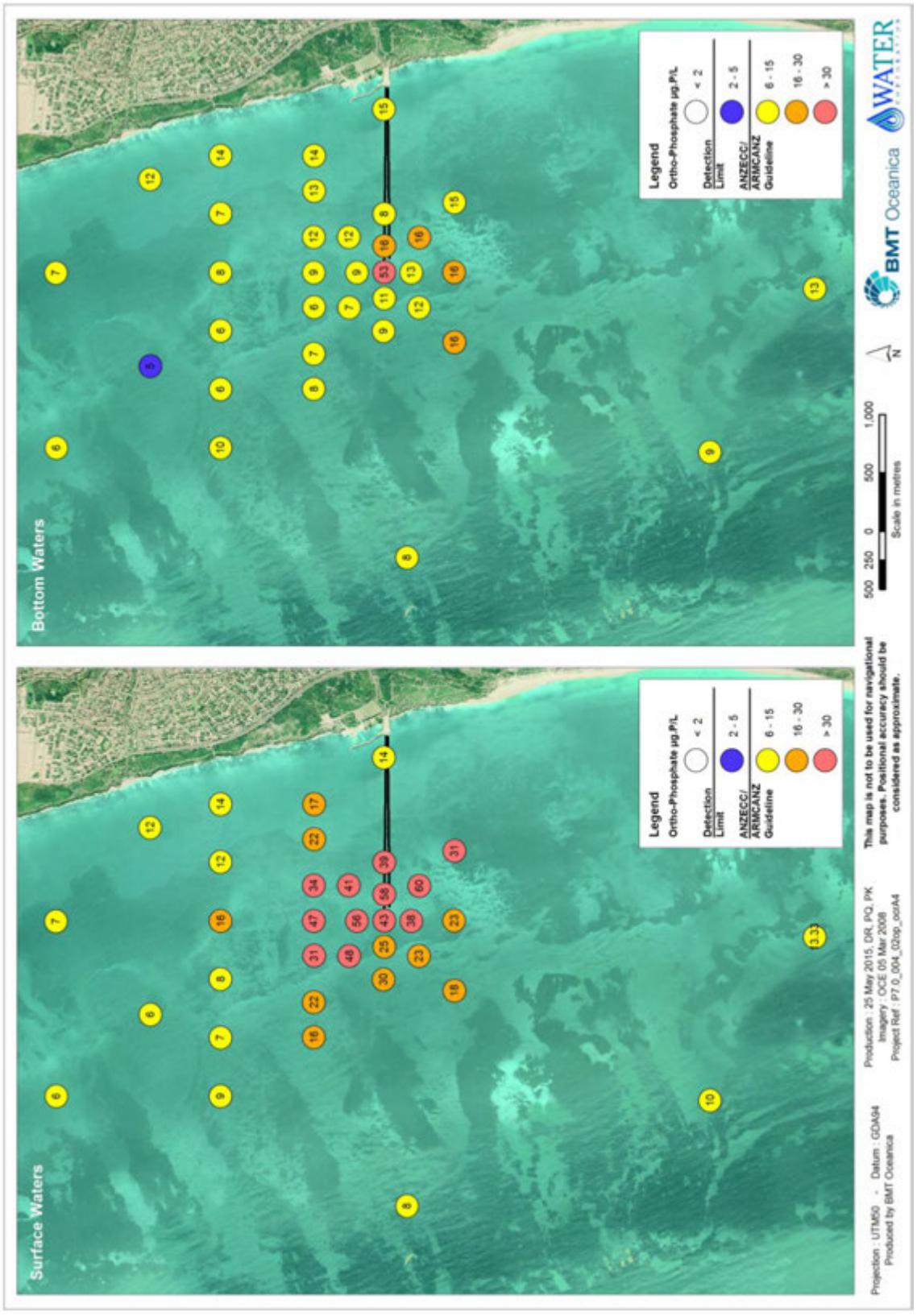
Ortho-phosphate

- Offshore surface concentrations of ortho-phosphate ranged from 6 to 60 µg/L; concentrations at all sites exceeded the ANZECC/ARMCANZ (2000) guideline of 5 µg/L. Bottom concentrations of ortho-phosphate ranged from 5 to 53 µg/L with all sites except site 60 (97%) exceeding the ANZECC/ARMCANZ (2000) guideline.
- Surface concentrations of ortho-phosphate at 6 (17%) sites were below or equal to the 80th percentile reference value of 8 µg/L. Bottom concentrations of ortho-phosphate at 13 (37%) sites were below or equal to the 80th percentile reference value.
- Sites within 250 m from the diffuser had ortho-phosphate concentrations ranging between 25 and 58 µg/L (median of 43 µg/L) in surface waters and between 9 and 53 µg/L (median of 13 µg/L) in bottom waters. All sites within 250 m from the diffuser (surface and bottom) exceeded the ANZECC/ARMCANZ (2000) guideline (5 µg/L) and the 80th percentile of reference values (8 µg/L for both surface and bottom waters).
- Sites outside 250 m from the diffuser had ortho-phosphate concentrations ranging between 6 and 60 µg/L (median of 16.5 µg/L) in surface waters and between 5 and 16 µg/L (median of 13.2 µg/L) in bottom waters. All surface and all but one bottom site exceeded the ANZECC/ARMCANZ (2000) guideline (5 µg/L). Twenty-eight of 30 (93%) surface sites and 17 of 30 (57%) bottom sites exceeded the 80th percentile of reference values (8 µg/L for both surface and bottom waters).
- Ortho-phosphate concentrations at shoreline sites ranged from 10 µg/L (sites C and E) to 16 µg/L (site D) (Figure 3.11). Concentrations at all shoreline sites exceeded the ANZECC/ARMCANZ (2000) guideline of 5 µg/L.
- For surface waters, the highest ortho-phosphate concentrations occurred at sites immediately adjacent to and up to ~1 km surrounding the diffuser. In bottom waters, ortho-phosphate concentrations were highest adjacent to and south of the diffuser (Figure 3.12).



Note:
1. Dashed line indicates ANZECC/ARMCANZ (2000) guideline value.

Figure 3.11 Ortho-phosphate concentrations at Ocean Reef

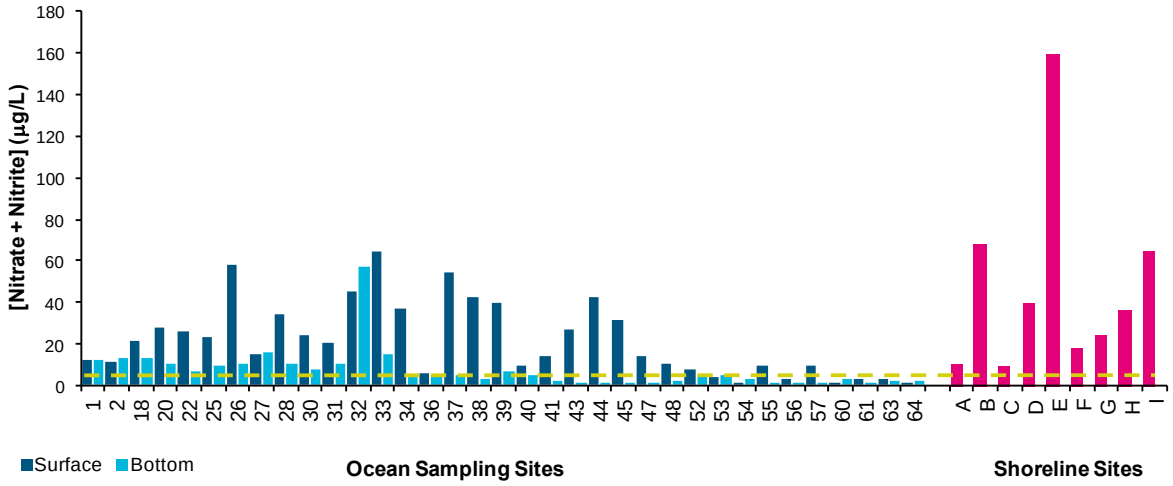


Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 3.3.
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline.

Figure 3.12 Spatial distribution of ortho-phosphate at Ocean Reef

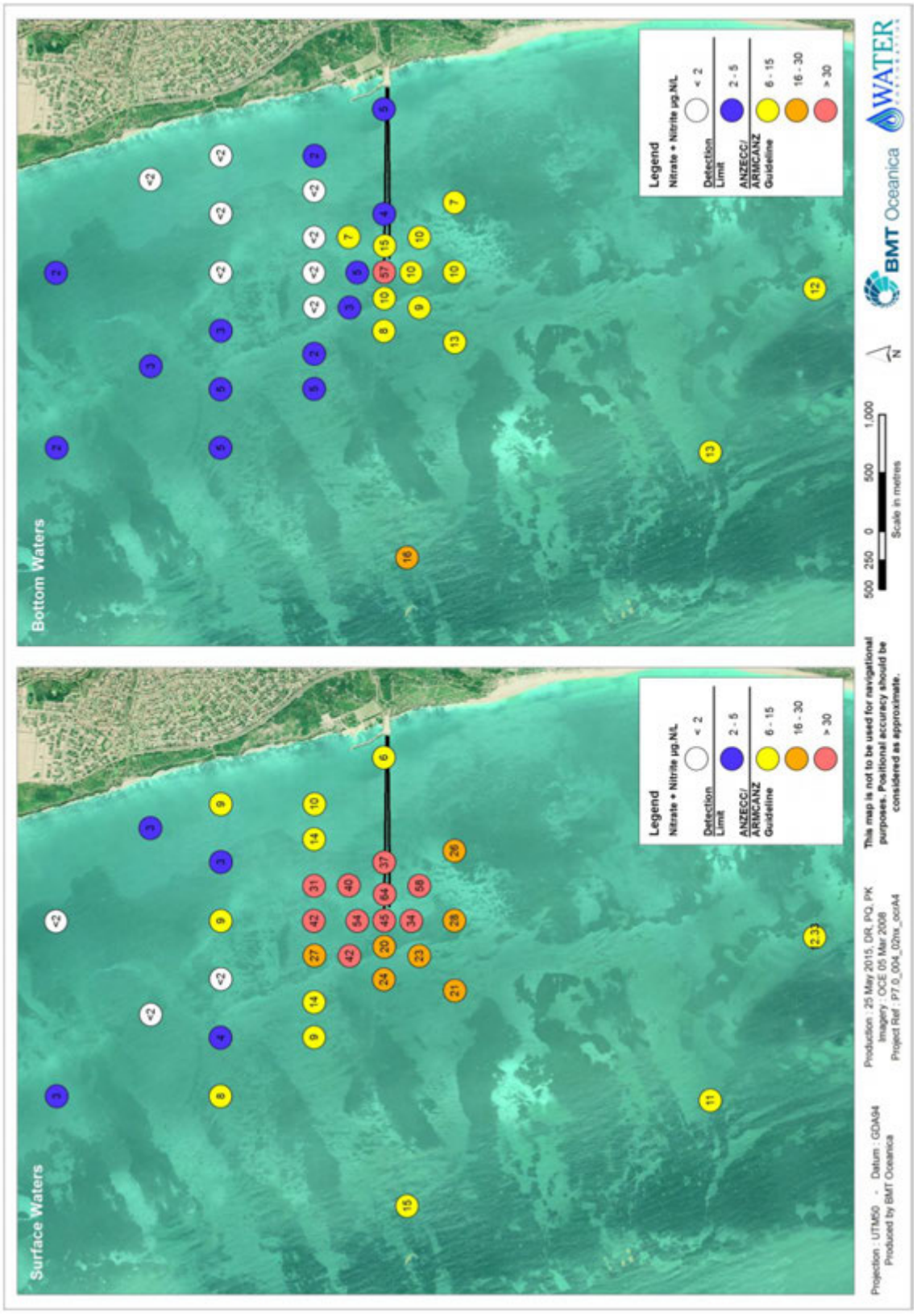
Nitrate+nitrite ($NO_2^-+NO_3^-$)

- Offshore surface concentrations of $NO_2^-+NO_3^-$ ranged from <2 to 64 µg/L with 7 (20%) sites below or equal to the ANZECC/ARMCANZ (2000) guideline of 5 µg/L. Bottom concentrations of ortho-phosphate ranged from <2 to 57 µg/L with 21 (60%) sites below or equal to the ANZECC/ARMCANZ (2000) guideline.
- Surface concentrations of $NO_2^-+NO_3^-$ at 14 (40%) sites were below or equal to the 80th percentile reference value of 12 µg/L. Bottom concentrations of $NO_2^-+NO_3^-$ at 21 (60%) sites were below or equal to the 80th percentile reference value.
- Sites within 250 m from the diffuser had $NO_2^-+NO_3^-$ concentrations ranging between 20 and 64 µg/L (median of 45 µg/L) in surface waters and between 5 and 57 µg/L (median of 1045 µg/L) in bottom waters. All surface sites and all but one bottom site within 250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline (5 µg/L). All surface sites and two bottom sites exceeded the 80th percentile reference value (12 µg/L).
- Sites outside 250 m from the diffuser had $NO_2^-+NO_3^-$ concentrations ranging between <2 and 58 µg/L (median of 13.2 µg/L) in surface waters and between <2 and 16 µg/L (median of 3.5 µg/L) in bottom waters. Twenty-three of 30 (77%) surface sites >250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline (5 µg/L) compared to 10 of 30 (33%) bottom sites. Sixteen surface and three bottom sites exceeded the 80th percentile of reference values (12 µg/L).
- Nitrate+nitrite concentrations at shoreline sites ranged from 9 µg/L (site C) to 160 µg/L (site E) (Figure 3.11). Shoreline $NO_2^-+NO_3^-$ concentrations at all sites exceeded the ANZECC/ARMCANZ (2000) guideline of 5 µg/L.
- For surface waters, the highest $NO_2^-+NO_3^-$ concentrations occurred at sites immediately adjacent and up to ~1 km surrounding the diffuser (Figure 3.12). In bottom waters, the highest $NO_2^-+NO_3^-$ concentrations were immediately adjacent and up to ~600 m south of the diffuser.



Note:
1. Dashed line indicates ANZECC/ARMCANZ (2000) guideline value

Figure 3.13 Nitrate+nitrite concentrations at Ocean Reef

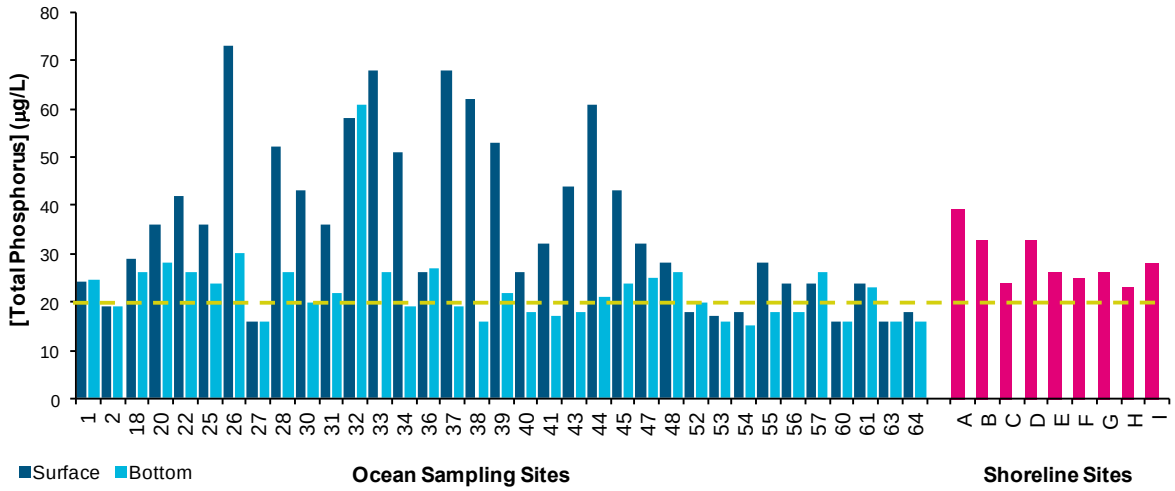


Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 3.3.
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline.

Figure 3.14 Spatial distribution of nitrate+nitrite at Ocean Reef

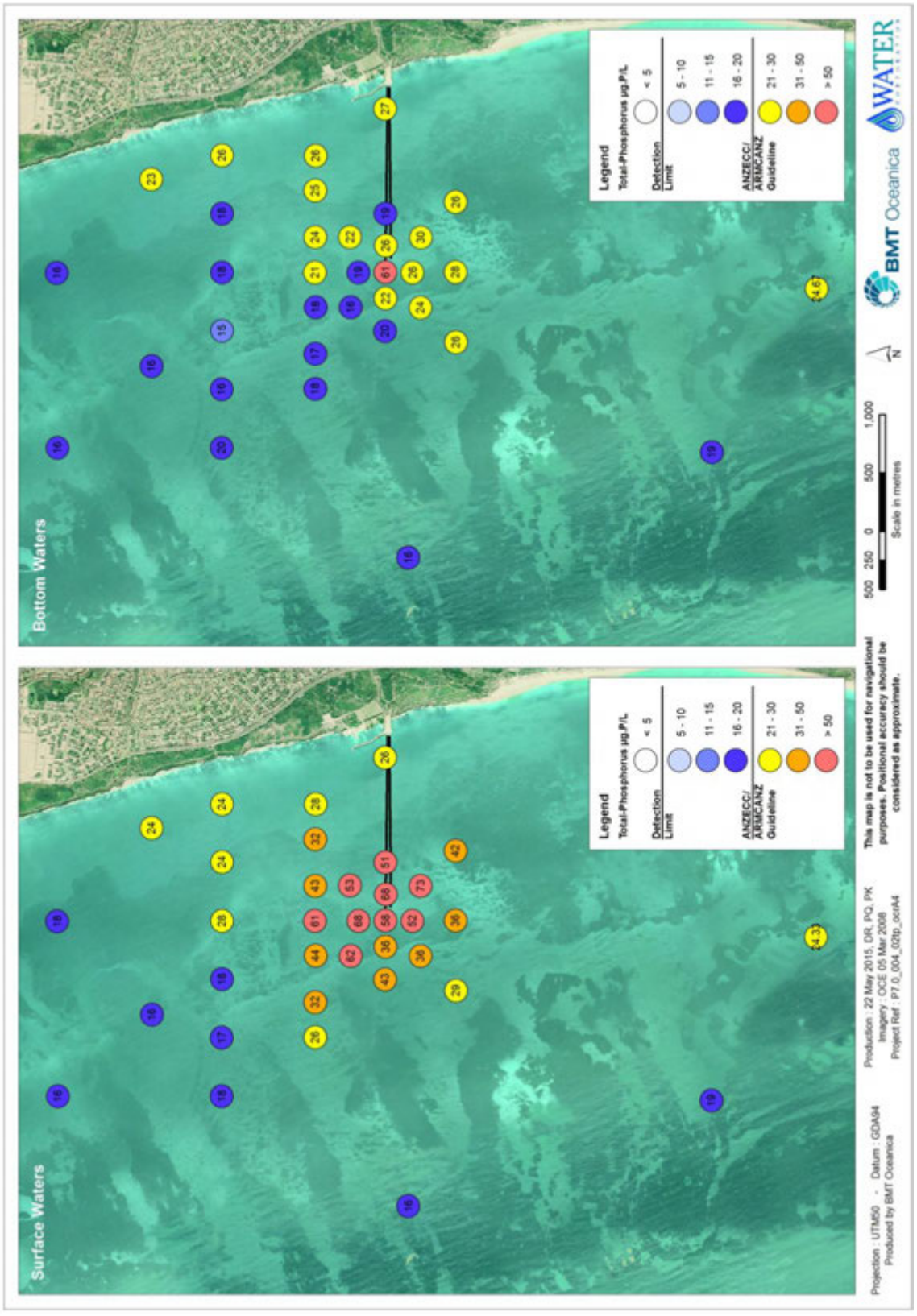
Total phosphorus (TP)

- Offshore surface concentrations of TP ranged from 16 to 73 µg/L with 8 (23%) sites below or equal to the ANZECC/ARMCANZ (2000) guideline of 20 µg/L. Bottom concentrations of TP ranged from 15 to 61 µg/L with 17 (49%) sites below or equal to the ANZECC/ARMCANZ (2000) guideline.
- Surface concentrations of TP at 19 (54%) sites were below or equal to the 80th percentile reference value of 35 µg/L. Bottom concentrations of TP at 34 (97%) sites were below or equal to the 80th percentile reference value.
- Sites within 250 m from the diffuser had TP concentrations ranging between 36 and 68 µg/L (median of 58 µg/L) in surface waters and between 19 and 61 µg/L (median of 26 µg/L) in bottom waters. All surface sites and all but one bottom site <250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline (20 µg/L). All surface sites exceeded the 80th percentile of reference values (35 µg/L), whereas the only bottom site to exceed the 80th percentile of reference values (33 µg/L) was site 32, directly above the diffuser.
- Sites outside 250 m from the diffuser had TP concentrations ranging between 16 and 73 µg/L (median of 28 µg/L) in surface waters and between 15 and 30 µg/L (median of 20 µg/L) in bottom waters. Twenty-two of 30 (73%) surface sites outside 250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline (20 µg/L) compared to 14 of 30 (47%) bottom sites. Eleven surface sites exceeded the 80th percentile of reference values (35 µg/L). There were no exceedances of the 80th percentile of reference values (33 µg/L) at bottom sites.
- TP concentrations at shoreline sites ranged from 23 µg/L (site H) to 39 µg/L (site A) (Figure 3.11). All shoreline sites exceeded the ANZECC/ARMCANZ (2000) guideline of 20 µg/L.
- TP concentrations in surface and bottom water were elevated north, east and south of the diffuser. Lower TP concentrations (within ANZECC/ARMCANZ (2000) guideline value of 20 µg/L) were recorded at sites west of the diffuser (Figure 3.12).



Note:
1. Dashed line indicates ANZECC/ARMCANZ (2000) guideline value.

Figure 3.15 Total phosphorus concentrations at Ocean Reef

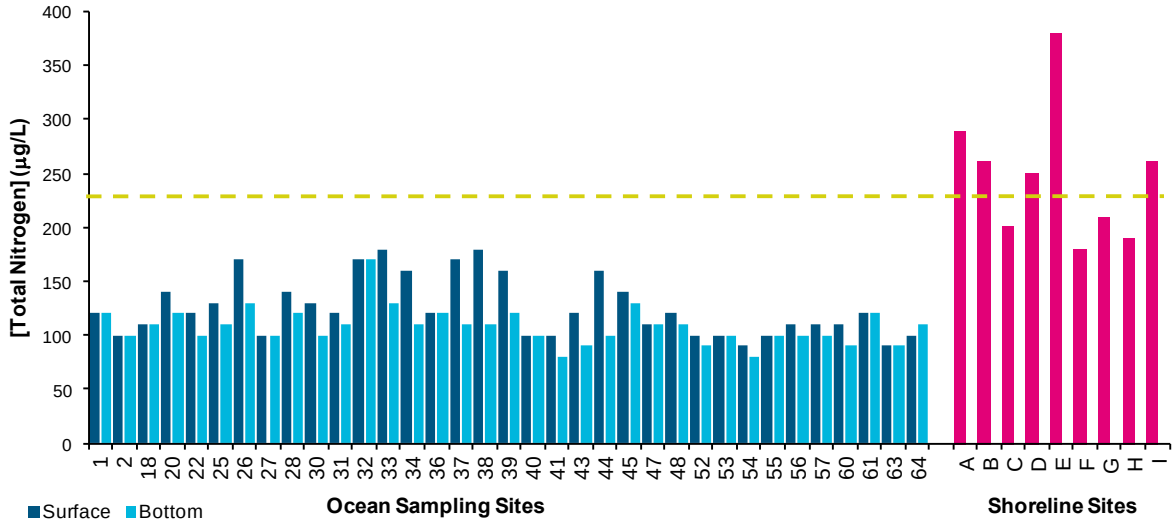


Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 3.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline.

Figure 3.16 Spatial distribution of total phosphorus at Ocean Reef

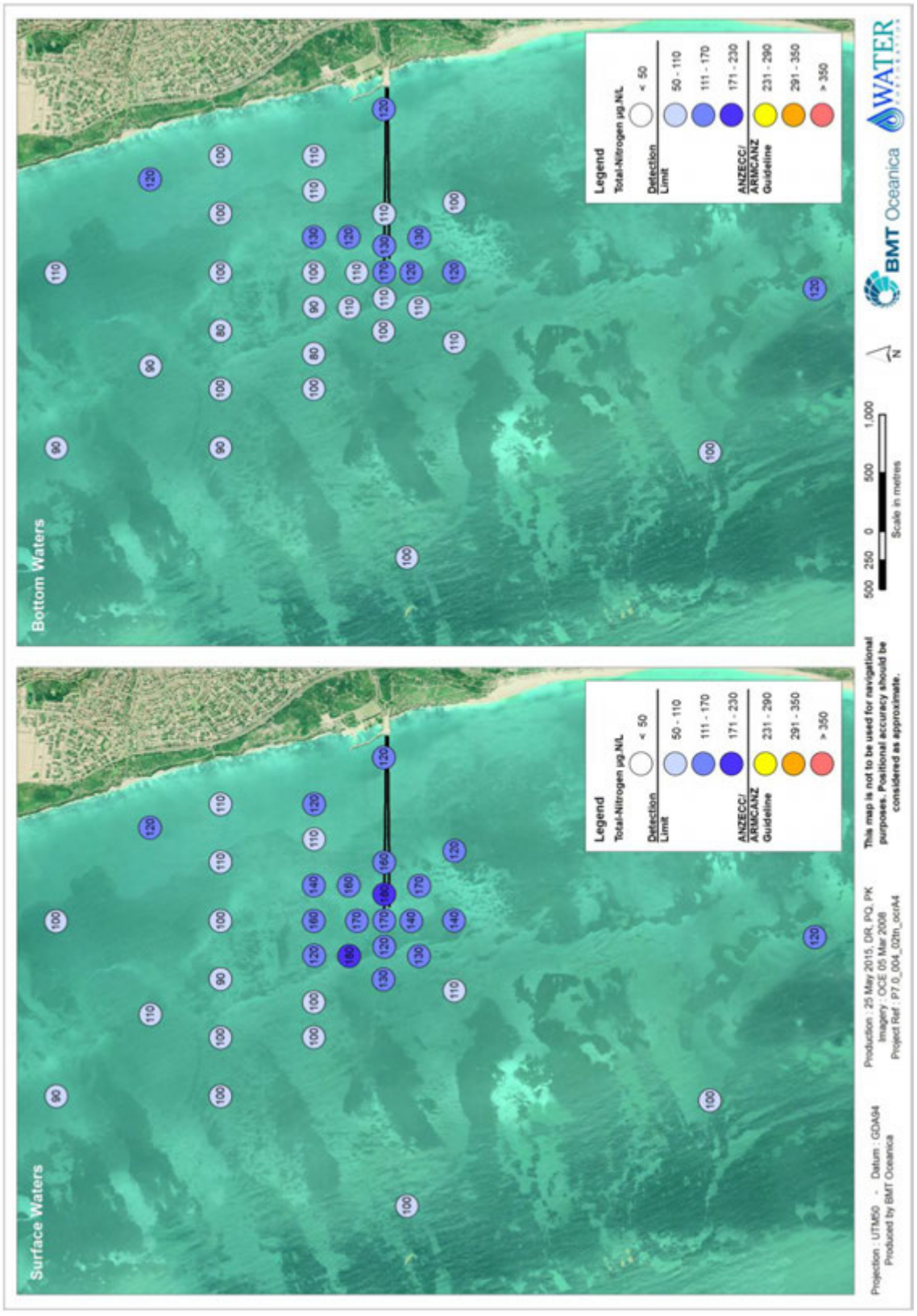
Total nitrogen (TN)

- Offshore surface concentrations of TN ranged from 90 to 180 µg/L and bottom concentrations of TN ranged from 80 to 170 µg/L. Surface and bottom concentrations at all sites were below the ANZECC/ARMCANZ (2000) guideline of 230 µg/L.
- Surface concentrations of TN at 27 (77%) sites were below or equal to the 80th percentile reference value of 140 µg/L. Bottom concentrations of TN at 34 (97%) sites were below or equal to the 80th percentile reference value of 130 µg/L.
- Sites within 250 m from the diffuser had TN concentrations ranging between 120 and 180 µg/L (median of 170 µg/L) in surface waters and between 110 and 170 µg/L (median of 120 µg/L) in bottom waters. All sites <250 m from the diffuser (surface and bottom) were below the ANZECC/ARMCANZ (2000) guideline of 230 µg/L. Three surface sites exceeded the 80th percentile of reference values (140 µg/L), whereas the only bottom site to exceeded the 80th percentile of reference values (130 µg/L) was site 32, located over the diffuser.
- Sites outside 250 m from the diffuser had TN concentrations ranging between 90 and 180 µg/L (median of 115 µg/L) in surface waters and between 80 and 130 µg/L (median of 100 µg/L) in bottom waters. . All sites >250 m from the diffuser (surface and bottom) were below the ANZECC/ARMCANZ (2000) guideline of 230 µg/L. Seven of 30 (23%) surface sites >250 m from the diffuser exceeded the 80th percentile of reference values (140 µg/L) whereas no bottom sites exceeded the 80th percentile of reference values (130 µg/L).
- TN concentrations at shoreline sites ranged from 180 µg/L (site G) to 380 µg/L (site E) (Figure 3.11). TN concentrations at 4 (44%) shoreline sites were below or equal to the ANZECC/ARMCANZ (2000) guideline of 230 µg/L.
- For surface and bottom waters, the highest TN concentrations occurred at sites adjacent to the diffuser (Figure 3.12). Concentrations remained within ANZECC/ARMCANZ (2000) guideline values at all sites.



Note:
1. Dashed line indicates ANZECC/ARMCANZ (2000) guideline value.

Figure 3.17 Total nitrogen concentrations at Ocean Reef



Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 3.3.
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline.

Figure 3.18 Spatial distribution of total nitrogen at Ocean Reef

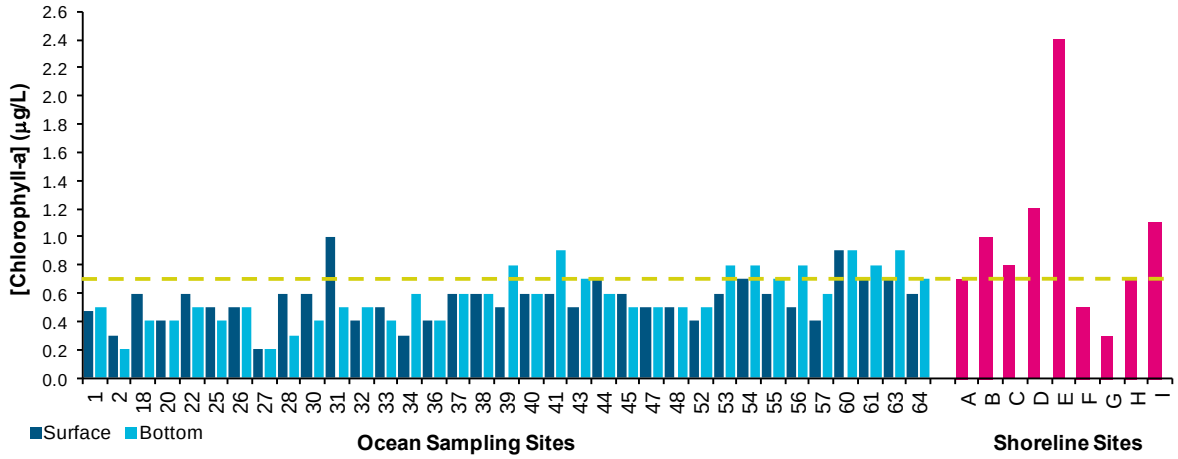
3.5.4 Phytoplankton biomass and distribution

Phaeophytin

- Phaeophytin concentrations (Appendix D) were measured in surface waters at six offshore sites (sites 1, 27, 36, 44, 60 and 64). Phaeophytin concentrations ranged from <0.2 to 0.3 µg/L.
- Phaeophytin concentrations were also measured at the nine shoreline sites, where concentrations ranged from 0.4 µg/L (site A) to 2.9 µg/L (site D).

Chlorophyll-a [14]

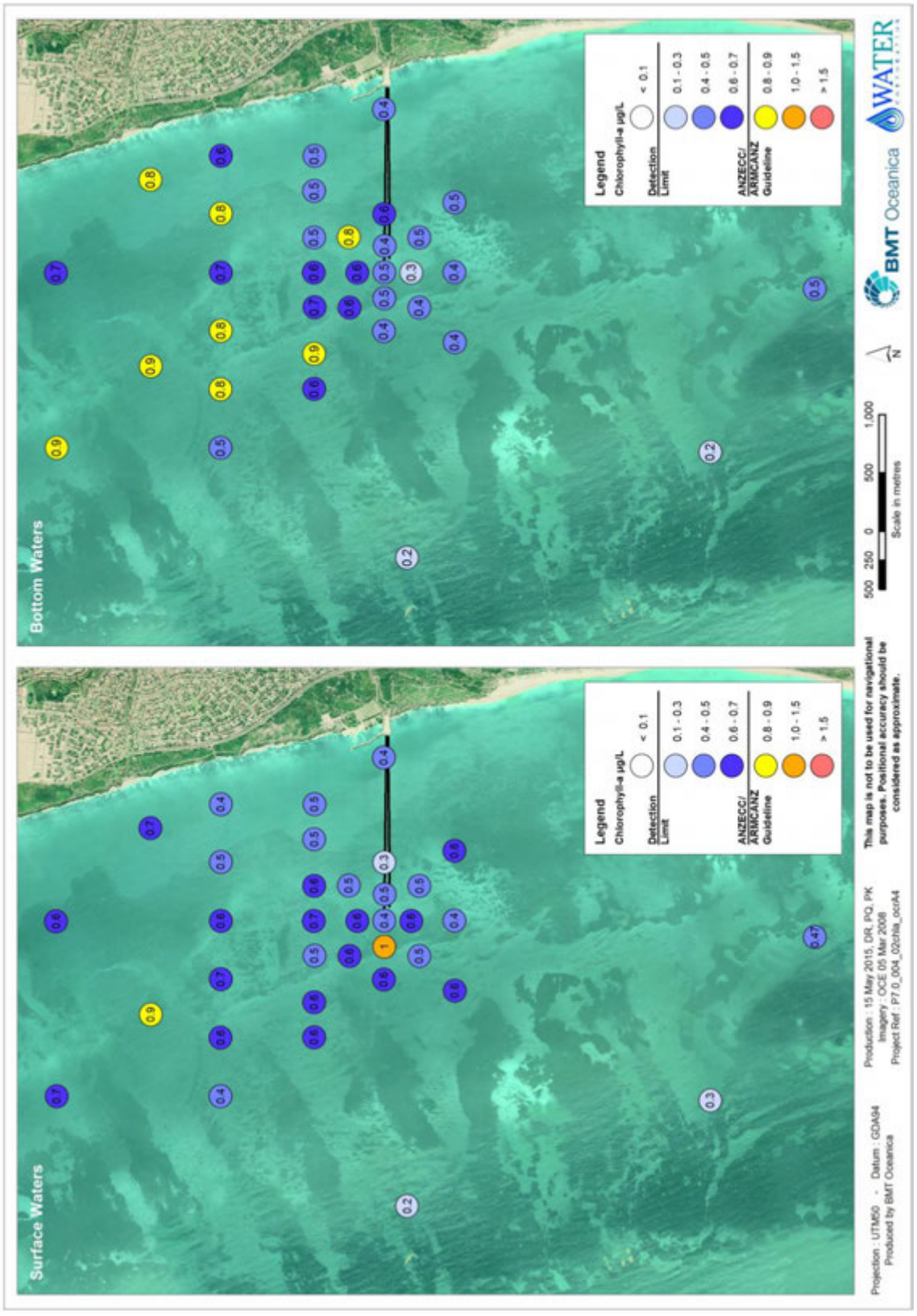
- Offshore surface concentrations of chlorophyll-a ranged from 0.2 to 1.0 µg/L with 33 (94%) sites below or equal to the ANZECC/ARMCANZ (2000) guideline of 0.7 µg/L. Bottom concentrations of chlorophyll-a ranged from 0.2 to 0.9 µg/L with 27 (77%) sites below or equal to the ANZECC/ARMCANZ (2000) guideline.
- Surface concentrations of chlorophyll-a at 17 (49%) sites were below or equal to the 80th percentile reference value of 0.5 µg/L. Bottom concentrations of chlorophyll-a at 18 (51%) sites were below or equal to the 80th percentile reference value.
- The chlorophyll-a concentration at shoreline sites ranged from 0.3 µg/L (site G) to 2.4 µg/L (site E) (Figure 3.19). Concentrations at 17 (49%) shoreline sites were below or equal to the ANZECC/ARMCANZ (2000) guideline value of 0.7 µg/L.
- Chlorophyll-a concentrations at Ocean Reef sites showed no obvious spatial patterns (Figure 3.20). Chlorophyll-a concentrations in surface and bottom waters at some reference sites >1 km from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline value of 0.7 µg/L.



Note:
1. Dashed line indicates ANZECC/ARMCANZ (2000) guideline value.

Figure 3.19 Chlorophyll-a concentrations at Ocean Reef

[14] *Chlorophyll-a concentrations at surface and bottom offshore sites were determined in-situ using a fluorometer; chlorophyll-a concentrations at shoreline sites were analysed using an acetone extraction method.*



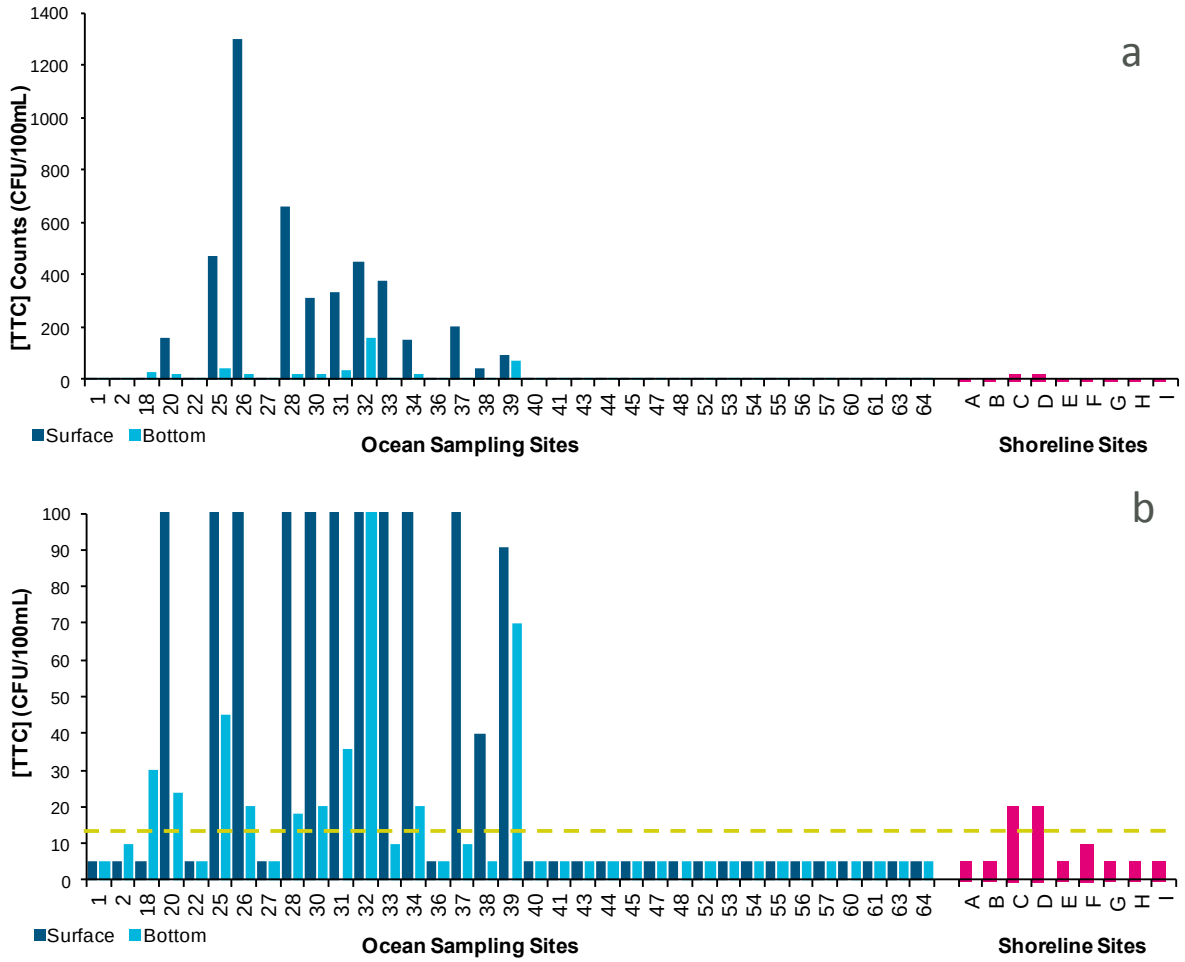
Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 3.3.
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline.

Figure 3.20 Spatial distribution of chlorophyll-a at Ocean Reef

3.5.5 Bacterial concentrations and distribution

Thermotolerant coliforms (TTC)

- The highest offshore surface concentration of TTC was 1300 CFU/100 mL at site 26, positioned 424 m west of the diffuser (Figure 3.21a). The next highest concentrations were 660 CFU/100 mL at site 28 and 470 CFU/100 mL at site 25 (located 151 and 425 m from the diffuser, respectively). The majority (23) of sites had TTC concentrations less than the detection limit of 10 CFU/100 mL (Figure 3.21b).
- The highest offshore bottom concentration of TTC was 160 CFU/100 mL at site 32 located above the diffuser (Figure 3.21b). The next highest concentration was 70 CFU/100 mL at site 39, located 428 m from the diffuser. The majority (22) sites had TTC concentrations less than the detection limit of 10 CFU/100 mL.
- All but two shoreline sites had TTC concentrations less than the reporting limit of 10 CFU/100 mL (Figure 3.21b). Shoreline sites A and F had TTC concentrations of 20 and 63 CFU/100 mL, respectively.
- The median TTC concentration at surface sites located <250 m from the diffuser was above the EQG and EQS, whereas the median TTC concentration at bottom sites was above the EQG but below the EQS. Median surface and bottom TTC concentrations for sites located >250 m were below the EQG and EQS (Table 3.3).
- TTC concentrations in surface and bottom waters exceeding the EQG occurred nearby and up to ~600 m south of the diffuser (Figure 3.22).



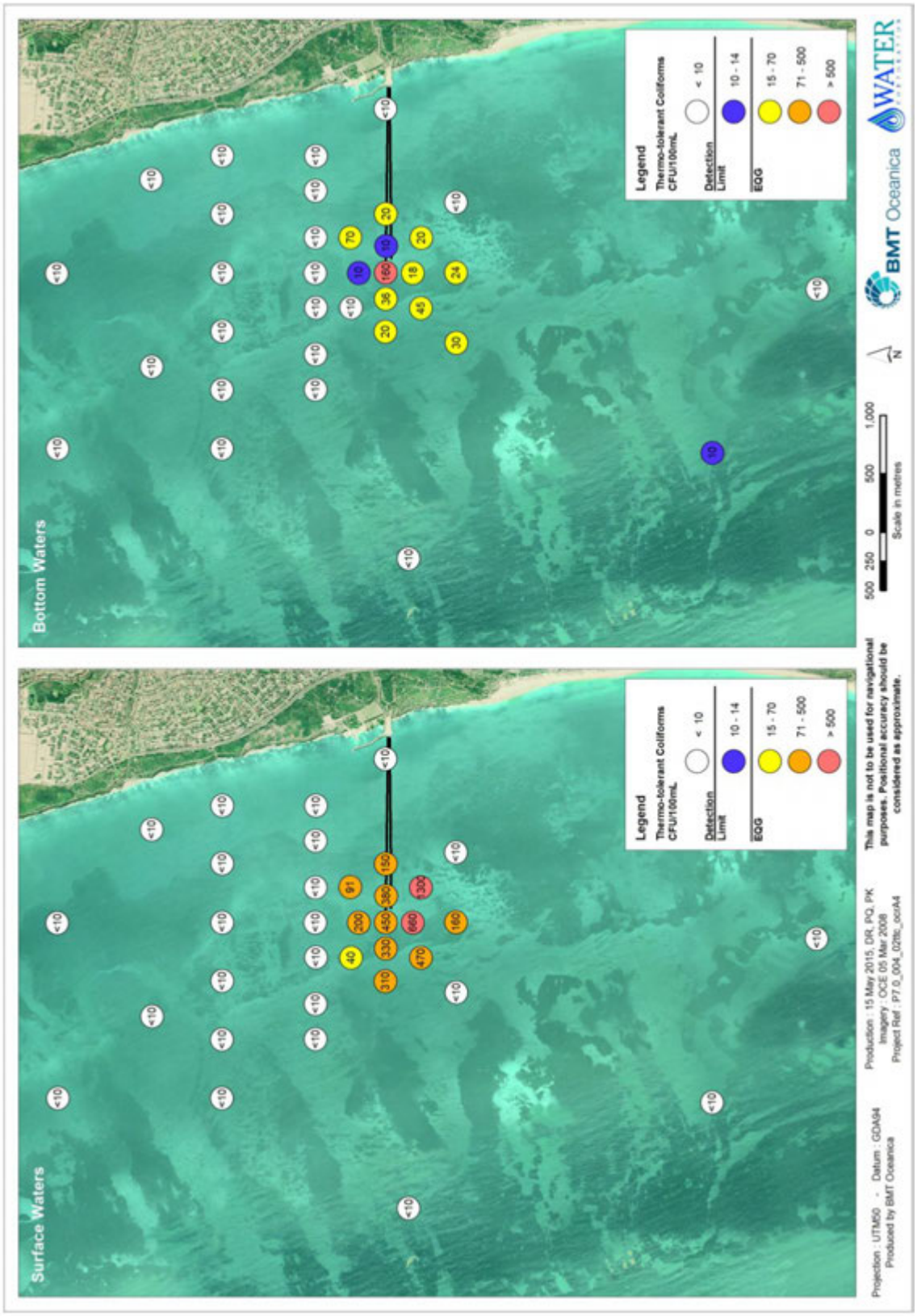
Note:
1. Dashed line indicates EQG (EPA 2005) guideline value.

Figure 3.21 Concentration of thermotolerant coliforms at Ocean Reef

Table 3.3 Median thermotolerant coliform concentration at Ocean Reef

Sites	Surface	Bottom	EQC (EPA 2005)
<250 m from the diffuser	380 CFU/100 mL	18 CFU/100 mL	14 CFU/100 mL (EQG) 70 CFU/100 mL (EQS)
>250 m from the diffuser	<10 CFU/100 mL(1)	<10 CFU/100 mL(1)	
Shoreline	<10 CFU/100 mL(1)	-	

Note:
1. 10 CFU/100 mL is the lower assay limit for the parameter.

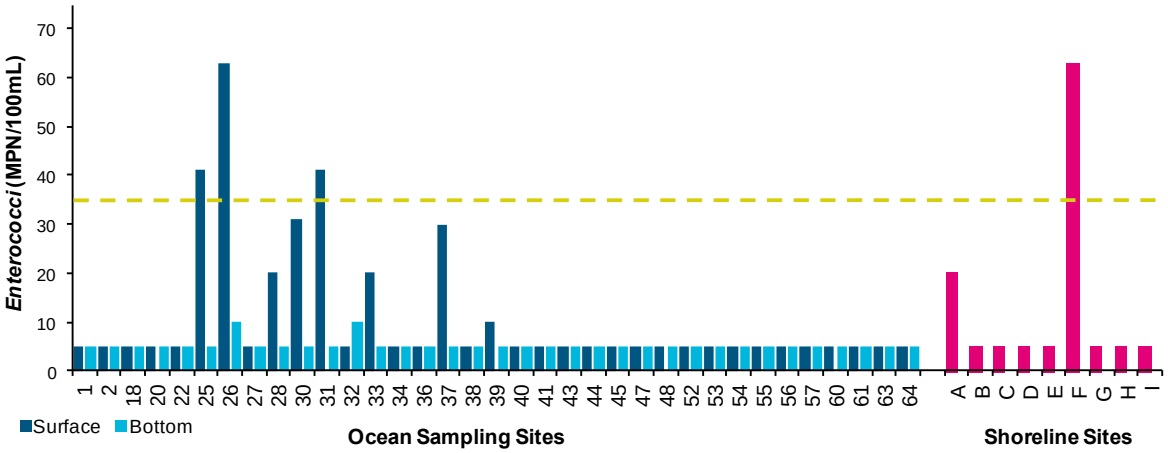


Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 3.3.
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or EQG.

Figure 3.22 Spatial distribution of thermotolerant coliform concentrations at Ocean Reef

Enterococci spp.

- The highest offshore surface concentration of *Enterococci* spp. was 63 MPN/100 mL at site 26, positioned 424 m west of the diffuser. The next highest concentrations were 41 MPN/100 mL at sites 25 and 31 (located 425 and 90 m from the diffuser, respectively). The majority (27) of sites had *Enterococci* spp. concentrations less than the reporting limit of 10 MPN/100 mL (Figure 3.23).
- Offshore bottom concentrations of *Enterococci* spp. were less than the reporting limit at all but two sites (Figure 3.23). Sites 26 and 32 (located 424 m and 3 m from the diffuser, respectively) had concentrations of 10 MPN/100 mL.
- Concentrations of *Enterococci* spp were less than the reporting limit at all but two shoreline sites (Figure 3.23). Sites A and F had concentrations of 20 and 63 MPN/100 mL, respectively.
- Median *Enterococci* spp. concentrations at offshore sites <250 m from the diffuser (surface and bottom), offshore sites >250 m from the diffuser (surface and bottom) and shoreline sites were all below ANZECC/ARMCANZ (2000) guidelines for primary and secondary contact recreation (Table 3.4).
- Surface sites immediately adjacent to the diffuser had slightly elevated *Enterococci* spp. concentrations (Figure 3.24). No pattern was evident in bottom water *Enterococci* spp. concentrations.



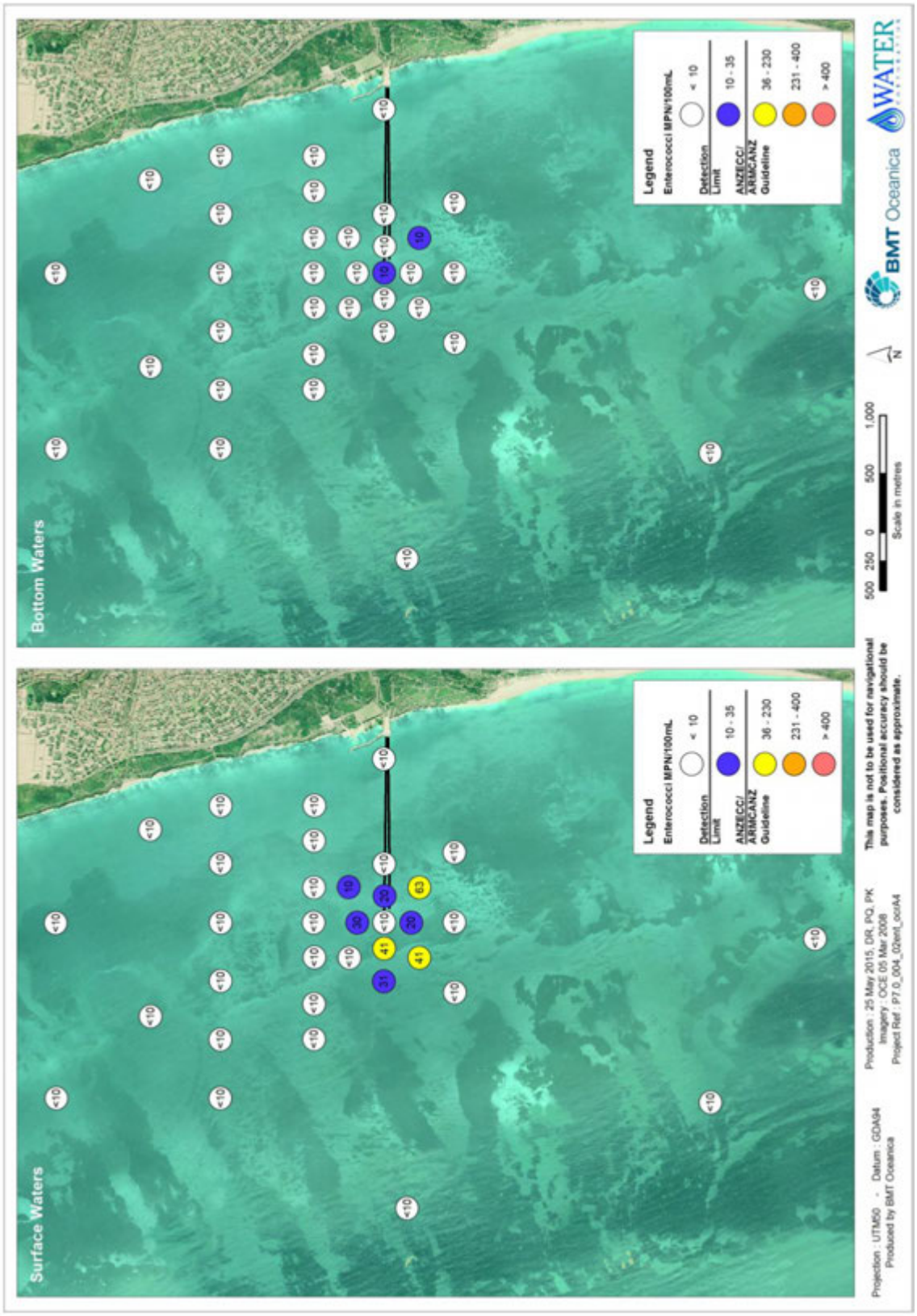
Note:
1. Dashed line indicates ANZECC/ARMCANZ (2000) guideline value.

Figure 3.23 Concentration of *Enterococci* spp. at Ocean Reef

Table 3.4 Median *Enterococci* spp. concentration at Ocean Reef

Sites	Surface	Bottom	ANZECC/ARMCANZ (2000)
<250 m from the diffuser	20	<10(1)	35 MPN/100 mL (primary contact)
>250 m from the diffuser	<10(1)	<10(1)	230 MPN/100 mL (secondary contact)
Shoreline	<10(1)		

Note:
1. 10 MPN/100 mL is the lower assay limit for the parameter.



Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 3.3.
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline.

Figure 3.24 Spatial distribution of *Enterococci* spp. at Ocean Reef

3.6 Conclusions

During the survey on 3 February 2015 at Ocean Reef, the treated wastewater plume was initially buoyant (as indicated by the generally higher concentrations of nutrients and microbiological indicators in surface waters than in bottom waters) and was advecting in a north-easterly direction from the outlets.

The survey provided a one-day snapshot of the extent of elevated nutrient concentrations related to the discharge of treated wastewater at the Ocean Reef outlets. Generally, nutrient concentrations in surface and bottom waters were higher near the outlets than at sites located further from the outlets.

The summer water quality surveys were not specifically designed to provide information suitable for comparison with ANZECC/ARMCANZ (2000) guidelines, or with 80th percentile of reference values. For information only, water quality parameters at sites located <250 m and >250 m from the diffuser were compared with the ANZECC/ARMCANZ (2000) guidelines and 80th percentile of reference values.

ANZECC/ARMCANZ (2000) suggests that an exceedance of a trigger value should be regarded as an 'early warning' and trigger values are not intended as a means of assessing 'compliance'. Parameters with medians exceeding the ANZECC/ARMCANZ (2000) guideline values during the 2015 survey at Ocean Reef were (Table 3.5):

- NH4$^+$ in surface waters at sites <250 m from the diffuser and at shoreline sites
- Ortho-phosphate in surface and bottom waters <250 m and >250 m from the diffuser, and shoreline sites
- NO_2^-+NO_3^- in surface waters <250 m and >250 m from the diffuser, in bottom waters <250 m from the diffuser and shoreline sites
- Total phosphorus in surface waters <250 m and >250 m from the diffuser, in bottom waters <250 m from the diffuser and shoreline sites
- Total nitrogen at shoreline sites
- Chlorophyll-a at shoreline sites

Nitrogen is a nutrient limiting primary productivity in Perth's near-shore coastal waters (Lord & Hillman 1995). Historical concentrations of total nitrogen and NH_4^+ measured at Ocean Reef are generally below the ANZECC/ARMCANZ (2000) guideline values; this is demonstrated by the lower 80th percentile of reference values. Parameters with medians exceeding the ANZECC/ARMCANZ (2000) guideline values during the 2015 survey at Ocean Reef (Table 3.5):

- NH4$^+$ in surface waters at sites <250 m from the diffuser and at shoreline sites
- Ortho-phosphate in surface and bottom waters <250 m and >250 m from the diffuser, and shoreline sites
- NO_2^-+NO_3^- in surface waters <250 m and >250 m from the diffuser and shoreline sites
- Total phosphorus in surface waters <250 m from the diffuser and shoreline sites
- Total nitrogen in surface waters <250 m from the diffuser and at shoreline sites
- Chlorophyll-a in surface waters <250 m and >250 m from the diffuser, in bottom waters >250 m from the diffuser and shoreline sites

Table 3.5 Summary comparison of median nutrient and chlorophyll-a values with guidelines at Ocean Reef

Parameter	ANZECC/ARMCANZ (2000) guideline values				
	Inside the mixing zone (sites <250 m from diffuser)		Outside the mixing zone (sites >250 m from diffuser)		Shoreline
	Surface	Bottom	Surface	Bottom	
Total ammonia nitrogen					
Ortho-phosphate					
Nitrate+nitrite					
Total phosphorus					
Total nitrogen					
Chlorophyll-a					
Parameter	**80th percentile of reference values**				
	Inside the mixing zone (sites <250 m from diffuser)		Outside the mixing zone (sites >250 m from diffuser)		Shoreline
	Surface	Bottom	Surface	Bottom	
Total ammonia nitrogen					
Ortho-phosphate					
Nitrate+nitrite					
Total phosphorus					
Total nitrogen					
Chlorophyll-a					

Notes:
1. Assessment criteria for surface, bottom and shoreline sites:
2. Green = Nutrient median values ≤ ANZECC/ARMCANZ (2000) guideline values / ≤80th percentile reference values.
3. Red = Nutrient median values > ANZECC/ARMCANZ (2000) guideline values / >80th percentile reference values.

The microbiological indicators in surface waters showed elevated concentrations in the immediate vicinity of the diffuser and a decline in concentrations away from the outlet, indicating die-off of the microbes. Thermotolerant coliform concentrations exceeded the EQG limit for the maintenance of seafood safe for human consumption in surface and bottom waters <250 m from the diffuser. However, the guidelines were met at sites >250 m from the diffuser as well as at shoreline sites (Table 3.6). Median concentrations of *Enterococci* spp. were below the guideline for primary contact recreation in surface and bottom waters <250 m and >250 m from the diffuser (Table 3.7). Shoreline monitoring found no indication of contamination beaches east of the outlets (Table 3.7).

Table 3.6 Summary comparison of the EQG with the median concentrations of thermotolerant coliforms at Ocean Reef

Parameter	Environmental Quality Guideline (EPA 2005)[1]				
	<250 m		>250 m		Shoreline
	Surface	Bottom	Surface	Bottom	
Thermotolerant coliforms					

Notes:
1. For the maintenance of seafood safe for human consumption.
2. Green= median values ≤ EQG.
3. Red = median values > EQG.

Table 3.7 Summary comparison of the ANZECC/ARMCANZ guideline with the median concentrations of *Enterococci* spp. at Ocean Reef

Parameter	ANZECC/ARMCANZ (2000)[1]				
	<250 m		>250 m		Shoreline
	Surface	Bottom	Surface	Bottom	
Enterococci spp.					

Notes:
1. Results for primary contact recreation.
2. Green = median values ≤ ANZECC/ARMCANZ (2000) guideline.
3. Red = median values > ANZECC/ARMCANZ (2000) guideline.

The results from the summer water quality survey on 3 February 2015 indicate that the WWTP at Ocean Reef was operating effectively and the plume of treated wastewater dissipated relatively rapidly once the wastewater entered the environment. Despite elevated levels of water quality parameters at some sites outside the immediate zone of influence of the outlet, the water quality conditions required for ecosystem protection and public health criteria were met.

Summer Water Quality Survey

Swanbourne

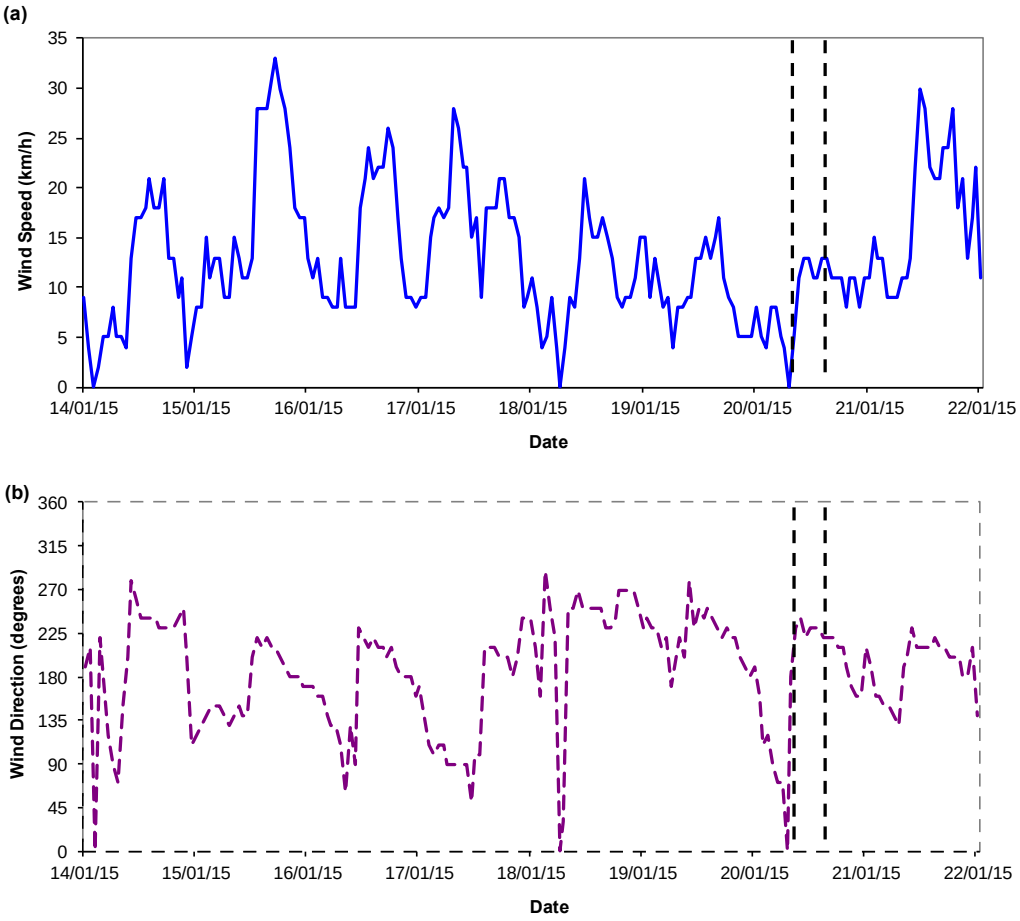
20 January 2015

WATER CORPORATION

4. Swanbourne Summer Water Quality Survey – Results and Interpretation

4.1 Wind, wave and tide conditions

The survey at Swanbourne was undertaken on 20 January 2015. For 24 hours prior to the survey, the winds at Swanbourne were gentle westerlies (averaging 12.8 km/h) swinging to light southerlies (average 5.9 km/h) 12 hours prior to sampling. By 6 hours prior to sampling winds had swung to easterlies averaging 5.8 km/h. During sampling, the area experienced light winds from the west and southwest (averaging 11.0 km/h) (Figure 4.1).



Note:
1. Dashed lines (- -) show approximate timing of the summer water quality survey.
2. a = wind speed
3. b = wind direction

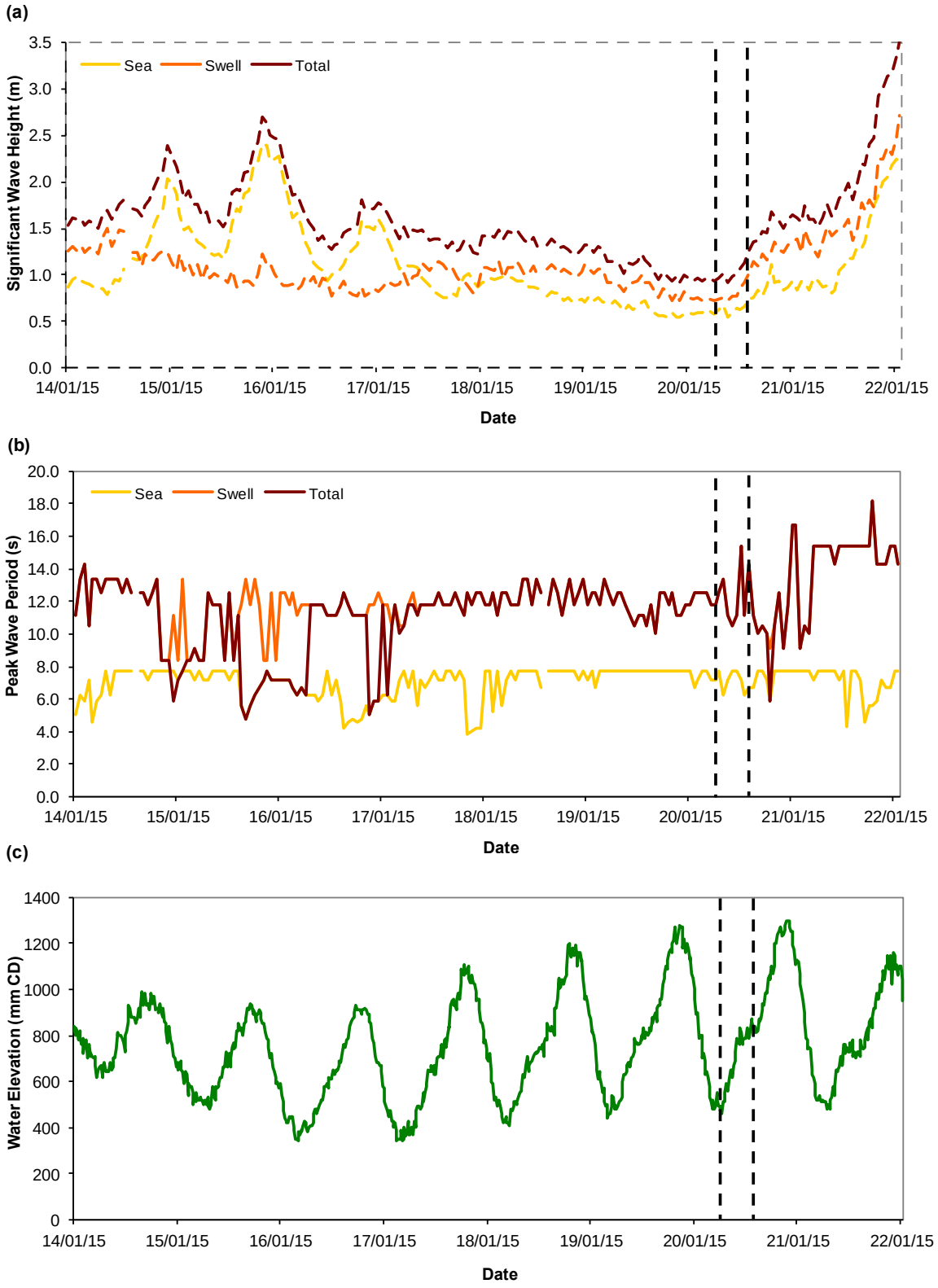
Figure 4.1 Wind speed and direction at Swanbourne

For 24 hours prior to the survey, the average significant wave height[15] offshore from Rottnest Island was 1.03 m[16], with an average peak wave period[17] of 11.73 s[16] (Figure 4.2a and b). During the survey the average offshore significant wave height was 1.08 m and the average peak wave period increased to 12.27 s. The survey was undertaken during a rising tide (Figure 4.2c).

[15] *The significant wave height (in metres) is defined as the average height of the highest one-third of waves recorded (source: http//www.dpi.wa.gov.au/).*

[16] *Value based on 'total' wave conditions i.e. the combined sea and swell conditions.*

[17] *The wave period (in seconds) is the time between consecutive wave crests. The peak wave period is the wave period of those waves that are producing the most energy in a wave record.*



Note:
1. Dashed lines (- -) show approximate timing of the summer water quality survey.
2. a = significant wave height
3. b = peak wave period
4. c = water level elevation

Figure 4.2 Significant wave heights (offshore Rottnest Island), peak wave periods (offshore Rottnest Island) and water level elevation (Fremantle Fishing Boat Harbour)

4.2 Discharge from outlets

The characteristics of the treated wastewater from Subiaco WWTP measured from a 24-hour composite sample collected prior to and during the survey at Swanbourne on 20 January 2015 are presented in Table 4.1. At the time of the survey, all 20 ports were operational.

Table 4.1 Characteristics of the Subiaco WWTP treated wastewater on 20 January 2015

Parameter	Concentration
Total phosphorus	5.5 mg/L
Total nitrogen	29.0 mg/L
Total ammonia nitrogen	26.0 mg/L
Nitrate+nitrite	2.6 mg/L
Thermotolerant coliforms	>100 000 CFU/100 mL
Enterococci spp.	>24 000 MPN/100 mL
Total suspended solids	14 mg/L
Biological oxygen demand	8 mg/L
Total flow	65.0 ML/d

4.3 Surface drogue movement

The surface drogue, released at the centre of the diffuser at the beginning of the survey, initially drifted in a southerly direction for ~150 m. The drogue then moved in an east to north-east direction for another ~850 m. The average velocity of the drogue was calculated to be 0.07 m/s. At the time of the survey and based on drogue movements, it is expected that discharged treated wastewater would overall be advecting north and inshore of the diffuser (Figure 4.3).

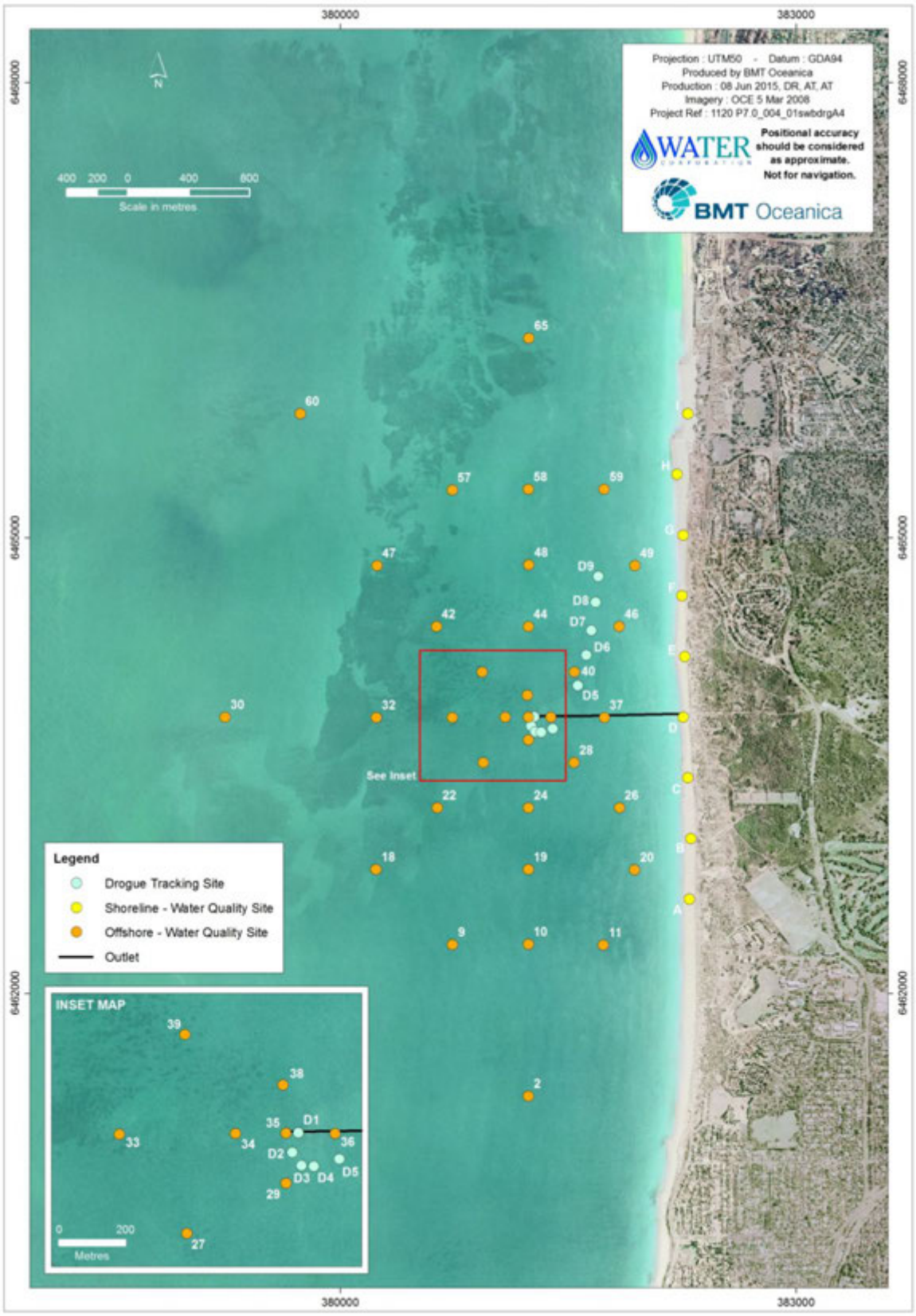
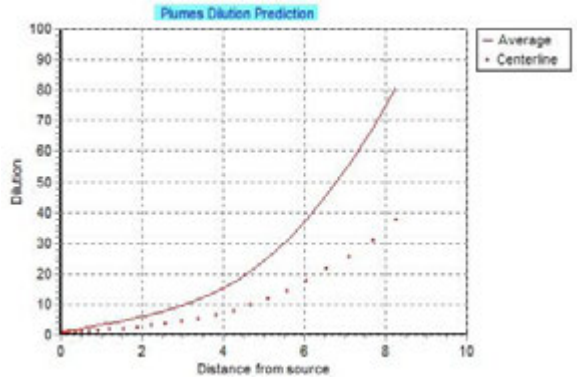


Figure 4.3 Swanbourne ocean outlet summer water quality survey and drogue tracking sites, 20 January 2015

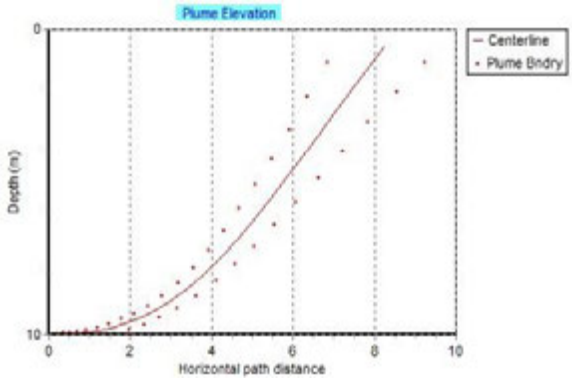
4.4 Initial dilution modelling

For the ambient conditions at the time of the summer water quality survey on 20 January 2015, the modelling predicted average initial dilutions of 1:81 and centreline dilutions of 1:38 (Figure 4.4a). The plume was predicted to first reach the surface within ~7 m (horizontal distance) from the discharge point (see the ambient boundary[18] of the plume in Figure 4.4b). The full model output is included in Appendix B.

(a)



(b)



Notes:
1. a = predicted average and centreline dilution
2. b = predicted plume elevation

Figure 4.4 Predicted average and centreline dilutions and predicted plume elevation trajectory at Swanbourne

4.5 Water quality

The grid for light or moderate flow conditions at Swanbourne was sampled during the survey on 20 January 2015, as drogue movement (Section 4.3) and prevailing wind data (Section 4.1) suggested variable currents. Water samples were collected from the surface and bottom waters of 35 offshore sites and nine shoreline sites (Figure 4.3). Tables containing the concentrations of all water quality parameters taken during the summer survey are included in Appendix D.

4.5.1 Water column structure

Water column profiles were collected at seven sites (29, 34, 35, 36, 38, 44, and 48). Water temperature ranged from 23.21°C to 24.10°C, salinity ranged from 35.90 to 36.34 and dissolved oxygen varied from 6.67 mg/L to 7.43 mg/L (equivalent to 96.6–107.8% saturation) (Figure 4.5 and Figure 4.6). Profiles revealed evidence of a thermocline at all sites, with surface water temperatures ~0.5 °C warmer than bottom waters. Salinity profiles showed generally constant salinities at most sites. Sites 29, 34 and 35 appeared to have a layer of less saline water at the surface, which may indicate the presence of the treated wastewater plume. The dissolved oxygen profiles varied among sites (difference of 0.77 mg/L between minimum and maximum values) but were not indicative of the presence of the treated wastewater plume.

[18] *The ambient boundary corresponds to the plume boundary at which concentrations are estimated to be equal to ambient conditions.*

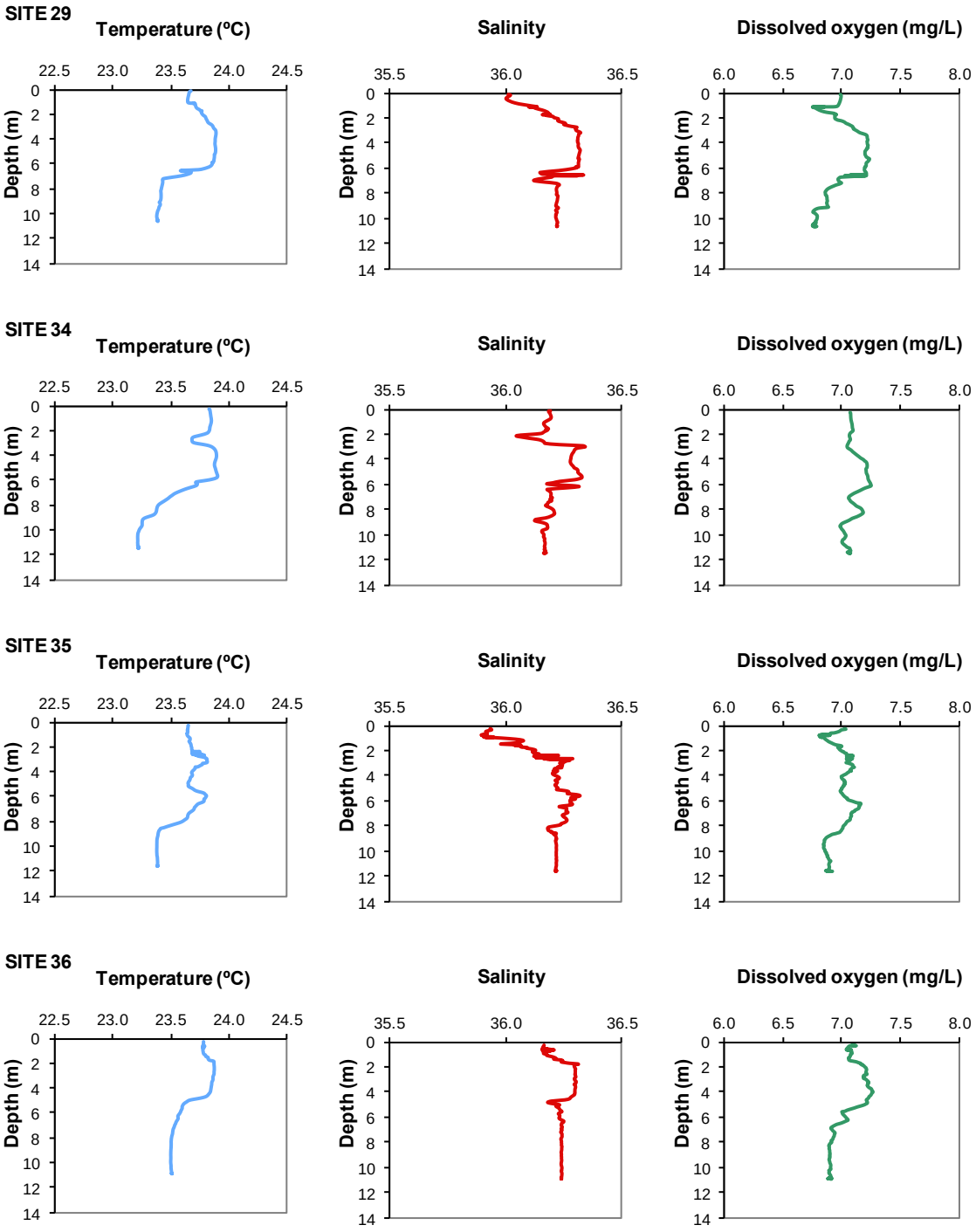


Figure 4.5 Temperature, salinity and dissolved oxygen vertical profiles at Swanbourne

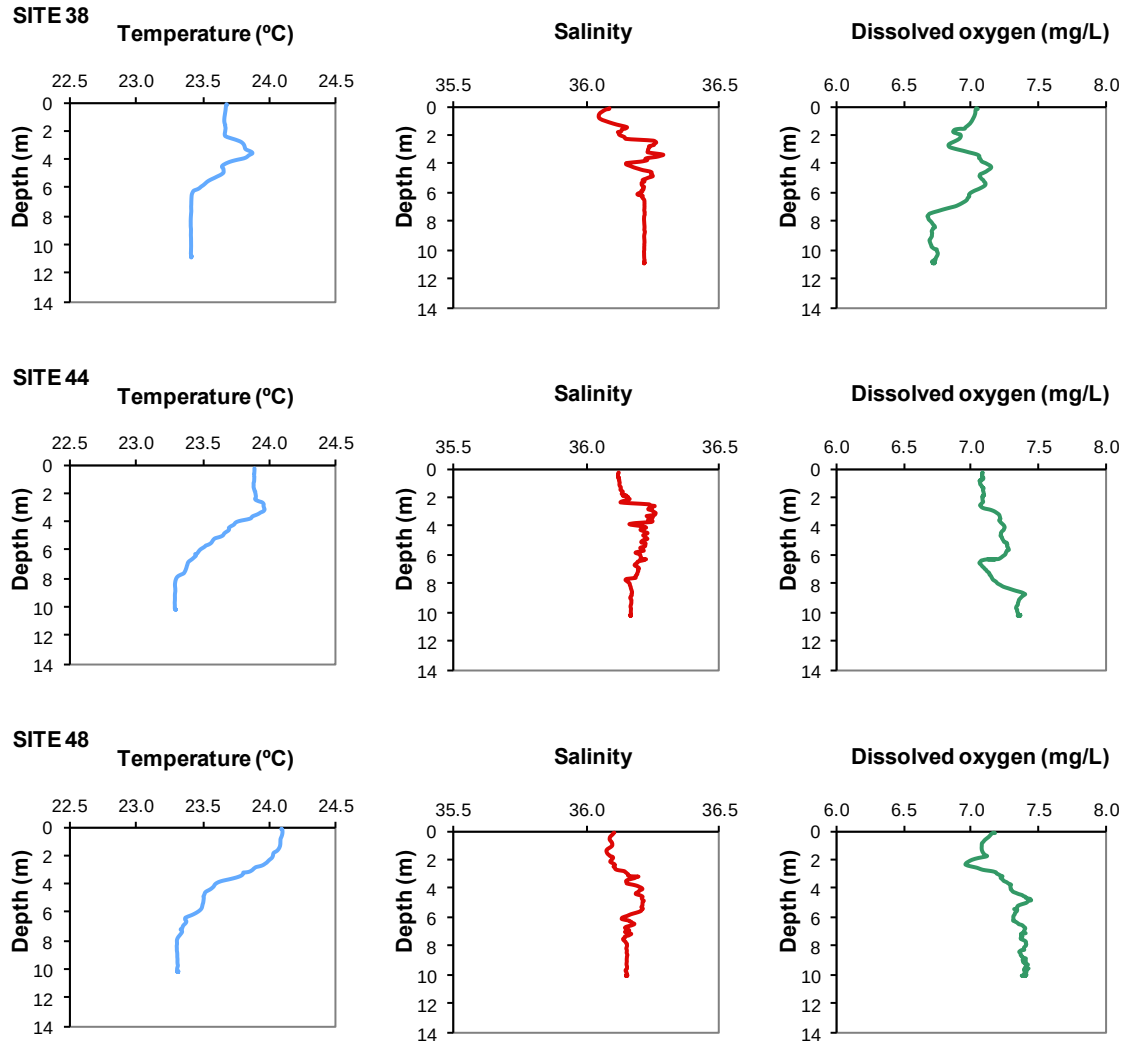
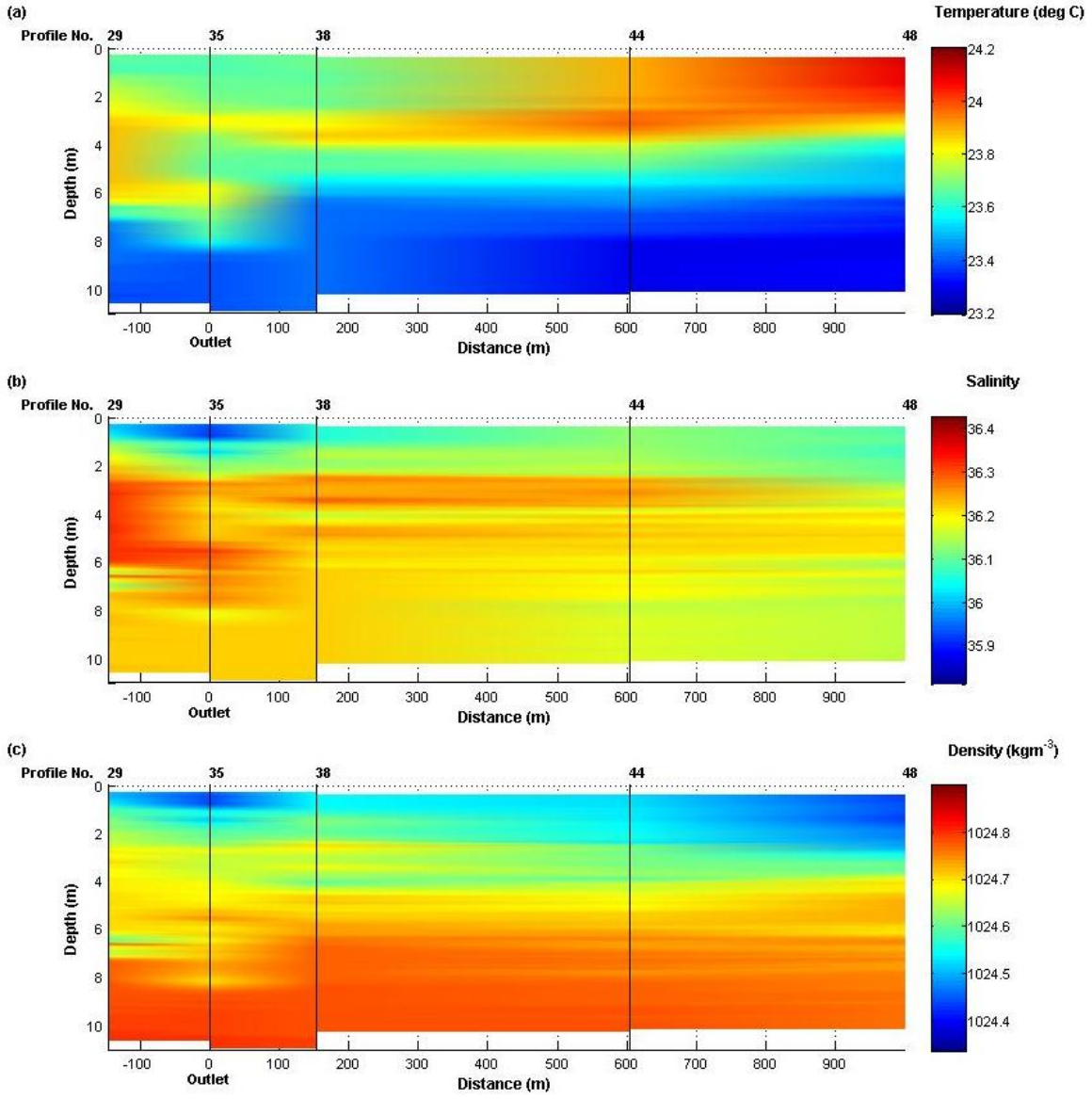


Figure 4.6 Temperature, salinity and dissolved oxygen vertical profiles at Swanbourne

The effect of the discharged wastewater on the physical structure of the water column is illustrated in Figure 4.7. The colour scales used in Figure 4.7 range from the minimum to the maximum of each parameter, thus exaggerating small differences in measurements. Water temperature throughout the water column appeared to increase with increasing distance from the diffuser with the highest temperatures observed at the site 48, 1 km north of the diffuser (Figure 4.7a). Temperature showed vertical stratification at all sites; water temperature generally decreased with depth irrespective of distance from the diffuser. Salinity concentrations were generally constant throughout the water column at all sites, with the exception of a patch of lower-salinity surface water above the diffuser (Figure 4.7b). Water density was stratified at all sites; density increased with depth irrespective of distance from the diffuser (Figure 4.7c).



Notes:
1. a = temperature
2. b = salinity
3. c = density

Figure 4.7 Temperature, salinity and density transect at Swanbourne

4.5.2 Replicate samples

Variance in measurements of water quality parameters may be introduced by small-scale spatial variability in the water column or by variability among laboratory analyses. To examine the range of this variance, three surface samples were collected at site 2 (Table 4.2). The results indicated that in general, the variability amongst replicates was small. The mean value of these replicate samples was used as representative of the water quality parameters at site 2.

Table 4.2 Replicate surface samples from site 2, Swanbourne, 20 January 2015

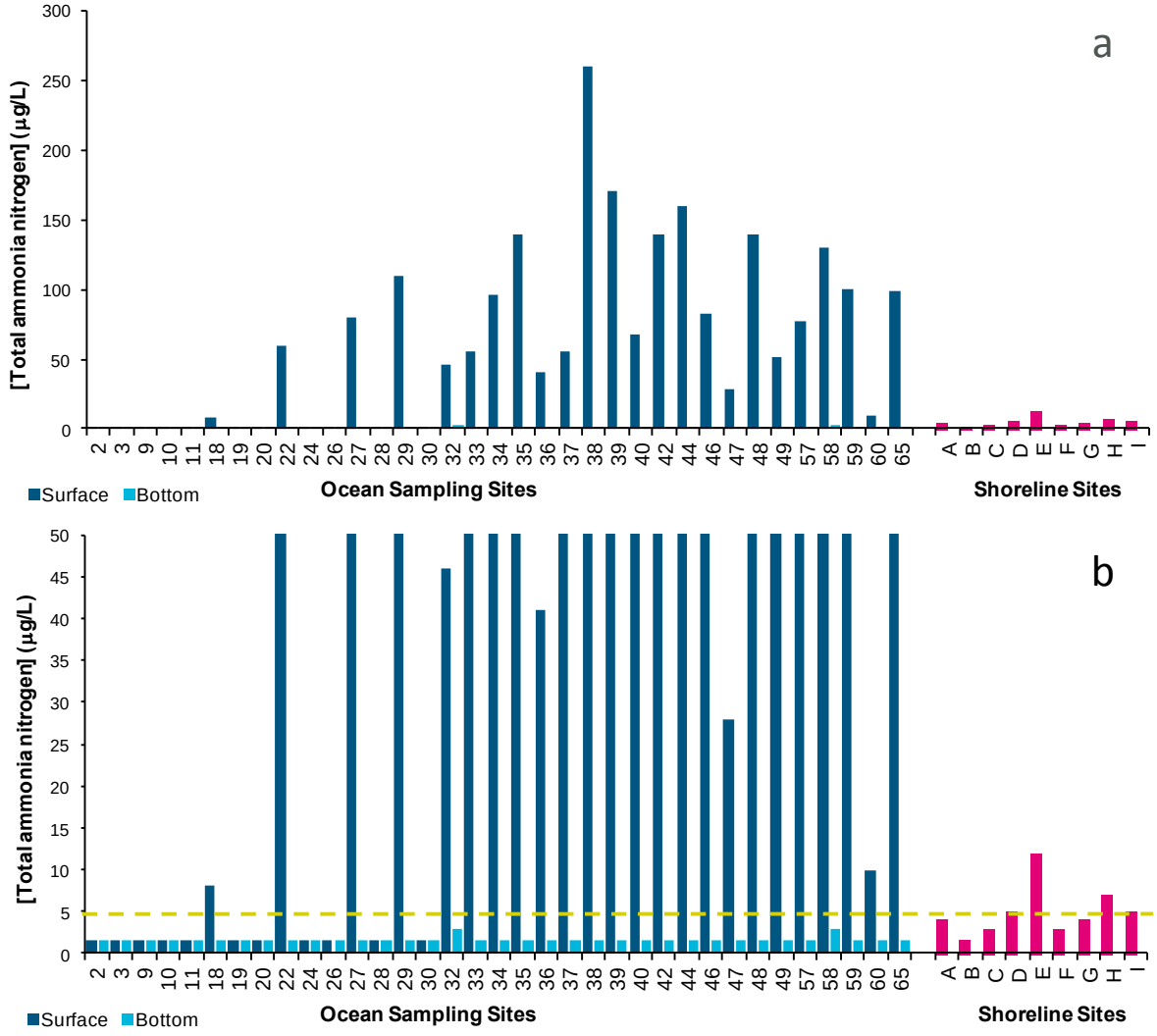
Parameter	Total ammonia nitrogen	Ortho-phosphate	Nitrate+nitrite	Total phosphorus	Total nitrogen
Units	µg/L	µg/L	µg/L	µg/L	µg/L
Reporting limit	<3	<2	<2	<5	<50
Surface rep 1	<3	3.0	1.0	12.0	100.0
Surface rep 2	<3	2.0	1.0	12.0	90.0
Surface rep 3	<3	3.0	1.0	12.0	100.0
Mean	*<3*	*2.7*	*1.0*	*12.0*	*96.7*
Parameter	**Chlorophyll-a *(fluorometry)***	**Chlorophyll-a *(acetone)***	**Phaeophytin**	**Thermotolerant coliforms**	***Enterococci* spp.**
Units	µg/L	µg/L	µg/L	CFU/100 mL	MPN/100 mL
Reporting limit	<0.1	<0.1	<0.2	<10	<10
Surface rep 1	0.2	0.1	0.1	<10	<10
Surface rep 2	0.2	0.1	0.1	<10	<10
Surface rep 3	0.05	0.1	0.1	<10	<10
Mean	*0.15*	*0.1*	*0.1*	*<10*	*<10*

Note:
1. Mean values were calculated by replacing values below the reporting limit as half the reporting limit.

4.5.3 Nutrient concentrations and distributions

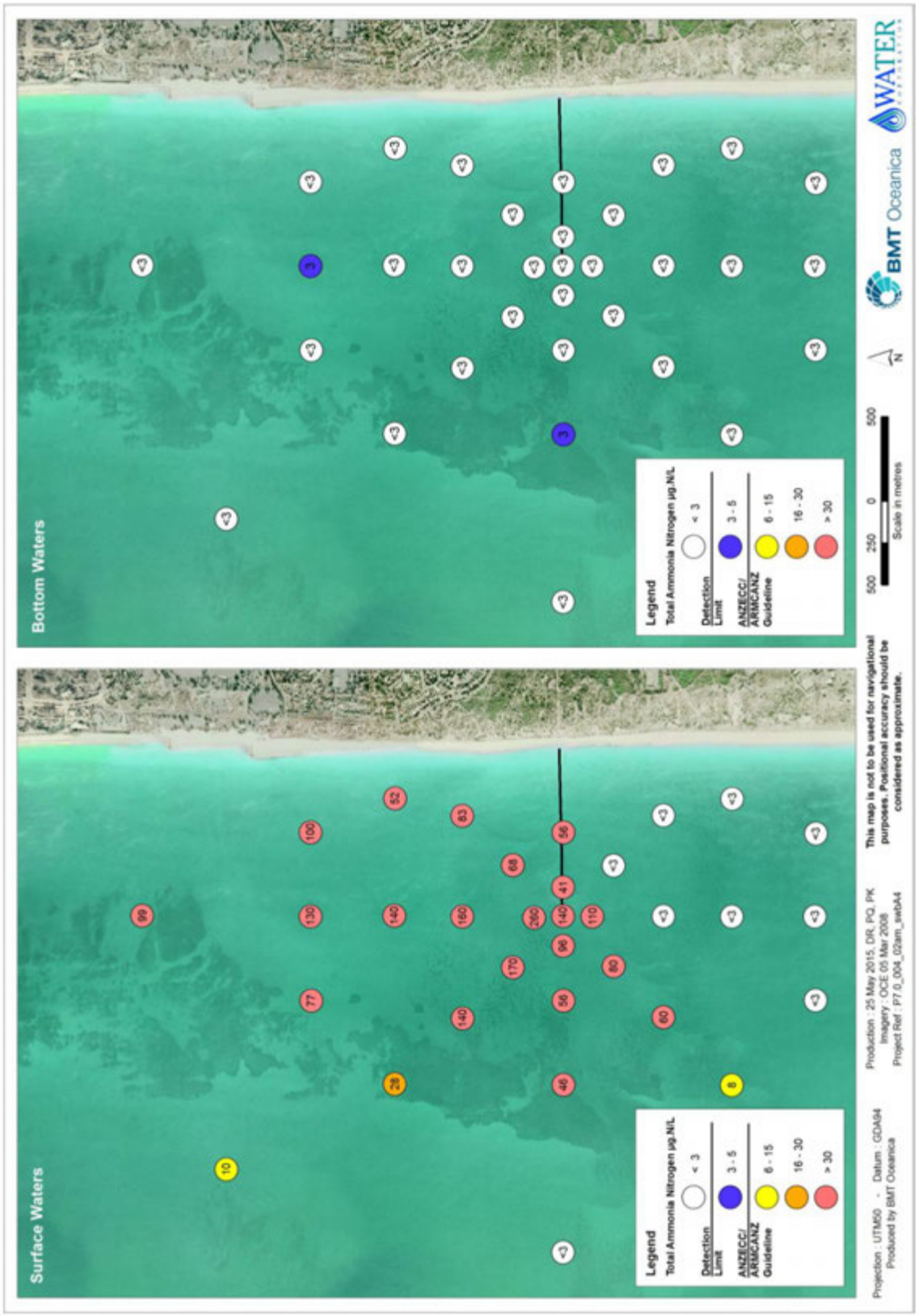
Total ammonia nitrogen (NH_4^+)

- Offshore surface concentrations of NH_4^+ ranged from <3 to 260 µg/L with 11 (31%) sites below or equal to the ANZECC/ARMCANZ (2000) guideline of 5 µg/L (Figure 4.8a). Bottom concentrations of total ammonia nitrogen ranged from <3 to 3 µg/L; concentrations at all sites were below the ANZECC/ARMCANZ (2000) guideline (Figure 4.8b).
- NH_4^+ concentrations in surface waters of 11 (31%) sites were below or equal to the 80th percentile reference value of 4 µg/L. Concentrations in bottom waters at all sites were below or equal to the 80th percentile reference value of 3 µg/L.
- Sites within 250 m from the diffuser had NH_4^+ concentrations ranging between 41 and 260 µg/L (median of 110 µg/L) in surface waters. NH_4^+ concentrations in bottom waters at all sites within 250 m were below the detection limit (<3 µg/L). All surface sites within 250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline (5 µg/L) and the 80th percentile of reference values (4 µg/L). None of the concentrations at bottom sites exceeded the ANZECC/ARMCANZ (2000) guideline or the 80th percentile of reference values (3 µg/L).
- Sites outside 250 m from the diffuser had NH_4^+ concentrations ranging between <2 and 170 µg/L (median of 49 µg/L) in surface waters and between <2 and 3 µg/L (median of <2 µg/L) in bottom waters. Nineteen out of 30 (63%) surface sites outside 250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline (5 µg/L) and the 80th percentile of reference values (4 µg/L). None of the bottom sites had concentrations exceeding the ANZECC/ARMCANZ (2000) guideline or the 80th percentile of reference values (3 µg/L).
- NH_4^+ concentrations at all 7 (78%) shoreline sites were below or equal to ANZECC/ARMCANZ (2000) guideline value of 5 µg/L (Figure 4.8b).
- NH_4^+ concentrations in surface waters were highest surrounding and to the north of the diffuser (Figure 4.9). There were no spatial patterns of NH_4^+ concentrations evident in bottom waters.



Note:
1. Dashed line indicates ANZECC/ARMCANZ (2000) guideline value

Figure 4.8 Total ammonia nitrogen concentrations at Swanbourne

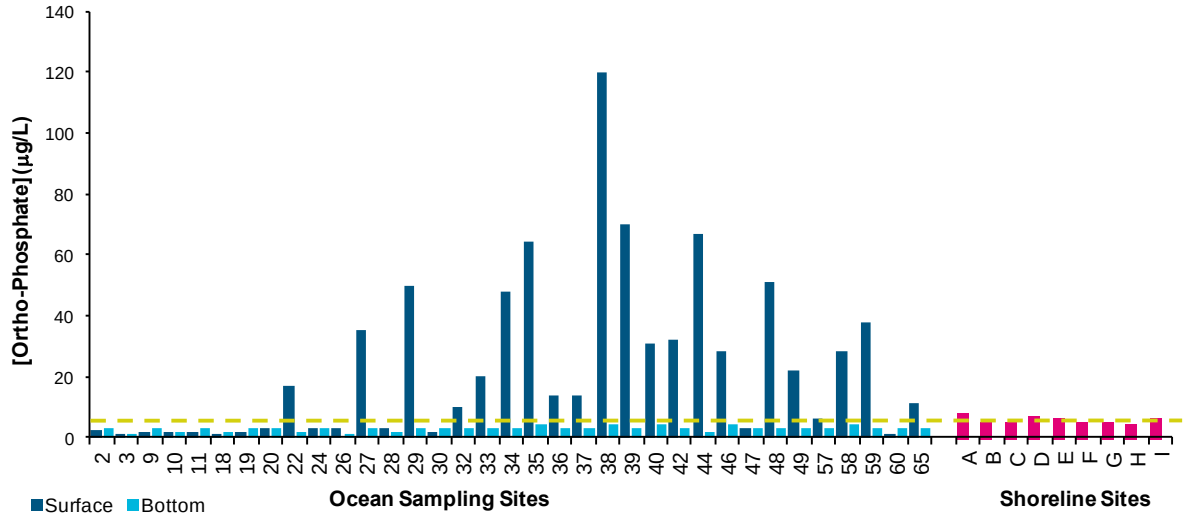


Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 4.3.
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline.

Figure 4.9 Spatial distribution of total ammonia nitrogen at Swanbourne

Ortho-phosphate[19]

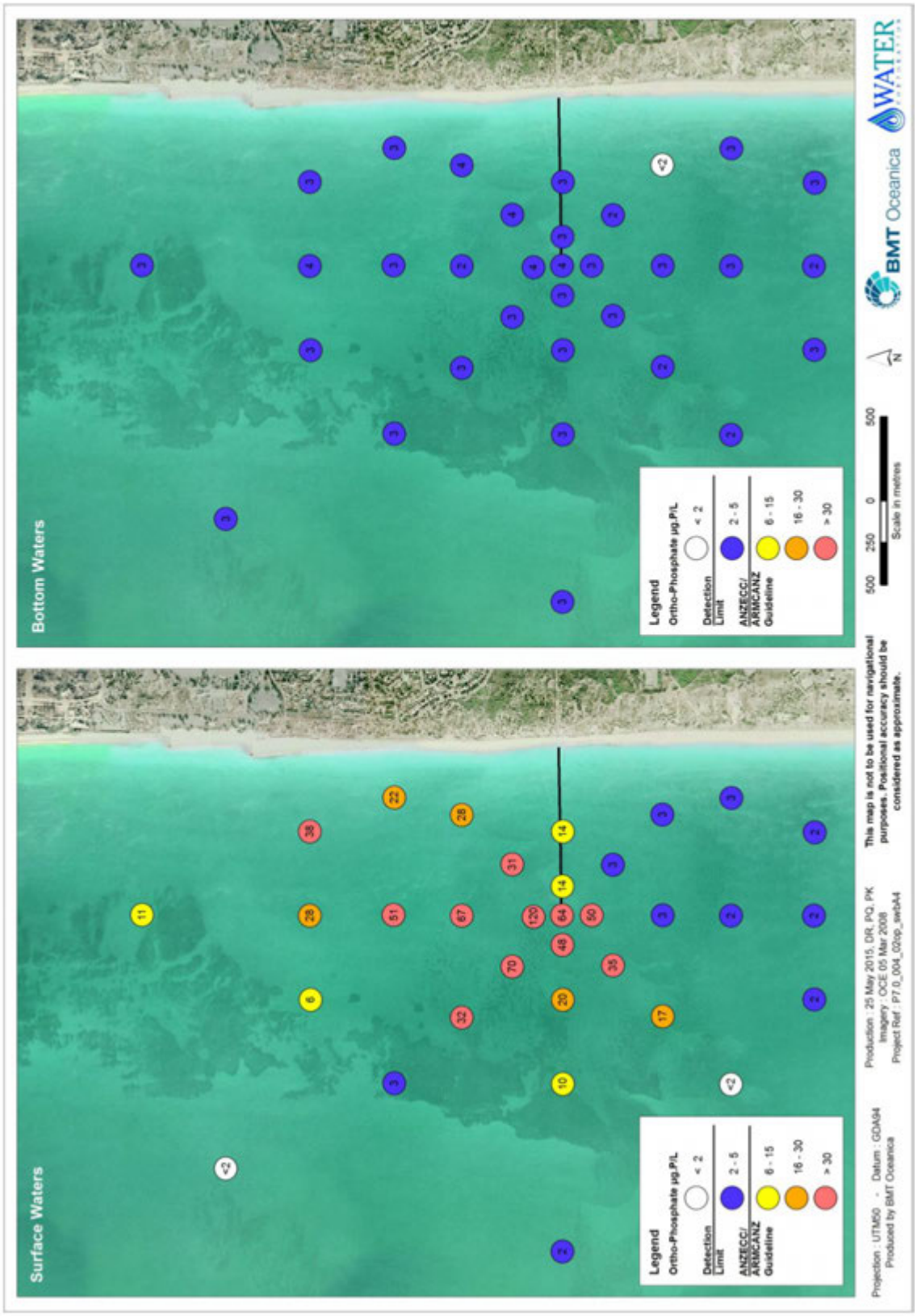
- Offshore surface concentrations of ortho-phosphate ranged from <2 to 120 µg/L with 14 (40%) sites below or equal to the ANZECC/ARMCANZ (2000) guideline of 5 µg/L. Bottom concentrations of ortho-phosphate ranged from <2 to 4 µg/L; concentrations at all sites were below the ANZECC/ARMCANZ (2000) guideline (Figure 4.10).
- Surface concentrations of ortho-phosphate at 15 (43%) sites were below or equal to the 80th percentile reference value of 8 µg/L. Bottom concentrations of ortho-phosphate at all sites were below the 80th percentile reference value.
- Sites within 250 m of the diffuser had ortho-phosphate concentrations ranging between 14 and 120 µg/L (median of 50 µg/L) in surface waters and between 3 and 4 µg/L (median of3 µg/L) in bottom waters. All surface sites within 250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline (5 µg/L) and the 80th percentile of reference values (8 µg/L) (surface and bottom). All concentrations at bottom sites <250 m from the diffuser were within guideline and reference values.
- Sites outside 250 m from the diffuser had ortho-phosphate concentrations ranging between <2and 70 µg/L (median of 8 µg/L) in surface waters and between <2 and 4 µg/L (median of 3 µg/L) in bottom waters. 16 out of 30 (53%) surface sites outside 250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline of 5 µg/L compared to none of the bottom sites. 15 surface sites positioned up to 2500 m from the diffuser exceeded the 80th percentile reference value of 8 µg/L.
- Ortho-phosphate concentrations at shoreline sites ranged from 4 µg/L (site H) to 8 µg/L (site A) (Figure 4.10). Ortho-phosphate concentrations at 5 (56%) of shoreline sites were below the ANZECC/ARMCANZ (2000) guideline of 5 µg/L.
- Surface ortho-phosphate concentrations (Figure 4.11) were highest immediately around and to north of the diffuser. There were no spatial patterns in bottom water orth-phosphate.



Note:
1. Dashed line indicates ANZECC/ARMCANZ (2000) guideline value

Figure 4.10 Ortho-phosphate concentrations at Swanbourne

[19] *Bottom water concentration of ortho-phosphate at site 35 was not taken.*

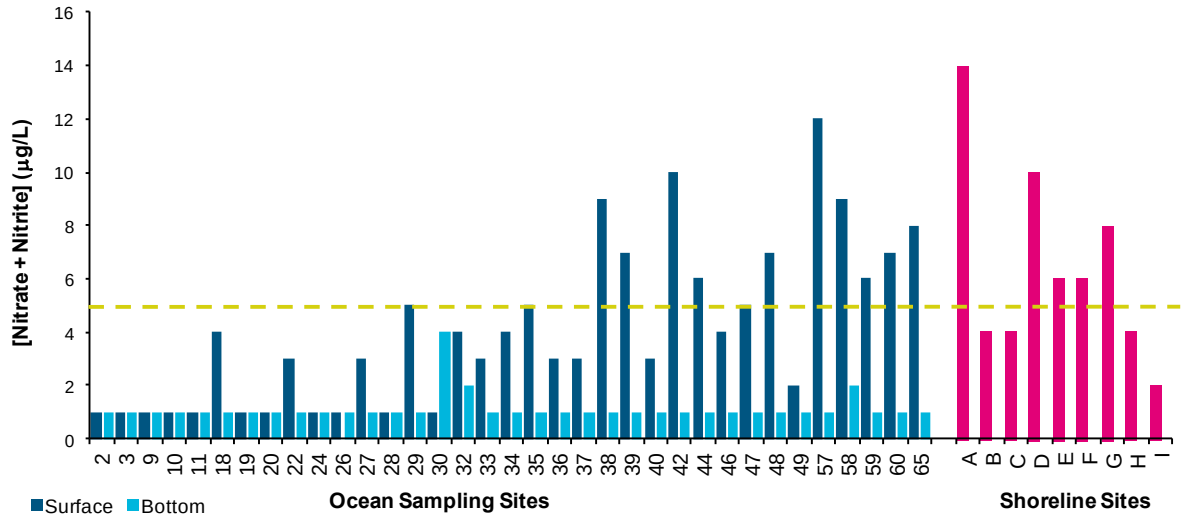


Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 4.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline.

Figure 4.11 Spatial distribution of ortho-phosphate at Swanbourne

Nitrate+nitrite (NO_2^-+NO_3^-)[20]

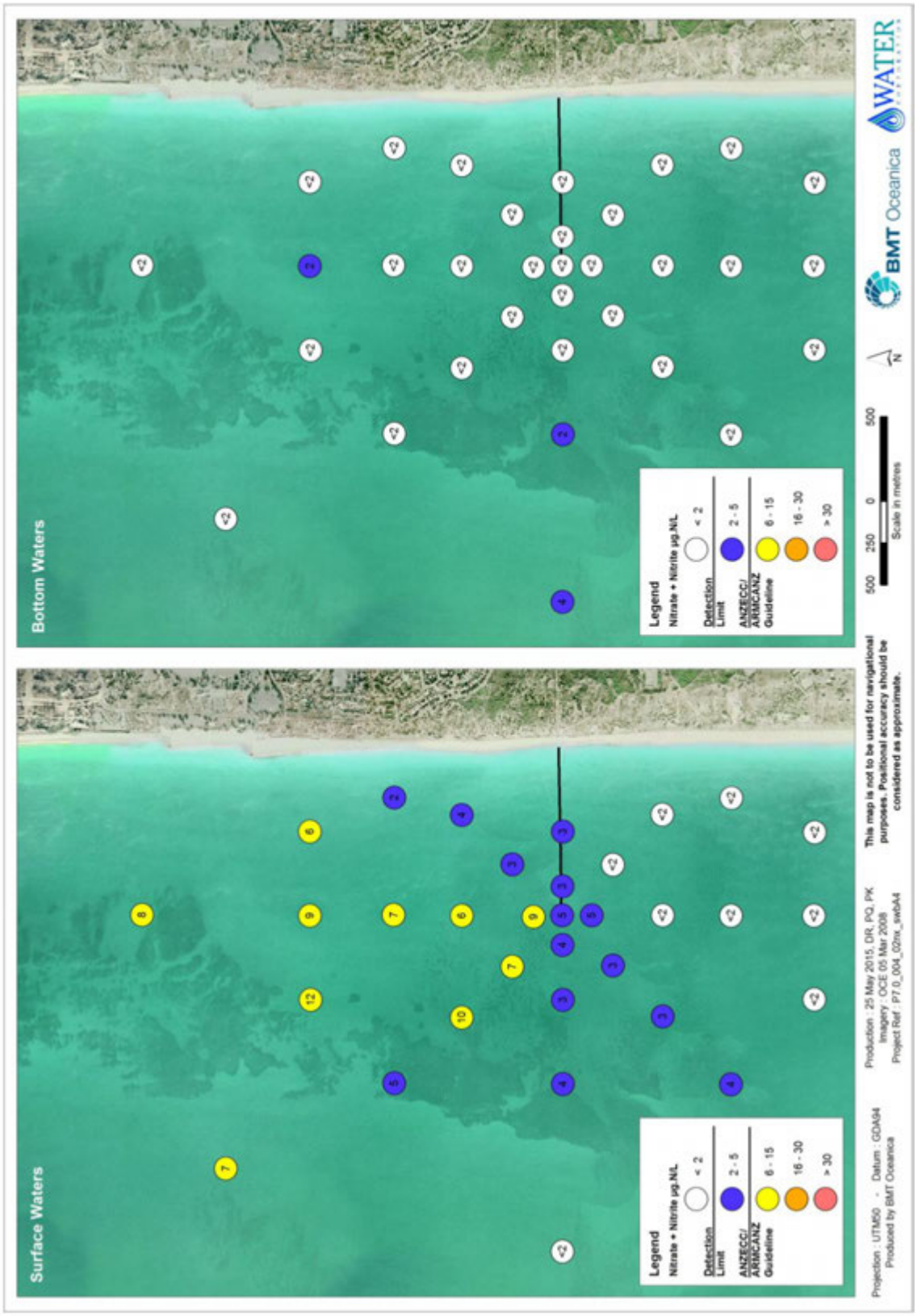
- Offshore surface concentrations of NO_2^-+NO_3^- ranged from <2 to 12 µg/L with 25 (71%) sites below or equal to the ANZECC/ARMCANZ (2000) guideline of 5 µg/L. Bottom concentrations of NO_2^-+NO_3^- ranged from <2 to 4 µg/L and all were below the ANZECC/ARMCANZ (2000) guideline of 5 µg/L (Figure 4.12).
- NO_2^-+NO_3^- surface concentrations at 34 (97%) sites were below or equal to the 80th percentile reference value of 11 µg/L. Bottom concentrations of NO_2^-+NO_3^-at all sites were below or equal to the 80th percentile reference value.
- Sites within 250 m from the diffuser had NO_2^-+NO_3^-concentrations ranging between 3 and 9 µg/L (median of 5 µg/L) in surface waters. All samples in bottom water were <2 µg/L (median of <2 µg/L) in bottom waters. One (20%) surface site within 250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline of 5 µg/L and 4 sites (80%) exceeded the 80th percentile reference value of 3 µg/L. All bottom sites within 250 m from the diffuser were within the guideline and reference values.
- Sites outside 250 m from the diffuser had NO_2^-+NO_3^-concentrations ranging between <2 and 12 µg/L (median of 3 µg/L) in surface waters and between <2 and 4 µg/L (median of <2µg/L) in bottom waters. Nine out of 30 (30%) surface sites outside 250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline of 5 µg/L compared to none of the bottom sites. Thirteen surface and one bottom water site positioned up to 2500 m from the diffuser exceeded the reference value of 3 µg/L.
- NO_2^-+NO_3^- concentrations at shoreline sites ranged from 2 µg/L (site I) to 14 µg/L (site A) (Figure 4.12). Concentrations at 4 (44%) of shoreline sites were below or equal to the ANZECC/ARMCANZ (2000) guideline of 5 µg/L.
- Surface NO_2^-+NO_3^- concentrations (Figure 4.13) were elevated immediately around and to the north of the diffuser. (Figure 4.12).



Note:
1. Dashed line indicates ANZECC/ARMCANZ (2000) guideline value.

Figure 4.12 Total nitrate+nitrite concentrations at Swanbourne

[20] *Bottom water concentration of nitrate+nitrite at site 35 was not taken.*

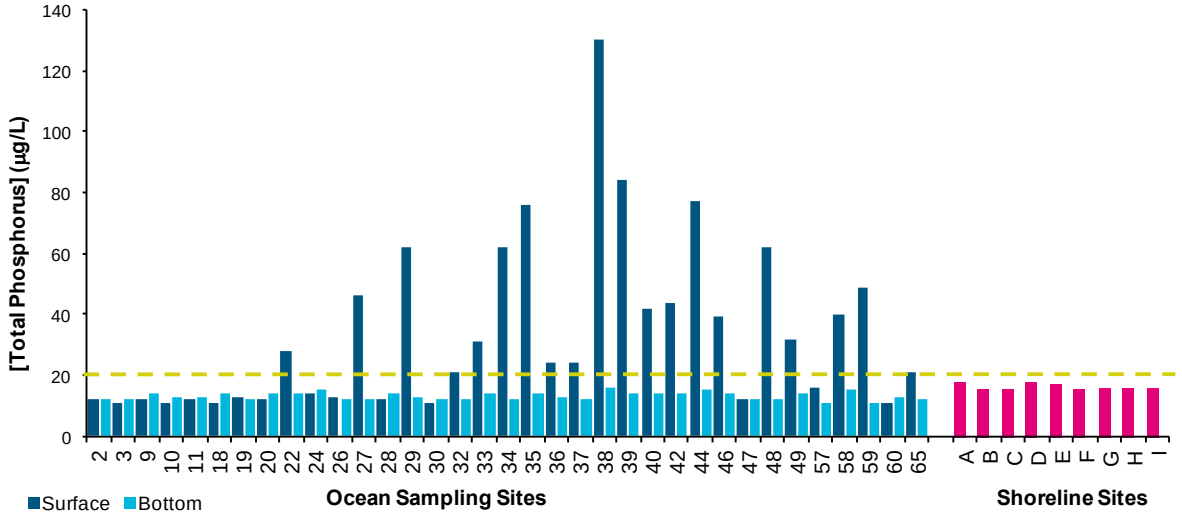


Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 4.3.
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline.

Figure 4.13 Spatial distribution of nitrate+nitrite at Swanbourne

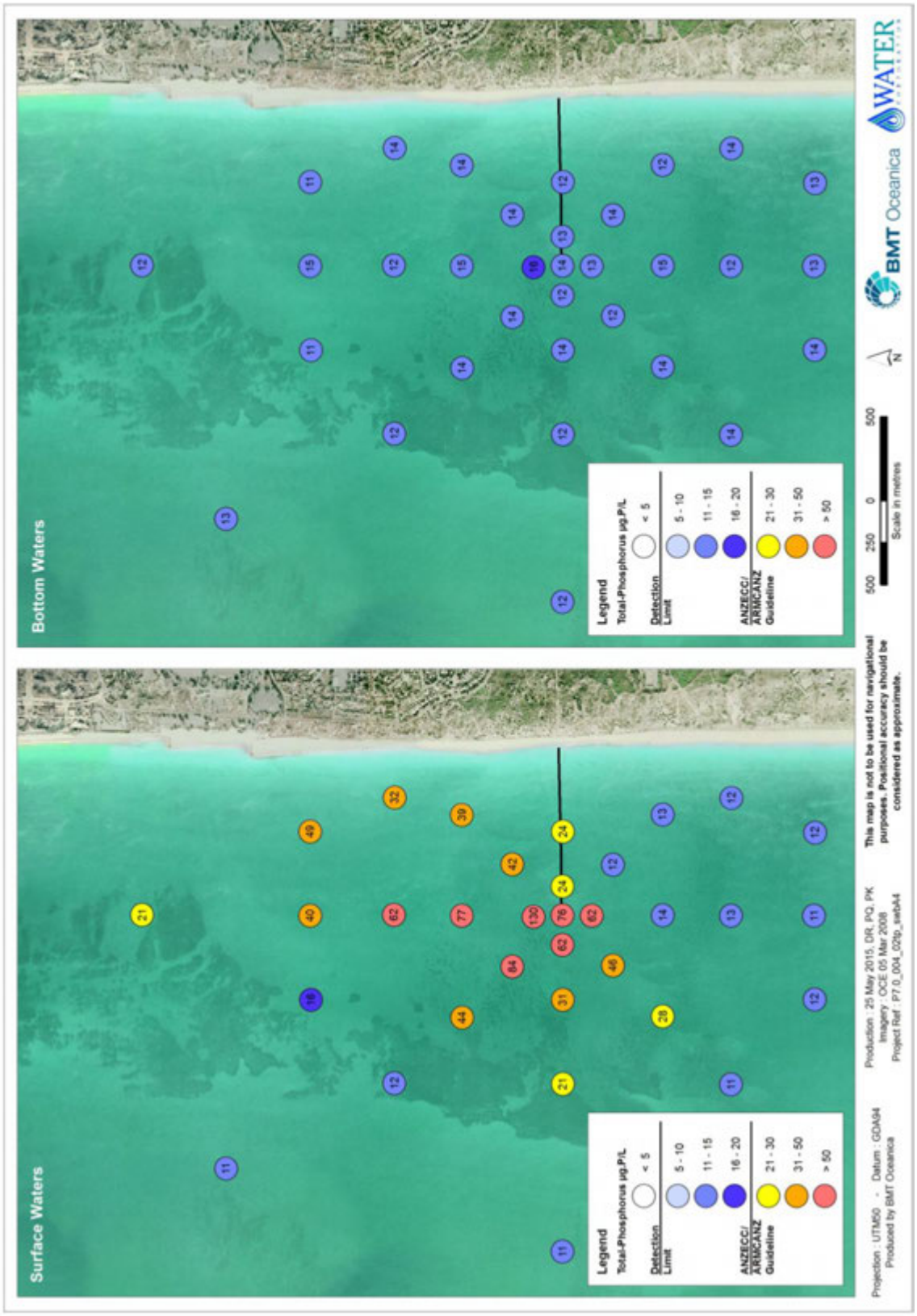
Total phosphorus (TP)

- Offshore surface concentrations of TP ranged from 11 to 130 µg/L with 15 (43%) sites below or equal to the ANZECC/ARMCANZ (2000) guideline of 20 µg/L. Bottom concentrations of TP ranged from 11 to 16µg/L; concentrations at all sites were below the ANZECC/ARMCANZ (2000) guideline (Figure 4.14).
- Surface concentrations of TP at 22 (63%) sites were below or equal to the 80th percentile reference value of 35 µg/L. Bottom concentrations of TP at all sites were below or equal to the 80th percentile reference value of 33 µg/L.
- Sites within 250 m from the diffuser had TP concentrations ranging between 24 and 130 µg/L (median of 62 µg/L) in surface waters and between 12 and 16 µg/L (median of 13 µg/L) in bottom waters. All surface sites within 250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline of 20 µg/L while four out of five surface sites exceeded the 80th percentile reference value of 35 µg/L. All bottom sites within 250 m from the diffuser were within guideline and reference values.
- Sites outside 250 m from the diffuser had TP concentrations ranging between 11 and 84 µg/L (median of 18.5 µg/L) in surface waters and between 12 and 15 µg/L (median of 13 µg/L) in bottom waters. Fifteen out of 30 (50%) surface sites outside 250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline of 20 µg/L compared to none of the bottom sites. Nine surface (and no bottom) sites exceeded the 80
- percentile reference value of 35 µg/L.
- TP concentrations at shoreline sites ranged from 15 µg/L (sites B, C and F) to 18 µg/L (sites A and D) (Figure 4.14). TP concentrations were below the ANZECC/ARMCANZ (2000) guideline of 20 µg/L at all shoreline sites.
- TP concentrations were elevated immediately around and to the north-west of the diffuser, while in bottom waters only one site north of the diffuser showed elevated TP concentrations (Figure 4.15).



Note:
1. Dashed line indicates ANZECC/ARMCANZ (2000) guideline value.

Figure 4.14 Total phosphorus concentrations at Swanbourne

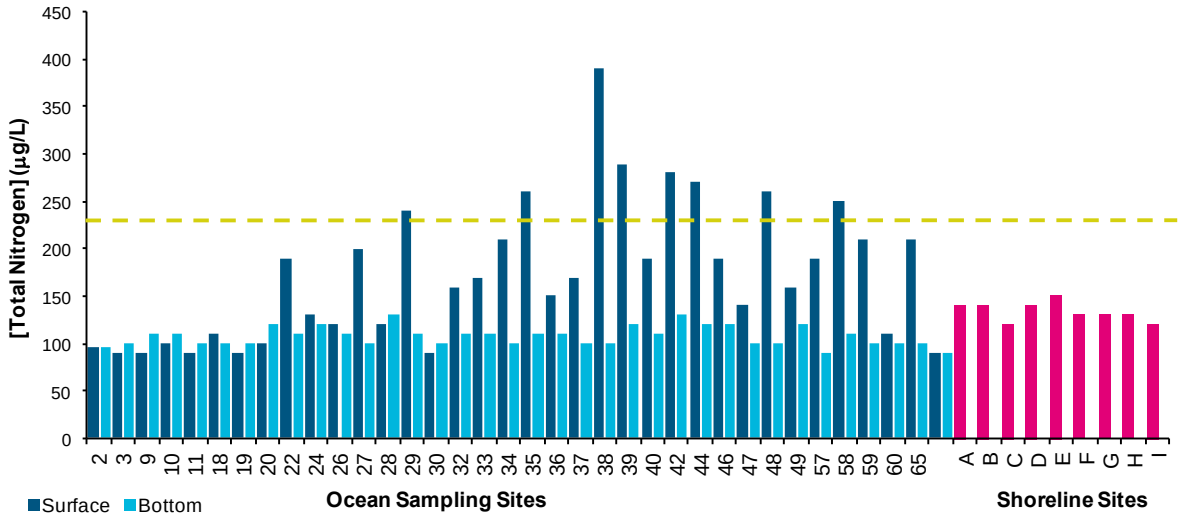


Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 4.3.
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline.

Figure 4.15 Total phosphorus concentrations at Swanbourne

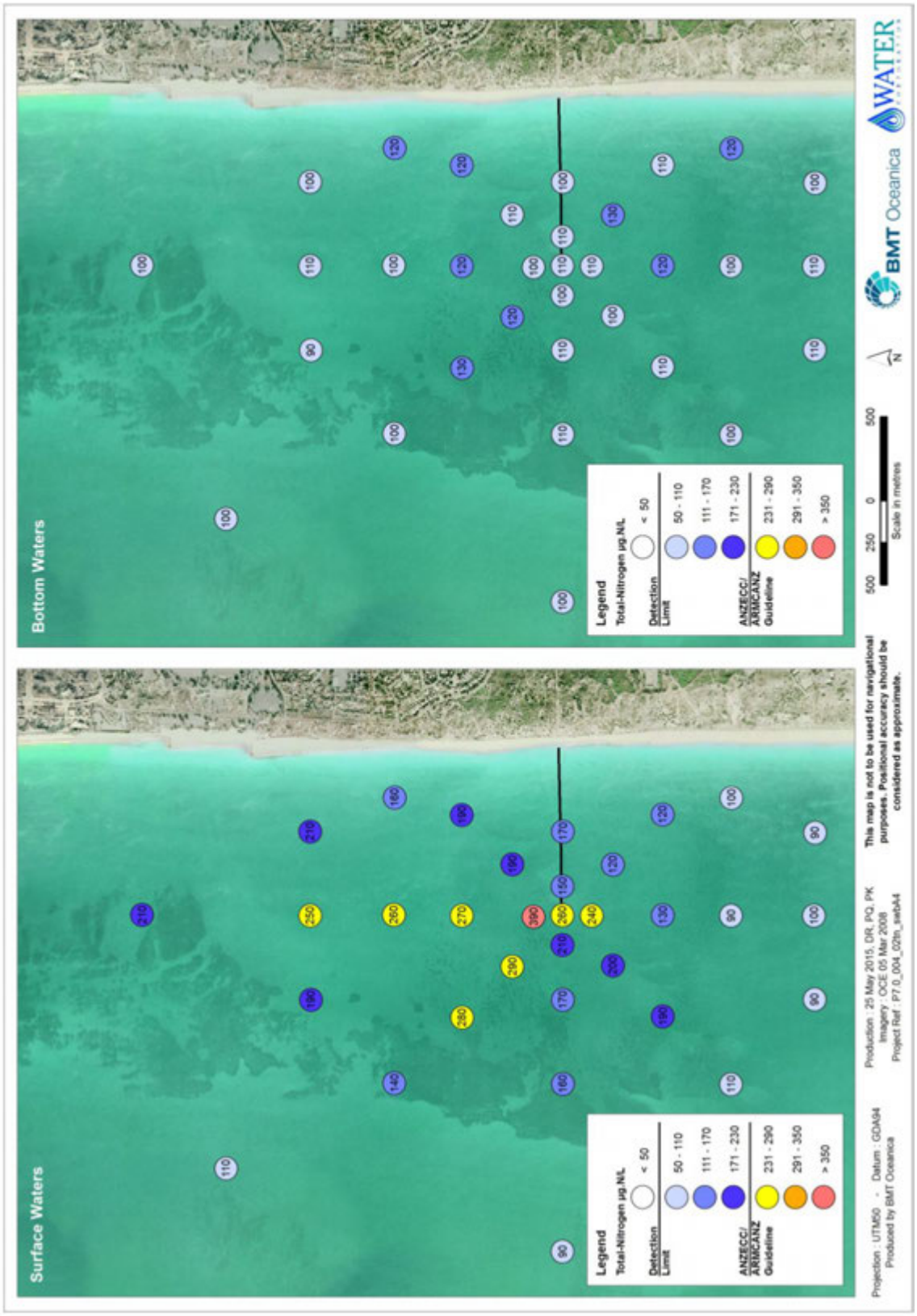
Total nitrogen (TN)

- Offshore surface concentrations of TN ranged from 90 to 390 µg/L with 27 (77%) sites below the ANZECC/ARMCANZ (2000) guideline of 230 µg/L. Bottom concentrations of TN ranged from 90 to 130 µg/L also with all sites below the ANZECC/ARMCANZ (2000) guideline (Figure 4.16).
- Surface concentrations of TN at 14 (40%) sites were below or equal to the 80th percentile reference value of 140 µg/L for surface waters. Bottom concentrations of TN at all sites were below or equal to the 80th percentile reference value of 130 µg/L.
- Sites within 250 m from the diffuser had TN concentrations ranging between 150 and 390 µg/L (median of 240 µg/L) in surface waters and between 100 and 110 µg/L (median of 110 µg/L) in bottom waters. Three out of five surface and all bottom TN concentrations at sites within 250 m from the diffuser were below the ANZECC/ARMCANZ (2000) guideline of 230 µg/L. All surface samples exceeded the surface 80th percentile reference values of 140 µg/L, while all the bottom values were below the 80th percentile bottom value (130 µg/L).
- Sites outside 250 m from the diffuser had TN concentrations ranging between 90 and 290 µg/L (median of 160 µg/L) in surface waters and between 90 and 130 µg/L (median of 110 µg/L) in bottom waters. Five surface samples outside 250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline of 230 µg/L. All bottom sites outside 250 m from the diffuser had TN concentrations below the ANZECC/ARMCANZ (2000) guideline of 230 µg/L. Sixteen surface sites outside 250 m from the diffuser exceeded the TN 80th percentile reference value of 140 µg/L (surface). All bottom sites outside 250 m from the diffuser had TN concentrations below or equal to the 80th percentile reference values of 140 µg/L (surface) and 130 µg/L (bottom).
- Total nitrogen concentrations at shoreline sites ranged from 120 µg/L (sites C and I) to 150 µg/L (site E) (Figure 4.16). All shoreline TN concentrations were below the ANZECC/ARMCANZ (2000) guideline of 230 µg/L.
- Surface TN concentrations were elevated immediately around and to the north of the diffuser (Figure 4.17).



1. Note:
2. Dashed line indicates ANZECC/ARMCANZ (2000) guideline value.

Figure 4.16 Total nitrogen concentrations at Swanbourne



Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 4.3.
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline.

Figure 4.17 Spatial distribution of total nitrogen at Swanbourne

4.5.4 Phytoplankton biomass and distribution

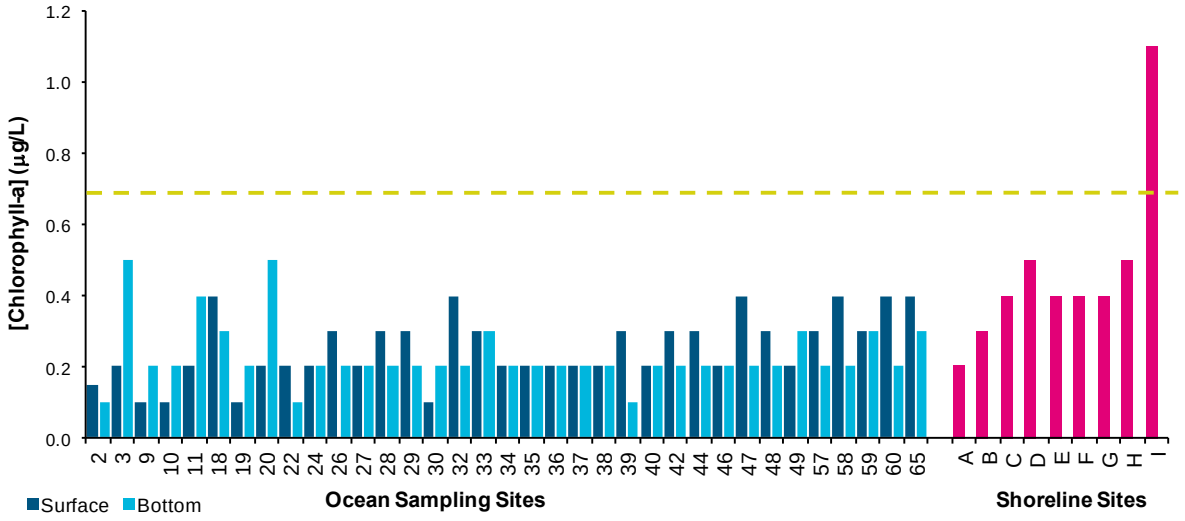
Phaeophytin

- Phaeophytin concentrations (Appendix D) were measured in surface waters at five offshore sites (sites 2, 20, 30, 49, 65). All samples were below the 0.2 µg/L detection limit.
- Phaeophytin concentrations at shoreline sites ranged from 0.2 to 0.4 µg/L.

Chlorophyll-a[21]

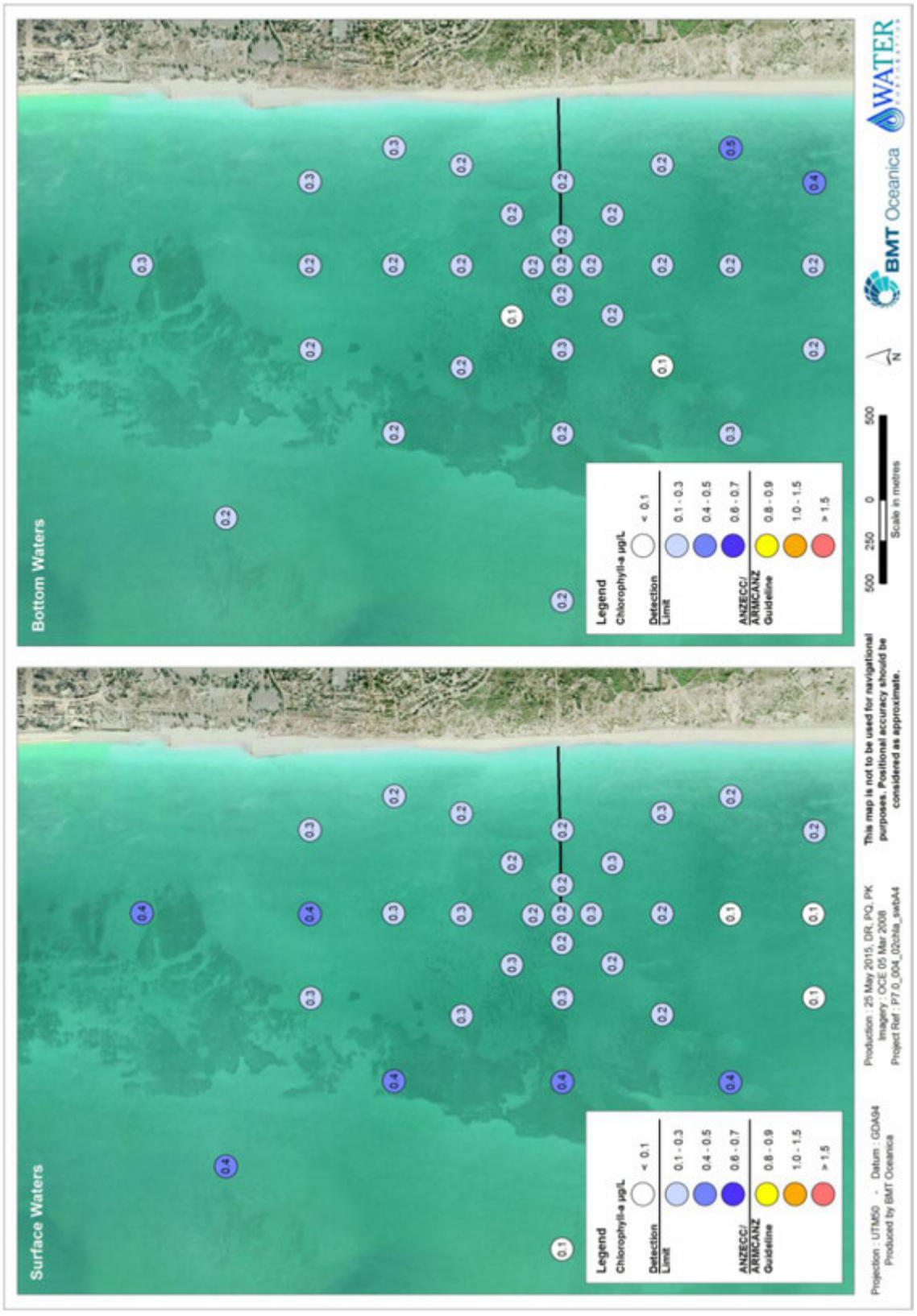
- Offshore surface concentrations of chlorophyll-a ranged from 0.1 to 0.4 µg/L, and bottom concentrations ranged from 0.1 to 0.5 µg/L. Surface and bottom concentrations at all sites were below the ANZECC/ARMCANZ (2000) guideline of 0.7 µg/L.
- Concentrations of chlorophyll-a at all sites were below the 80th percentile reference value of 0.5 µg/L (surface and bottom).
- Sites within 250 m from the diffuser had chlorophyll-a concentrations ranging between 0.2 and 0.3 µg/L (median of 0.2 µg/L) in surface waters. In bottom waters, concentration in all samples were 0.2 µg/L. All surface and bottom samples were within the ANZECC/ARMCANZ (2000) guideline of 0.7 µg/L and the 80th percentile reference value of 0.5 µg/L (surface and bottom).
- Sites outside 250 m from the diffuser had chlorophyll-a concentrations ranging between 0.1 and 0.4 µg/L in surface waters and bottom waters (median of 0.25 and 0.2 µg/L, respectively). There were no exceedances of the ANZECC/ARMCANZ (2000) guideline of 7 µg/L or the 80th percentile reference value of 0.5 µg/L.
- Chlorophyll-a concentrations at shoreline sites ranged from 0.2 µg/L (site A) to 1.1 µg/L (site I) (Figure 4.18). Concentrations at 8 (89%) of shoreline sites were below the ANZECC/ARMCANZ (2000) guideline (0.7 µg/L).
- There were no consistent spatial patterns in chlorophyll-a concentration (Figure 4.19).

[21] *Chlorophyll a concentrations at surface and bottom offshore sites were determined in-situ using a fluorometer; chlorophyll a concentrations at shoreline sites were analysed using an acetone extraction method.*



Note:
1. Dashed line indicates ANZECC/ARMCANZ (2000) guideline value.

Figure 4.18 Chlorophyll-a concentrations at Swanbourne



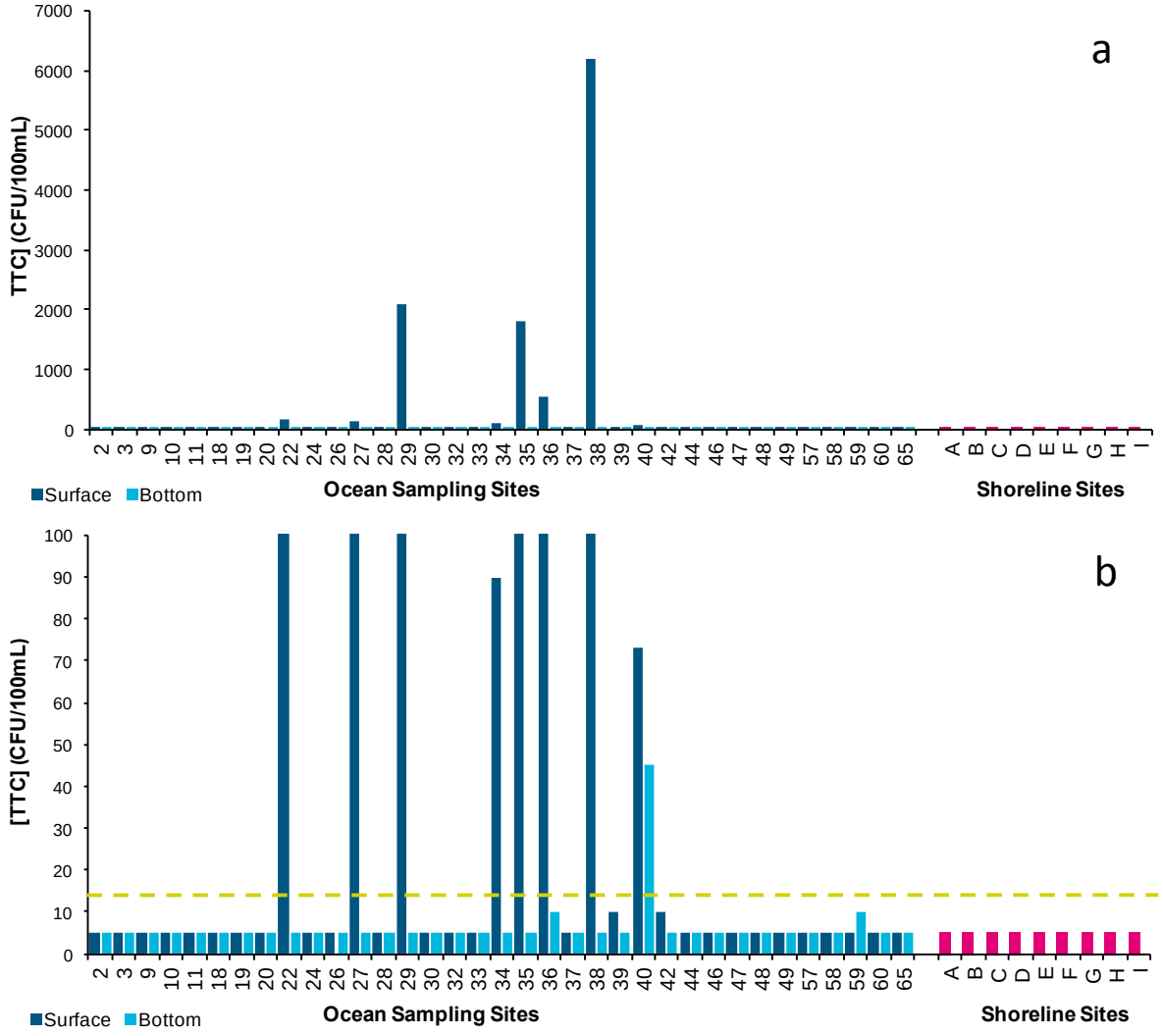
Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 4.3.
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline.

Figure 4.19 Spatial distribution of chlorophyll-a concentrations at Swanbourne

4.5.5 Bacterial concentrations and distribution

Thermotolerant coliforms (TTC)

- The highest offshore surface concentration of TTC was 6200 CFU/100 mL at site 38, located 148 m from the diffuser (Figure 4.20a). The next highest concentration was 2100 CFU/100 mL at site 29, located 160 m from the diffuser. The majority (25) of sites had surface TTC concentrations below the reporting limit (10 CFU/100 mL).
- The highest offshore bottom concentration of TTC was 45 CFU/100 mL at site 40, 394 m west of the diffuser (Figure 4.20b). The next highest concentration was 10 CFU/100 mL at sites 36 and 59. All remaining sites had bottom TTC concentrations below the reporting limit of 10 CFU/100 mL.
- All shoreline sites had TTC concentrations of <10 CFU/100 mL.
- Median TTC concentrations at surface sites <250 m from the diffuser exceeded the EQG and EQS trigger values (Table 4.3). Median TTC concentrations at surface sites >250 m from the diffuser, and all bottom sites were below the EQG (Table 4.3).
- The median TTC concentration of shoreline sites was below the EQG and EQS trigger values (Table 4.3).
- Elevated TTC concentrations (Figure 4.21) in surface waters were evenly distributed around the diffuser. For bottom waters the single elevated sample was a moderate distance north-east of the diffuser.



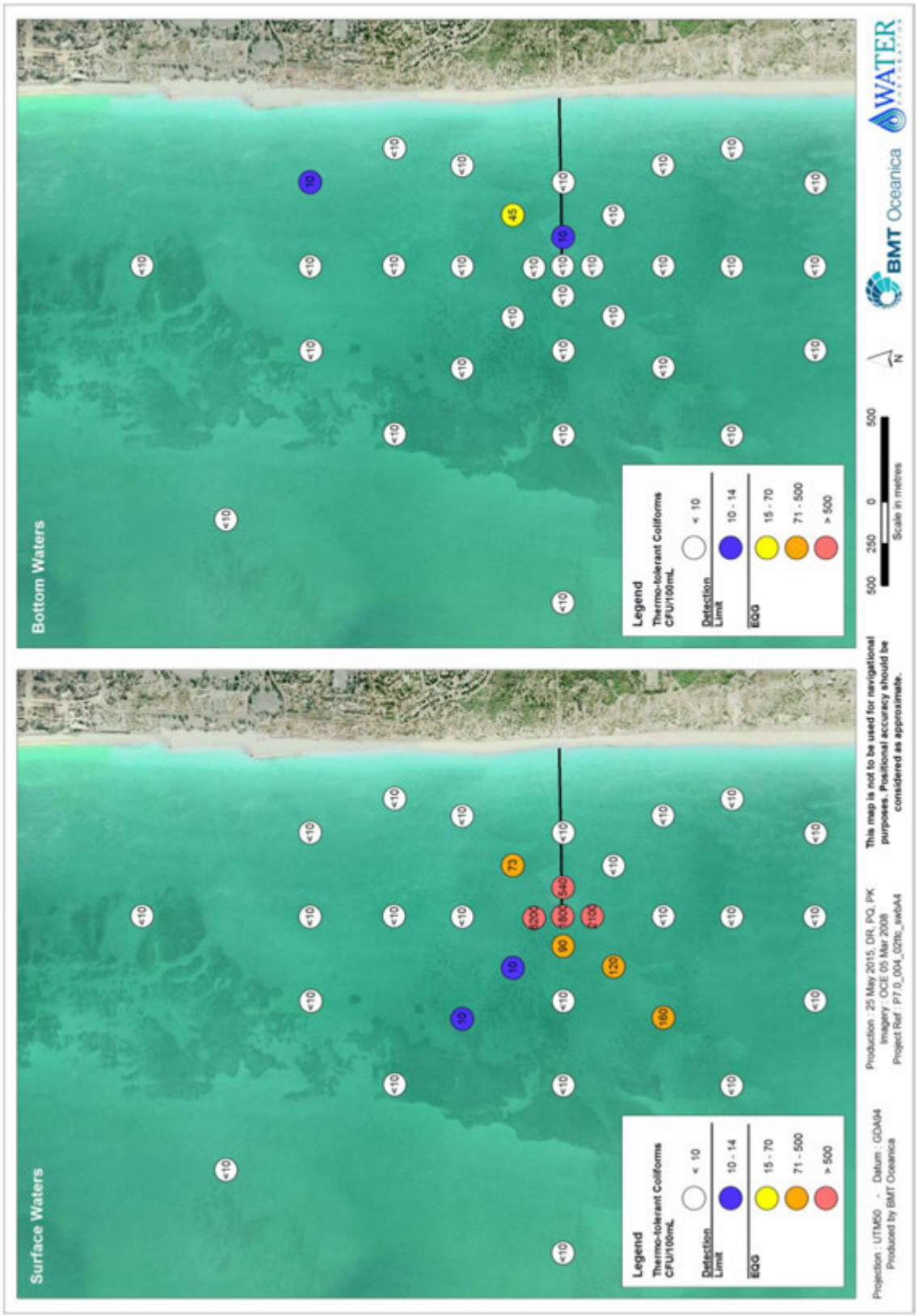
Note:
1. Dashed line indicates EQG (EPA 2005) guideline value

Figure 4.20 Thermotolerant coliform concentrations at Swanbourne

Table 4.3 Median thermotolerant coliforms concentrations at Swanbourne

Sites	Surface	Bottom	EQC[2]
<250 m from the diffuser	1800 CFU/100 mL	<10 CFU/100 mL	14 CFU/100mL (EQG)
>250 m from the diffuser	<10 CFU/100 mL[1]	<10 CFU/100 mL[1]	70 CFU/100 mL (EQS)
Shoreline	<10 CFU/100 mL[1]	–	

Notes:
1. 10 CFU/100 mL is the lower assay limit for the parameter.
2. From EPA (2005)

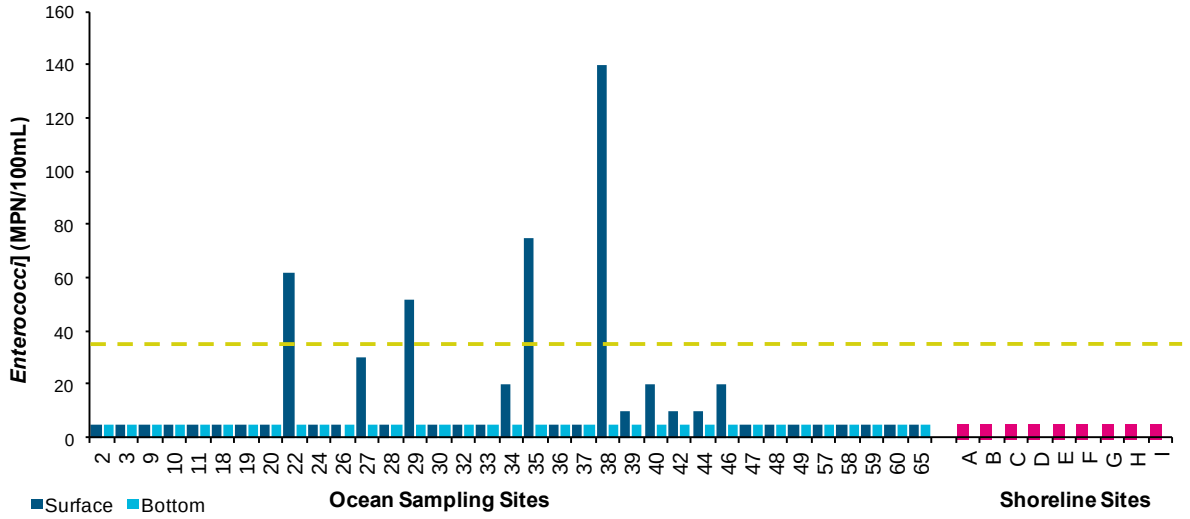


1. Notes:
2. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 4.3.
3. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or EQG.

Figure 4.21 Spatial distribution of thermotolerant coliform concentrations at Swanbourne

Enterococci spp.

- The highest offshore surface concentration of *Enterococci* spp. was 140 MPN/100 mL at site 38. The next highest *Enterococci* spp. concentration of 75 MPN/100 mL at sites 35. The majority (24) of sites had *Enterococci* spp. concentrations below the reporting limit of 10 MPN/100 mL (Figure 4.22)
- The offshore bottom concentration of *Enterococci* spp. was below the reporting limit of 10 MPN/100 mL at all sites.
- Median *Enterococci* spp. concentrations at surface sites <250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guidelines for primary contact recreation, but were below the guideline for secondary contact recreation. Median *Enterococci* spp. concentrations at surface sites >250 m from the diffuser, and at all bottom sites were below the guideline values (Table 4.4).
- All shoreline sites had concentrations of *Enterococci* spp. <10 MPN/100 mL.
- Concentrations of *Enterococci* spp. (Figure 4.23) in surface waters were evenly distributed around the diffuser.



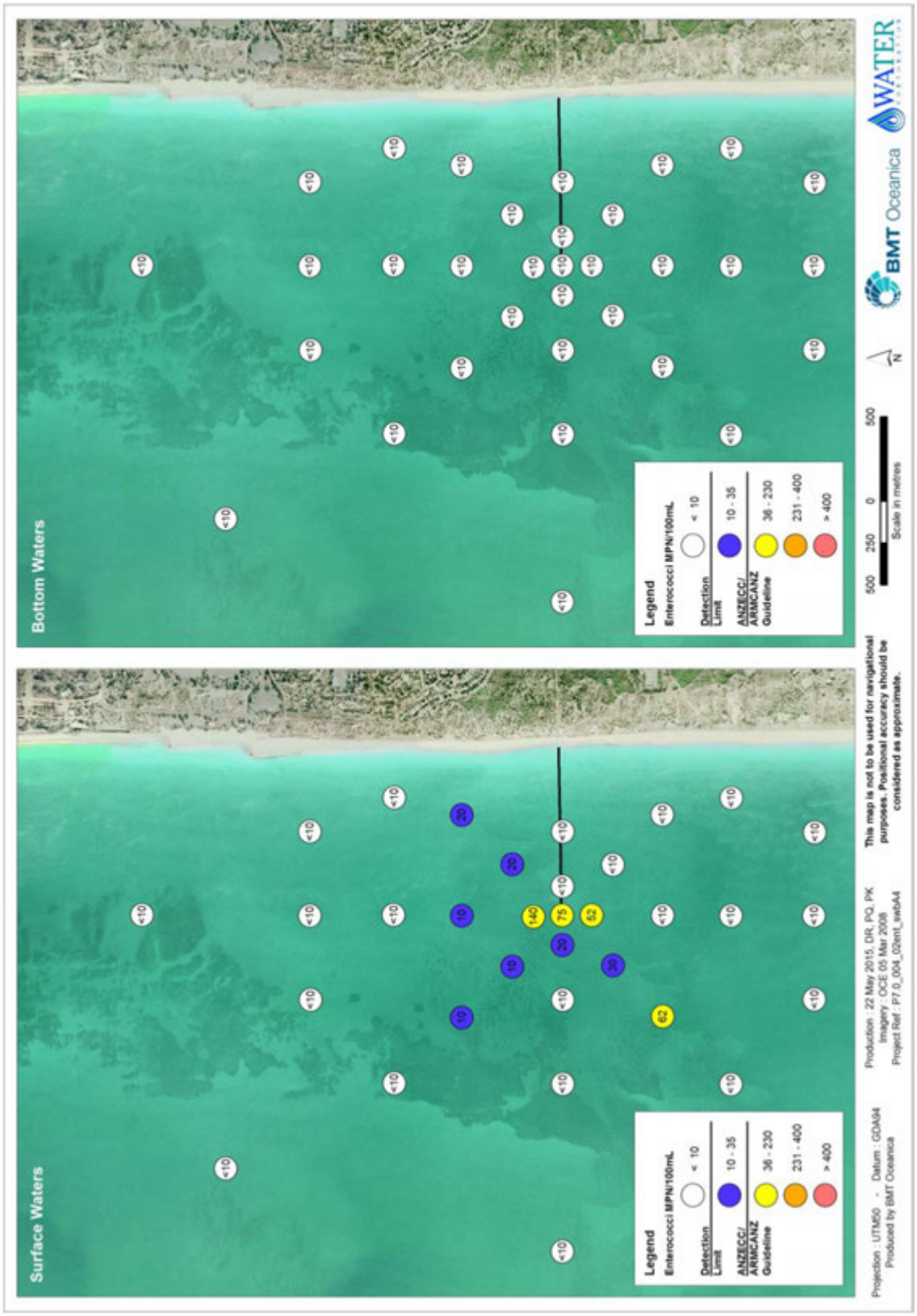
Note:
1. Dashed line indicates ANZECC/ARMCANZ (2000) guideline value.

Figure 4.22 *Enterococci* spp. concentrations at surface Swanbourne

Table 4.4 Median *Enterococci* spp. concentrations at Swanbourne

Sites	Surface	Bottom	ANZECC/ARMCANZ (2000)
<250 m from the diffuser	52	<10	35 MPN/100 mL (primary contact) 230 MPN/100 mL (secondary contact)
>250 m from the diffuser	<10(1)	<10(1)	
Shoreline	<10(1)		

Note:
1. 10 MPN/100 mL is the lower assay limit for the parameter.



Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 4.3.
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline.

Figure 4.23 Spatial distribution of *Enterococci* spp. at Swanbourne

4.6 Conclusions

During the survey on 20 January 2015 at Swanbourne, the treated wastewater plume was initially buoyant (as indicated by the slightly higher concentrations of nutrients and microbiological indicators in surface waters than in bottom waters) and was advecting in a northerly direction from the outlet.

The survey captured the extent of the elevated nutrient concentrations related to the discharge of treated wastewater into the marine environment at the Swanbourne ocean outlet. Generally, nutrient concentrations were higher at surface sites closer to the diffuser than at sites located further from the outlet.

The summer water quality surveys were not specifically designed to provide information suitable for comparison with ANZECC/ARMCANZ (2000) guidelines or with 80th percentile of reference values. For information only, water quality parameters at sites located <250 m and >250 m from the diffuser were compared with the ANZECC/ARMCANZ (2000) guidelines and 80th percentile of reference values.

ANZECC/ARMCANZ (2000) suggests that an exceedance of a trigger value should be regarded as an 'early warning' and, furthermore, that trigger values are not intended as a means of assessing 'compliance'. Parameters with medians exceeding the ANZECC/ARMCANZ (2000) guideline values during the 2015 survey at Swanbourne (Table 4.5):

- $NH4^+$ in surface waters at sites <250 m from the diffuser
- Ortho-phosphate in surface waters <250 m from the diffuser
- NO_2^-+NO_3^- at the shoreline sites
- Total phosphorus in surface waters <250 m from the diffuser
- Total nitrogen in surface waters <250 m from the diffuser
- Chlorophyll-a at shoreline sites

Nitrogen is a nutrient limiting primary productivity in Perth's near-shore coastal waters (Lord & Hillman 1995). Historical concentrations of total nitrogen and NH_4^+ measured at Swanbourne are generally below the ANZECC/ARMCANZ (2000) guideline values; this is demonstrated by the lower 80th percentile of reference values. Parameters with medians exceeding the ANZECC/ARMCANZ (2000) guideline values during the 2015 survey at Swanbourne (Table 4.5):

- $NH4^+$ in surface waters at sites <250 and >250 m from the diffuser
- Ortho-phosphate in surface waters <250 m from the diffuser
- Total phosphorus in surface waters <250 m from the diffuser
- Total nitrogen in surface waters <250 and >250 m from the diffuser
- Chlorophyll-a at shoreline sites

Table 4.5 Summary comparison of median nutrient and chlorophyll-a values with the 80th percentile of background concentrations at Swanbourne

ANZECC/ARMCANZ (2000) guideline values					
Parameter	**Inside the mixing zone (sites <250 m from diffuser)**		**Outside the mixing zone (sites >250 m from diffuser)**		**Shoreline**
	Surface	**Bottom**	**Surface**	**Bottom**	
Total ammonia nitrogen					
Ortho-phosphate					
Nitrate+nitrite					
Total phosphorus					
Total nitrogen					
Chlorophyll-a					
80th percentile of reference values					
Parameter	**Inside the mixing zone (sites <250 m from diffuser)**		**Outside the mixing zone (sites >250 m from diffuser)**		**Shoreline**
	Surface	**Bottom**	**Surface**	**Bottom**	
Total ammonia nitrogen					
Ortho-phosphate					
Nitrate+nitrite					
Total phosphorus					
Total nitrogen					
Chlorophyll-a					

Notes:
1. Assessment criteria for surface, bottom and shoreline sites:
2. Green = Nutrient median values ≤ ANZECC/ARMCANZ (2000) guideline values / ≤80th percentile reference values.
3. Red = Nutrient median values > ANZECC/ARMCANZ (2000) guideline values / >80th percentile reference values.

Median thermotolerant coliform (TTC) concentrations were below or equal to the EQG for the maintenance of seafood safe for human consumption in surface and bottom waters >250 m from the diffuser (Table 4.6). A decline in concentrations away from the outlet indicates die-off of the microbes.

Table 4.6 Summary comparison of the EQG with the median concentrations of thermotolerant coliforms at Swanbourne

Parameter	**Environmental Quality Guideline (EPA 2005)[1]**				
	<250 m		**>250 m**		**Shoreline**
	Surface	**Bottom**	**Surface**	**Bottom**	
Thermotolerant coliforms					

Notes:
1. For the maintenance of seafood safe for human consumption.
2. Green= median values ≤ EQG.
3. Red = median values > EQG.

Concentrations of Enterococci spp. met the guideline for primary contact recreation in all cases except surface waters <250 m from the diffuser (Table 4.7). Shoreline monitoring found no indication of contamination of any beaches adjacent to the outlets (Table 4.7).

Table 4.7 Summary comparison of the ANZECC/ARMCANZ guideline with the median concentrations of *Enterococci* spp. at Swanbourne

Parameter	ANZECC/ARMCANZ (2000)[1]				
	<250 m		>250 m		Shoreline
	Surface	Bottom	Surface	Bottom	
Enterococci spp.					

Notes:
1. Results for primary contact recreation.
2. Green = median values ≤ ANZECC/ARMCANZ (2000) guideline.
3. Red = median values > ANZECC/ARMCANZ (2000) guideline.

The results from the summer water quality survey on 20 January 2015 indicate that the WWTP at Swanbourne was operating effectively and the plume of treated wastewater rapidly dissipated once it entered the environment. Despite elevated levels of water quality parameters at some individual sites outside the immediate zone of influence of the outlet, the water quality conditions required for ecosystem protection and public health criteria were met.

Summer Water Quality Survey

Sepia Depression

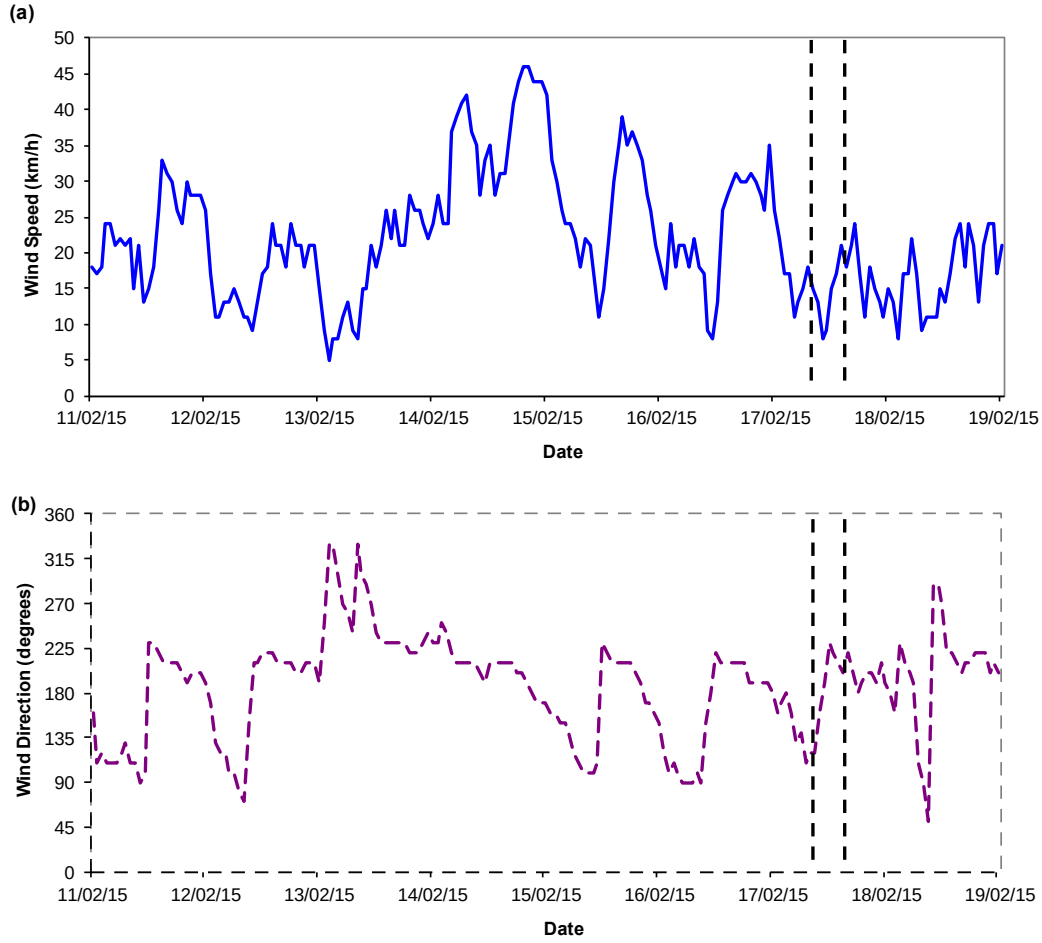
17 February 2015

WATER CORPORATION

5. Sepia Depression Summer Water Quality Survey – Results and Interpretation

5.1 Wind, wave and tide conditions

The survey at Sepia Depression was undertaken on 17 February 2015. For 24 hours prior to the survey, winds at Sepia Depression were moderate southerly breezes that averaged 22.7 km/h. During the survey, winds at Sepia Depression were gentle to easterlies (average 15.3 km/h) changing to gentle southerlies (average 14.0 km/h) (Figure 5.1a and b).



Note:
1. Dashed lines (- -) show approximate timing of the summer water quality survey.
2. a = wind speed
3. b = wind direction

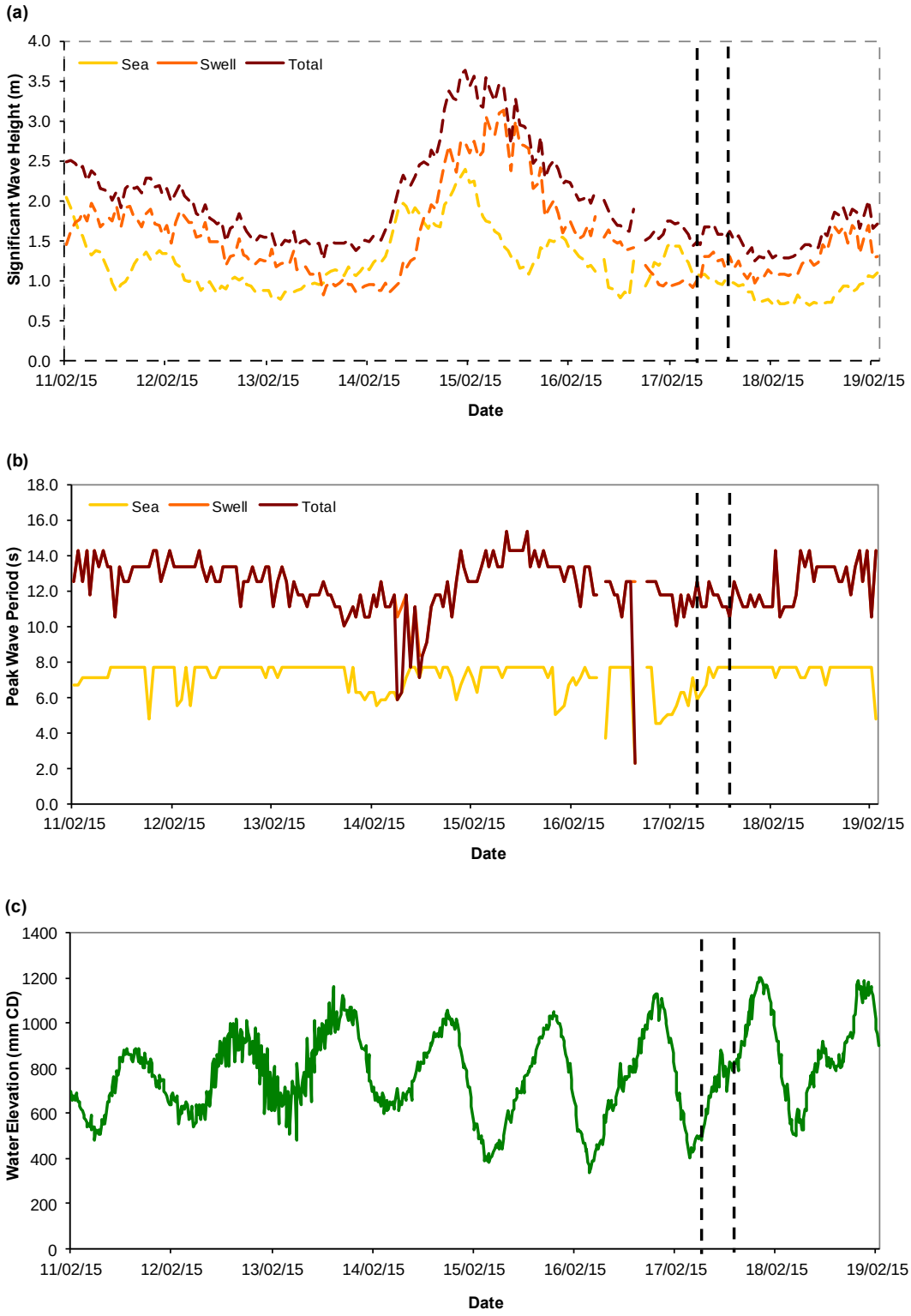
Figure 5.1 Wind speed and direction at Sepia Depression

For the 24 hours prior to the survey, the average significant wave height[22] offshore from Rottnest Island was 1.67 m[23], with an average peak wave period[24] of 11.36 s[23] (Figure 5.2a and b). During the survey, the average offshore significant wave height decreased to 1.59 m, while the peak wave period was 11.53 s. The survey was undertaken during a rising tide (Figure 5.2c).

[22] *The significant wave height (in metres) is defined as the average height of the highest one-third of waves recorded (source: http//www.dpi.wa.gov.au/).*

[23] *All significant wave heights and wave periods presented are for the 'total' wave conditions, that is, the combined sea and swell conditions.*

[24] *The wave period (in seconds) is the time between consecutive wave crests. The peak wave period is the wave period of those waves that are producing the most energy in a wave record.*



Notes:
1. Dashed lines (- -) show approximate timing of the summer water quality survey.
2. For the period shown, the swell component of peak wave period (graph (b)) exactly matched the total wave period.
3. a = significant wave height
4. b = peak wave height
5. c = water level elevation

Figure 5.2 Significant wave heights (offshore Rottnest Island), peak wave periods (offshore Rottnest Island) and water level elevation (Fremantle Fishing Boat Harbour)

5.2 Discharge from outlet

The characteristics of the treated wastewater from Point D on the Sepia Depression Ocean Outlet Landline (SDOOL) measured from a 24-hour composite sample collected prior to and during the survey at Sepia Depression on 17 February 2015are presented in Table 5.1.

Table 5.1 Characteristics of the Point D SDOOL treated wastewater on 17 February 2015

PARAMETER	Concentration
Total phosphorus	5.7 mg/L
Total nitrogen	26 mg/L
Total ammonia nitrogen	21 mg/L
Nitrate+nitrite	0.6 mg/L
Thermotolerant coliforms	>1000000 CFU/100 mL
Enterococci spp.	240000 MPN/100 mL
Total suspended solids	81 mg/L
Biological oxygen demand	46 mg/L
Total flow	145.26 ML/d

5.3 Surface drogue movement

The surface drogue, released over the centre of the diffuser at the beginning of the survey, drifted in a north-westerly direction with an average velocity of 0.14 m/s (Figure 5.3). At the time of the survey it was expected that the discharged treated wastewater would advect to the north and offshore of the diffuser.

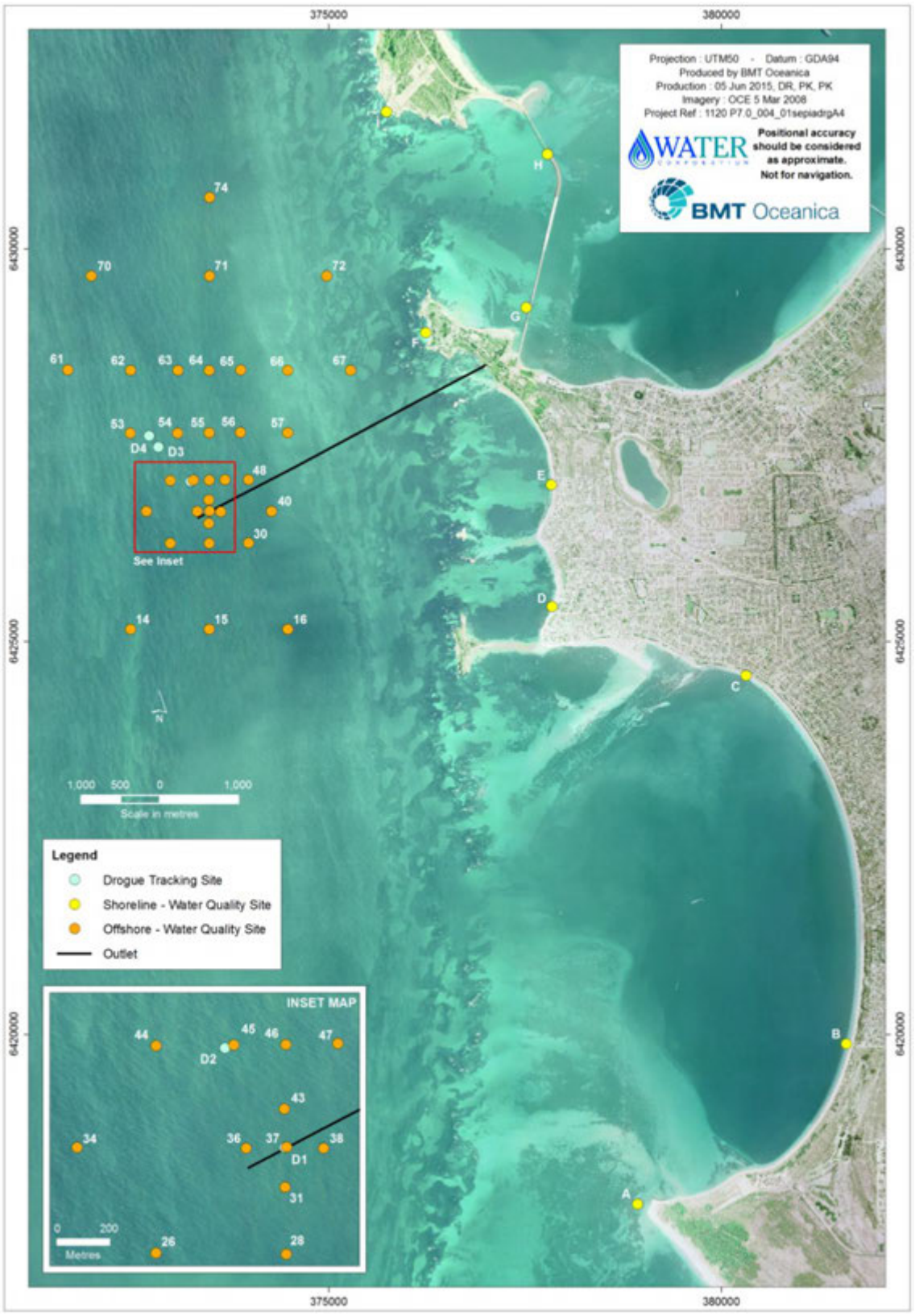
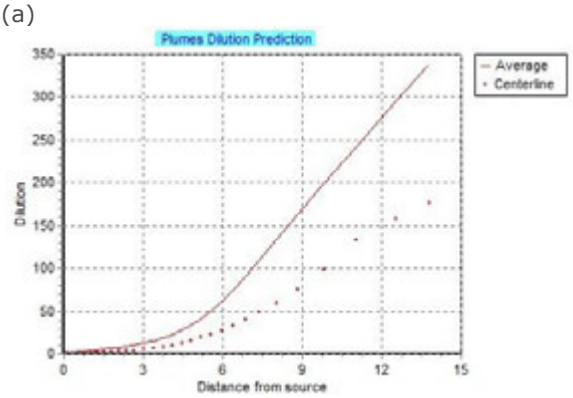


Figure 5.3 Sepia Depression ocean outlet summer water quality survey sites and drogue tracking sites, 17 February 2015

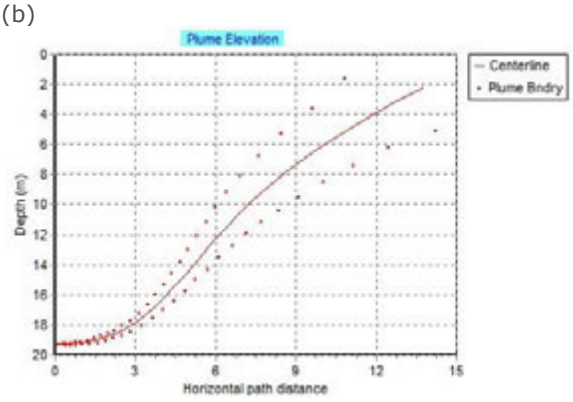
5.4 Initial dilution modelling

For the ambient conditions at the time of the summer water quality survey on 17 February 2015, the modelling predicted an average initial dilution of 1:338 and a centreline dilution of 1:176 (Figure 5.4a). The plume was predicted to first reach the surface within approximately 14 m (horizontal distance) from the discharge point (see the ambient boundary[25] of the plume in Figure 5.4b). The full model output is included in Appendix B.

(a)



(b)



Notes:
1. a = predicted average and centreline dilution
2. b = predicted plume elevation

Figure 5.4 predicted average and centreline dilutions and predicted plume elevation trajectory at Sepia Depression

5.5 Water quality

The grid for northerly flow conditions at Sepia Depression was sampled during the survey on 17 February 2015, given prevailing southerly winds during the survey period (Section 5.1). Water samples were collected from the surface and bottom waters of the 34 offshore sites and from the nine shoreline sites (Figure 5.3). Tables containing the concentrations of all water quality parameters taken during the summer survey are included in Appendix D.

5.5.1 Water column structure

Water column profiles were collected at eight sites (sites 31, 36, 37, 38, 43, 46, 55 and 64). Water temperature ranged from 22.59°C to 23.19°C, salinity ranged from 35.74 to 36.12[26] and dissolved oxygen varied from 6.30 mg/L to 6.60 mg/L (equivalent to 89.8–94.3% saturation) (Figure 5. and Figure 5.6). Temperature was relatively constant with depth at all sites except 55 and 64, which showed evidence of a thermocline with surface waters ~0.5 °C warmer than bottom waters. The salinity profiles at sites 31, 36, 37, 38, 43 and 46 suggest a body of lower-salinity water in the top ~5 m.
The dissolved oxygen profiles at all sites showed little variation with depth (difference of 0.3 mg/L between minimum and maximum values) and were not indicative of the presence of the treated wastewater plume.

[25] *The ambient boundary corresponds to the plume boundary at which concentrations are estimated to be equal to ambient conditions.*
[26] *Salinity throughout this report is referred to without units according to the Practical Salinity Scale. On this scale salinity is defined as the ratio of conductivities and therefore cannot have units. Seawater typically has a salinity in the range of 34–36.*

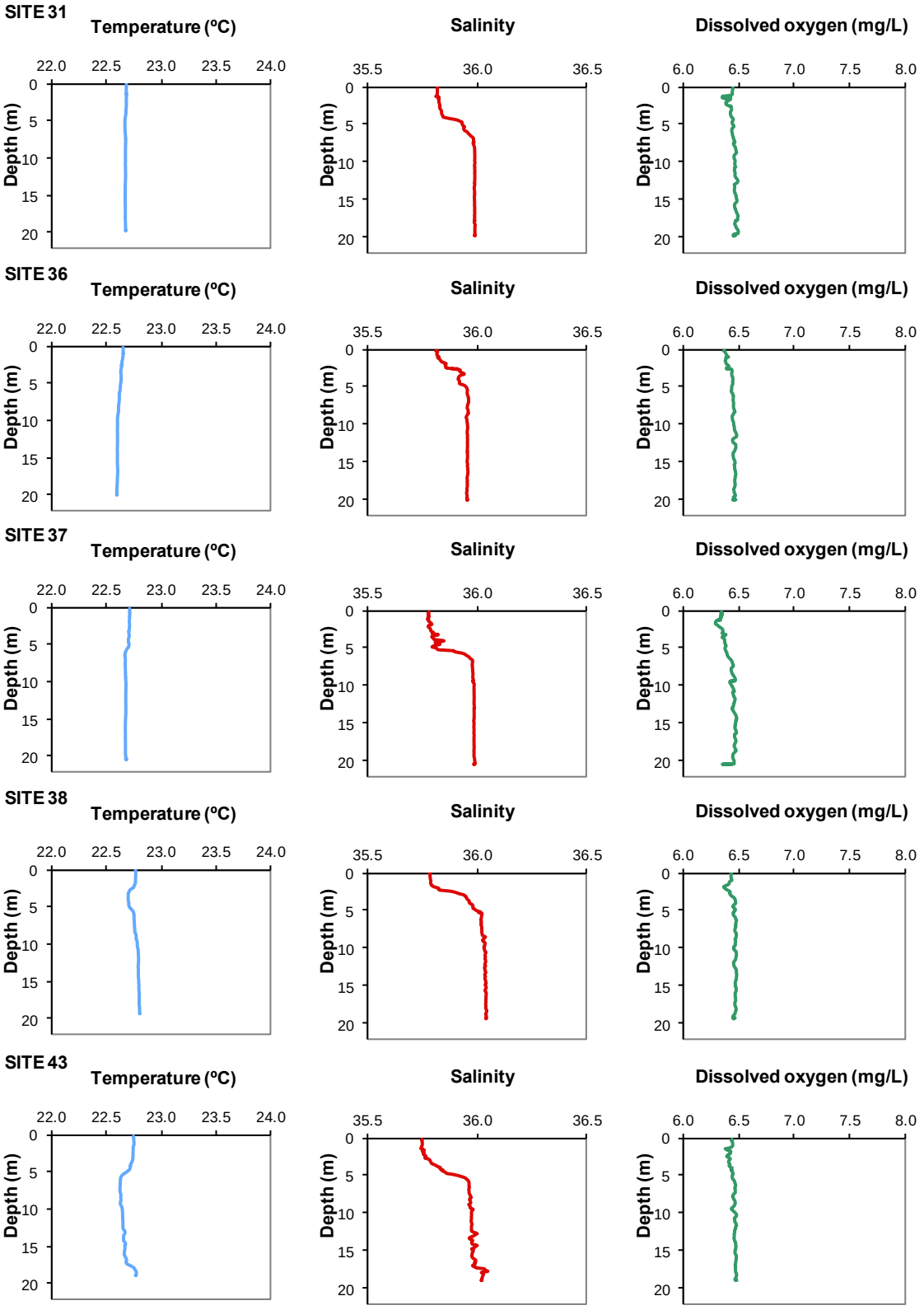


Figure 5.5 Temperature, salinity and dissolved oxygen vertical profiles at Sepia Depression

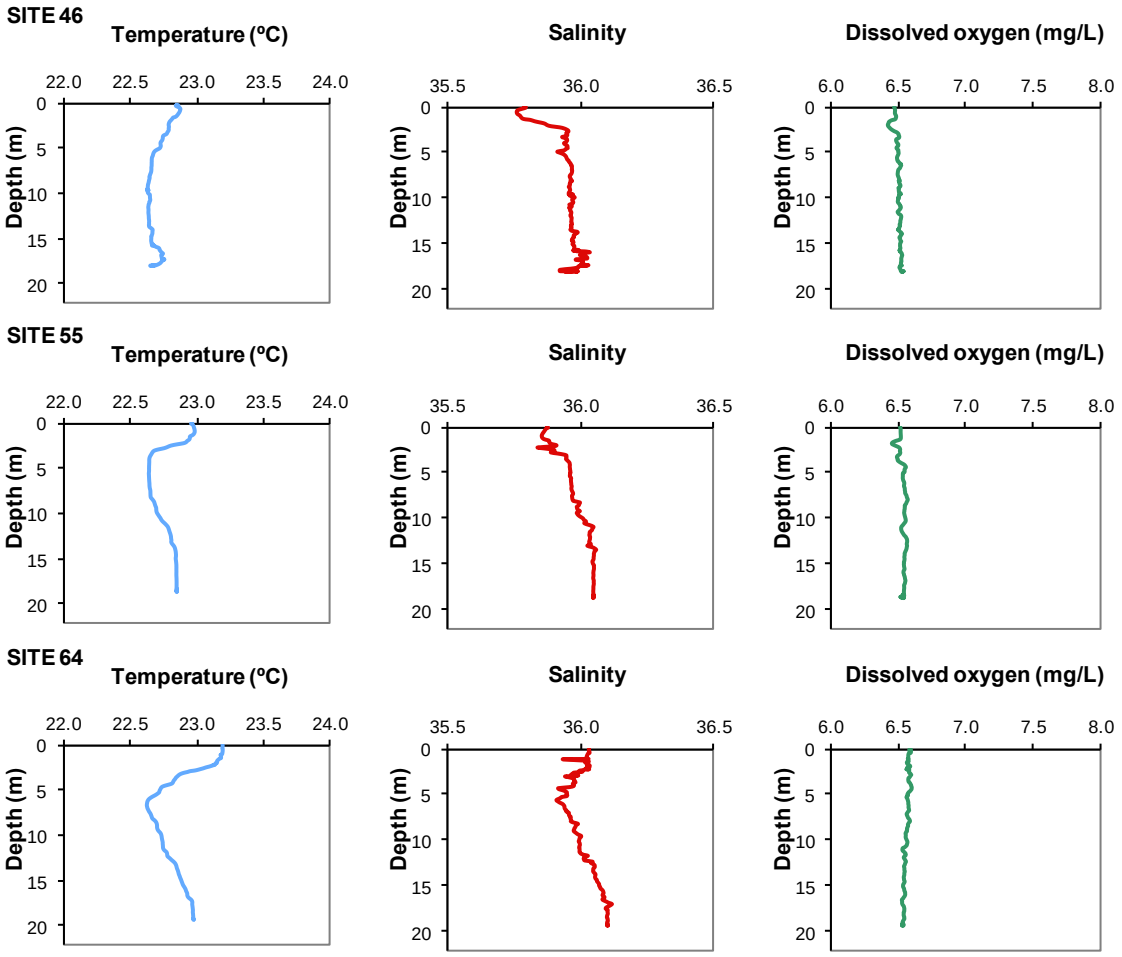
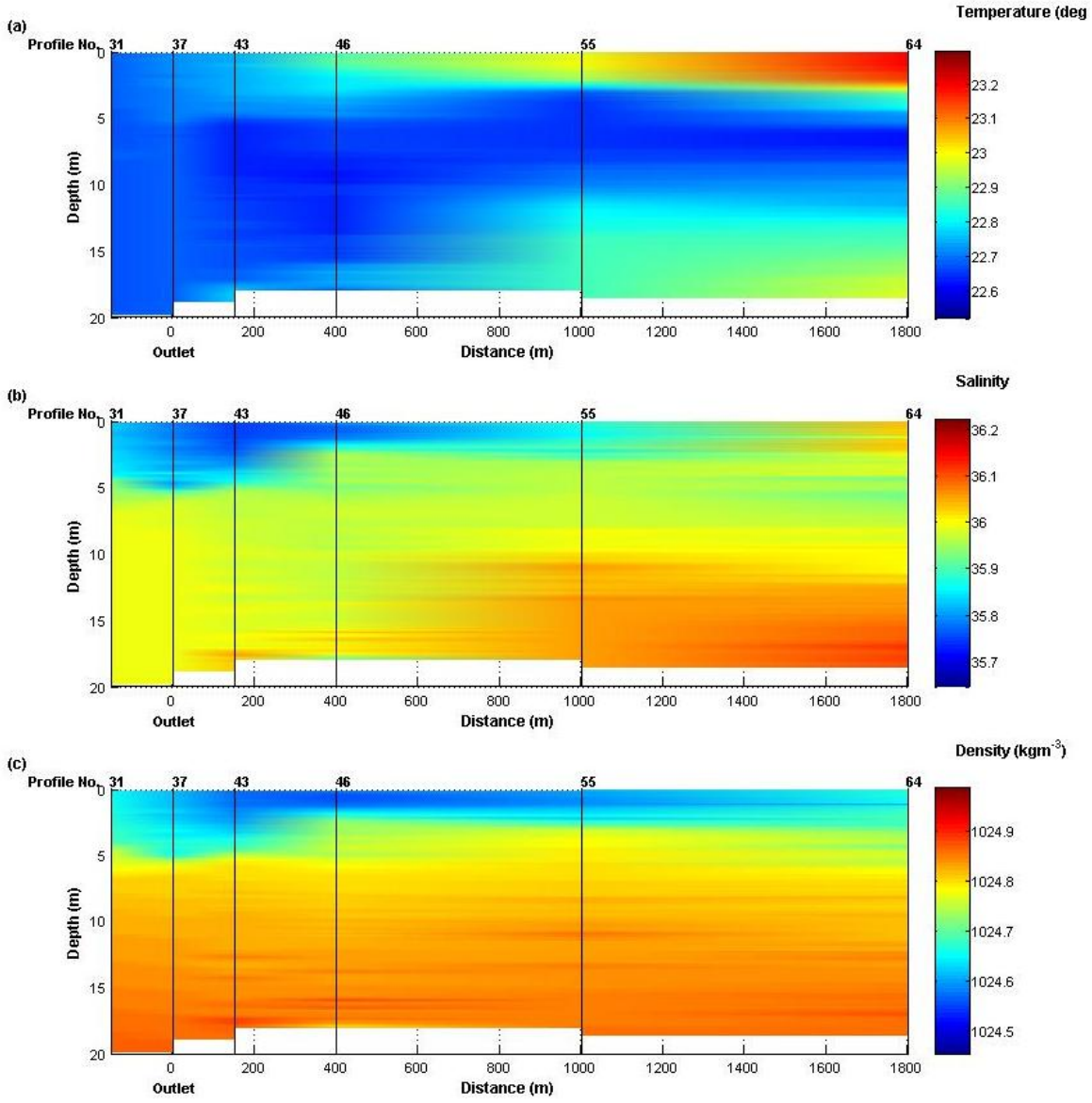


Figure 5.6 Temperature, salinity and dissolved oxygen vertical profiles at Sepia Depression

The effect of the discharged wastewater on the physical structure of the water column is illustrated in Figure 5.7. The colour scales used in Figure 5.7 range from the minimum to the maximum of each parameter, thus exaggerating small differences in measurements. Water temperature was generally coolest near the outlet (sites 31, 37 and 43) before warming in surface waters approximately 400 m north of the diffuser (Figure 5.7a). A body of lower-salinity surface water was evident above the diffuser and extending ~1.5 km north before reaching background salinities (Figure 5.7b). Density showed a stratified profile at all sites; the top ~5 m had lower water density than bottom waters (Figure 5.7c).



Notes:
1. a = temperature
2. b = salinity
3. c= density

Figure 5.7 Temperature, salinity and density transect at Sepia Depression

5.5.2 Replicate samples

Variance in measurements of water quality parameters may be introduced by small-scale spatial variability in the water column or by variability among laboratory analyses. To examine the range of this variance, three surface samples were collected at site 15 (Table 5.2). The results indicated that in general, the variability amongst replicates was small. The mean value of these replicate samples was used as representative of the water quality parameters at site 15.

Table 5.2 Replicate surface samples from site 15, Sepia Depression, 17 February 2015

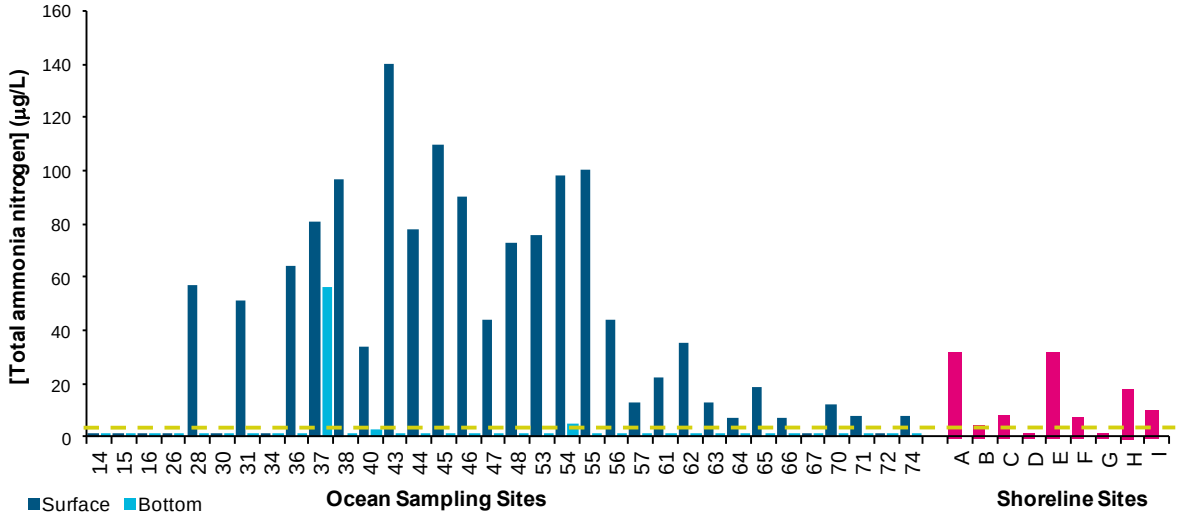
Parameter	Total ammonia nitrogen	Ortho-phosphate	Nitrate+nitrite	Total phosphorus	Total nitrogen
Units	µg/L	µg/L	µg/L	µg/L	µg/L
Reporting limit	<3	<2	<2	<5	<50
Surface rep 1	<3	<2	<2	11	80
Surface rep 2	<3	<2	<2	10	70
Surface rep 3	<3	<2	<2	10	80
Mean	*<3*	*<2*	*<2*	*10.3*	*76.7*
Parameter	**Chlorophyll-a** *(fluorometry)*	**Chlorophyll-a** *(Acetone)*	**Phaeophytin**	**Thermotolerant coliforms**	***Enterococci* spp.**
Units	µg/L	µg/L	µg/L	CFU/100mL	MPN/100mL
Reporting Limit	<0.1	<0.1	<0.2	<10	<10
Surface rep 1	0.3	0.3	<0.2	<10	<10
Surface rep 2	0.4	0.4	<0.2	<10	<10
Surface rep 3	0.4	0.4	<0.2	<10	<10
Mean	*0.37*	*0.37*	*<0.2*	*<10*	*<10*

Note:
1. Mean values were calculated by replacing values below the reporting limit as half the reporting limit.

5.5.3 Nutrient concentrations and distribution

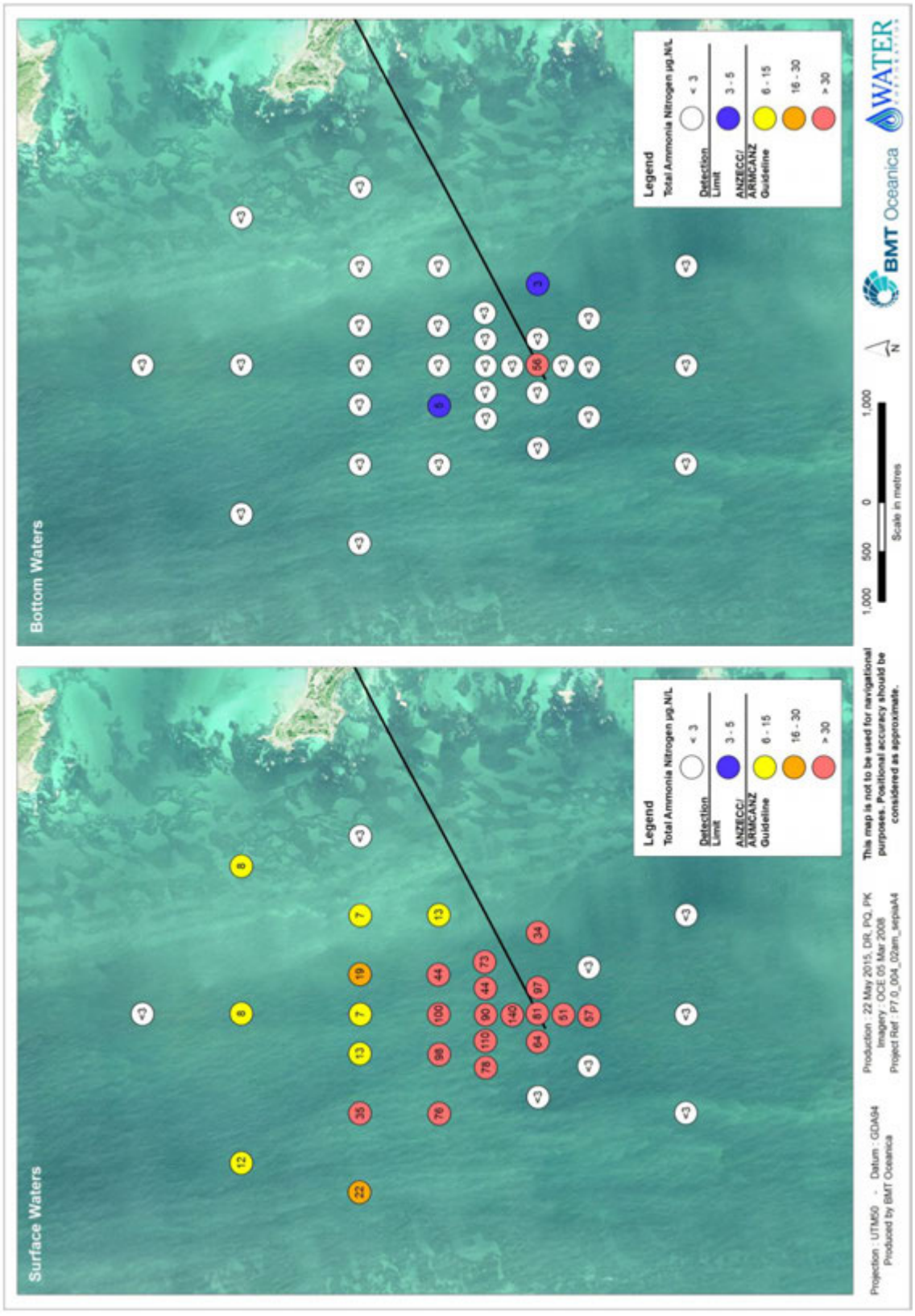
Total ammonia nitrogen (NH_4^+)

- Offshore surface concentrations of NH_4^+ ranged from <3 to 140 µg/L with 8 (26%) sites below the ANZECC/ARMCANZ (2000) guideline of 5 µg/L. Bottom concentrations of NH_4^+ ranged from <3 to 56 µg/L with 33 (97%) sites below the ANZECC/ARMCANZ (2000) guideline.
- Surface concentrations of NH_4^+ at 8 (26%) sites were below the 80th percentile reference value of 6 µg/L. Bottom concentrations of NH_4^+ at 32 (94%) sites were below the 80th percentile reference value of 4 µg/L.
- Sites within 250 m from the diffuser had NH_4^+ concentrations ranging between 51 and 140 µg/L (median of 81 µg/L) in surface waters and between <3 and 56 µg/L (median of <3 µg/L) in bottom waters. All surface sites within 250 m from the diffuser and one bottom site (37) exceeded the ANZECC/ARMCANZ (2000) guideline of 5 µg/L. All surface sites within 250 m exceeded the 80th percentile of reference value of 6 µg/L (surface waters). NH_4^+ concentrations at all but one bottom site were below the bottom water 80th percentile reference value of 4 µg/L.
- Sites outside 250 m from the diffuser had NH_4^+ concentrations ranging between <3 and 110 µg/L (median of 13 µg/L) in surface waters and between <3 and 5 µg/L (median of <3 µg/L) in bottom waters. Twenty one out of 29 (73%) surface sites outside 250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline (5 µg/L) and the 80th percentile of reference values (6 µg/L). No samples from the bottom sites exceeded the ANZECC/ARMCANZ (2000) guideline (5 µg/L) but there was one exceedance of the 80th percentile of reference values (6 µg/L).
- NH_4^+ concentrations at shoreline sites ranged from <3 µg/L (sites D and G) to 32 µg/L (sites A and E) (Figure 5.8). Shoreline NH_4^+ concentrations at 3 (25%) sites were below the ANZECC/ARMCANZ (2000) guideline of 5 µg/L.
- The highest concentrations of NH_4^+ occurred at sites immediately around and north of the diffuser with concentrations generally decreasing with increasing distance from the diffuser (Figure 3.12). Only one site, immediately adjacent to the diffuser, had an elevated NH_4^+ concentration in the bottom waters.



Note:
1. Dashed line indicates ANZECC/ARMCANZ (2000) guideline value.

Figure 5.8 Total ammonia nitrogen concentrations at Sepia Depression

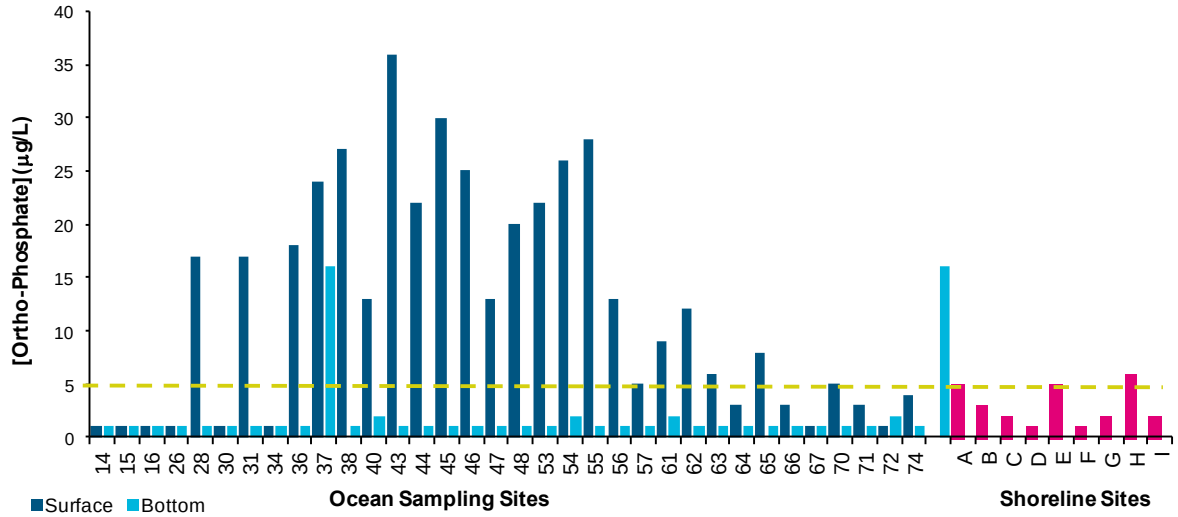


Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 5.3.
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline.

Figure 5.9 Spatial distribution of total ammonia nitrogen at Sepia Depression

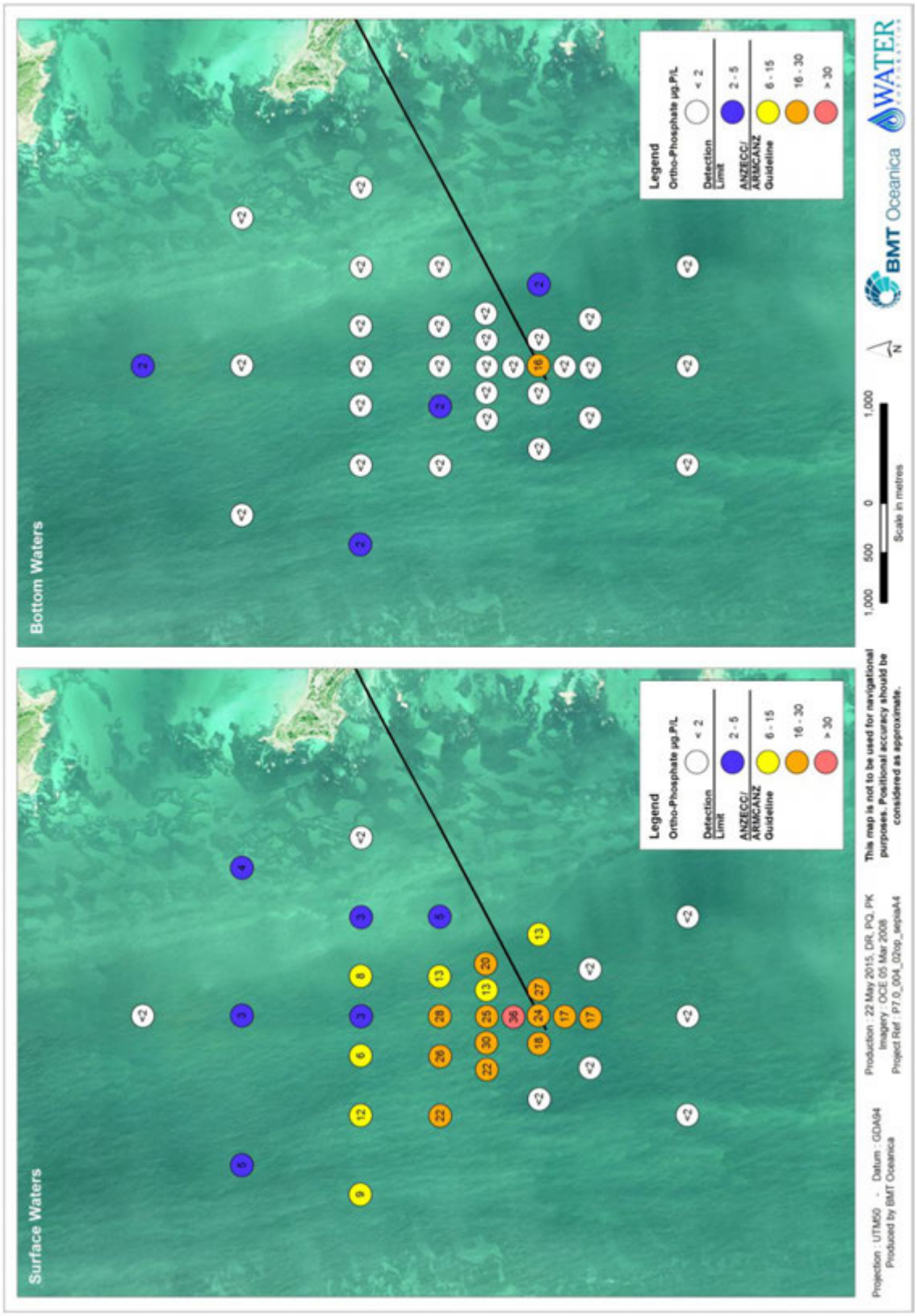
Ortho-phosphate

- Offshore surface concentrations of ortho-phosphate ranged from <2 to 36 µg/L with 14 (43%) sites below or equal to the ANZECC/ARMCANZ (2000) guideline of 5 µg/L. Bottom concentrations of ortho-phosphate ranged from <2 to 16 µg/L with 33 (97%) sites below or equal to the ANZECC/ARMCANZ (2000) guideline.
- Surface concentrations of ortho-phosphate at 15 (44%) sites were below the 80th percentile reference value of 6 µg/L. Bottom concentrations of ortho-phosphate at 33 (97%) sites were below or equal to the 80th percentile reference value of 5 µg/L
- Sites within 250 m from the diffuser had ortho-phosphate concentrations ranging between 17 and 36 µg/L (median of 24 µg/L) in surface waters and between <2 and 16 µg/L (median of <2 µg/L) in bottom waters. All surface sites within 250 m from the diffuser and one bottom site (37) exceeded the ANZECC/ARMCANZ (2000) guideline of 5 µg/L and the 80th percentile of reference value of (6 and 5 µg/L, for surface and bottom, respectively).
- Sites outside 250 m from the diffuser had ortho-phosphate concentrations ranging between <2 and 30 µg/L (median of 6 µg/L) in surface waters and between <2 and 2 µg/L (median of <2 µg/L) in bottom waters. Fifteen out of 29 (52%) surface sites outside 250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline of 5 µg/L compared to no bottom sites. Fourteen surface sites exceeded the 80th percentile of reference value of 6 µg/L.
- Ortho-phosphate concentrations at shoreline sites ranged from <2 µg/L (sites D and F) to 6 µg/L (site H) (Figure 5.10). Ortho-phosphate concentrations were below or equal to the ANZECC/ARMCANZ (2000) guideline of 5 µg/L at 15 (44%) of shoreline sites.
- The highest concentrations occurred at sites immediately adjacent to and north of the diffuser (Figure 5.11). In bottom waters, ortho-phosphate concentration was highest at the site closest to the diffuser. No other spatial pattern was evident.



Note:
1. Dashed line indicates ANZECC/ARMCANZ (2000) guideline value.

Figure 5.10 Ortho-phosphate concentrations at Sepia Depression

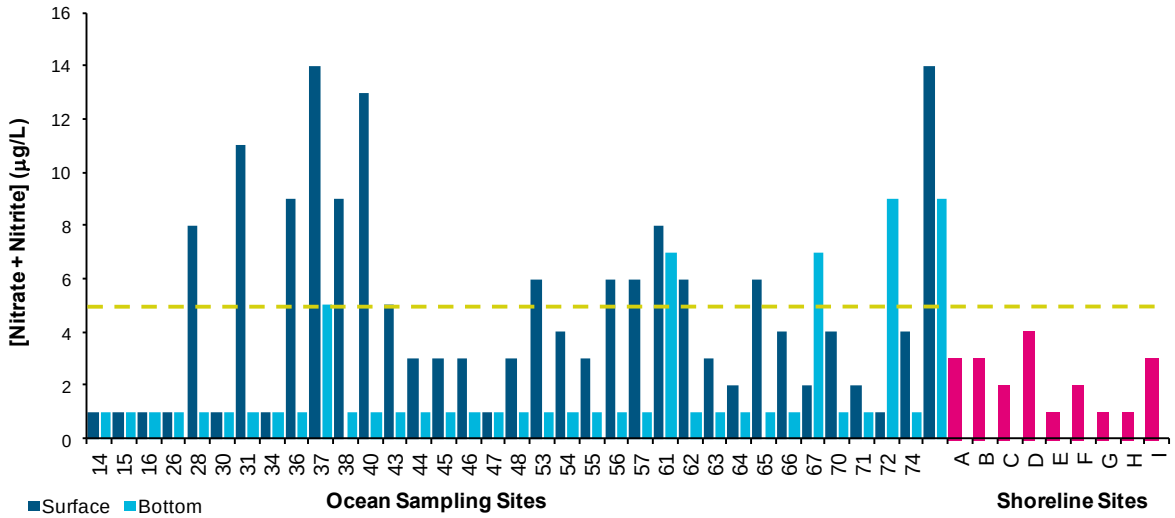


Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 5.3.
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline.

Figure 5.11 Spatial distribution of ortho-phosphate at Sepia Depression

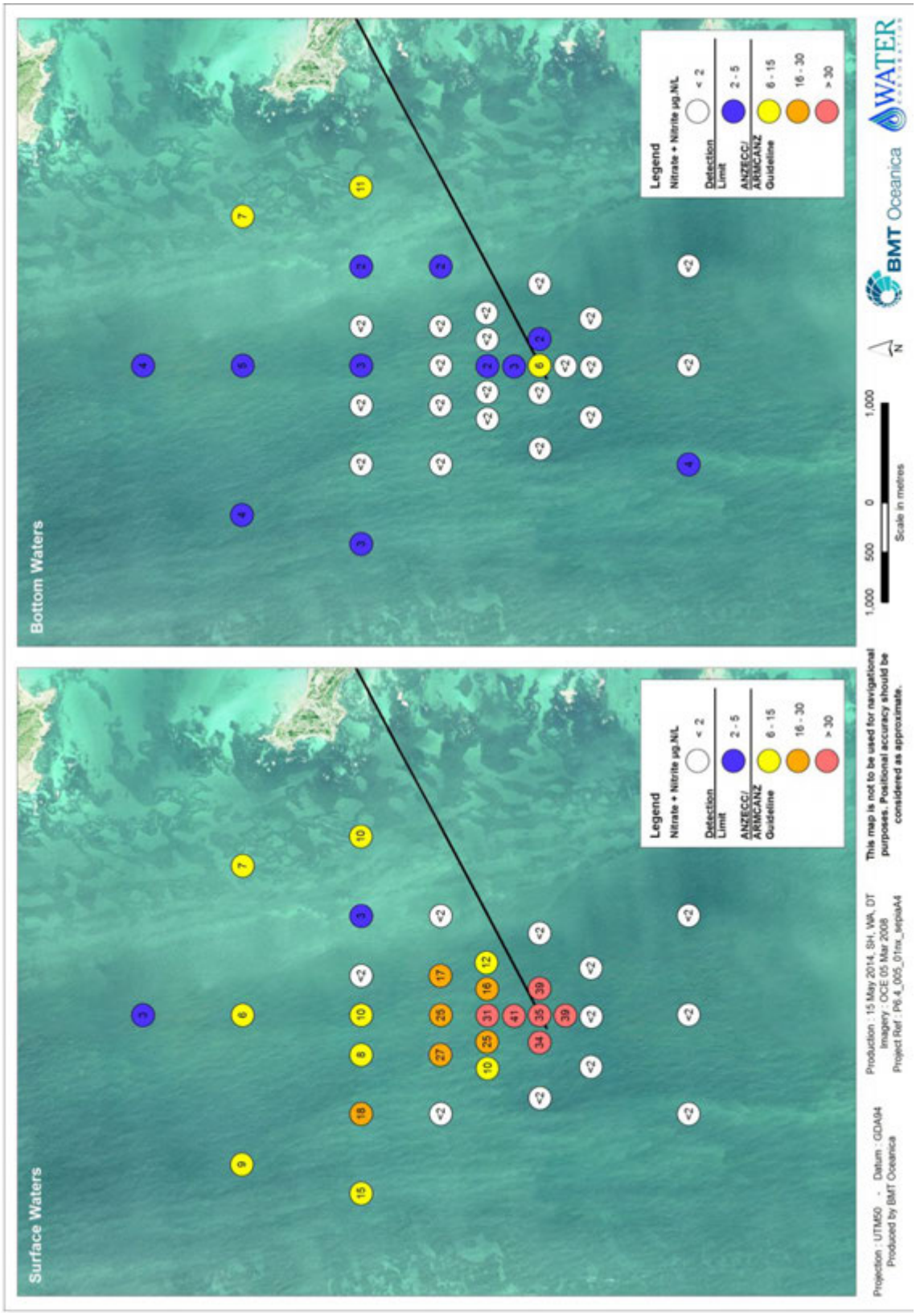
Nitrate+nitrite (NO_2-+NO_3-)

- Offshore surface concentrations of NO_2^-+NO_3^- ranged from <2 to 14 µg/L with 22 (66%) sites below or equal to the ANZECC/ARMCANZ (2000) guideline of 5 µg/L. Bottom concentrations of NO_2^-+NO_3^- ranged from <2 to 19 µg/L with 31 (91%) sites below or equal to the ANZECC/ARMCANZ (2000) guideline.
- Surface concentrations of NO_2^-+NO_3^- at 22 (66%) sites were below or equal to the 80th percentile reference value of 5 µg/L. Bottom concentrations of NO_2^-+NO_3^- at 30 (89%) sites were below the 80th percentile reference value of 4 µg/L,
- Sites within 250 m from the diffuser had NO_2^-+NO_3^- concentrations ranging between 5 and 14 µg/L (median of 9 µg/L) in surface waters and between <2 and 5 µg/L (median of <2 µg/L) in bottom waters. Surface samples from four out of the five sites within 250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline of 5 µg/L and the 80th percentile of reference value (also 5 µg/L). All the bottom sites were below the ANZECC/ARMCANZ (2000) guideline of 5 µg/L but one sample exceeded the bottom water 80th percentile of reference value (4 µg/L).
- Sites outside 250 m from the diffuser had NO_2^-+NO_3^- concentrations ranging between <2 and 13 µg/L (median of 3 µg/L) in surface waters and between <2 and 9 µg/L (median of <2 µg/L) in bottom waters. Eight out of 29 (28%) surface sites outside 250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline and the 80th percentile of reference value (both 5 µg/L). Three bottom sites (10%). exceeded the ANZECC/ARMCANZ (2000) guideline (5 µg/L) and the 80th percentile of reference value of (4 µg/L).
- NO_2^-+NO_3^- concentrations at shoreline sites ranged from <2 µg/L (sites E, G and H) to 4 µg/L (site D) (Figure 5.12). NO_2^-+NO_3^- concentrations were below the ANZECC/ARMCANZ (2000) guideline of 5 µg/L at all shoreline sites.
- Surface NO_2^-+NO_3^- concentrations were elevated concentrations at sites immediately around and to the north of the diffuser (Figure 5.13).



Note:
1. Dashed line indicates ANZECC/ARMCANZ (2000) guideline value.

Figure 5.12 Nitrate+nitrite concentrations at Sepia Depression

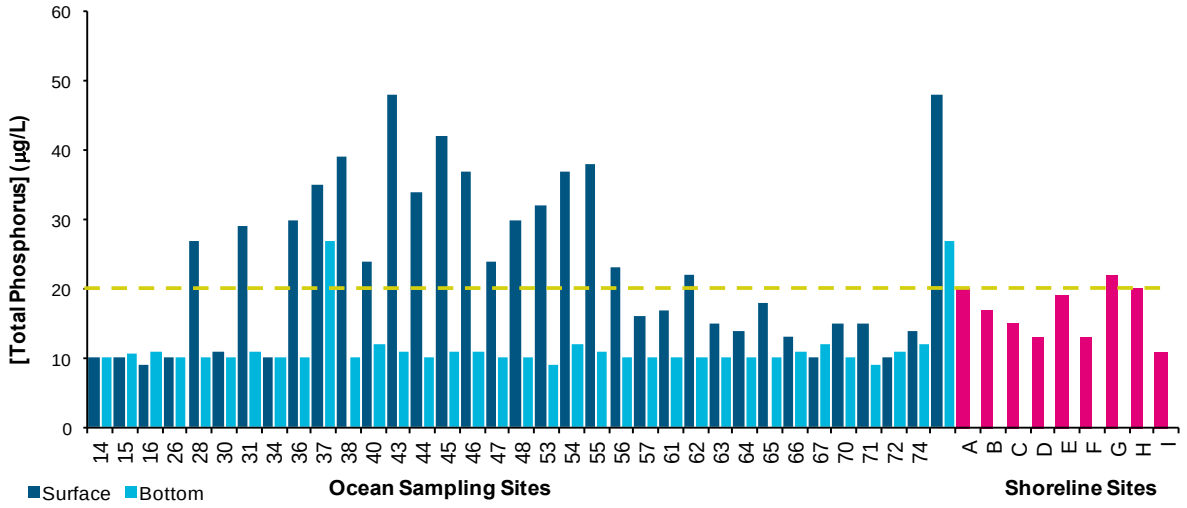


Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 5.3.
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline.

Figure 5.13 Spatial distribution of nitrate+nitrite at Sepia Depression

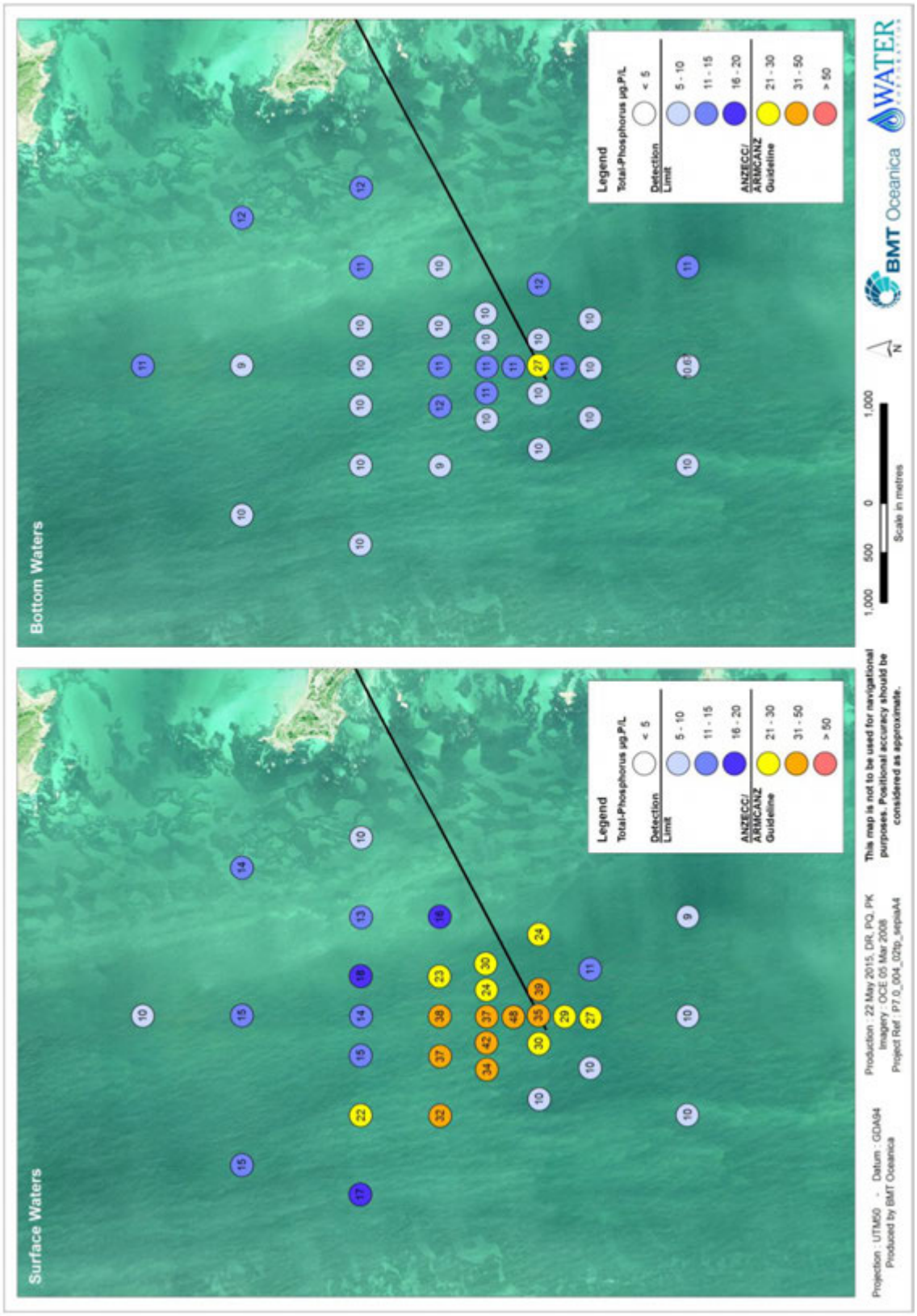
Total phosphorus (TP)

- Offshore surface concentrations of total phosphorus ranged from 9 to 48 µg/L with 17 (50%) sites (14–16, 26, 30, 34, 57, 61, 63–67, 70–72 and 74) below the ANZECC/ARMCANZ (2000) guideline of 20 µg/L. Bottom concentrations of total phosphorus ranged from 9 to 27 µg/L with 33 (97%) sites below the ANZECC/ARMCANZ (2000) guideline of 20 µg/L.
- Total phosphorus surface concentrations at 25 (74%) sites were below or equal to the 80th percentile reference value of 31 µg/L. Bottom concentrations of total phosphorus at all sites were below the 80th percentile reference value (31 µg/L)
- Sites within 250 m from the diffuser had total phosphorus concentrations ranging between 29 and 48 µg/L (median of 35 µg/L) in surface waters and between 10 and 27 µg/L (median of 11 µg/L) in bottom waters. All surface sites within 250 m from the diffuser and one bottom sites exceeded the ANZECC/ARMCANZ (2000) guideline of 20 µg/L. Four out of the five surface but no bottom sites within 250 m exceeded the 80th percentile of reference value of 31 µg/L.
- Sites >250 m from the diffuser had total phosphorus concentrations ranging between 9 and 42 µg/L (median of 16 µg/L) in surface waters and between 9 and 12 µg/L (median of 10 µg/L) in bottom waters. 12 out of 29 (41%) surface sites outside 250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline of 20 µg/L compared to no bottom sites. Six surface sites exceeded the 80th percentile of reference value of 31 µg/L.
- Total phosphorus concentrations at shoreline sites ranged from 11 µg/L (site I) to 22 µg/L (site G) (Figure 5.14). Shoreline total phosphorus concentrations were below or equal to the ANZECC/ARMCANZ (2000) guideline of 20 µg/L at all but one site.
- Total phosphorus concentrations were elevated around and to the north–west of the diffuser (Figure 5.15). In bottom waters, total phosphorus concentrations showed no strong spatial patterns.



Note:
1. Dashed line indicates ANZECC/ARMCANZ (2000) guideline value.

Figure 5.14 Total phosphorus concentrations at Sepia Depression

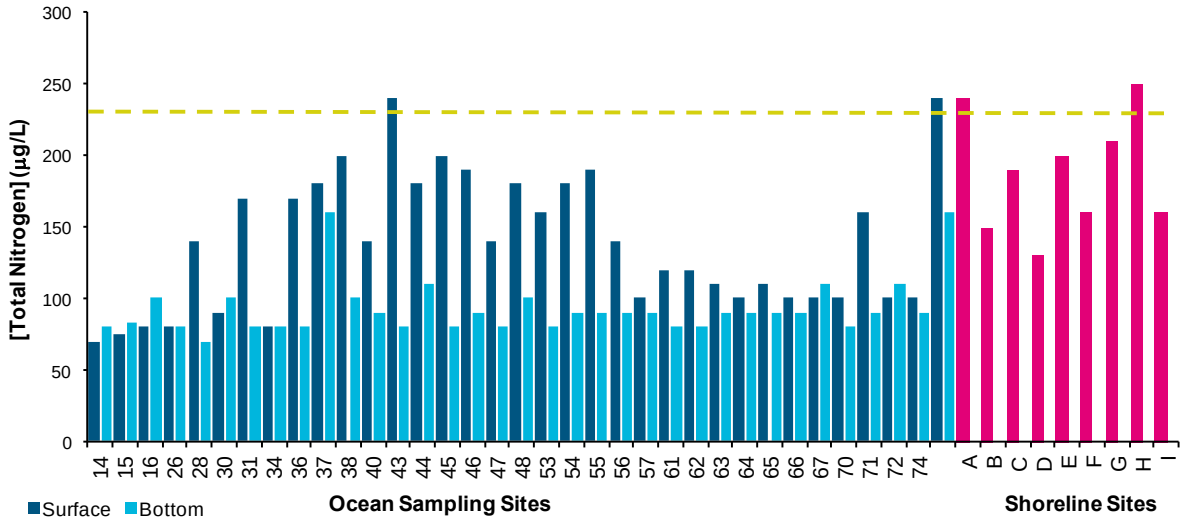


Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 5.3.
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline.

Figure 5.15 Spatial distribution of total phosphorus at Sepia Depression

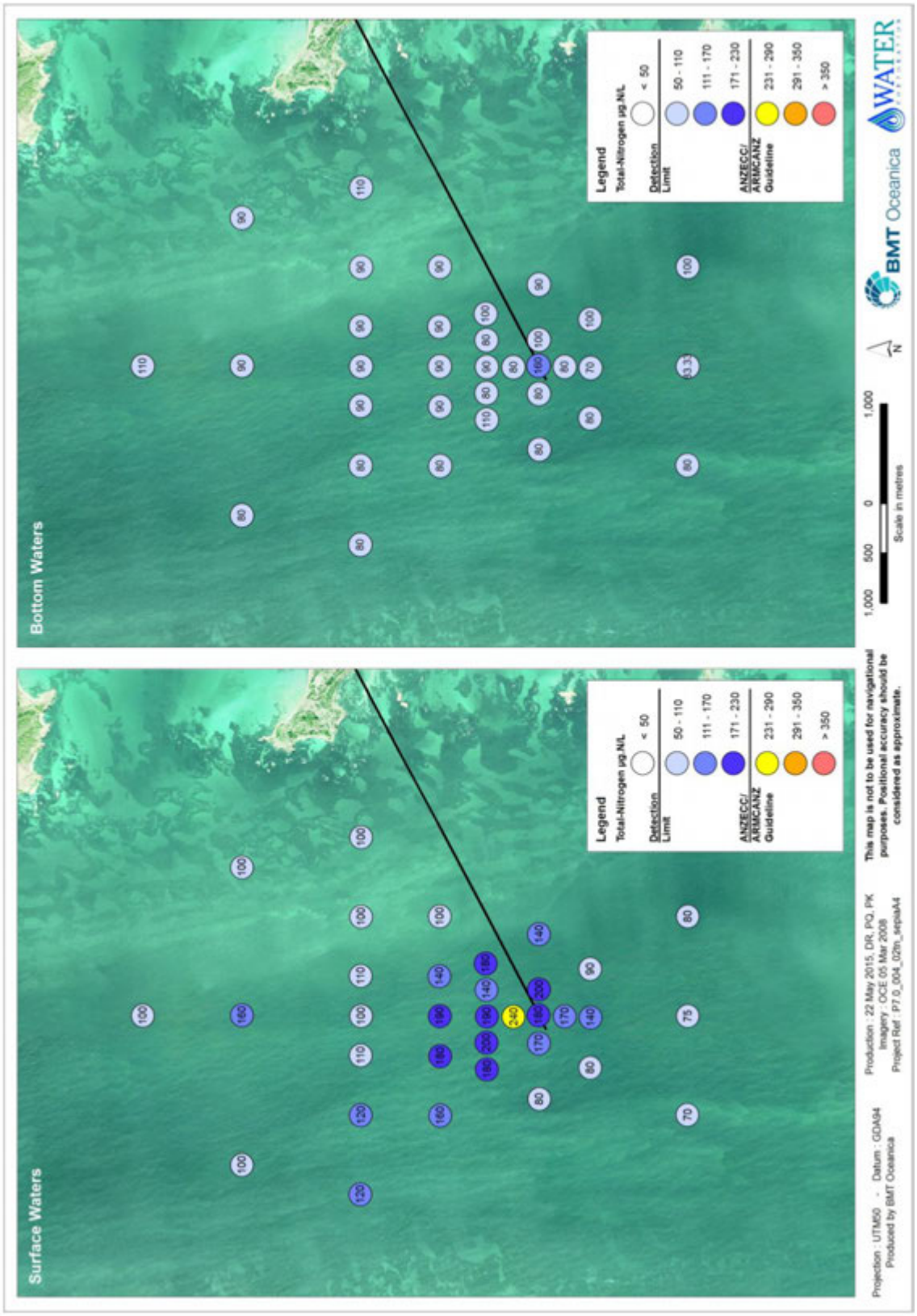
Total nitrogen (TN)

- Offshore surface concentrations of total nitrogen ranged from 70 to 240 µg/L with all sites but one (site 43) below the ANZECC/ARMCANZ (2000) guideline of 230 µg/L. Bottom concentrations of total nitrogen ranged from 80 to 160 µg/L with all (100%) sites below the ANZECC/ARMCANZ (2000) guideline of 230 µg/L.
- Total nitrogen surface concentrations at 21 (62%) sites (14–16, 26, 28, 30, 34, 40, 47, 56, 57, 61–67, 70, 72 and 74) were below or equal to the 80th percentile reference value of 146 µg/L. Bottom concentrations of total nitrogen at all but one site (site 37) were below or equal to the 80th percentile reference value (150 µg/L).
- Sites within 250 m from the diffuser had total nitrogen concentrations ranging between 170 and 240 µg/L (median of 180 µg/L) in surface waters and between 80 and 160 µg/L (median of 80 µg/L) in bottom waters. One surface site within 250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline of 230 µg/L. All surface and one bottom sites within 250 m exceeded the 80th percentile of reference value (146 and 150 µg/L, respectively).
- Sites outside 250 m from the diffuser had total nitrogen concentrations ranging between 70 and 200 µg/L (median of 110 µg/L) in surface waters and between 70 and 110 µg/L (median of 90 µg/L) in bottom waters. No surface or bottom sites outside 250 m from the diffuser exceeded the ANZECC/ARMCANZ (2000) guideline of 230 µg/L. Eight surface sites exceeded the 80th percentile of reference value of 146 µg/L.
- Total nitrogen concentrations at shoreline sites ranged from 130 µg/L (site D) to 250 µg/L (site H) (Figure 5.16). Shoreline total nitrogen concentrations were below or equal to the ANZECC/ARMCANZ (2000) guideline of 230 µg/L at seven out of nine sites.
- Total nitrogen concentrations were elevated at sites around and north–west of the diffuser (Figure 5.17). No spatial patterns were evident in bottom waters.



Note:
1. Dashed line indicates ANZECC/ARMCANZ (2000) guideline value.

Figure 5.16 Total nitrogen concentrations at Sepia Depression



Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 5.3.
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline.

Figure 5.17 Spatial distribution of total nitrogen concentrations in surface and bottom water samples from Sepia Depression, 17 February 2015

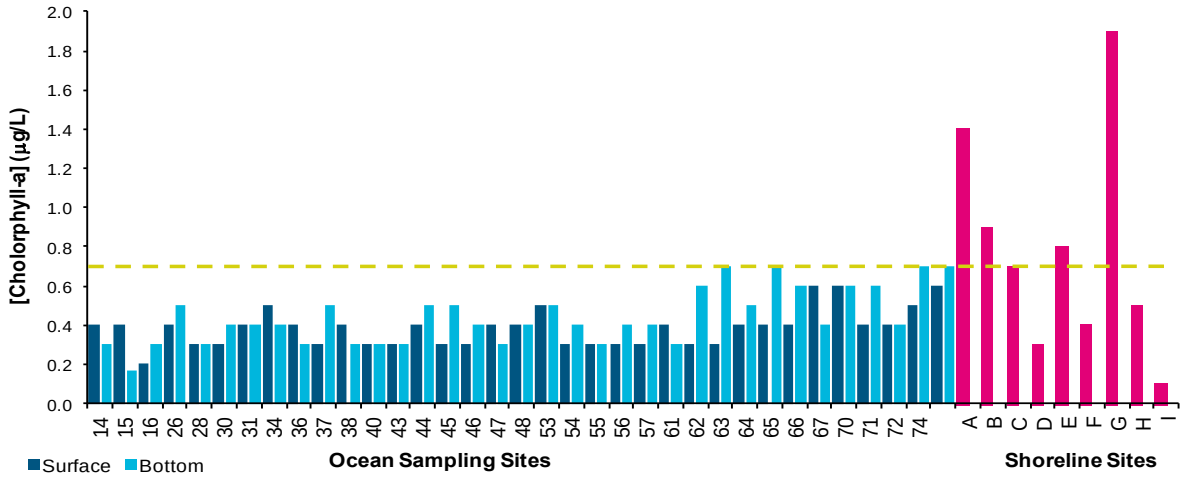
5.5.4 Phytoplankton biomass and distribution

Phaeophytin

- Phaeophytin concentrations (Appendix D) measured at eight offshore surface sites were below the 0.2 µg/L detection limit.
- Phaeophytin concentrations were measured at nine shoreline sites ranged from <0.4 µg/L to 0.6 µg/L.

Chlorophyll-a[27]

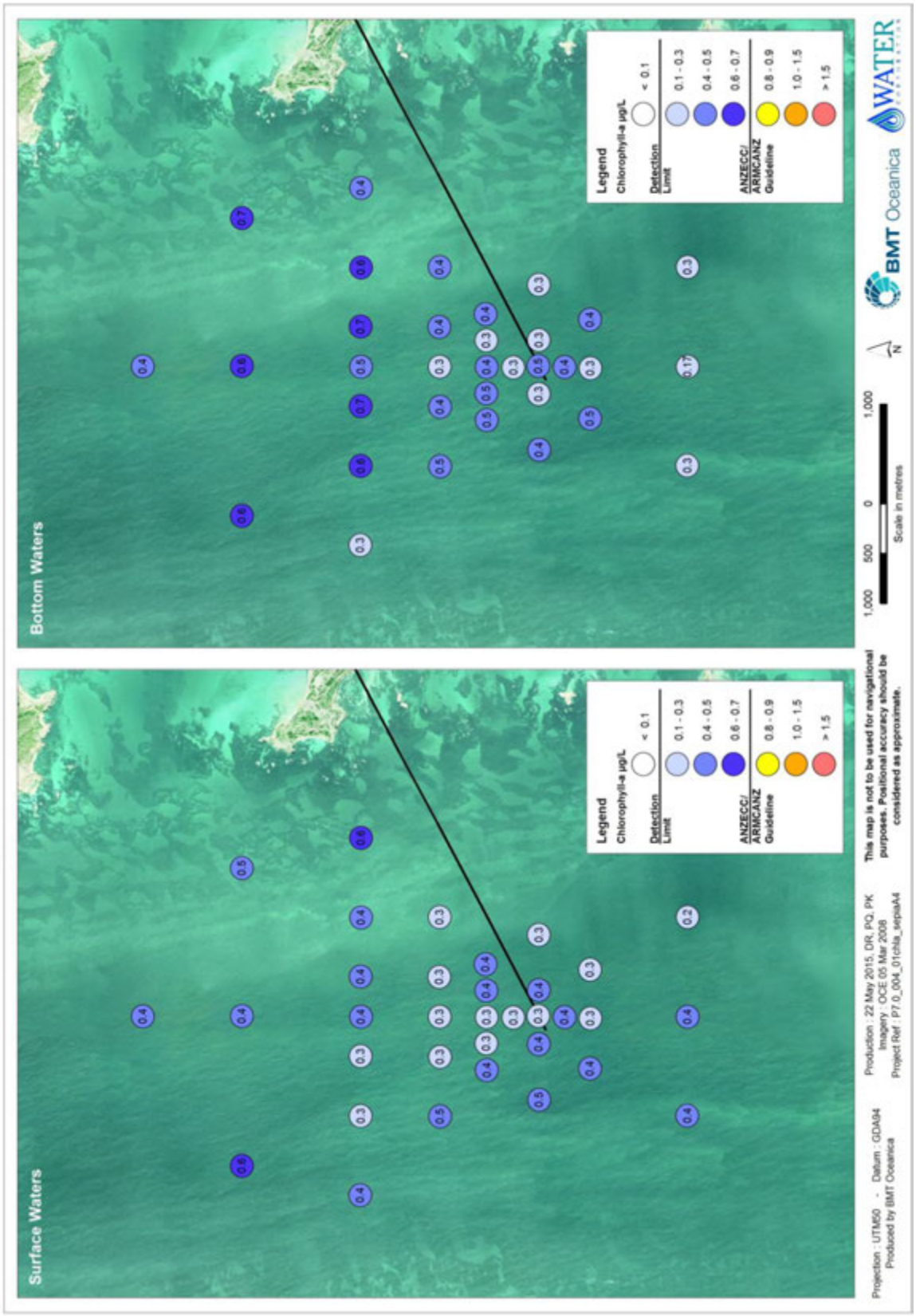
- Offshore surface concentrations of chlorophyll-a ranged from 0.2 to 0.6 µg/L with all sites below the ANZECC/ARMCANZ (2000) guideline of 0.7 µg/L. Bottom concentrations of chlorophyll-a ranged from 0.2 to 0.7 µg/L with all sites below or equal to the ANZECC/ARMCANZ (2000) guideline of 0.7 µg/L (Figure 4.10).
- All surface and bottom chlorophyll-a surface concentrations at all sites were below or equal to the 80th percentile reference value (0.6 and 0.7 µg/L for surface and bottom, respectively).
- Sites within 250 m from the diffuser had chlorophyll-a concentrations ranging between 0.3 and 0.4 µg/L (median of 0.4 µg/L) in surface waters and between 0.3 and 0.3 µg/L (median of 0.3 µg/L) in bottom waters. All surface and bottom sites were within the ANZECC/ARMCANZ (2000) guideline of 0.7 µg/L and below the 80th percentile reference value of 0.5 µg/L (0.6 and 0.7 µg/L for surface and bottom, respectively).
- Sites outside 250 m from the diffuser had chlorophyll-a concentrations ranging between 0.3 and 0.6 µg/L (median of 0.4 µg/L) in surface waters and between 0.3 and 0.7 µg/L (median of 0.4 µg/L) in bottom waters. All were below or equal to the ANZECC/ARMCANZ (2000) guideline of 0.7 µg/L and the 80th percentile reference value.
- Chlorophyll-a concentrations at shoreline sites ranged from 0.3 µg/L (site D) to 1.9 µg/L (site G) (Figure 5.18). Chlorophyll-a concentrations at four of the shoreline sites (A, B, E and G) were above the ANZECC/ARMCANZ (2000) guideline (0.7 µg/L).
- There were no spatial patterns in chlorophyll-a concentrations (Figure 5.19).



Note:
1. Dashed line indicates ANZECC/ARMCANZ (2000) guideline value

Figure 5.18 Chlorophyll-a concentrations at Sepia Depression

[27] *Chlorophyll a concentrations at surface and bottom offshore sites were determined in-situ using a fluorometer; chlorophyll a concentrations at shoreline sites were analysed using acetone extraction methods.*



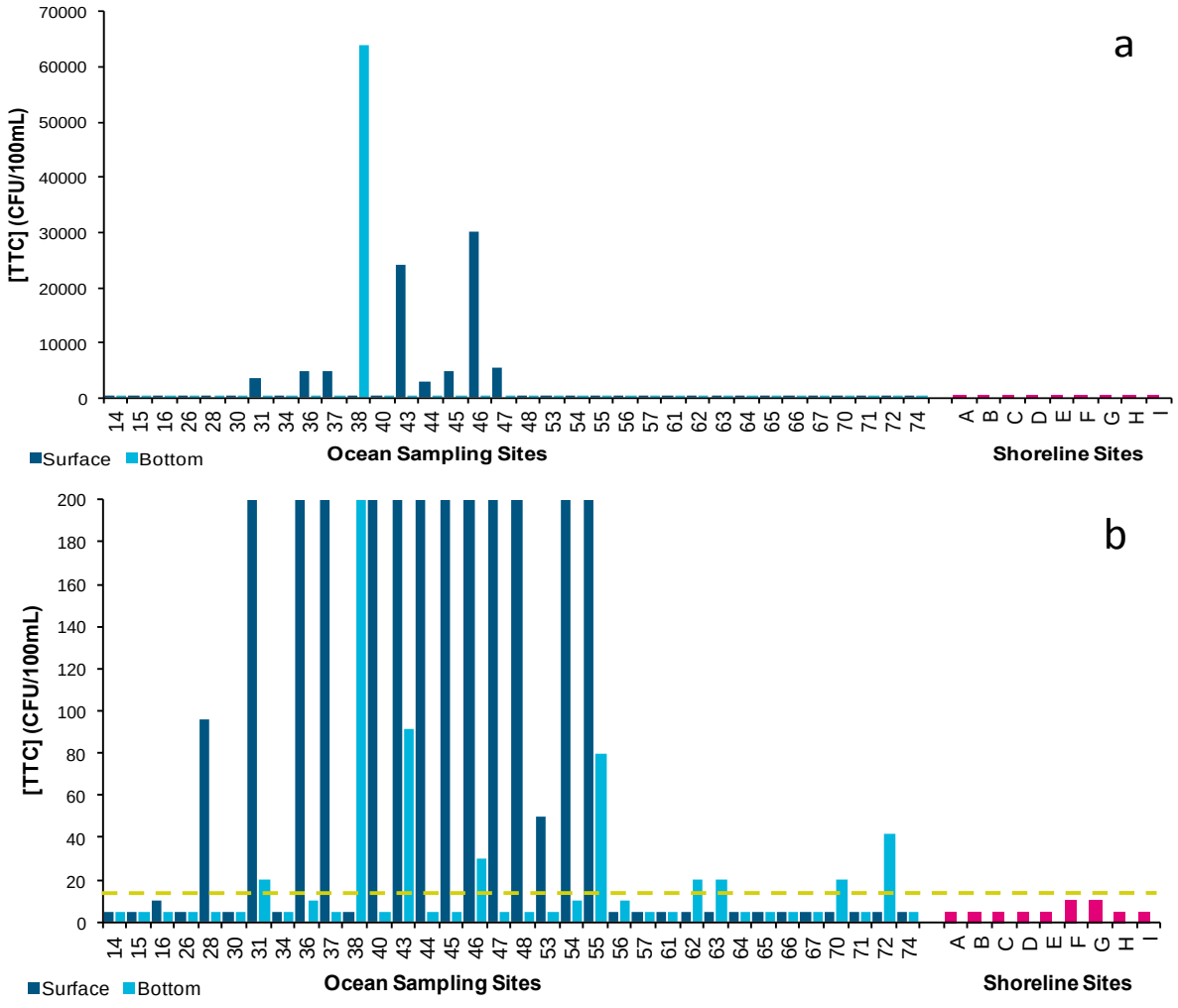
Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 5.3.
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline.

Figure 5.19 Spatial distribution of chlorophyll-a at Sepia Depression

5.5.5 Bacterial concentrations and distribution

Thermotolerant coliforms (TTC)

- The highest offshore surface concentrations of TTC was 30 000 CFU/100 mL at site 46 Figure 5.20)
- The highest offshore bottom concentration of TTC (site 37) was64 000 CFU/100 mL at site 38 (Figure 5.20).
- Shoreline concentrations of TTC ranged from <10 CFU/100 mL (sites D, E and I) to 10 CFU/100 mL.
- Median TTC concentrations at surface (4900 CFU/100 mL) and bottom (20 CFU/100 mL) sites <250 m from the diffuser were above the EQG for both surface and bottom and the EQS at the surface. Median TTC concentrations at surface and bottom sites >250 m from the diffuser, and median shoreline sites were all <10 CFU/100 mL and below the EQG trigger value (Table 5.3).
- TTC concentrations (Figure 5.21) that exceeded the EQG for surface and bottom waters, occurred immediately around the diffuser.



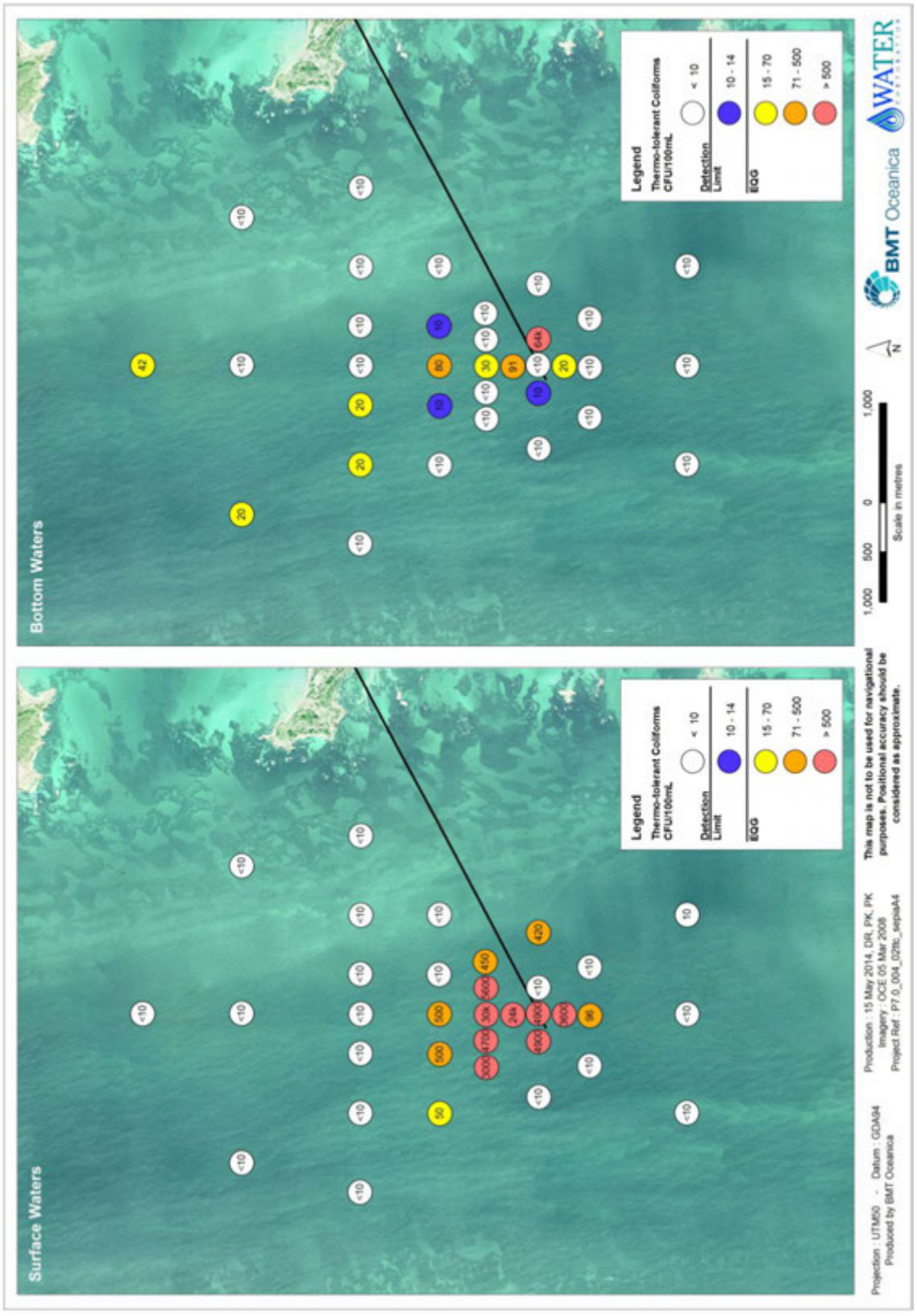
Notes:
1. Dashed line indicates EQG (EPA 2005) guideline value.
2. TCC concentrations above the reporting limit (i.e. >1000 CFU/100 mL) have been graphed as half the reporting limit to show lower concentrations more clearly

Figure 5.20 Thermotolerant coliform concentrations at Sepia Depression

Table 5.3 Median thermotolerant coliform concentrations at Sepia Depression

Sites	Surface	Bottom	EQC (EPA 2005)
<250 m from the diffuser	4900 CFU/100 mL	20 CFU/100 mL	14 CFU/100 mL (EQG) 70 CFU/100 mL (EQS)
>250 m from the diffuser	<10 CFU/100 mL[2]	<10 CFU/100 mL[2]	
Shoreline	<10 CFU/100 mL	–	

Notes:
1. 10 CFU/100 mL is the lower assay limit for the parameter.

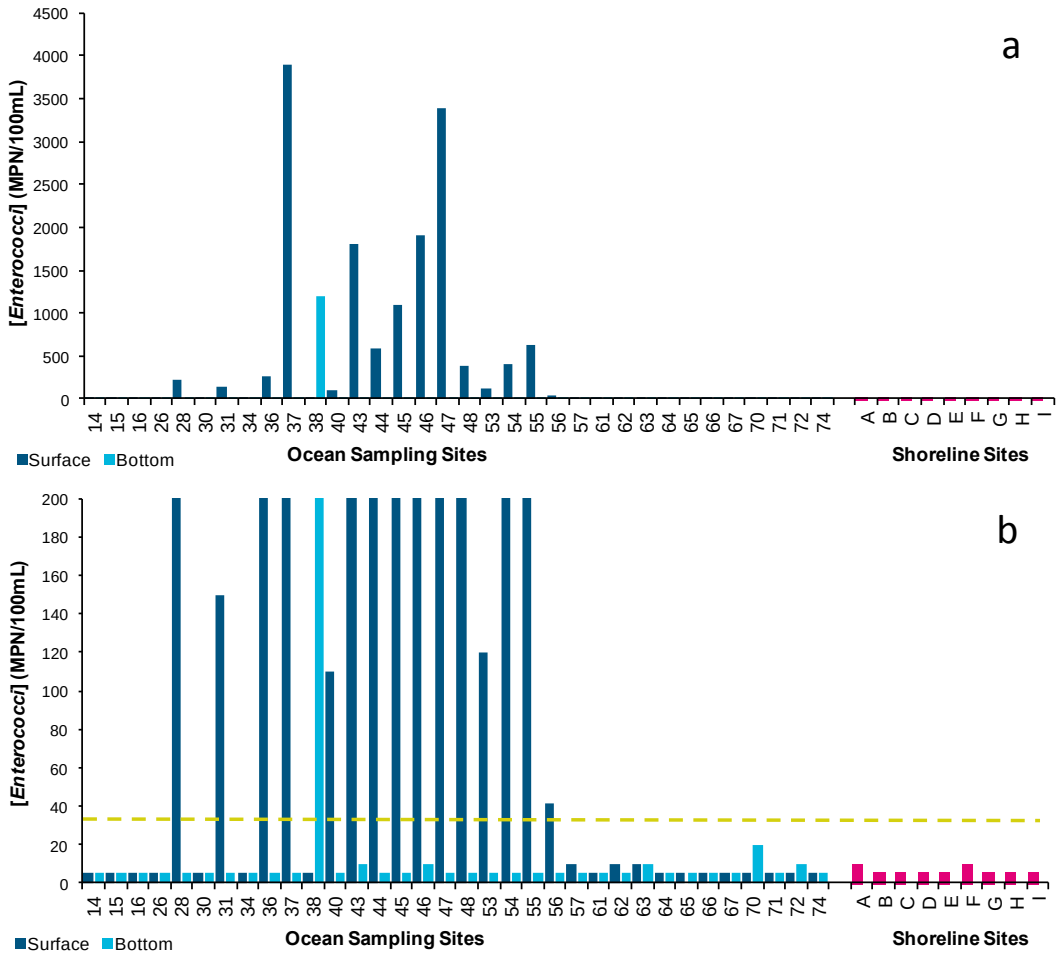


Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 5.3.
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or EQG.

Figure 5.21 Spatial distribution of thermotolerant coliforms at Sepia Depression

Enterococci spp.

- The three highest offshore surface concentrations of *Enterococci* spp. were 3900 MPN/100 mL at site 37 (above the diffuser), 3400 MPN/100 mL at site 47 (450 m north-west of the diffuser) and 1900 MPN/100 mL at site 46 (400 m from the diffuser) (Figure 5.22).
- The highest offshore bottom concentrations of *Enterococci* spp. was 1200 MPN/100 mL at site 38, 150 m from the diffuser and 20 MPN/100 mL at site 70, located 3360 m from the diffuser. All other sites had concentrations of *Enterococci* spp. equal to or below the 10 MPN/100 mL detection limit (Figure 5.22).
- The highest shoreline concentration of *Enterococci* spp. was 31 MPN/100 mL at site A. All other shoreline sites had concentrations of *Enterococci* spp. below or equal to the 10 MPN/100 mL detection limit (Figure 5.22).
- The median concentration of *Enterococci* spp. at surface sites within the post upgrade boundary (260 MPN/100 mL) was above the ANZECC/ARMCANZ (2000) guideline for primary and secondary contact. The median *Enterococci* spp. concentrations at bottom sites within the post upgrade boundary, and at surface and bottom sites outside the post upgrade boundary (all <10 MPN/100 mL), were below the ANZECC/ARMCANZ (2000) guidelines for both primary and secondary contact (Table 5.4)
- *Enterococci* spp. concentrations (Figure 5.23) in surface and bottom waters exceeded at sites within the 'after upgrade' boundary with four additional exceeedances observed in surface waters immediately north of the 'after upgrade' boundary.



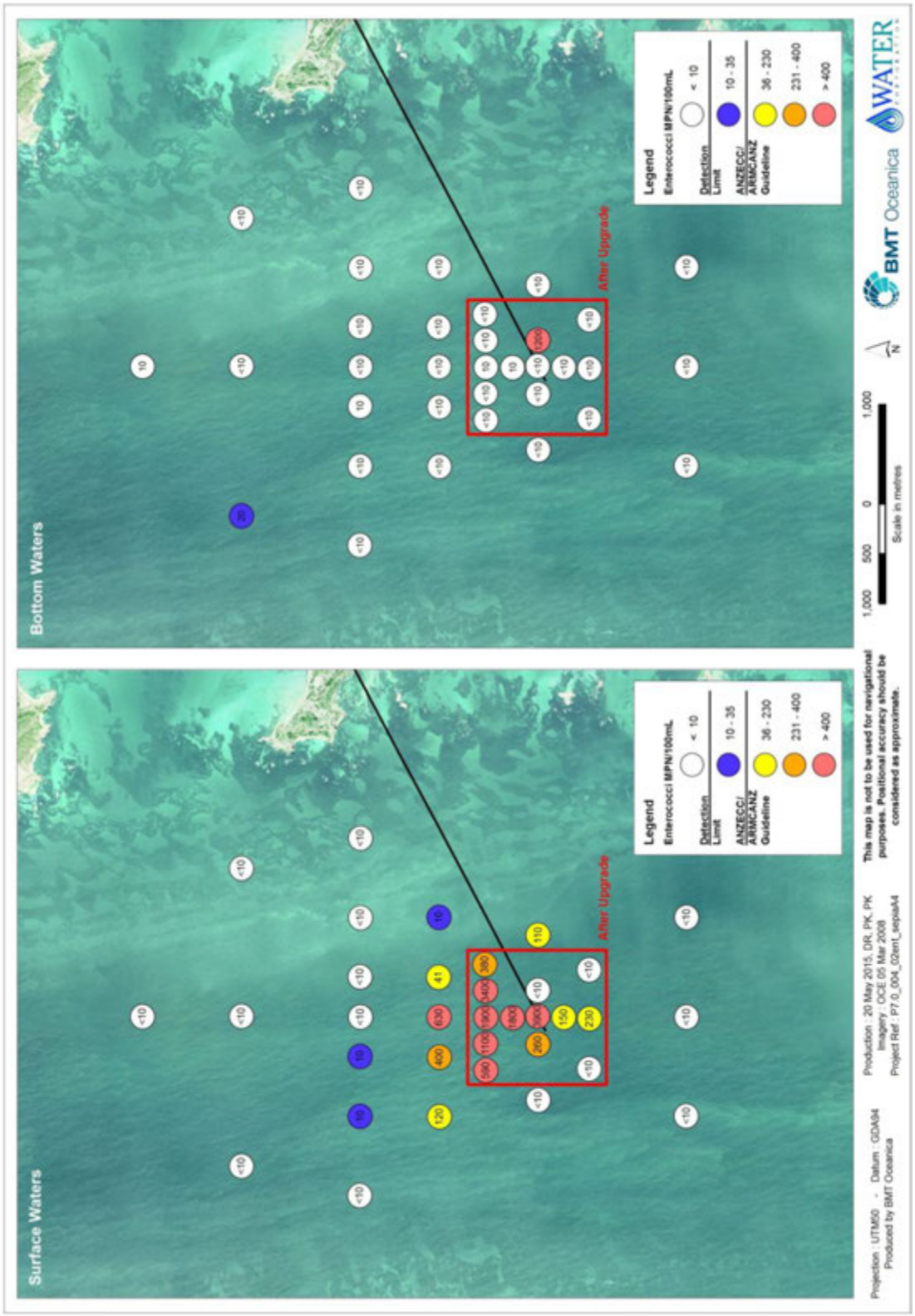
Note:
1. Dashed line indicates ANZECC/ARMCANZ (2000) guideline value

Figure 5.22 Enterococci spp. concentrations at Sepia Depression

Table 5.4 Median Enterococci spp. concentrations at Sepia Depression

Site	Surface	Bottom	ANZECC/ARMCANZ (2000)
Inside the post-upgrade boundary	260 MPN/100 mL	10 MPN/100 mL[1]	35 MPN/100 mL (primary contact)
Outside the post-upgrade boundary	18 MPN/100 mL(1)	<10 MPN/100 mL[1]	230 MPN/100 mL (secondary contact)
Shoreline	<10 MPN/100 mL(1)	-	

Note:
1. 10 MPN/100 mL is the lower assay limit for the parameter.



Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 5.3
2. The scale of the 'After Upgrade' boundary has been exaggerated to clarify which sites are located inside or outside the boundary
3. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 5.23 Spatial distribution of Enterococci spp. concentrations at Sepia Depression

5.6 Conclusions

During the survey on 17 February 2015 at Sepia Depression, the treated wastewater plume was advecting in a northerly direction away from the outlet. The survey captured the extent of the elevated nutrient concentrations related to the discharge of treated wastewater into the marine environment. Nutrient concentrations were generally, higher at sites closer to the diffuser and in the downstream plume, than at sites located further from the influence of the outlet.

The summer water quality surveys were not specifically designed to provide information suitable for comparison with ANZECC/ARMCANZ (2000) guidelines or with 80th percentile of reference values. For information only, comparison of water quality parameters at sites located <250 m of the diffuser and >250 m from the diffuser with the ANZECC/ARMCANZ (2000) guidelines and 80th percentile of reference values were made.

ANZECC/ARMCANZ (2000) suggests that an exceedance of a trigger value should be regarded as an 'early warning' and, furthermore, that trigger values are not intended as a means of assessing 'compliance'. Parameters with medians exceeding the ANZECC/ARMCANZ (2000) guideline values during the 2015 survey at Sepia Depression (Table 5.5):

- $NH4^+$ in surface waters at sites <250 and >250 m from the diffuser and shoreline sites
- Ortho-phosphate in surface waters <250 and >250 m from the diffuser
- NO_2^-+NO_3^- in surface waters <250 m from the diffuser
- Total phosphorus in surface waters <250 m from the diffuser

Nitrogen is a nutrient limiting primary productivity in Perth's near-shore coastal waters (Lord & Hillman 1995). Historical concentrations of total nitrogen and NH_4^+ measured at Sepia Depression are generally below the ANZECC/ARMCANZ (2000) guideline values; this is demonstrated by the lower 80th percentile of reference values. Parameters with medians exceeding the ANZECC/ARMCANZ (2000) guideline values during the 2015 Sepia Depression survey (Table 5.5):

- $NH4^+$ in surface waters at sites <250 and >250 m from the diffuser and shoreline sites
- Ortho-phosphate in surface waters <250 m from the diffuser
- NO_2^-+NO_3^- in surface waters <250 m from the diffuser
- Total phosphorus in surface waters <250 m from the diffuser
- Total nitrogen in surface waters <250 m from the diffuser and at the shoreline sites

Table 5.5 Summary comparison of median nutrient and chlorophyll-a values with the 80th percentile of background concentrations at Sepia Depression

ANZECC/ARMCANZ (2000) guideline values					
Parameter	**Inside the mixing zone (sites <250 m from diffuser)**		**Outside the mixing zone (sites >250 m from diffuser)**		**Shoreline**
	Surface	**Bottom**	**Surface**	**Bottom**	
Total ammonia nitrogen					
Ortho-phosphate					
Nitrate+nitrite					
Total phosphorus					
Total nitrogen					
Chlorophyll-a					
80th percentile reference values					
Parameter	**Inside the mixing zone (sites <250 m from diffuser)**		**Outside the mixing zone (sites >250 m from diffuser)**		**Shoreline**
	Surface	**Bottom**	**Surface**	**Bottom**	
Total ammonia nitrogen					
Ortho-phosphate					
Nitrate+nitrite					
Total phosphorus					
Total nitrogen					
Chlorophyll-a					

Notes:
1. Assessment criteria for surface, bottom and shoreline sites:
2. Green = Nutrient median values ≤ ANZECC/ARMCANZ (2000) guideline values / ≤80th percentile reference values.
3. Red = Nutrient median values > ANZECC/ARMCANZ (2000) guideline values / >80th percentile reference values.

The microbiological indicators showed elevated concentrations in the immediate vicinity of the diffuser and a decline in concentrations away from the outlet, indicating die-off of the microbes. Thermotolerant coliform concentrations were above the EQG and EQS for the maintenance of seafood safe for human consumption in surface and bottom waters near the outlet (<250 m). However, the guidelines were met in surface and bottom waters at distances >250 m from the diffuser and at shoreline sites (Table 5.6). Human health concerns relating to seafood are not considered an issue at Sepia Depression, as there is no harvesting of seafood or aquaculture activities in the waters 1–2 km offshore.

Table 5.6 Summary comparison of the EQG with the median concentrations of thermotolerant coliforms at Sepia Depression

Parameter	**Environmental Quality Guideline (EPA 2005)[1]**				
	<250 m		**>250 m**		**Shoreline**
	Surface	**Bottom**	**Surface**	**Bottom**	
Thermotolerant coliforms					

Notes:
1. For the maintenance of seafood safe for human consumption.
2. Green= median values ≤ EQG.
3. Red = median values > EQG.

Median concentrations of *Enterococci* spp. were above the ANZECC/ARMCANZ (2000) guideline for primary contact in surface waters inside the post upgrade boundary. However median concentrations of *Enterococci* spp. were below or equal to the ANZECC/ARMCANZ (2000) guideline in bottom waters inside the post upgrade boundary, in surface and bottom waters outside the post upgrade boundary, and at shoreline sites (Table 5.7). Public health concerns relating to primary (whole-body) contact recreation are not considered to be an issue at Sepia Depression because there is no primary contact recreational use of the waters 1–2 km offshore. Furthermore, the Environmental Protection Authority (2005) notes in the Manual of Standard Operating Procedures for Environmental Monitoring Against the Cockburn Sound Environmental Quality Criteria (2003–2004) that the Environmental Quality Criteria for primary and secondary contact recreation are only appropriate for evaluation of data collected from waters at recreational beaches, where they protect regular beach users.

Table 5.7 Summary comparison of the ANZECC/ARMCANZ (2000) guideline with the median concentrations of *Enterococci* spp. at Sepia Depression

Parameter	ANZECC/ARMCANZ (2000)[1]				
	Within post-upgrade boundary		Outside post-upgrade boundary		Shoreline
	Surface	Bottom	Surface	Bottom	
Enterococci spp.					

Notes:
1. Results for primary contact recreation:
2. Green = median values ≤ ANZECC/ARMCANZ (2000) guideline.
3. Red = median values > ANZECC/ARMCANZ (2000) guideline.

The results from the summer water quality survey on 17 February 2016 indicate that the WWTP expelling treated wastewater at Sepia Depression ocean outlet was operating effectively and the plume of treated wastewater rapidly dissipated once it entered the environment. Despite elevated levels of water quality parameters at some individual sites outside the immediate zone of influence of the outlet, the water quality conditions required for ecosystem protection and public health criteria were met.

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Appendix A – Wastewater Treatment Plant Licence Conditions

Beenyup Wastewater Treatment Plant Licence

Department of
Environment and Conservation

Your ref: DEC625-02
Our ref: L7882/1991/13
Enquiries: Tanya Gilders
Phone: 9333 7527
Fax: 9333 7550
Email: Tanya.Gilders@dec.wa.gov.au

Mr Guy Watson
Environmental Branch
Water Corporation
PO Box 100
LEEDERVILLE WA 6902

Dear Mr Watson

ENVIRONMENTAL PROTECTION ACT 1986 – LICENCE

Premises: Beenyup Wastewater Treatment Plant
Location: Lot 8278 on Plan 30778, Ocean Reef Road, Craigie WA 6025
Licence: L7882/1991/13

You are advised that your application for a licence to operate the works prescribed under the *Environmental Protection Act 1986* at the above-mentioned location has been approved subject to the attached conditions. Enclosed is your licence number **L7882/1991/13**.

If any aspect of the conditions of licence aggrieves you, you may lodge an appeal, accompanied by the $50.00 fee, with the Minister for the Environment within 21 days from the date on which this licence is received. Members of the public may also appeal conditions. Please contact the Appeals Registrar at the Office of the Appeals Convenor on 9221 8711 after the closing date of appeals to check whether any appeals were received.

Under Section 58 of the *Environmental Protection Act 1986*, it is an offence to contravene a licence condition. This offence carries a penalty of up to $125,000, with a daily penalty of up to $25,000. The Department considers that a breach of this section, or any other section, of the *Environmental Protection Act 1986* to be extremely serious.

If you have any questions relating to the licence or licence conditions, please do not hesitate to contact Tanya Gilders on 9333 7527 for clarification or discussion of any grievances you have.

Yours faithfully

Paul Byrnes
A/ Principal Environmental Officer

31 October 2008

encl: Environmental Protection ACT 1986 – Licence L7882/1991/13
copy to: Local Government Authority: City of Joondalup

WESTERN AUSTRALIA

DEPARTMENT OF ENVIRONMENT AND CONSERVATION

Environmental Protection Act 1986

ISSUED LICENCE

LICENCE NUMBER: L7882/1991/13 **FILE NUMBER: DEC625-02**

LICENSEE AND OCCUPIER:
Water Corporation
PO Box 100
LEEDERVILLE WA 6902

NAME AND LOCATION OF PREMISES:
Beenyup Wastewater Treatment Plant
Lot 8278 on Plan 30778, Ocean Reef Road
Craigie WA 6025

Environmental Protection Regulations 1987
CLASSIFICATION(S) OF PREMISES:

Category: 61 Liquid waste facility;
Category: 54 Sewage facility

COMMENCEMENT DATE OF LICENCE: 1 November 2008

EXPIRY DATE OF LICENCE: 31 October 2011

CONDITIONS OF LICENCE:
As described and attached:

DEFINITION(S)
GENERAL CONDITION(S): 3
AIR CONTROL CONDITION(S): 3
WATER CONTROL CONDITION(S): 6
SOLID WASTE CONTROL CONDITION(S): 1
ATTACHMENT(S): 4

.....

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

Date of Issue: Friday, 31 October 2008

WESTERN AUSTRALIA

DEPARTMENT OF ENVIRONMENT & CONSERVATION

Environmental Protection Act 1986

LICENCE NUMBER: L7882/1991/13 **FILE NUMBER: DEC625-02**

PREAMBLE

The following statements in this Preamble either reflect important sections of the Environmental Protection Act 1986 or provide relevant background information for the licensee. They should not be regarded as conditions of licence.

Applicability

This licence is issued to the Water Corporation for the Beenyup Wastewater Treatment Plant (WWTP) located at Lot 8278 on Plan 30778, Ocean Reef Road, Craigie (Attachment 1), which is a prescribed premises within Schedule 1 of the *Environmental Protection Regulations 1987* as outlined in Table 1.

Table 1: Categories under which Beenyup WWTP at Lot 8278 on Plan 30778 Ocean Reef Road, Craigie is prescribed.

Category number	*Category name*	*Description*
54	Sewage facility	Premises on which sewage is treated (excluding septic tanks); or from which treated sewage is discharged onto land or into waters.
61	Liquid waste facility	Premises on which liquid waste produced on other premises (other than sewerage waste) is stored, reprocessed, treated or irrigated.

Under the *Environmental Protection (Controlled Waste) Regulations 2004*, the licensee is only permitted to accept the following tankered controlled wastes at the premises:

(i) biological wastes (categories 1.02 and 1.05).

Nominal Rated Throughput

The nominal rated throughput of the premises covered by this licence is as follows:

- Quantity of wastewater treated: 120 megalitres per day
- Quantity of liquid waste accepted: 50 000 tonnes per year

Ministerial Conditions

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

Odour Control

The licensee should manage and operate the premises such that odours emanating from the premises do not unreasonably interfere with the health, welfare, convenience, comfort or amenity of any person at an odour sensitive premises.

This licence recognises that residential encroachment has generated a situation whereby odours generated by the WWTP may impact upon nearby residences. However, this does not override the requirements of the paragraph above, and the Water Corporation is expected to adopt continuous improvement with respect to odour control.

Emergency, Accident or Malfunction

The licensee should inform the Director as soon as practicable of the identification of any discharge of waste which has occurred as a result of an emergency, accident or malfunction, or extreme weather conditions, otherwise than in accordance with any condition of this licence and has caused or is likely to cause pollution.

Alteration to Premises

Prior to making any significant alterations to the premises which may affect the air, water or noise emissions from the premises the licensee must submit a proposal to the Director accompanied by supporting information and plans which allow the environmental impact of that change to be assessed.

General Requirements

The following statements reflect important sections of the *Environmental Protection Act 1986* and are included for the information of the licensee:

- The licensee should take all reasonable and practicable measures to prevent pollution of the environment.
- Noise emissions from operations on site are required to comply with the *Environmental Protection (Noise) Regulations 1997.*
- The licensee should take all reasonable and practicable measures to prevent or minimise the discharge of waste and the emission of noise, odours or electromagnetic radiation from the premises.
- The licensee should inform the Director at least 24 hours prior to the commencement of any planned non-standard operations, which may have the potential to cause pollution.

CONDITIONS OF LICENCE

DEFINITIONS

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

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

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

'Director' or 'Department of Environment & Conservation' for the purpose of correspondence means-

Program Manager, Industry Regulation
Swan Region
Department of Environment & Conservation
Locked Bag 104
Bentley Delivery Centre WA 6983
Address:
181-205 Davy Street
Booragoon WA 6154

Telephone: (08) 9333 7510
Facsimile: (08) 9333 7550

'inform' means inform by telephone or facsimile;

'licensed' means licensed or registered under the *Environmental Protection Act 1986* unless otherwise specified.

'mg/L' means milligram per litre;

'mL' means millilitre;

'µg/L' means micrograms per litre;

'mg/m^3' means milligram per cubic metre;

'NATA' means National Association of Testing Authorities.

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

'premises' means Beenyup Wastewater Treatment Plant located at Lot 8278 on Plan 30778, Ocean Reef Road, Craigie, as shown in Attachment 1.

'routine maintenance' means the servicing of the pre-treatment or primary treatment areas of the plant.

'STP' means standard temperature and pressure.

GENERAL CONDITIONS

ANNUAL MONITORING REPORT

G1(a) The licensee shall provide to the Director, by **1 September each year**, an Annual Monitoring Report containing data collected over the previous financial year (**1 July to 30 June**). The report shall contain but not be limited to:

(i) monitoring data or other collected data required by any condition of this licence;
(ii) an assessment of the data against any limits set or other environmental guidelines or policies referred to in this licence and data from previous years' monitoring;
(iii) a summary of any data exceeding those limits, guidelines or policies including information on why the exceedence occurred (if known) and action taken by the licensee to prevent recurrence of such exceedences.
(iv) a summary of the number and type of complaints received;
(v) any changes to site boundaries, surface drainage channels and on-site or off-site impacts or pollution; and
(vi) a list of any monitoring methods used to collect and analyse data required by any condition of this licence to demonstrate they comply with the methods specified in this licence.

G1(b) The licensee shall use the following units in reports required by part (a) of this condition:

Parameter	**Unit**
Monthly cumulative volume discharged	Cubic metres per day (monthly average)

pH	pH units
E. coli	Colony forming units per 100 ml
Faecal enterococci	Most probable number per 100 ml
All other parameters (treated wastewater)	mg/L
All other parameters (marine)	µg/L
Nitrogen and phosphorus load	kilograms per day (monthly average)

COMPLAINTS

G2 The licensee shall keep a written record of complaints received regarding emissions from the premises. For each such complaint the following information shall be recorded (if known or provided):

(i) name and address of complainant(s);
(ii) date and time of complaint;
(iii) a general description of the nature of complaint;
(iv) any on-site activities (if any) that may have led to the emission;
(v) wind direction, wind speed and temperature at the time of the complaint;
(vi) likely source of the reported problem; and
(vii) action taken in response to the complaint.

G3 ANNUAL AUDIT COMPLIANCE REPORT

The licensee shall by 1 September in each year, provide to the CEO an annual audit compliance report in the form in attachment 4 to this licence, signed and certified in the manner required by Section C of the form, indicating the extent to which the licensee has complied with the conditions of this licence, and any previous licence issued under Part V of the Act for the Premises, during the period beginning 1 July the previous year and ending on 30 June in that year.

AIR POLLUTION CONTROL CONDITIONS

COVERING OF PRE TREATMENT, PRIMARY TREATMENT AND SECONDARY TREATMENT AREAS

A1(a) The licensee shall maintain covers over the pre-treatment, primary treatment and secondary treatment areas of the plant, except for routine maintenance or emergency situations.

A1(b) The licensee shall maintain a chemical scrubbing system for the removal of odorous compounds from the pre-treatment, primary treatment and secondary treatment areas, prior to their emission through the scrubber stack except for routine maintenance or emergency situations.

STACK MONITORING

A2(a) The licensee shall monitor and record each of the following parameters, at the frequency stated using the method specified, in the exit gases emitted from the scrubber stack as specified on Attachment 2:

Parameter to be monitored	Monitoring frequency	Units	Monitoring method
Hydrogen	Monthly	mg/m³ at STP,	VicEPA method

sulphide		dry	B18
Volumetric flow rate	Monthly	m^3/sec	USEPA method 2
Stack exit temperature	Monthly	°Celsius	n/a

A2(b) The licensee shall ensure that all hydrogen sulphide samples referred to in condition A2(a) are analysed in a laboratory holding NATA accreditation for that parameter.

ODOUR CONTROL LIMIT

A3 The licensee shall ensure that the emissions from the scrubber stack, monitored as per condition A2, do not exceed the following limits:

Emission	Concentration limit	Mass emission rate limit
Hydrogen sulphide	5 mg/m^3 at STP, dry	140 mg/sec at STP, dry

WATER POLLUTION CONTROL CONDITIONS

DISCHARGE AND SAMPLING POINT

W1(a) The licensee shall discharge treated wastewater from the premises to the environment through the Ocean Reef ocean outlet or to reuse schemes.

W1(b) The licensee shall maintain a sampling point in the outlet channel from the treatment plant so that representative water samples can be easily taken there from.

FLOW MONITORING

W2(a) The licensee shall monitor and record the cumulative monthly volumes of treated wastewater being discharged to the Ocean Reef ocean outlet and re-use schemes.

W2(b) The monthly flow results shall be recorded and presented in the next annual monitoring report in a tabular form.

WATER MONITORING AND REPORTING

W3(a) The licensee shall, at the frequencies stated, take representative water samples from the following monitoring sites, and have them analysed for the parameters listed:

Monitoring Sites	Sampling Frequency	Parameters to be sampled
Outlet channel	Monthly	pH, Total Suspended Solids, (filtered) 5-Day Biochemical Oxygen Demand, Total Nitrogen, Ammonium-nitrogen, Nitrate+Nitrite-nitrogen, Total Phosphorus
Outlet channel	3-monthly	*E.coli*, Oil and Grease, arsenic, cadmium,

		copper, chromium, lead, mercury, nickel, zinc
Ocean monitoring sites depicted in Attachment 3 (depending on ocean current)	Annually every summer	Total Nitrogen, Nitrate + Nitrite-nitrogen, Ammonium-nitrogen, Total Phosphorus, Filterable Reactive Phosphorus, Chlorophyll 'a', *E.coli*, Faecal enterococci

W3(b) The licensee shall collect, handle and preserve all water samples in accordance with the relevant part(s) of Australian Standard 5667:1998. With respect to marine sampling, it is accepted that the licensee (or its contractor) does not need to collect, container and transport blanks or field spikes in accordance with the above standard.

W3(c) The licensee shall analyse all water samples in its own quality assured laboratory, or ensure that samples are analysed in a laboratory holding NATA accreditation for the analyses specified. If the licensee uses its own laboratory, then at least one set of samples per year shall also be submitted to a laboratory holding NATA accreditation for the analysis specified in condition W3(a). The licensee shall report these duplicate results to the Director in the following annual monitoring report, specifying the laboratory in which each analysis was performed.

W3(d) The licensee shall keep the original laboratory analysis reports (or copies thereof) on record for the duration of this licence.

CALCULATION OF CONTAMINANT LOAD

W4 The licensee shall determine the monthly load of each contaminant in the treated wastewater discharged from the premises (except pH and bacteria) using flow-weighted data. The loads shall be based on the treated wastewater discharge rate and the concentration as measured in accordance with conditions W2 and W3. Monthly and annual average loads of the contaminants shall be reported in the Annual Monitoring Report in kilograms per day.

TOTAL PHOSPHORUS AND NITROGEN LOAD LIMIT

W5(a) The licensee shall ensure that the load for total phosphorus in treated wastewater discharged from the Beenyup WWTP to the ocean through the Ocean Reef ocean outlet does not exceed an annual average of 1500 kilograms per day recorded over the financial year.

W5(b) The licensee shall ensure that the load for total nitrogen in treated wastewater discharged from the Beenyup WWTP to the ocean through the Ocean Reef ocean outlet does not exceed an annual average of 3600 kilograms per day recorded over the financial year.

TANKERED WASTE

W6 The licensee may accept biological wastes category 1.02 and 1.05 (from other Water Corporation assets) tankered into the premises at the pre-treatment works of the sewage treatment plant. The waste shall be delivered to the plant via an enclosed pipeline.

SOLID WASTE CONTROL CONDITIONS

SOLIDS DISPOSAL

S1(a) The licensee shall dispose of collected grit and screenings from the pre-treatment area to a licensed landfill.

S1(b) The licensee shall either tanker sludges to another Water Corporation asset for treatment or dispose of sludge and biosolids in accordance with the document *Western Australian Guidelines for Direct Land Application of Biosolids and Biosolids Products*, Department of Environmental Protection, Water and Rivers Commission and Department of Health (February, 2002).

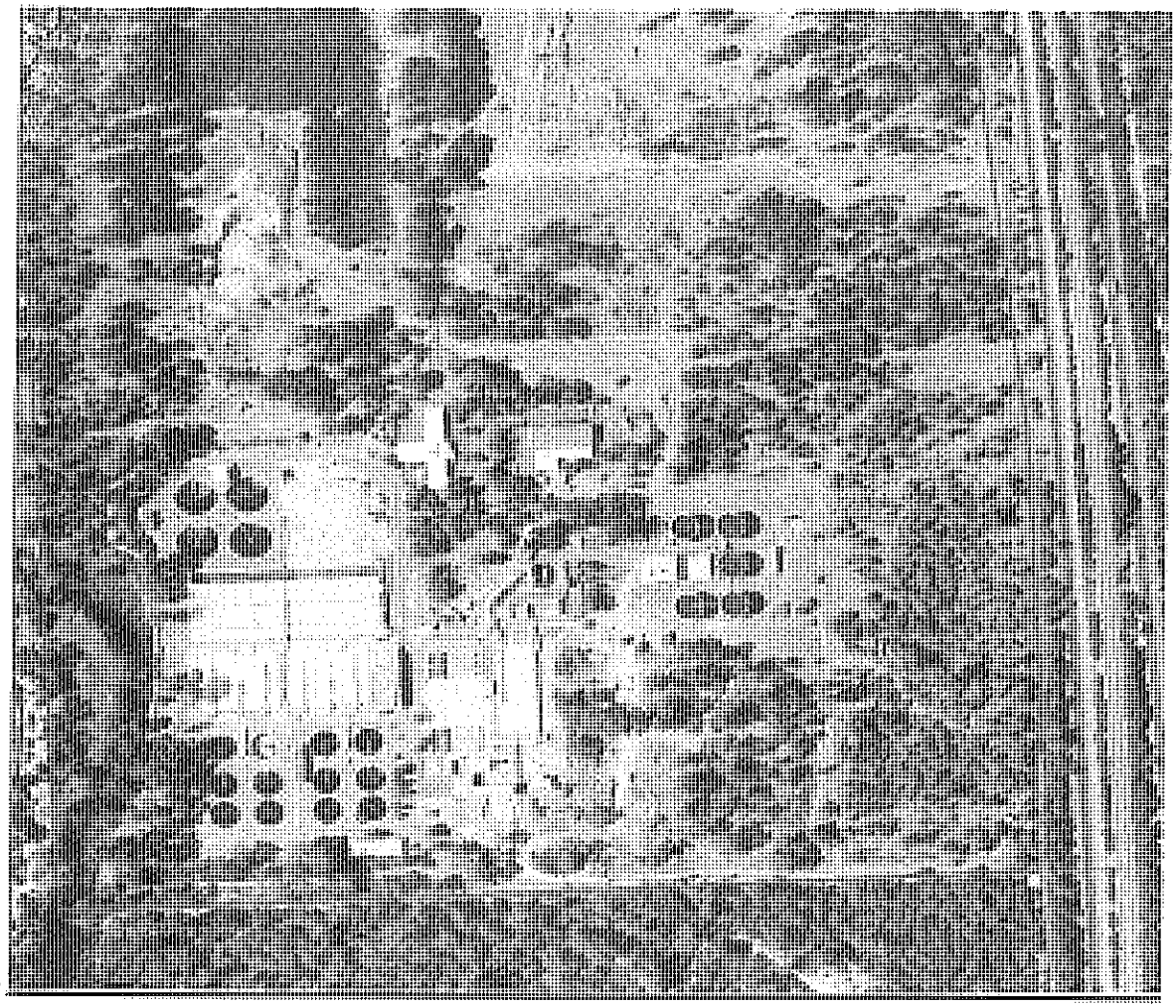
.....

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

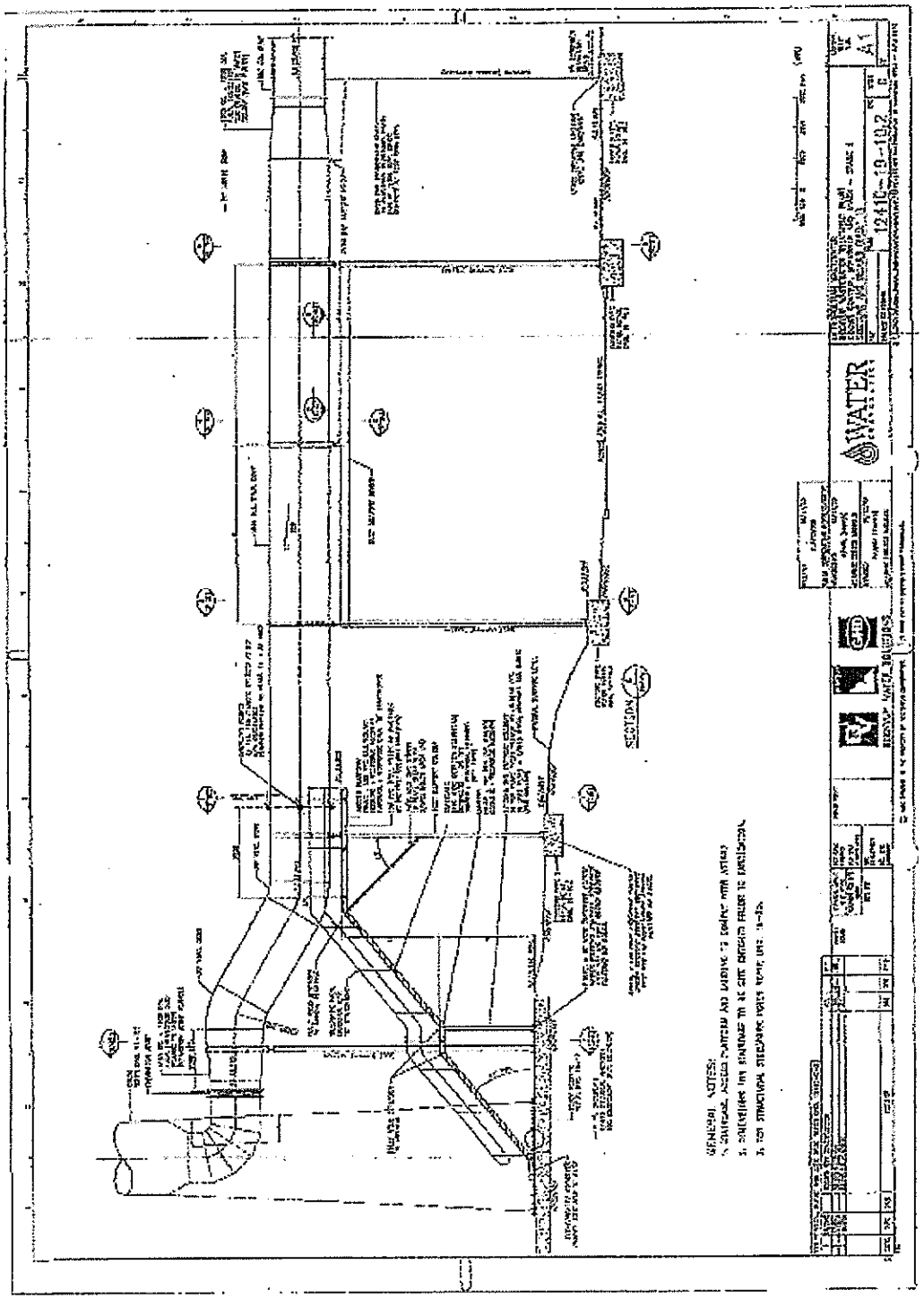
Date of Issue: 31 October 2008

ATTACHMENT 1

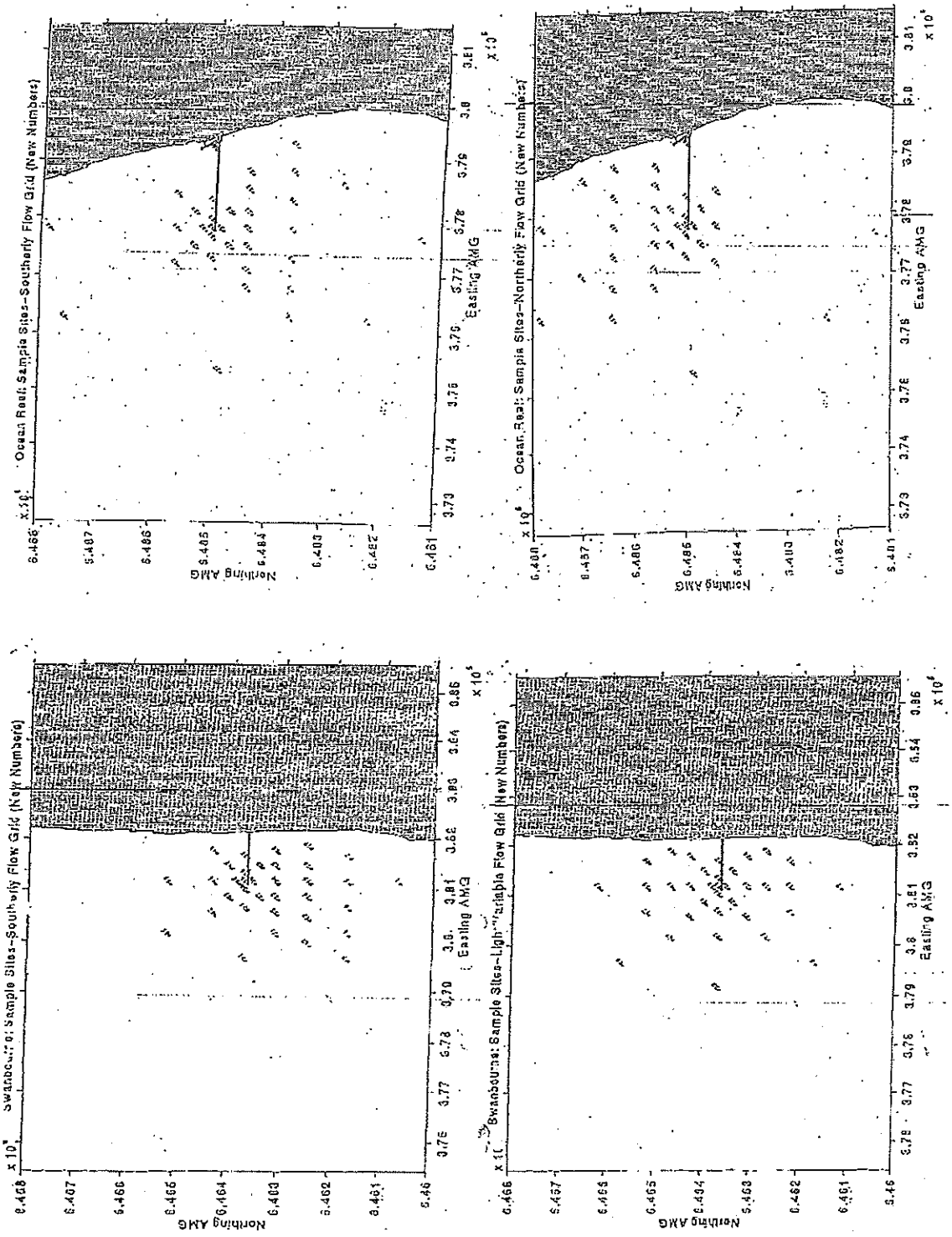
Lot 8278 on Plan 30778 Ocean Reef Road
Craigie WA 6025



ATTACHMENT 2



ATTACHMENT 3



ATTACHMENT 4

WESTERN AUSTRALIA

DEPARTMENT OF ENVIRONMENT & CONSERVATION

Environmental Protection Act 1986

LICENCE NUMBER: L7882/1991/13 **FILE NUMBER: DEC625-02**

SECTION A

LICENCE DETAILS

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

STATEMENT OF COMPLIANCE WITH LICENCE CONDITIONS

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

Yes ☐ Please proceed to Section C

No ☐ Please proceed to Section B

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

INITIAL:_____

SECTION B
DETAILS OF NON-COMPLIANCE WITH LICENCE CONDITION.

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

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

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

INITIAL:_____

SECTION C
SIGNATURE AND CERTIFICATION

This Annual Audit Compliance Report may only be signed by a person(s) with legal authority to sign it. The ways in which the Annual Audit Compliance Report must be signed and certified, and the people who may sign the statement, are set out below.

Please tick the box next to the category that describes how this Annual Audit Compliance Report is being signed. If you are uncertain about who is entitled to sign or which category to tick, please contact the licensing officer for your premises.

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

WESTERN AUSTRALIA

DEPARTMENT OF ENVIRONMENT & CONSERVATION

Environmental Protection Act 1986

LICENCE NUMBER: L7882/1991/13 **FILE NUMBER: DEC625-02**

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

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

SIGNATURE: _____ SIGNATURE: _____

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

POSITION: _____ POSITION: _____

DATE: _____/_____/_____ DATE: _____/_____/_____

SEAL (if signing under seal)

Subiaco Wastewater Treatment Plant Licence

Department of
Environment and Conservation

Your ref: DEC794-02
Our ref: L4726/1991/13
Enquiries: Tanya Gilders
Phone: 9333 7527
Fax: 9333 7550
Email: Tanya.Gilders@dec.wa.gov.au

Mr Guy Watson
Environmental Branch
Water Corporation
PO Box 100
LEEDERVILLE WA 6902

Dear Mr Watson

ENVIRONMENTAL PROTECTION ACT 1986 – LICENCE

Premises: Subiaco Wastewater Treatment Plant
Location: Lot 3150 on Plan 149501, Lot 5286 on Plan 162620 and Lot 6815 on Plan 166929 Lemnos Street, Shenton Park WA 6008
Licence: L4726/1991/13

You are advised that your application for a licence to operate the works prescribed under the *Environmental Protection Act 1986* at the above-mentioned location has been approved subject to the attached conditions. Enclosed is your licence number **L4726/1991/13**.

If any aspect of the conditions of licence aggrieves you, you may lodge an appeal, accompanied by the $50.00 fee, with the Minister for the Environment within 21 days from the date on which this licence is received. Members of the public may also appeal conditions. Please contact the Appeals Registrar at the Office of the Appeals Convenor on 9221 8711 after the closing date of appeals to check whether any appeals were received.

Under Section 58 of the *Environmental Protection Act 1986*, it is an offence to contravene a licence condition. This offence carries a penalty of up to $125,000, with a daily penalty of up to $25,000. The Department considers that a breach of this section, or any other section, of the *Environmental Protection Act 1986* to be extremely serious.

If you have any questions relating to the licence or licence conditions, please do not hesitate to contact Tanya Gilders on 9333 7527 for clarification or discussion of any grievances you have.

Yours faithfully

Paul Byrnes
A/ Principal Environmental Officer

31 October 2008

encl: Environmental Protection ACT 1986 – Licence L4726/1991/13
copy to: Local Government Authority: City of Nedlands

WESTERN AUSTRALIA

DEPARTMENT OF ENVIRONMENT AND CONSERVATION

Environmental Protection Act 1986

ISSUED LICENCE

LICENCE NUMBER: L4726/1991/13 **FILE NUMBER: DEC794-02**

LICENSEE AND OCCUPIER:
Water Corporation
PO Box 100
LEEDERVILLE WA 6902

NAME AND LOCATION OF PREMISES:
Subiaco Wastewater Treatment Plant
Lot 3150 on Plan 149501, Lot 5286 on Plan 162620 and Lot 6815 on Plan 166929 Lemnos Street
Shenton Park WA 6008

Environmental Protection Regulations 1987
CLASSIFICATION(S) OF PREMISES:

Category: 61 Liquid waste facility;
Category: 54 Sewage facility

COMMENCEMENT DATE OF LICENCE: 1 November 2008

EXPIRY DATE OF LICENCE: 31 October 2011

CONDITIONS OF LICENCE:
As described and attached:

DEFINITION(S)
REPORTING REQUIREMENT(S): 3
MONITORING REQUIREMENT(S): 4
EMISSION TOAIR CONDITION(S): 1
WATER CONTROL CONDITION(S): 2
ATTACHMENT(S): 5

.....

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

Date of Issue: Friday, 31 October 2008

DEFINITIONS

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

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

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

"Director" or 'Department of Environment & Conservation' for the purpose of correspondence means;

Program Manager, Environmental Regulation Unit
Swan Region
Department of Environment and Conservation
Locked Bag 104
Bentley Delivery Centre WA 6983

Address:
181-205 Davy Street
Booragoon WA 6154

Telephone: 9333 7510
Facsimile: 9333 7550

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

"Continuous monitor" means a monitor that measures the instantaneous concentration of exit gas every fifteen minute.

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

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

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

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

"Monitoring period" means 1 July to 30 June.

"NATA" means National Association of Testing Authorities.

"Odour boundary" means the outer boundary of odour modelled at 5 OU at 99.9 percentile 1 hour averaging (as referred to in Attachment 4).

"Scrubber stack" means the stack from the chemical scrubbing system as depicted on Attachment 2.

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

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

"Swanbourne Ocean Outlet" means Swanbourne Ocean Outlet extending 1.1 kilometres off the shore shown in Attachment 3.

"USEPA" means United States Environmental Protection Agency.

"Victorian EPA" means Victorian Environmental Protection Authority.

"Subiaco Main Drain" means Subiaco Main Drain Outlet extending approximately 50 metres off the shore as shown in Attachment 3.

REPORTING REQUIREMENTS

ANNUAL MONITORING REPORT

R1 The licensee shall submit to the Director, by **1 September** each year, an annual monitoring report providing the following information obtained during the monitoring period from 1 July to 30 June:

(i) A histogram showing the monthly recorded average flow rate, temperature and concentration of hydrogen sulphide being emitted through the scrubber stack, measured in accordance with condition M1.

(ii) A histogram showing the daily maximum and daily average concentrations of hydrogen sulphide emitted through the scrubber stack, as measured in accordance with condition M2.

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

(iv) A histogram showing the volumes of treated wastewater discharged each month through the Swanbourne Ocean Outlet and approved re-use schemes.

(v) A histogram showing the date and volume of treated wastewater discharged to the Subiaco Main Drain.

(vi) A histogram showing the monthly average loadings for total phosphorus and total nitrogen in treated wastewater discharged to the ocean from Subiaco WWTP through the Swanbourne Ocean Outlet in kg/day.

(vii) A histogram showing the results of treated wastewater monitoring as per condition M3 (b) including duplicate NATA accredited laboratory results.

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

(ix) The daily average concentration of hydrogen sulphide emitted through the scrubber stack, as determined from the hydrogen sulphide concentrations recorded as per condition M2 and an estimate of the air flow rate.

(x) Monitoring data reliability against the bench marks of 90% of the time in a calendar month and 95% of the time over the monitoring period.

ACCESS TO DATA

R2 The licensee shall make available complaint data, calibration or monitoring data, results of analytical data or any other information collected under any condition of this licence to an Inspector, on request.

ANNUAL AUDIT COMPLIANCE REPORT

R3 The licensee shall by 1 September in each year, provide to the Director an annual audit compliance report in the form in Attachment 5 to this licence, signed and certified in the manner required by Section C of the form, indicating the extent to which the licensee has complied with the conditions of this licence, and any previous licence issued under Part V of the Act for the Premises, during the period beginning 1 July the previous year and ending on 30 June in that year.

MONITORING REQUIREMENTS

STACK MONITORING

M1 (a) The licensee shall monitor and record each of the following parameters, at the frequency stated using the method specified, in the exit gases emitted from the scrubber stack as specified on Attachment 2:

Parameter to be monitored	Monitoring frequency	Units	Monitoring method
Hydrogen sulphide	March, June, September and December	mg/m³ at STP, dry	Vic EPA method B18
Volumetric flow rate	March, June, September and December	m³/sec	USEPA method 2
Stack exit temperature	March, June, September and December	°Celsius	n/a

M1 (b) The licensee shall ensure that all hydrogen sulphide samples referred to in condition M1 (a) are analysed in a laboratory holding NATA accreditation for that parameter.

OPERATIONAL EMISSION MONITORING

M2 The licensee shall operate and maintain a continuous hydrogen sulphide monitor in accordance with the manufacturer's instructions to measure and record hydrogen sulphide emitted from the scrubber.

MONITORING OF DISCHARGED TREATED WASTEWATER

M3 (a) The licensee shall monitor and record the cumulative monthly volumes of treated wastewater being discharged to the Swanbourne Ocean Outlet and re-use schemes.

M3(b) The licensee shall monitor and record the concentration of the following parameters, at the frequencies stated, in treated wastewater being discharged from the Subiaco WWTP to the ocean through the Swanbourne Ocean Outlet as shown in Attachment 3 at the treated wastewater sampling point depicted on Attachment 1:

Parameter to be monitored	**Monitoring frequency**	**Units**
Total Nitrogen, Total Phosphorus	Monthly	mg/L
Total suspended solids, 5-Day Biochemical Oxygen Demand (filtered), Oil and Grease, Arsenic, Cadmium, Copper, Chromium, Lead, Mercury, Nickel and Zinc	6 Monthly	

M3(c) The licensee shall ensure that all water samples are collected, handled and preserved in accordance with the relevant parts of the Australian Standard 5667 - 1998.

M3 (d) The licensee shall ensure that all water samples are analysed in accordance with the current "Standard Methods for Examination of Water and Wastewater," APHA-AWWA-WEF.

M3 (e) The licensee shall analyse all water samples in its own laboratory, or ensure that samples are analysed in a laboratory holding NATA accreditation for the analyses specified. If the licensee uses its own laboratory, then at least one set of samples per year shall also be submitted to a laboratory holding NATA accreditation for the analysis specified in condition M3(b).

RECORDING OF COMPLAINTS

M4 The licensee shall maintain a written register of complaints received regarding alleged emissions from the premises. For each such complaint the following information shall be recorded (if known or provided):

(i) the name and address of the complainant;
(ii) the date and time of the complaint;
(iii) a general description of the complaint;
(iv) any on-site activities (if any) that may have led to the complaint;
(v) wind direction, wind speed and temperature at the time of the complaint;
(vi) likely source of the reported problem; and
(vii) action taken in response to the complaint.

EMISSION TO AIR

ODOUR CONTROL LIMIT

A1 The licensee shall ensure that the emissions from the scrubber stack, monitored as per condition M1, do not exceed the following limits:

Emission	Concentration limit	Mass emission rate limit
Hydrogen sulphide	5mg/m^3 at STP, dry	140mg/sec at STP, dry

DISCHARGE TO WATER

OCEAN DISCHARGE LOADING LIMITS

W2(a) The licensee shall ensure that the load for total phosphorus in treated wastewater discharged from the Subiaco WWTP to the ocean through the Swanbourne Ocean Outlet does not exceed an annual average of 1000 kilograms per day. The annual average shall be calculated over the monitoring period.

W2(b) The licensee shall ensure that the load for total nitrogen in treated wastewater discharged from the Subiaco WWTP to the ocean through the Swanbourne Ocean Outlet does not exceed an annual average of 3300 kilograms per day. The annual average shall be calculated over the monitoring period.

OTHER EMISSIONS MANAGEMENT CONDITIONS

ODOUR CONTROL

X1 The licensee shall ensure that odour generated at the premises as detected by the unaided nose of an Inspector beyond the odour boundary shown in Attachment 4 shall not be offensive at any time.

MANAGEMENT OF ODOUR CONTROL SYSTEM

X2(a) The licensee shall ensure that the covers on the pre-treatment and secondary aeration areas of the plant, as indicated on Attachment 1, are kept in place at all times except when removal is required for maintenance operations or during emergency situations.

X2(b) The licensee shall operate and maintain the chemical scrubbing system in accordance with the design/manufacturers specification and instructions or own standard operating procedures. As a minimum manufacturer's specification and instructions shall be complied with.

MANAGEMENT OF PROCESS SOLID WASTES

X3(a) The licensee shall dispose of collected grit and screenings from the pre-treatment area to a licensed or registered landfill.

X3(b) The licensee shall dispose of sludge and biosolids in accordance with the document *Western Australian Guidelines for Direct Land Application of Biosolids and Biosolids Products*, Department of Environmental Protection, Water and Rivers Commission and Department of Health (February, 2002) (as amended).

SECONDARY TREATED WASTEWATER CONTROL

X4(a) The licensee may, during unforeseen treated wastewater pump station failures, discharge treated wastewater from the premises to the emergency overflow basin and then into the Subiaco Main Drain.

X4(b) The licensee shall report all discharges of treated wastewater to the Subiaco Main Drain to the Director within 24 hours of becoming aware of such discharges.

TANKERED WASTE

X5 The licensee may accept up to 20,000 tonnes per annum of biological wastes category 1.02 and 1.05 (from other Water Corporation assets) into the premises for treatment. This waste shall be delivered to the treatment plant via a closed pipeline.

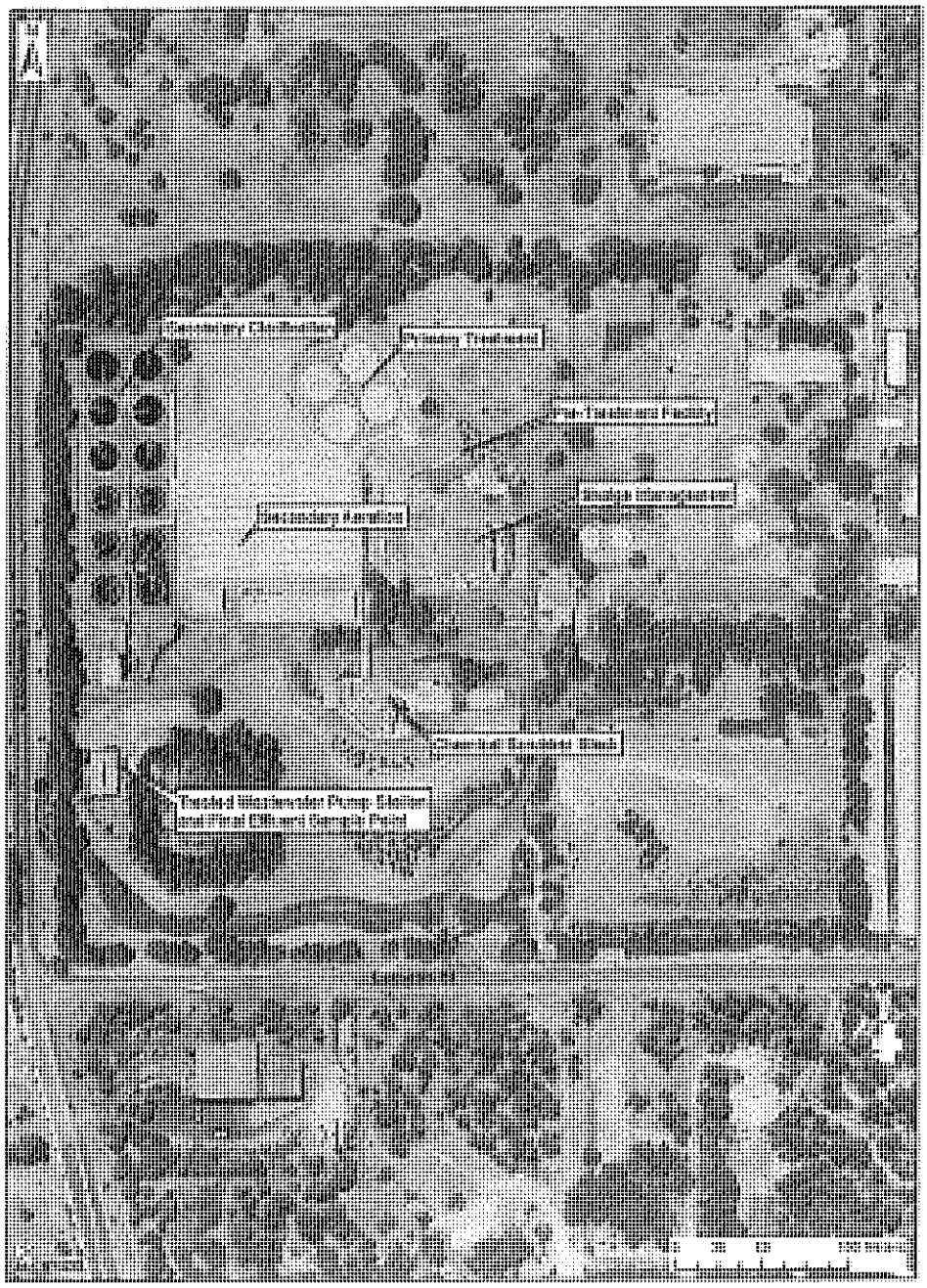
.....

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

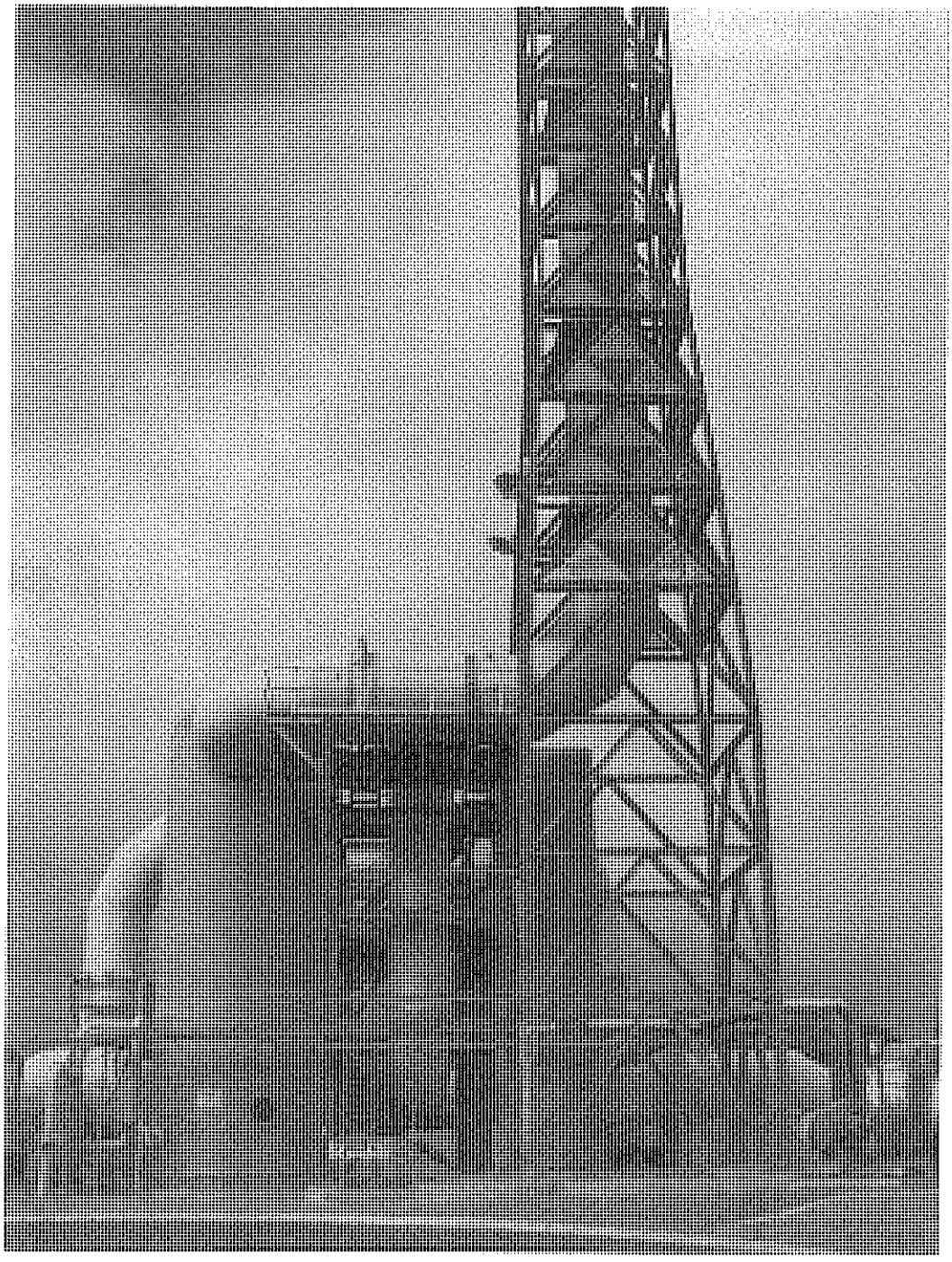
Date of Issue: 31 October 2008

ATTACHMENT 1

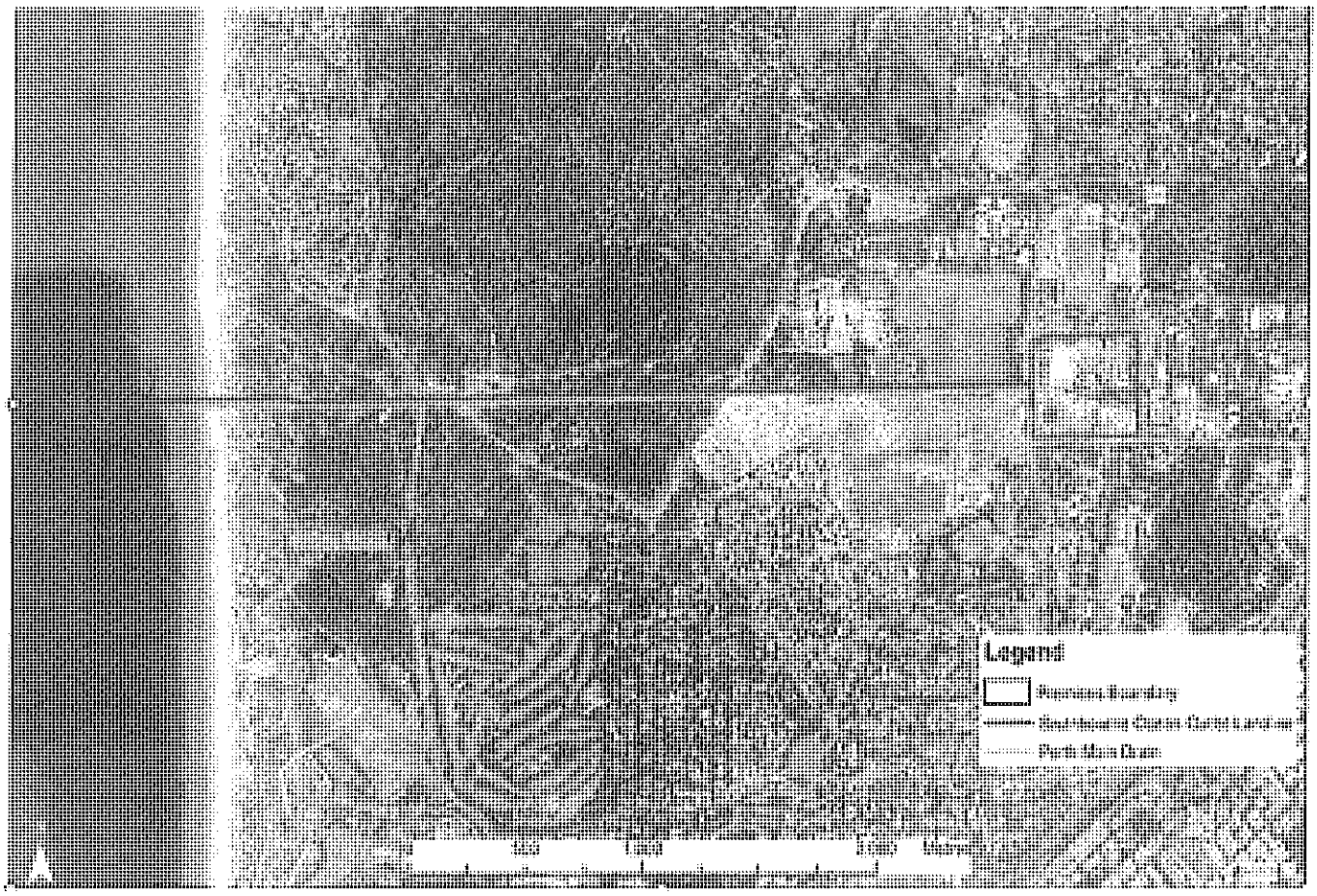
Subiaco WWTP



ATTACHMENT 2

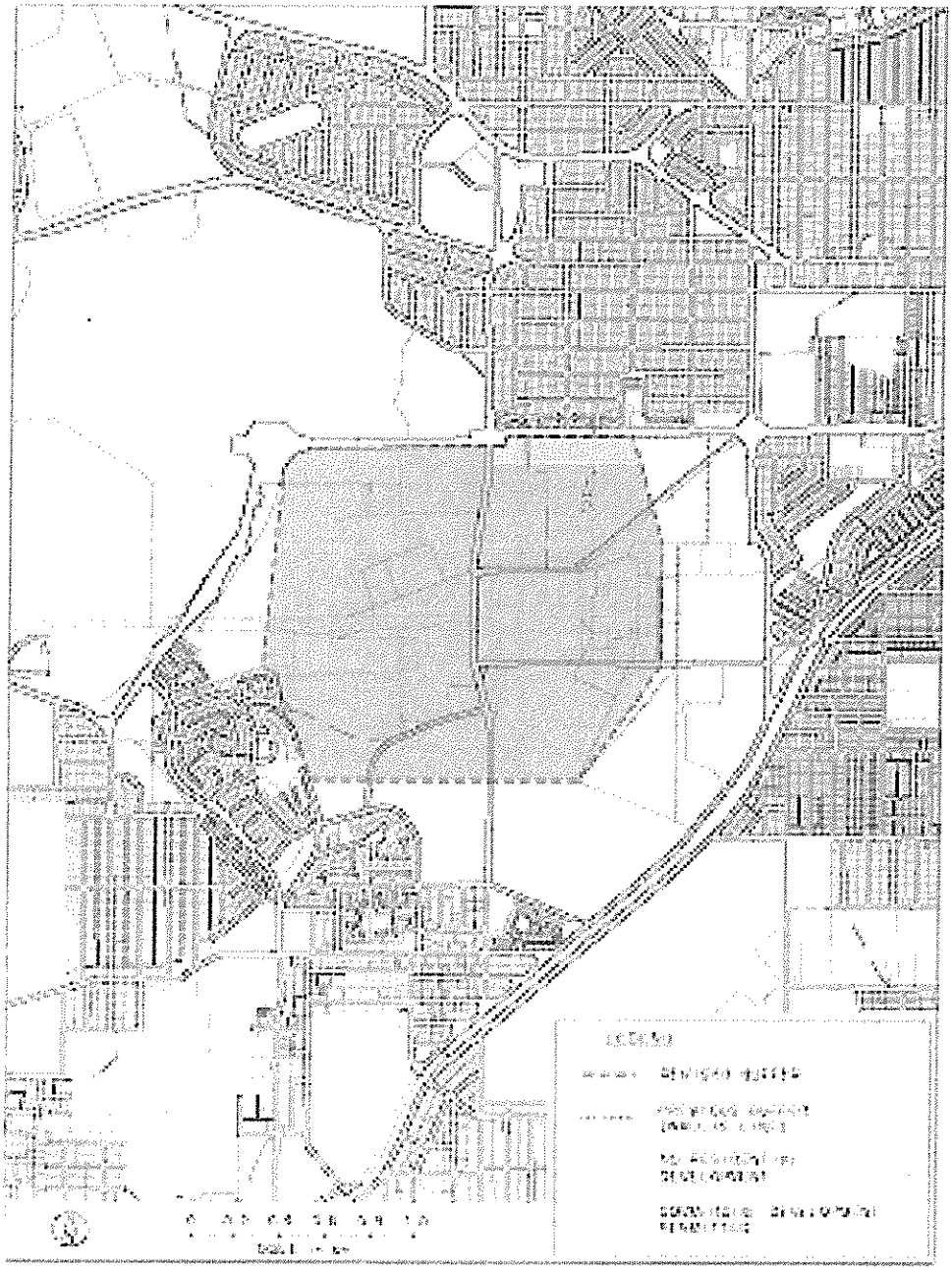


ATTACHMENT 3



ATTACHMENT 4

REVISED BUFFER ZONE
FOR SUBIACO WASTEWATER TREATMENT PLANT



ATTACHMENT 5

SECTION A

LICENCE DETAILS

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

STATEMENT OF COMPLIANCE WITH LICENCE CONDITIONS

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

Yes ☐ Please proceed to Section C

No ☐ Please proceed to Section B

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

INITIAL:_____

SECTION B

DETAILS OF NON-COMPLIANCE WITH LICENCE CONDITION.

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

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

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

INITIAL:_____

SECTION C

SIGNATURE AND CERTIFICATION

This Annual Audit Compliance Report may only be signed by a person(s) with legal authority to sign it. The ways in which the Annual Audit Compliance Report must be signed and certified, and the people who may sign the statement, are set out below.

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

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

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

INITIAL:_____

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

SIGNATURE: _____	SIGNATURE: _____
NAME: (printed) _____	NAME: (printed) _____
POSITION: _____	POSITION: _____
DATE: _____/_____/_____	DATE: _____/_____/_____

SEAL (if signing under seal)

Woodman Point Wastewater Treatment Plant Licence

Government of Western Australia
Department of Environment and Conservation

Your ref: L4201/1991/11
Our ref: DEC1658
Enquiries: Chris Malley
Phone: 9411 1706
Fax: 94195897
Email:

Chief Executive Officer
Water Corporation
PO Box 100
LEEDERVILLE WA 6902

Dear Sir/Madam

Environmental Protection Act 1986
Licence: L4201/1991/11
Occupier: Water Corporation
Premises: Woodman Point Wastewater Treatment Plant

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

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

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

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

Yours faithfully,

Peter Vasel
Manager, Works Approval & Emissions Licensing Section

Thursday, 28 October 2010

enc: Licence L4201/1991/11
copy to: Local Government Authority, City of Cockburn

Government of Western Australia
Department of Environment and Conservation

LICENCE FOR PRESCRIBED PREMISES
Environmental Protection Act 1986

LICENCE NUMBER: L4201/1991/11 **FILE NUMBER:** DEC1658

LICENSEE AND OCCUPIER OF PREMISES
Water Corporation
PO BOX 100
LEEDERVILLE WA 6902

NAME AND LOCATION OF PREMISES
Woodman Point Wastewater Treatment Plant
Lot 9 on Diagram 31097 Cockburn Road
Munster, W.A. 6166
(as depicted on Attachment 1)

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

CATEGORY	DESCRIPTION	CAPACITY
54	Sewage facility: premises on which sewage is treated (excluding septic tanks); or from which treated sewage is discharged onto land or into waters	160,000 cubic metres per day
61	Liquid waste facility: premises on which liquid waste produced on other premises (other than sewage waste) is stored, reprocessed, treated or irrigated.	50,000 tonnes per year

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

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

ISSUE DATE: Thursday, 28 october 2010
COMMENCEMENT DATE: Monday, 1 November 2010
EXPIRY DATE: Saturday, 31 October 2015

CONDITIONS OF LICENCE
Environmental Protection Act 1986

DEFINITIONS

In these conditions of licence, unless inconsistent with the text or subject matter:

"Bi-annual" for the purposes of sampling means twice per year with at least three months between each sampling event;

"Biological Waste," "Inorganic Chemicals" and "Low Strength Wastewater" with respect to the acceptance of controlled waste, means those waste categories specified and described in Table 7 of Attachment 7;

"Chemical Scrubber Outlet" means after the chemical scrubber but prior to entering the Odour Control Facility Discharge Stack;

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

"Director" for the purpose of correspondence means-

Manager, Industry Regulation, Swan Region
Department of Environment and Conservation
PO Box 454
KWINANA WA 6966

Telephone: (08) 9411 1777
Facsimile: (08) 9419 5897;

"g/s" means grams per second;

"Jervoise Bay Ocean Outlet", "Sepia Depression Ocean Outlet" and "Woodman Point Ocean Outlet" mean the marine discharge points labelled and depicted in Attachment 2;

"m^3/hr" means cubic metres per hour;

"mg/l" means milligrams per litre;

"ml" means millilitre;

"mg/m^3" means milligrams per cubic metre;

"m^3/s" means cubic metres per second;

"NATA" means National Association of Testing Authorities;

"Normal Operating Conditions" means operation of the wastewater treatment plant excluding start up, shutdown and upset conditions such as Routine Maintenance or Emergency Situations in relation to stack sampling or monitoring;

"Odour Control Facility" and "Odour Control Facility Discharge Stack" means those structures labelled and depicted in Attachment 1;

"OU" means odour units;

"STP" means standard temperature and pressure (0°Celsius and 101.325 kilopascals respectively);

"Tanker Receival Facility" and "Tanker Receival Facility Discharge Stack" means those structures labelled and depicted in Attachment 1;

"Usual Business Day" means the days Monday to Friday inclusive, excluding public holidays;

"°Celsius" means degrees celsius; and

"µg/l" means micrograms per litre.

GENERAL CONDITIONS

REPORTING

G1(a) The licensee shall provide to the Director, by **1 September each year**, an Annual Monitoring Report containing data collected **during the period beginning 1 July the previous year and ending on 30 June in that year** and shall contain but not be limited to:

(i) A histogram(s) showing the daily maximum and daily average concentrations of hydrogen sulphide and the volumetric flow measured in accordance with condition A3(a) of this licence;

(ii) Tabulated results of continuous monitor availability for each calendar month as specified in condition A3(c) of this licence;

(iii) Results of Odour Control Facility stack sampling undertaken in accordance with condition A4 of this licence;

(iv) Results of Tanker Receival Facility stack sampling undertaken in accordance with condition A10 of this licence;

(v) A graphical comparison of data presented in conditions G1(a)(iii) and (iv) of this licence against historical data obtained from 16 October 2009 onwards;

(vi) a summary of any data exceeding limits or targets specified in this licence including information on why the exceedence occurred (if known) and action taken by the licensee to prevent recurrence of such exceedences;

(vii) a tabular representation of nitrogen and phosphorus loads, concentrations and volumes discharged through the Sepia Depression Ocean Outlet Landline from the various inputs (if known);

(viii) a summary of complaints received about emissions from the premises including the date, time, the complaints address (street name and suburb only), a description of the complaint and the likely cause and findings of any investigations; and

(ix) the findings of an annual audit of the operational aspects of the existing odour control devices at the premises.

G1(b) The licensee shall use the units specified in column 2 of Table 1 for the corresponding parameters specified in column 1 of Table 1, in Annual Monitoring Reports required by condition G1(a) of this licence;

Table 1: Parameter units for reporting in the Annual Monitoring Report

Column 1	Column 2
Parameter	**Unit**
Monthly cumulative volume discharged	Cubic metres per day (monthly average)
pH	pH units
E. Coli	Most probable number per 100 ml
Other parameters (treated wastewater)	mg/l
Other parameters (marine)	µg/l
Nitrogen load	Kilograms per day (monthly average)

G2 The licensee shall by **1 September** in each year, provide to the Director an Annual Audit Compliance Report in the form in Attachment 3 to this licence, signed and certified in the manner required by Section C of the form, indicating the extent to which the licensee has complied with the conditions of this licence, and any previous licence issued under Part V of the Act for the premises, **during the period beginning 1 July the previous year and ending on 30 June in that year.**

AIR POLLUTION CONTROL CONDITIONS

PRE AND PRIMARY TREATMENT AREAS

A1 The licensee shall maintain covers over the pre-treatment and primary treatment areas of the plant, except during Routine Maintenance or Emergency Situations.

ODOUR CONTROL FACILITY

A2 The licensee shall operate and maintain odour scrubbing equipment on the Odour Control Facility in accordance with manufacturer's specifications for the Facility.

ODOUR CONTROL FACILITY – CONTINUOUS MONITORING

A3(a) The licensee shall continuously monitor the parameters specified in column 1 of Table 2 at the locations specified in column 2 of Table 2 and in the units specified in column 3 of Table 2.

Table 2: Continuous monitoring requirements in the Odour Control Facility

Column 1	Column 2	Column 3
Parameters	**Monitor Location**	**Units**
Hydrogen sulphide	Chemical scrubber inlet	ppm
	Chemical Scrubber Outlet (prior to entering the discharge stack)	ppm
Volumetric flow	Odour Control Facility Discharge Stack	m^3/hr

A3(b) The licensee shall ensure that the continuous monitors referred to in condition A3(a) of this licence are maintained and calibrated in accordance with the manufacturer's specifications.

A3(c) The licensee shall ensure that the continuous monitors referred to in condition A3(a) of this licence are operated to achieve at least a 90% availability per calendar month.

ODOUR CONTROL FACILITY – STACK SAMPLING

A4 The licensee shall implement a manual stack monitoring program for the location specified in column 1 of Table 3 which measures the parameters specified in column 2 of Table 3 at the frequency specified in column 3 of Table 3, using the sampling methods specified in column 4 of Table 3 and in the units specified in column 5 of Table 3 during Normal Operating Conditions.

Table 3: Odour Control Facility manual stack monitoring.

Column 1	Column 2	Column 3	Column 4	Column 5
Location	**Parameter to be measured**	**Frequency**	**Sampling Method**	**Units**
Exit gases from the Odour Control Facility Discharge Stack	Hydrogen sulphide	Bi-annual	NATA accredited method for the measurement and analysis of hydrogen sulphide emissions from stationary sources	mg/m³ at STP, dry
	Volumetric flow rate		USEPA method 2	m³/sec
	Stack exit temperature		n/a	°Celsius
	Odour Units	Annual	AS 4323.3:2001 for Dynamic Olfactometry	OU

ODOUR CONTROL FACILITY - TARGETS

A5(a) The licensee shall operate the Odour Control Facility to achieve a hydrogen sulphide **emission target of less than 1.5 ppm** at the Chemical Scrubber Outlet as monitored in accordance with condition A3(a) of this licence.

A5(b) The licensee shall take corrective action as soon as practicable to reduce hydrogen sulphide emissions upon becoming aware of any confirmed measurement which indicates that the emission target specified in condition A5(a) of this licence has been exceeded.

A6(a) The licensee shall notify the Director before 5pm on the next Usual Business Day after becoming aware of any confirmed measurement which indicates that the emission target specified in condition A5(a) of this licence has been exceeded.

A6(b) The licensee shall follow the notification referred to in condition A6(a) of this licence with a written report to the Director within five (5) working days of receiving the confirmed measurement and shall include, but not be limited to:

(i) the date and time of the exceedance;
(ii) results of continuous monitoring required by condition A3(a) of this licence at the time of the exceedance;
(iii) the cause of the exceedance;
(iv) the extent of the exceedance; and
(v) corrective actions taken in accordance with A5(b) and planned corrective actions to prevent a recurrence of the exceedance.

ODOUR CONTROL FACILITY – LIMITS

A7 The licensee shall operate the Odour Control Facility so that hydrogen sulphide emissions from the Odour Control Facility Discharge Stack do not exceed the limits specified in column 2 and column 3 of Table 4, monitored as required by condition A4 of this licence.

Table 4: Odour Control Facility Emission Limits

Column 1	Column 2	Column 3
Emission	**Concentration Limit**	**Emission Rate Limit**
Hydrogen sulphide	5 mg/m^3 at STP, dry	0.25 g/s at STP, dry

A8 The licensee shall notify the Director, in writing, before 5pm on the next Usual Business Day after becoming aware of any confirmed measurement which indicates that an emission limit specified in condition A7 of this licence has been exceeded and the notification shall include:

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

TANKER RECEIVAL FACILITY

A9(a) The licensee shall maintain covers on equipment where odour can be emitted to the atmosphere from the Tanker Receival Facility, except during Routine Maintenance or Emergency Situations.

A9(b) The licensee shall operate and maintain a chemical scrubbing system for the removal of odorous compounds from the Tanker Receival Facility, prior to their emission through the Tanker Receival Facility Discharge Stack.

TANKER RECEIVAL FACILITY – STACK SAMPLING

A10 The licensee shall implement a manual stack monitoring program for the location specified in column 1 of Table 5 which measures the parameters specified in column 2 of Table 5 at the frequency specified in column 3 of Table 5, using the sampling methods specified in column 4 of Table 5 and in the units specified in column 5 of Table 5 during Normal Operating Conditions.

Table 5: Tanker Receival Facility manual stack monitoring.

Column 1	Column 2	Column 3	Column 4	Column 5
Location	**Parameter to be measured**	**Frequency**	**Sampling method**	**Units**
Exit gases from the Tanker Receival Facility Discharge Stack	Hydrogen sulphide	Bi-annual	NATA accredited method for the measurement and analysis of hydrogen sulphide emissions from stationary sources	mg/m³ at STP, dry
	Volumetric flow rate	Bi-annual	USEPA method 2	m³/s
	Stack exit temperature	Bi-annual	n/a	°Celsius
	Odour Units	Annual	AS 4323.3:2001 for Dynamic Olfactometry	OU/s

STACK SAMPLING REQUIREMENTS

A11(a) The licensee shall ensure that sampling required under conditions A4 and A10 of this licence are undertaken in accordance with AS4323.1-1995 *Stationary Source Emissions Method 1: Selection of sampling positions.*

A11(b) The licensee shall ensure that all stack monitoring required by condition A4 and A10 of this licence are conducted by companies and laboratories with current NATA accreditation for the methods and analyses specified.

WATER POLLUTION CONTROL CONDITIONS

DISCHARGE POINTS

W1(a) Subject to condition W1(b) of this licence, the licensee shall discharge treated wastewater from the premises to the environment through the Sepia Depression Ocean Outlet.

W1(b) Pursuant to condition W1(a) of this licence, the licensee may, during Routine Maintenance or Emergency Situations, discharge treated wastewater from the premises to the environment:
(i) firstly through the Woodman Point Ocean Outlet; and
(ii) secondly through the Jervoise Bay Ocean Outlet.

W1(c) The licensee shall advise the Director prior to intended maintenance works on the Sepia Depression Ocean Outlet, which will require use of the Woodman Point Ocean Outlet or Jervoise Bay Ocean Outlet.

SAMPLING POINTS AND FLOW MONITORING

W2(a) The licensee shall maintain a treated wastewater sampling point in the channel from the Sequencing Batch Reactor to the Flow Balancing Dam (as depicted in Attachment 1) so that treated wastewater samples can be easily taken.

W2(b) The licensee shall maintain a Groundwater Abstraction Sampling Point on the pipeline leading to the treated wastewater wet well so that recovered groundwater samples can be easily taken (as depicted in Attachment 1).

W2(c) The licensee shall monitor and record the cumulative monthly volumes of wastewater treated at the premises (using the Munster Pump Station No. 3 Magnetic flow meters).

W2(d) The licensee shall monitor and record the cumulative monthly volumes of groundwater recovered from bores on the western side of the premises and directed to the Sepia Depression Ocean Outlet.

WATER MONITORING AND REPORTING

W3(a) The licensee shall take representative water samples from the sites specified in column 1 of Table 6, at the frequencies specified in column 2 of Table 6, for the parameters specified in column 3 of Table 6 and have them analysed.

Table 6: Water Monitoring Program

Column 1	Column 2	Column 3
Monitoring Sites	**Sampling Frequency**	**Parameters to be sampled**
Outlet Channel from the Sequencing Batch Reactor (as depicted in Attachment 1).	Monthly	pH, Total Suspended Solids, (filtered) 5-Day Biochemical Oxygen Demand, Total Nitrogen, Ammonium-nitrogen, Nitrate+Nitrite-nitrogen, Total Phosphorus
	3-monthly	*E. Coli*, Oil and Grease, arsenic, cadmium, copper, chromium, lead, mercury, nickel, zinc
Recovered Groundwater Abstraction Point (as depicted in Attachment 1).	3-monthly	Total Nitrogen
Ocean monitoring sites (as depicted in Attachments 3, 4 and 5 (depending on ocean current)	Annually every summer	Total Nitrogen, Nitrate + Nitrite-nitrogen, Ammonium-nitrogen, Total Phosphorus, Filterable Reactive Phosphorus, Chlorophyll 'a', *E. Coli*
Shoreline monitoring sites (as depicted in Attachment 6).		*E. Coli*

W3(b) The licensee shall collect, handle and preserve all water samples in accordance with the relevant part(s) of Australian Standard 5667:1998 and with respect to marine sampling, it is accepted that the licensee (or its contractor) does not need to collect, container and transport blanks or field spikes in accordance with the above standard.

W3(c) The licensee shall analyse all water samples in its own quality assured laboratory, or ensure that samples are analysed in a laboratory holding NATA accreditation for the analyses specified.

W3(d) If the licensee uses its own laboratory for analysis as noted in condition W3(c) of this licence, then at least one set of samples per year shall also be submitted to a laboratory holding NATA accreditation for the analysis specified in condition W3(a) of this licence and the licensee shall report these duplicate results to the Director in the annual monitoring report, as required in condition G1(a) of this licence, specifying the laboratory in which each analysis was performed.

CALCULATION OF CONTAMINANT LOAD

W4(a) The licensee shall determine the monthly load of each contaminant in the treated wastewater discharged from the premises (where applicable) using flow-weighted data. The loads shall be based on the treated wastewater discharge rate and the concentration as measured in accordance with conditions W2 and W3 of this licence. Monthly and annual average loads of the contaminants shall be reported in the Annual Monitoring Report in kilograms per day.

W4(b) The licensee shall determine the annual load of Total Nitrogen in the recovered groundwater discharged from the premises using flow-weighted data. The loads shall be based on the groundwater discharge rate and the concentration as measured in accordance with conditions W2 and W3 of this licence. Monthly and annual average Total Nitrogen loads shall be reported in the Annual Monitoring Report in kilograms per day.

TOTAL NITROGEN DISCHARGE LIMIT

W5 The licensee shall ensure that the load of total nitrogen discharged through the Sepia Depression Ocean Outlet does not exceed **1,778 tonnes per year** in any consecutive 12 month period.

TANKERED WASTE

W6(a) The licensee shall only accept third party liquid wastes tankered into the premises:
- (i) at the Tanker Receival Facility, or
- (ii) at the pre-treatment works of the sewage treatment plant if there is a breakdown of the tanker receival facility or a delay of more than 60 minutes to unload waste at the Tanker Receival Facility.

W6(b) The licensee shall only accept controlled waste in Biological Waste category 1.02 and category 1.05 (from other Water Corporation assets) tankered into the premises:
- (i) at the pre-treatment works of the sewage treatment plant; or
- (ii) at the Tanker Receival Facility where it is impractical to use the pre-treatment works.

W6(c) The licensee shall only accept third party tankered controlled waste at the premises if the licensee has undertaken a pH, conductivity and visual assessment of the characteristics of the waste and the licensee considers that the waste meets one of the following waste categories:
- (i) Biological Wastes - categories 1.01, 1.02, 1.03, 1.04 and 1.05;
- (ii) Inorganic chemicals - category 13.15; or
- (iii) Low Strength Wastewater - categories 14.01, 14.02, 14.03, 14.04.

W6(d) The licensee shall record the cumulative monthly volume and type of tankered waste accepted at either the Tanker Receival Facility or the pre-treatment works of the sewage treatment plant, with this data presented in a tabular form in the next Annual Monitoring Report, as required by condition G1(a) of this licence.

W6(e) The licensee shall record the date and time when tankered third party waste was accepted at the pre-treatment works of the sewage treatment plant, with this data being presented in a tabular form referencing the tracking form number in the next Annual Monitoring Report as required by condition G1(a) of this licence.

W6(f) The licensee shall direct waste streams from the Tanker Receival Facility to the following locations:
- (i) collected grit and screenings to a licensed landfill;
- (ii) sludges and biosolids to the on-site sludge treatment and de-watering facilities; and
- (iii) wastewater to the pre-treatment area of the sewage treatment plant.

BUNDING AND CONTAINMENT

W7 The licensee shall store environmentally hazardous chemicals including sodium hydroxide and hypochlorite (where the total volume of each substance stored on the premises exceeds 250 litres) within bunded areas in accordance with Australian Standard 3780-2008.

SOLID WASTE CONTROL CONDITIONS

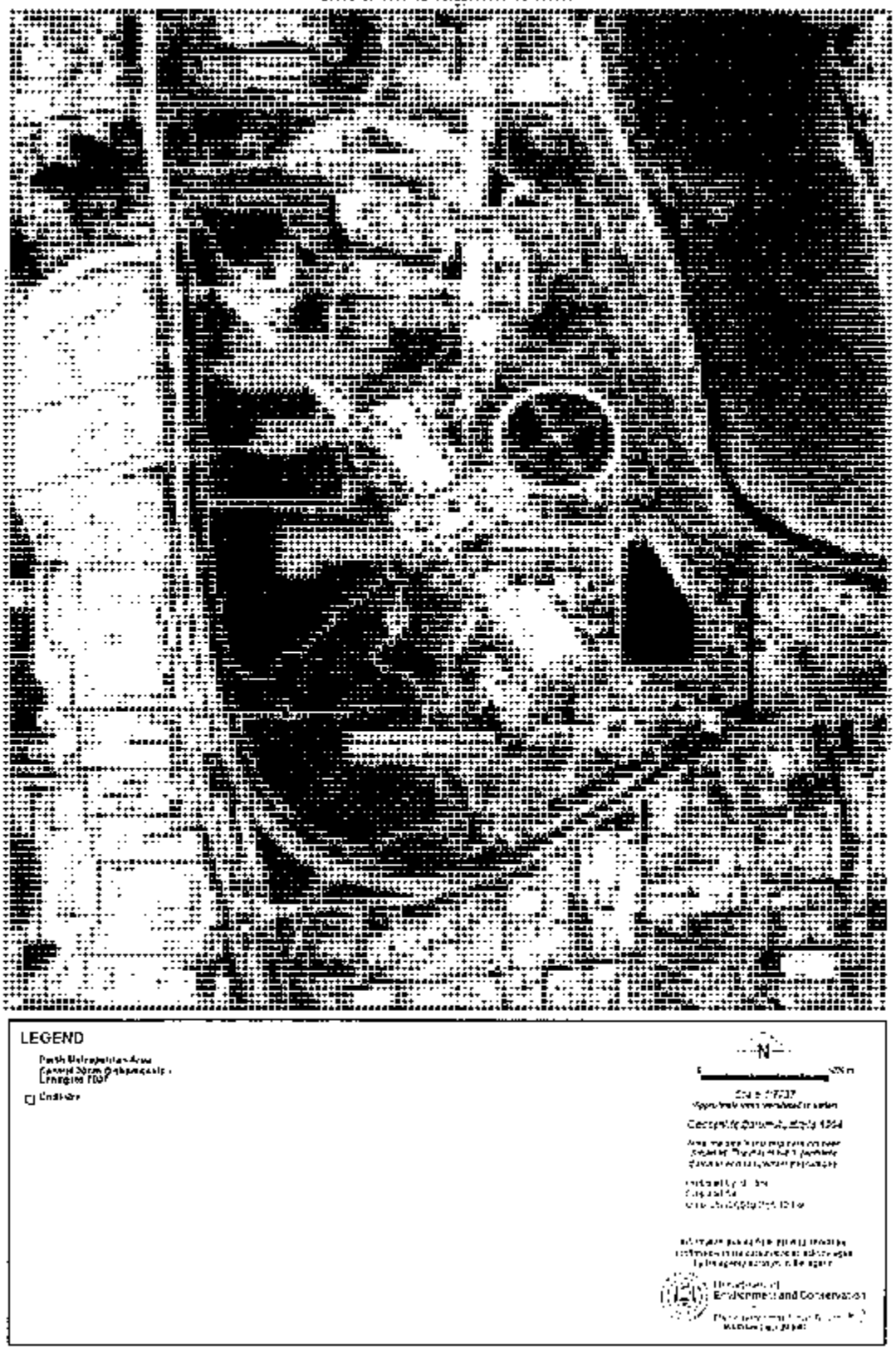
SOLIDS DISPOSAL

S1 The licensee shall dispose of sludge and biosolids in accordance with the document *Western Australian Guidelines for Direct Land Application of Biosolids and Biosolids Products*, Department of Environmental Protection, Water and Rivers Commission and Department of Health (February, 2002) (as amended).

ATTACHMENT 1
PLAN OF PREMISES

LICENCE NUMBER: L4201/1991/10 **FILE NUMBER:** DEC1658

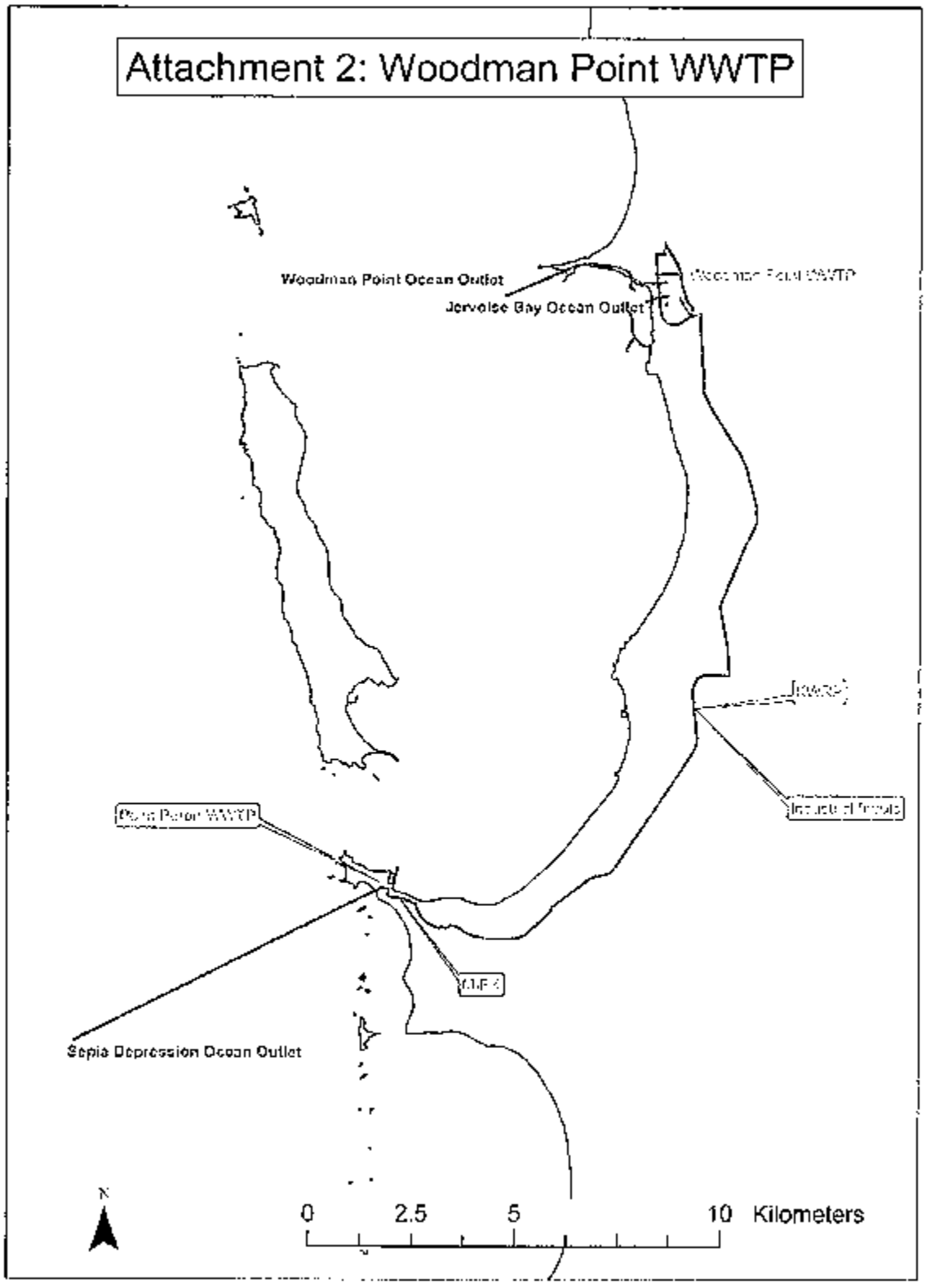
Woodman Point Wastewater Treatment Plant



ATTACHMENT 2

MAP OF OCEAN DISCHARGE POINTS

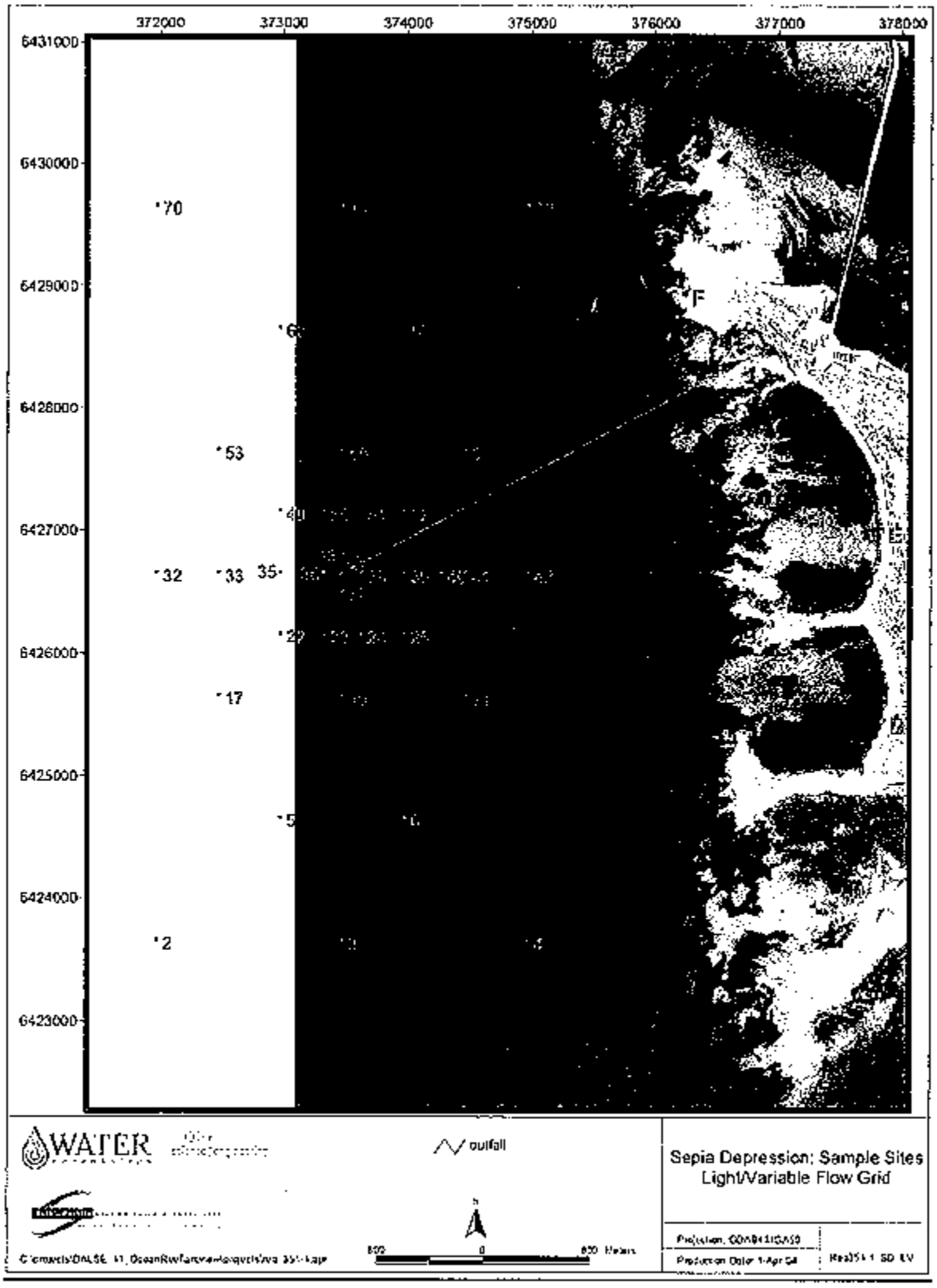
LICENCE NUMBER: L4201/1991/10 **FILE NUMBER:** DEC1658



ATTACHMENT 3

OCEAN SAMPLING SITES: LIGHT/VARIABLE FLOW GRID

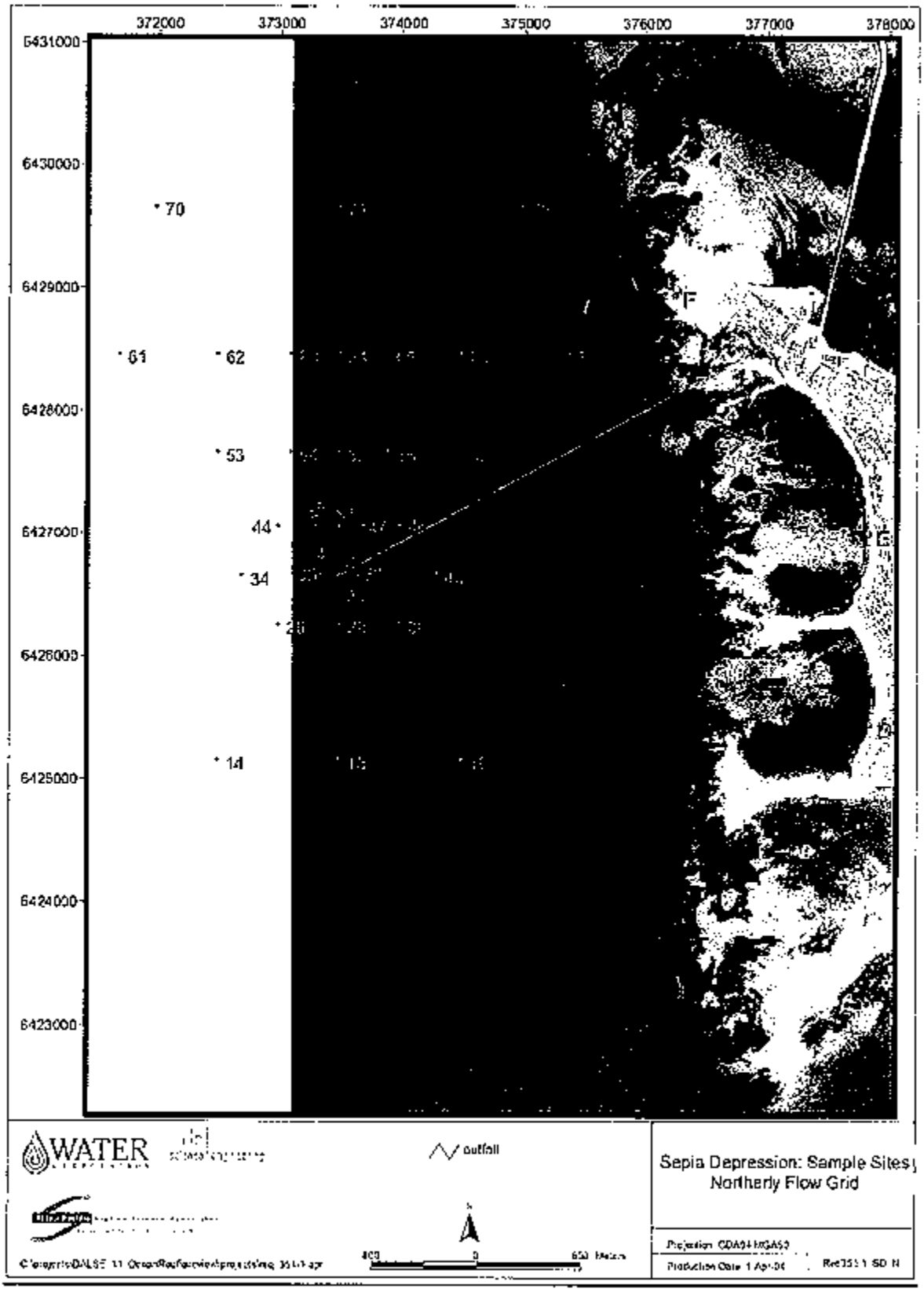
LICENCE NUMBER: L4201/1991/10 **FILE NUMBER:** DEC1658



ATTACHMENT 4

OCEAN SAMPLING SITES: NORTHERLY FLOW GRID

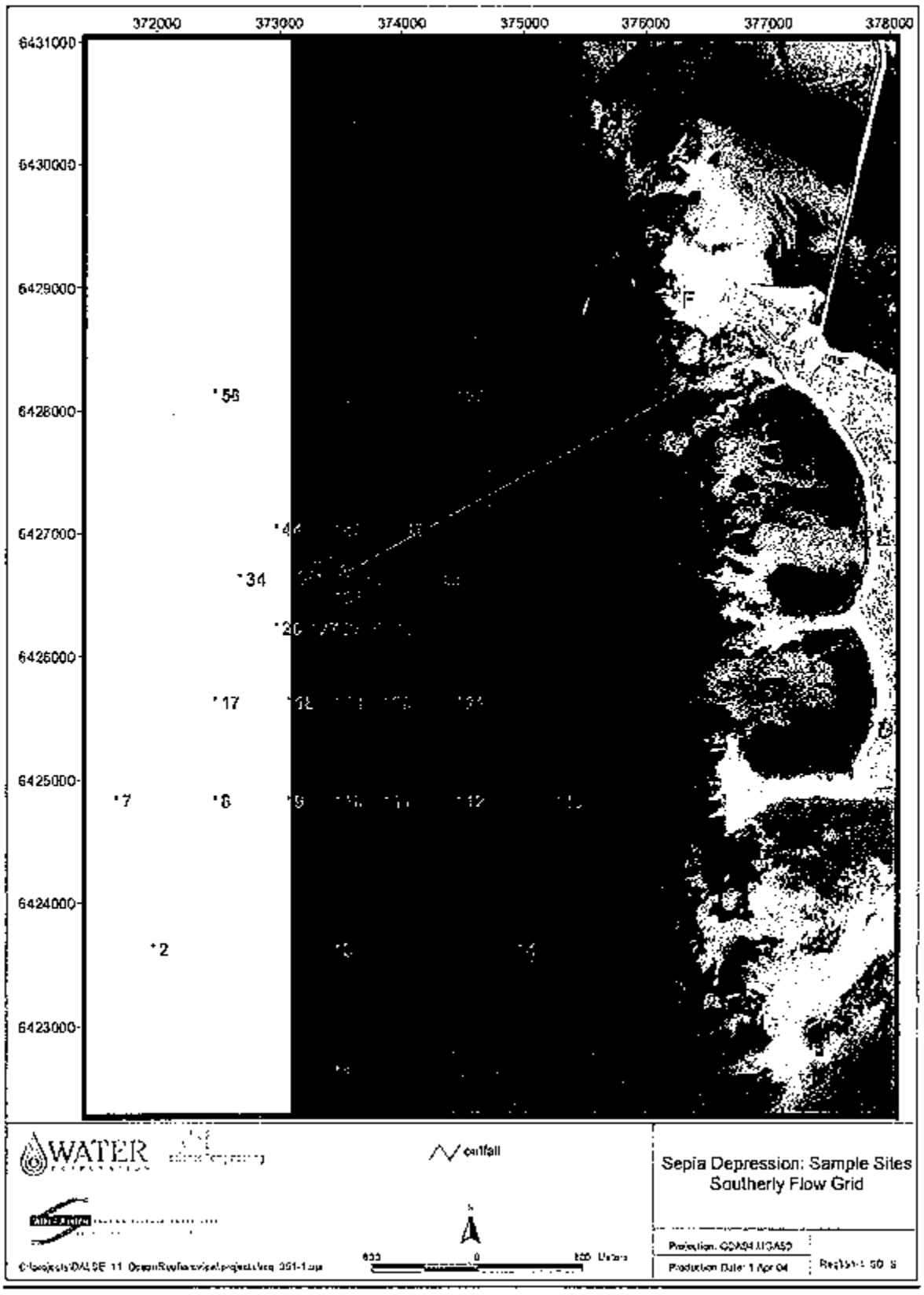
LICENCE NUMBER: L4201/1991/10 **FILE NUMBER:** DEC1658



ATTACHMENT 5

OCEAN SAMPLING SITES: SOUTHERLY FLOW GRID

LICENCE NUMBER: L4201/1991/10 **FILE NUMBER:** DEC1658



ATTACHMENT 6

OCEAN SHORE SAMPLING SITES

LICENCE NUMBER: L4201/1991/10 **FILE NUMBER:** DEC1658

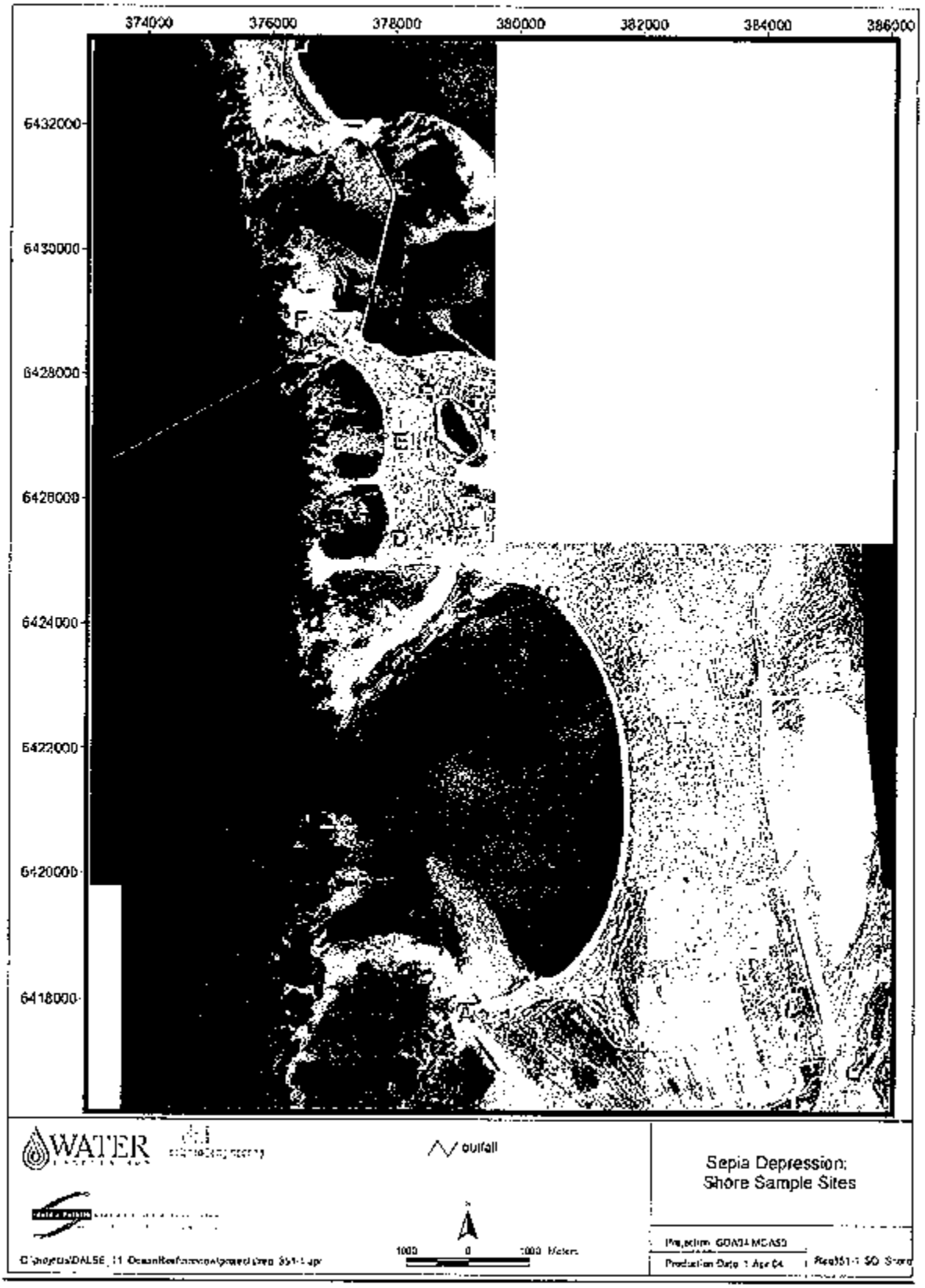


Table 7 – Controlled Waste Categories and Descriptions for acceptance at Woodman Point Wastewater Treatment Plant

Category Group No.	Category Group Name	Category No.	Description
1	Biological Wastes	1.01	Animal wastes – smallgoods; tallow; and animals slaughtered for quarantine purposes
		1.02	Septage wastes – wastes from apparatus for the treatment of sewage
		1.03	Grease wastes – wastes resulting from food preparation processes
		1.04	Vegetable oils and derivatives and other wastes (excluding wastes referred to in categories 1.01, 1.02 and 1.03)
		1.05	Sewage waste from the reticulated sewage system (i.e. Water Corporation)
13	Inorganic Chemicals	13.15	Non toxic salts
14	Low strength waste water	14.01	Industrial washwaters
		14.02	Stormwater
		14.03	Wash water
		14.04	Fire debris and washwater (may vary)

ATTACHMENT 8

ANNUAL AUDIT COMPLIANCE REPORT

LICENCE NUMBER: L4201/1991/10 **FILE NUMBER:** DEC1658

SECTION A

LICENCE DETAILS

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

STATEMENT OF COMPLIANCE WITH LICENCE CONDITIONS

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

Yes □ Please proceed to Section C

No □ Please proceed to Section B

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

INITIAL:_____

ATTACHMENT 8

ANNUAL AUDIT COMPLIANCE REPORT

LICENCE NUMBER: L4201/1991/10 **FILE NUMBER:** DEC1658

SECTION B - DETAILS OF NON-COMPLIANCE WITH LICENCE CONDITION

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

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

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

INITIAL:_____

SECTION C - SIGNATURE AND CERTIFICATION

This Annual Audit Compliance Report may only be signed by a person(s) with legal authority to sign it. The ways in which the Annual Audit Compliance Report must be signed and certified, and the people who may sign the statement, are set out below.

ATTACHMENT 8

ANNUAL AUDIT COMPLIANCE REPORT

LICENCE NUMBER: L4201/1991/10 **FILE NUMBER:** DEC1658

Please tick the box next to the category that describes how this Annual Audit Compliance Report is being signed. If you are uncertain about who is entitled to sign or which category to tick, please contact the licensing officer for your premises.

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

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

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

SIGNATURE: _____ NAME: _____

(printed) _____

POSITION: _____

DATE: _____/_____/_____

SIGNATURE: _____ NAME: _____

(printed) _____

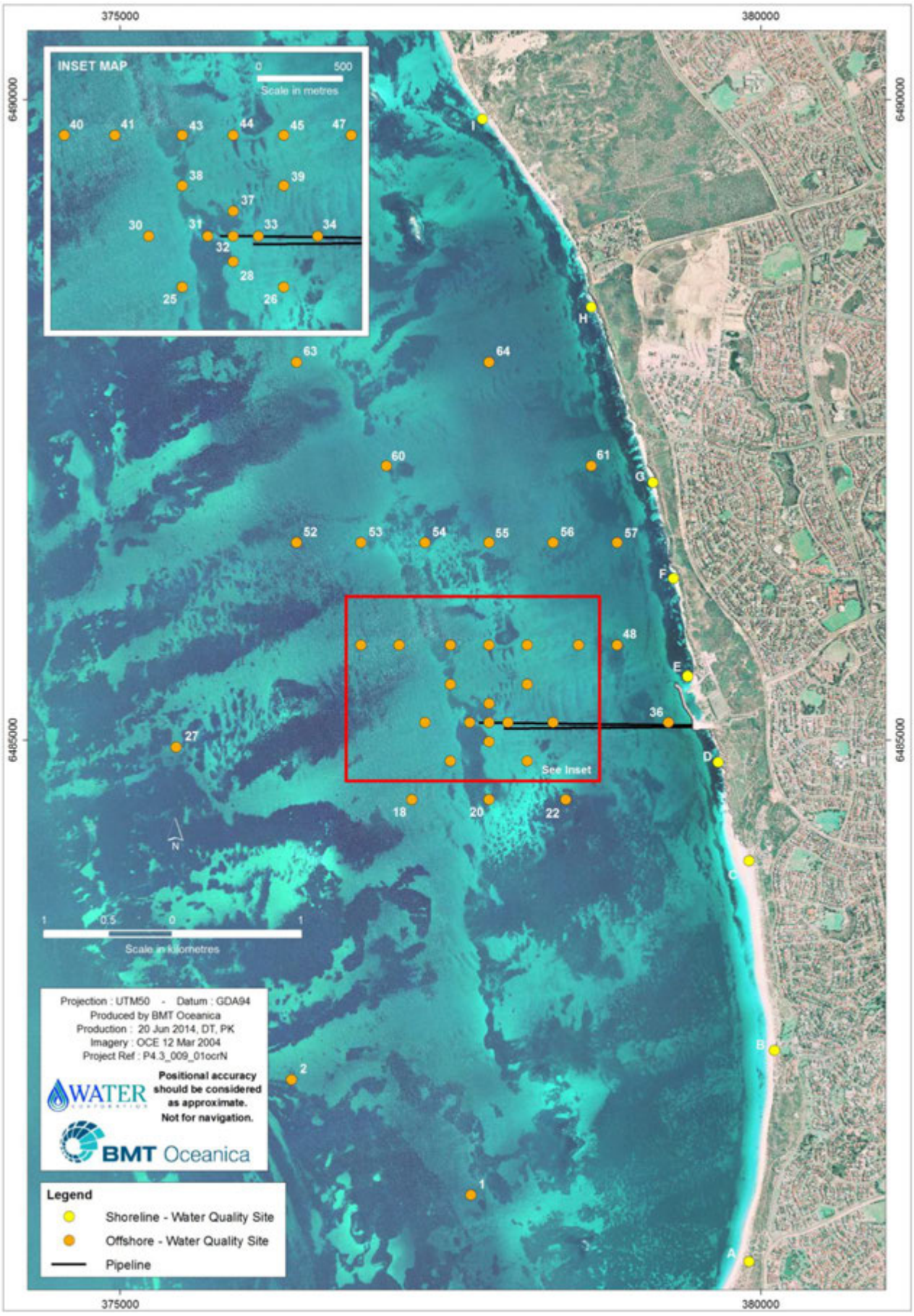
POSITION: _____

DATE: _____/_____/_____

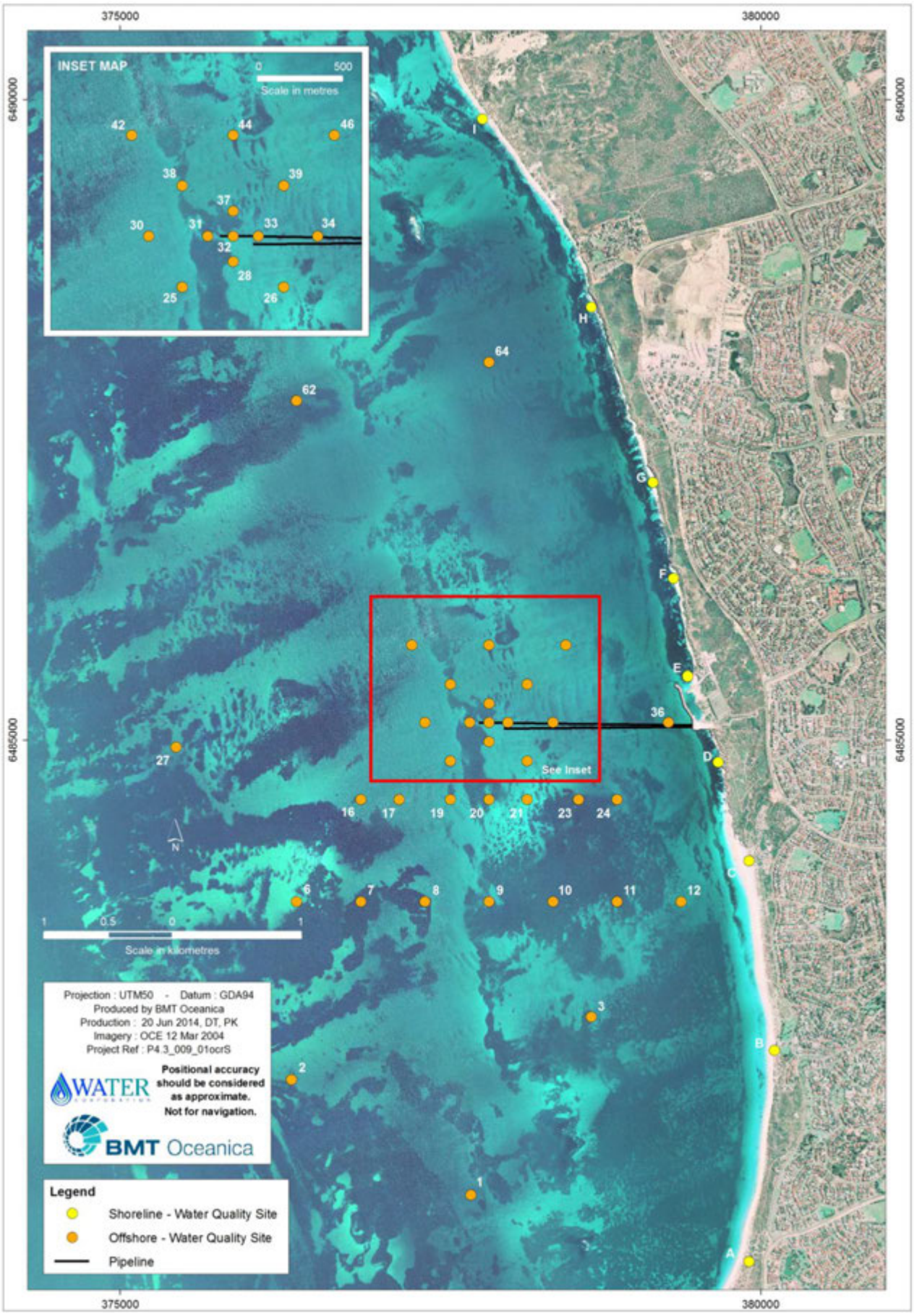
SEAL (if signing under seal)

Appendix B – Sampling Grids for Summer Water Quality Survey

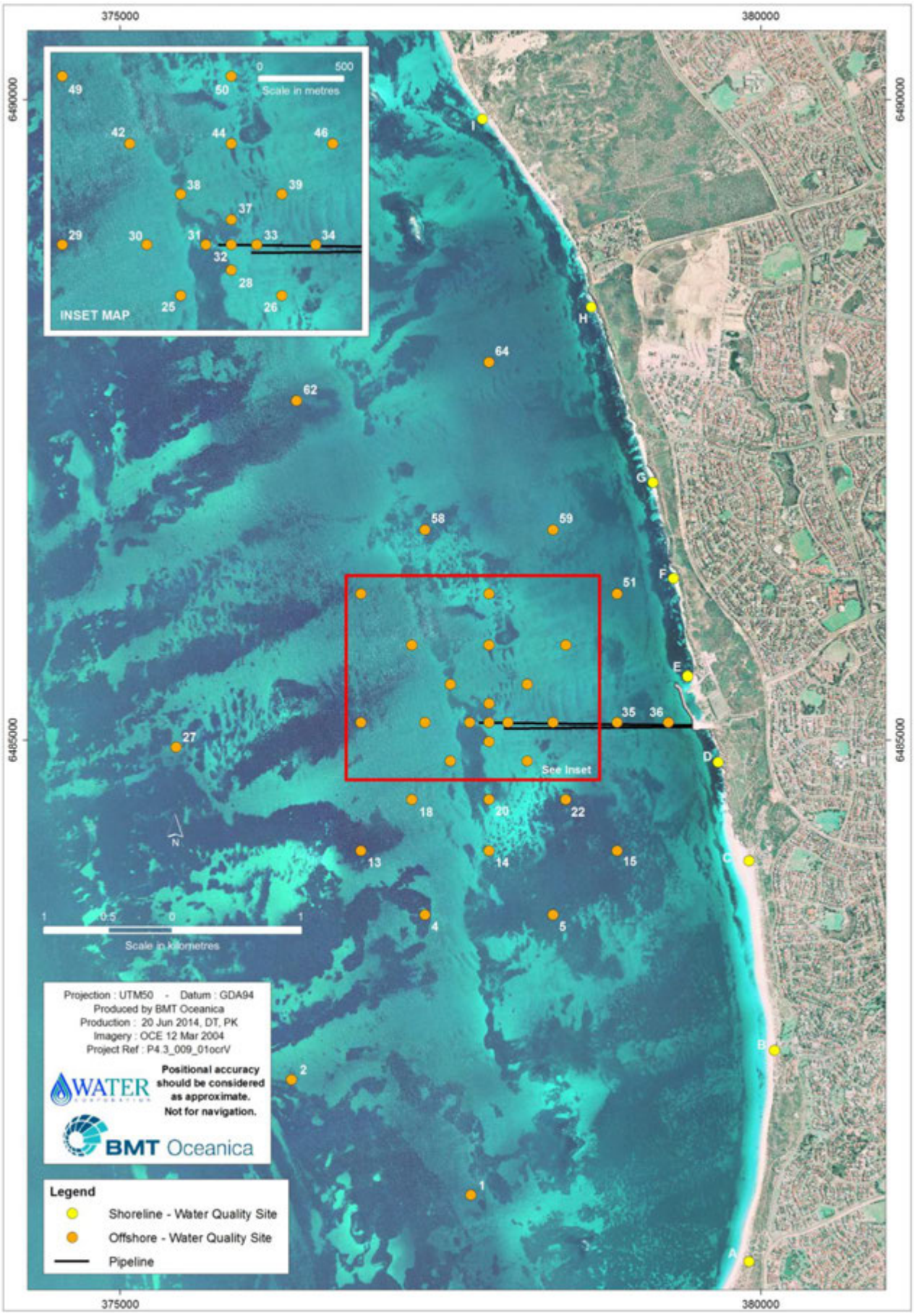
Ocean Reef Sample Sites – Northerly Flow Grid and Shoreline Sites



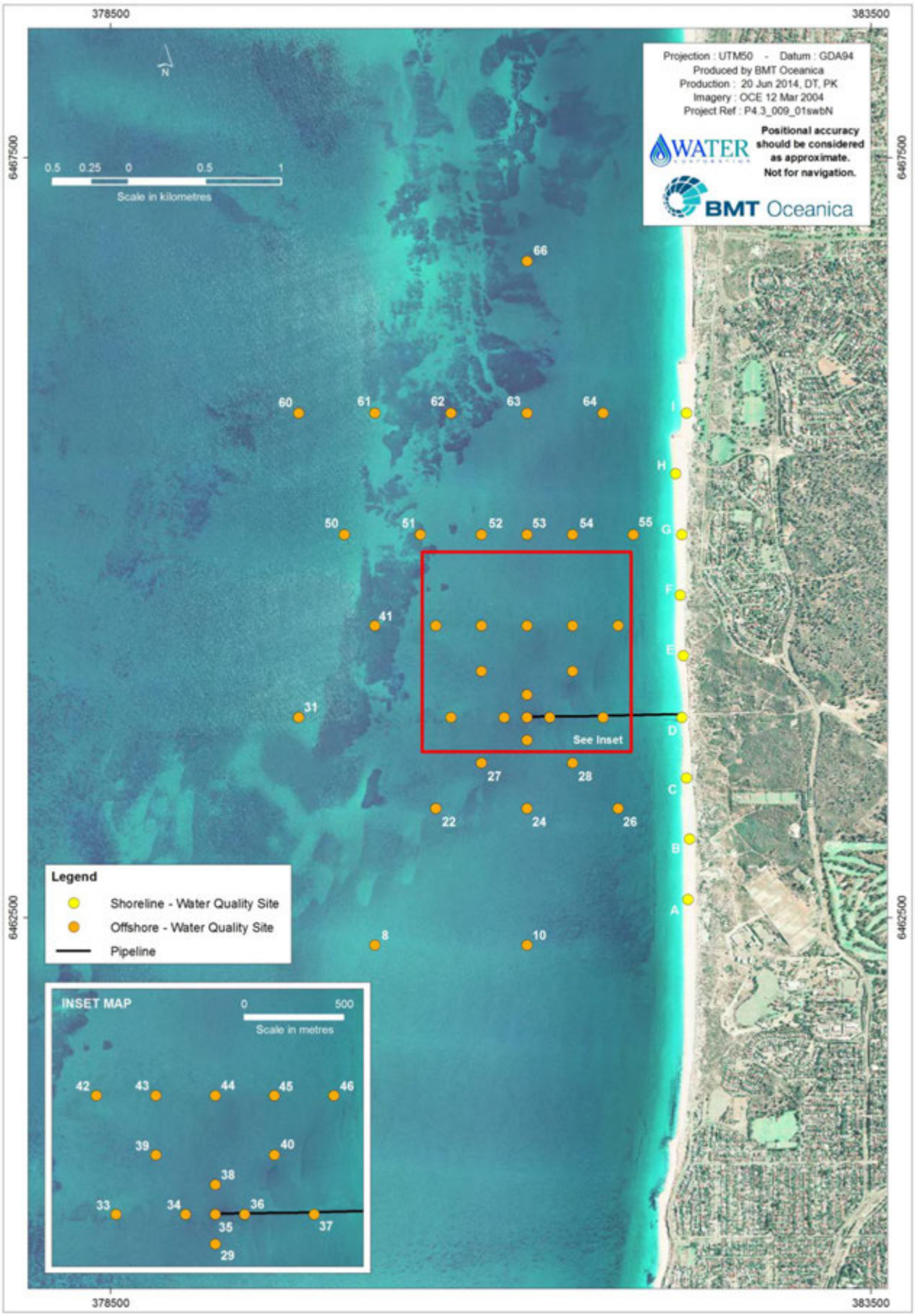
Ocean Reef Sample Sites – Southerly Flow Grid and Shoreline Sites



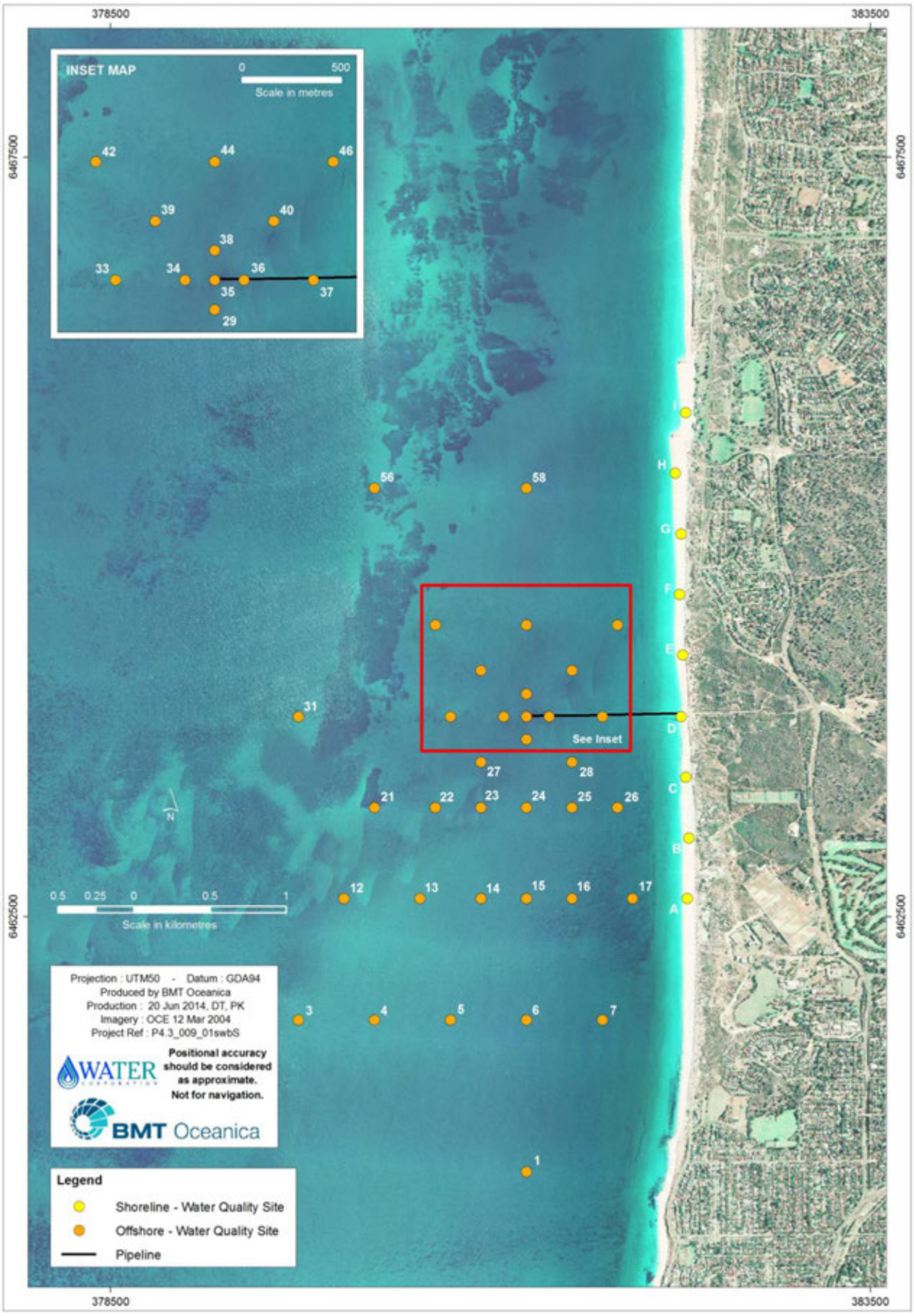
Ocean Reef Sample Sites – Light/Variable Flow Grid and Shoreline Sites



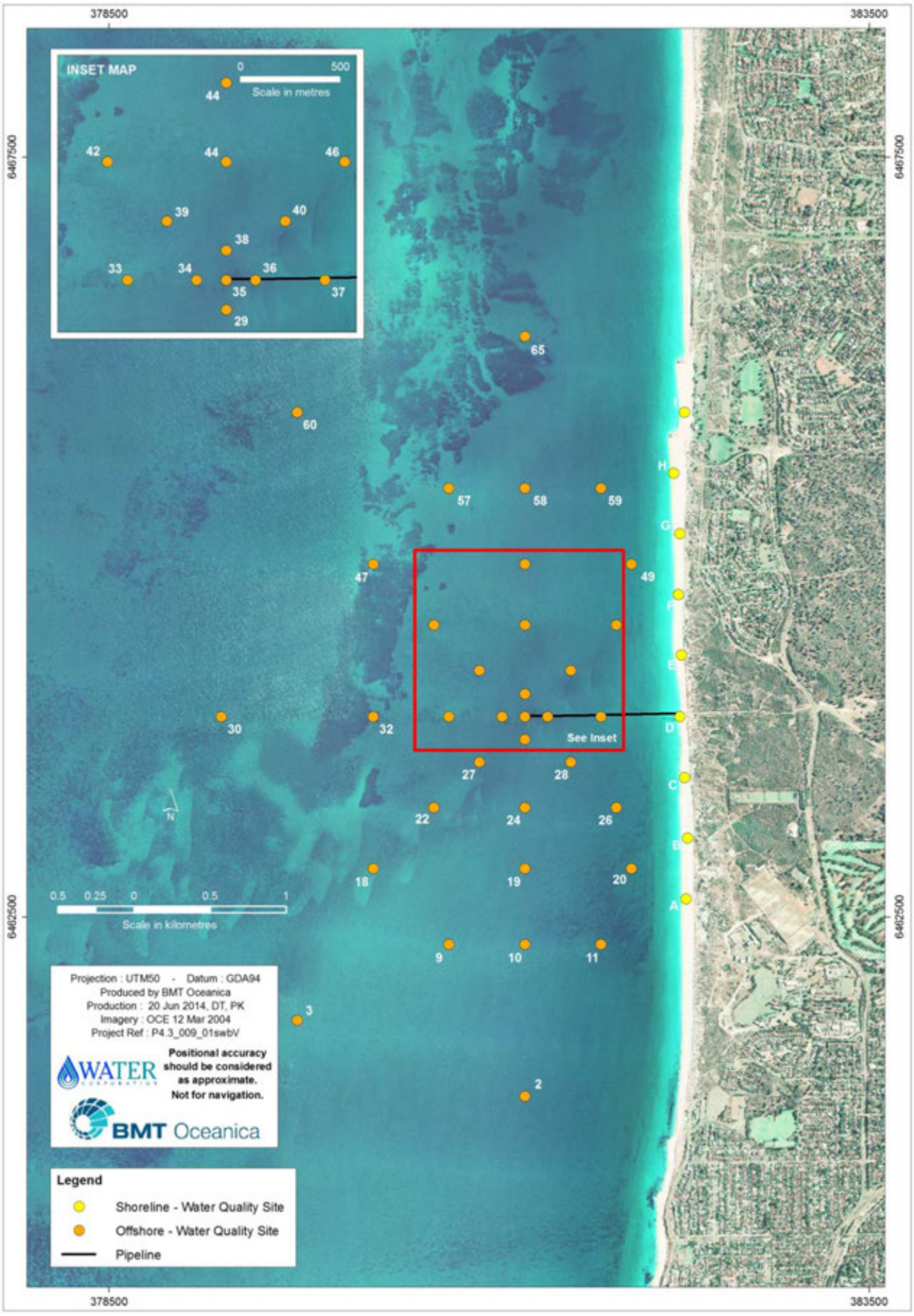
Swanbourne Sample Sites – Northerly Flow Grid and Shoreline Sites



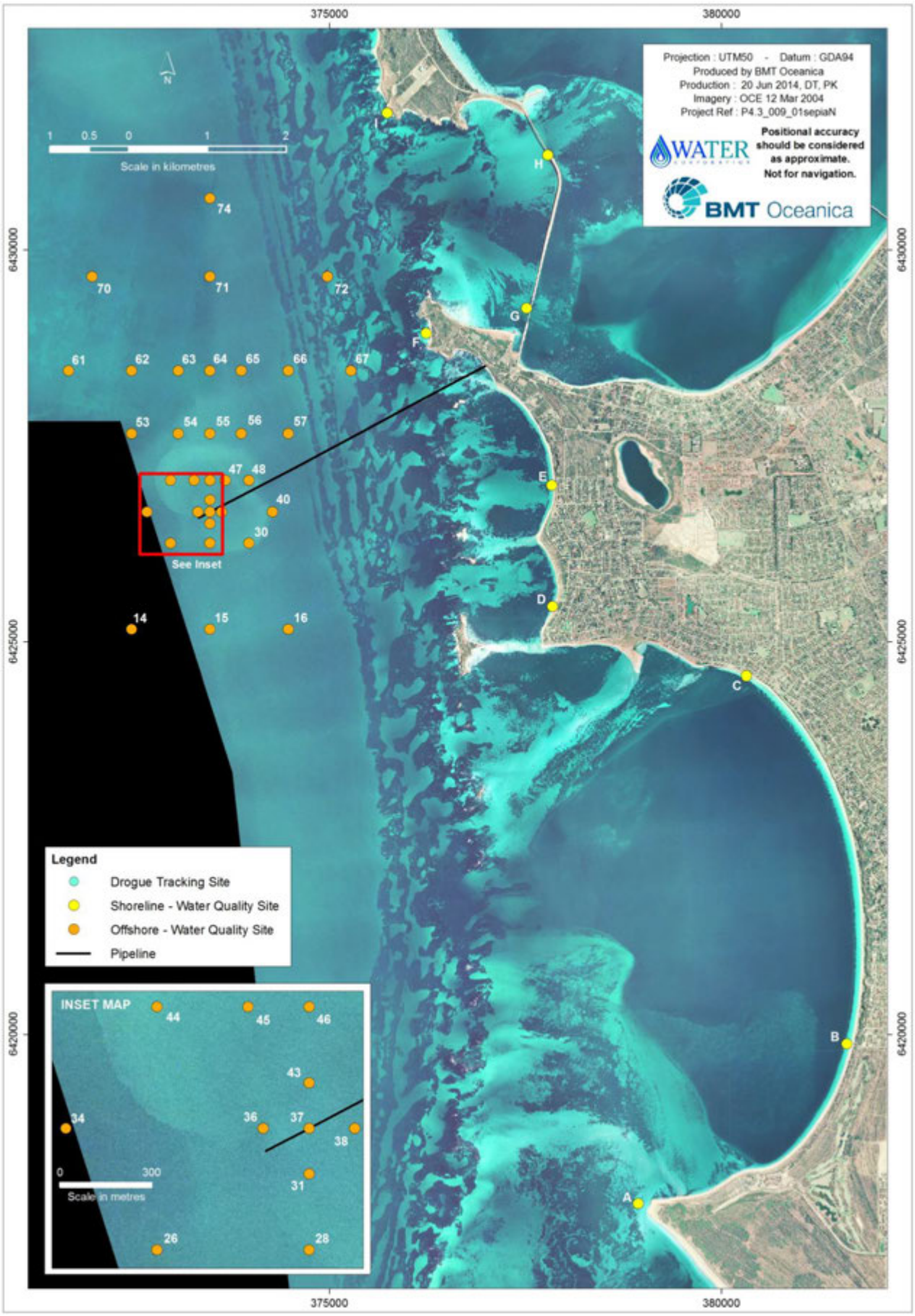
Swanbourne Sample Sites – Southerly Flow Grid and Shoreline Sites



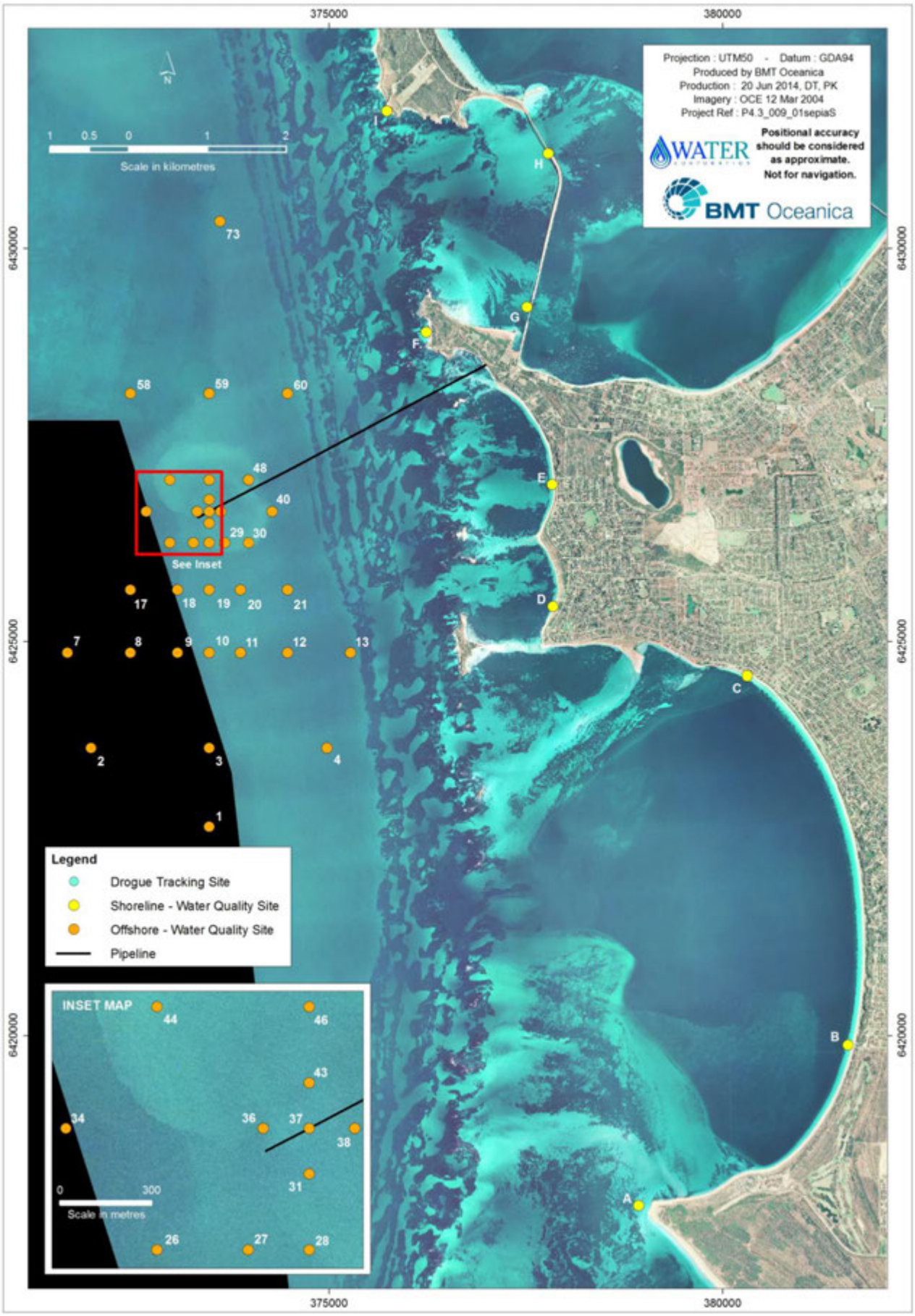
Swanbourne Sample Sites – Light/Variable Flow Grid and Shoreline Sites



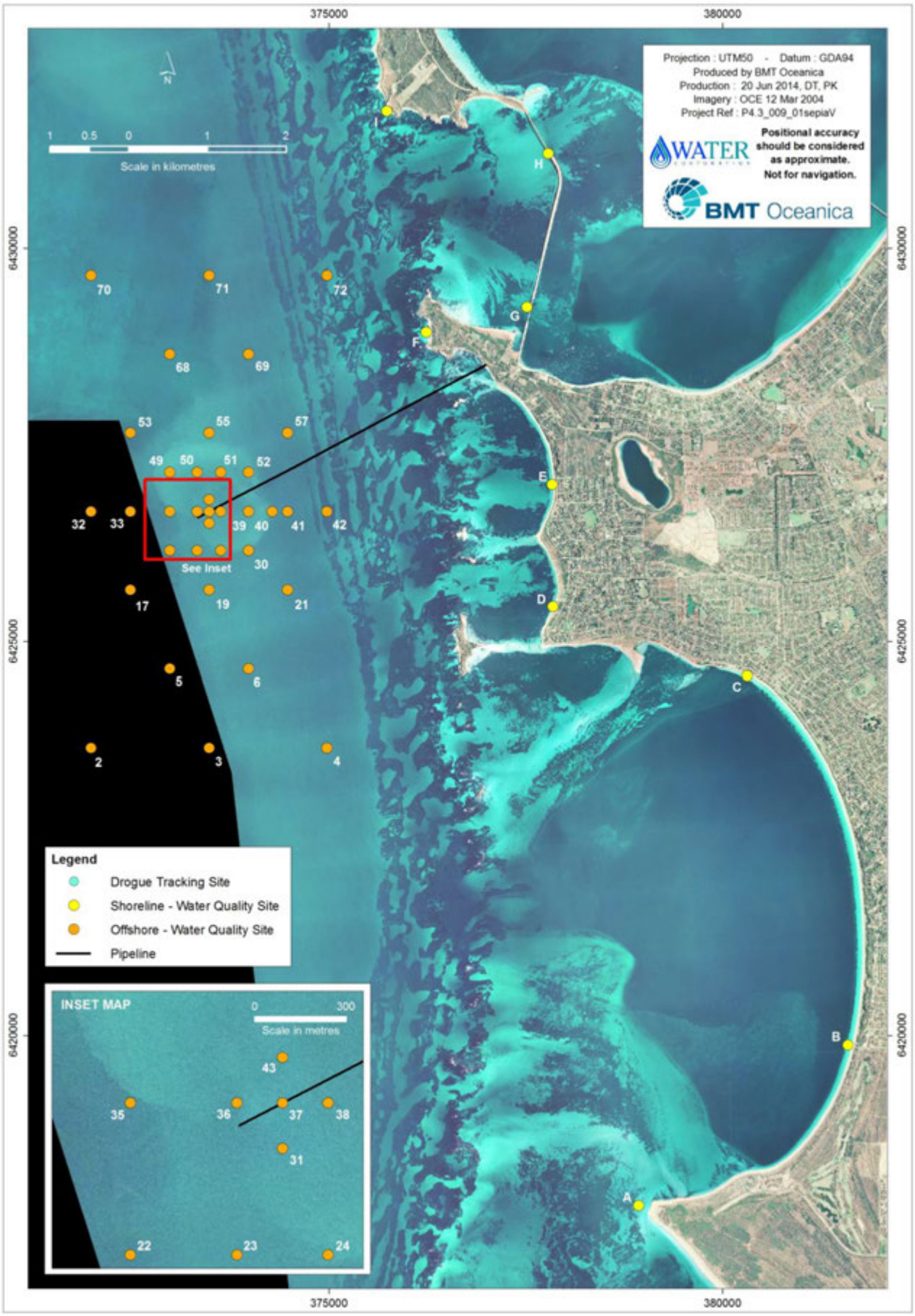
Sepia Depression Sample Sites – Northerly Flow Grid and Shoreline Sites



Sepia Depression Sample Sites – Southerly Flow Grid and Shoreline Sites



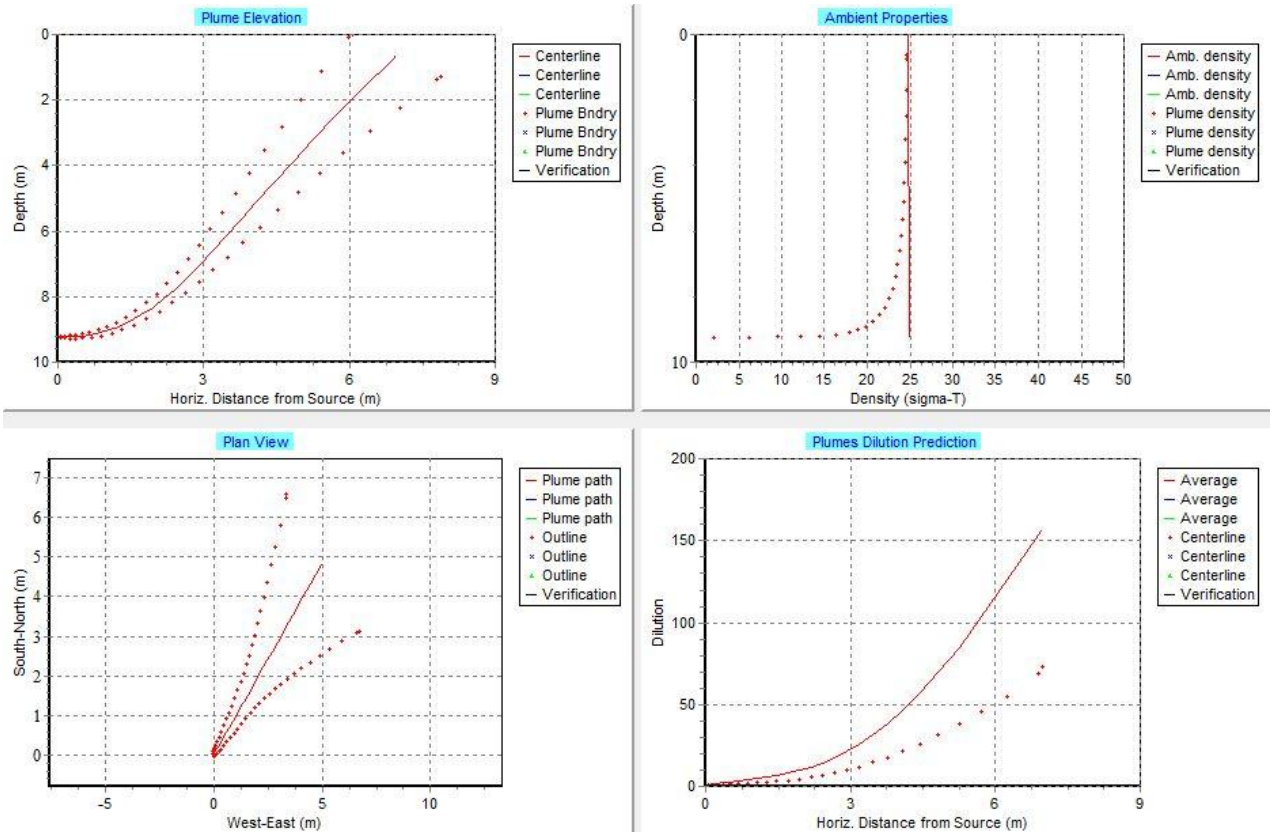
Sepia Depression Sample Sites – Light/Variable Flow Grid and Shoreline Sites



Appendix C – UM3 Initial Dilution Model Output

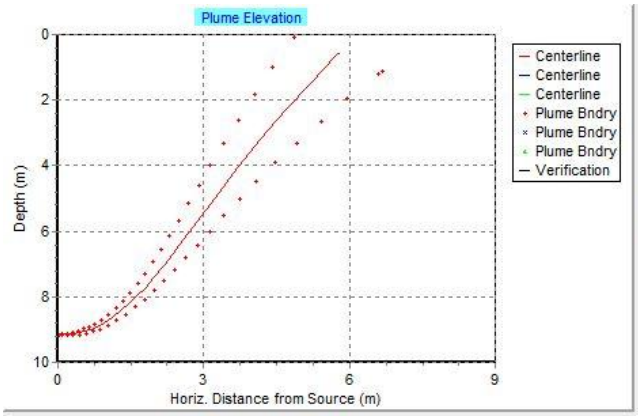
OCEAN REEF OUTLET A – INITIAL DILUTION MODELLING

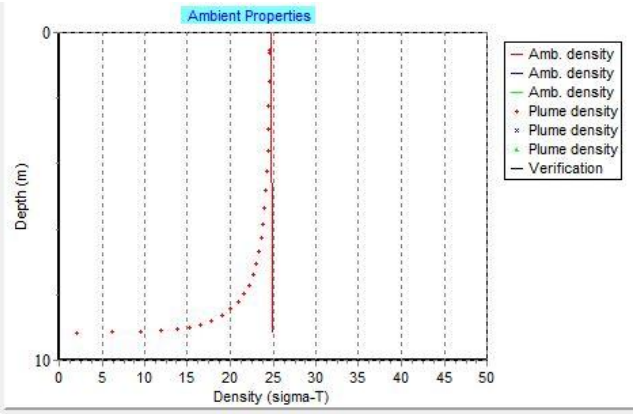
```
/ Windows UM3. 2/07/2015 10:20:24 AM
Case 1; ambient file c:\plumes\VP plume 3.001.db; Diffuser table record 1: ----------------------------------
      Depth     Amb-cur     Amb-dir     Amb-sal     Amb-tem     Amb-pol       Decay     Far-spd     Far-dir     Disprsn
          m         m/s         deg         psu           C       kg/kg         s-1         m/s         deg   m0.67/s2
        0.0        0.07        44.0       35.98       22.63         0.0         0.0  2.1416E+8  2.1416E+8         0.0
       9.24       0.062        44.0       35.98        22.5         0.0         0.0  2.1416E+8  2.1416E+8         0.0
   P-dia  P-elev V-angle H-angle   Ports Spacing AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()      (m)     (m)     (m)     (m)   (MLD)   (psu)     (C) (kg/kg)
   0.125    0.76     0.0    46.0    50.0     4.0   100.0   150.0    9.24   59.09    0.06    25.0     0.1
Froude number:      6.041
        Depth  Amb-cur    P-dia  Polutnt    Dilutn  CL-diln    x-posn    y-posn
Step      (m)  (cm/s)      (m)  (kg/kg)        ()      ()       (m)       (m)
   0     9.24     6.2    0.125     0.1       1.0     1.0       0.0       0.0;
 100    8.762    6.24     0.64   0.015     6.506   3.068      1.06     1.024;
 200    5.113   6.552    2.197 0.00208     46.84   21.88     2.942     2.841;
 233    2.993   6.735    3.303 0.00108     90.02    40.8     3.871     3.738; axial vel  0.0395 max dilution reached
 249    1.773    6.84    4.024 0.000788    123.6   54.86     4.446     4.294; merging,
 261    0.636   6.936    4.817 0.000621    156.7   72.77     5.015     4.843; axial vel   0.239 surface,
 .
10:20:25 AM. amb fills: 2
```

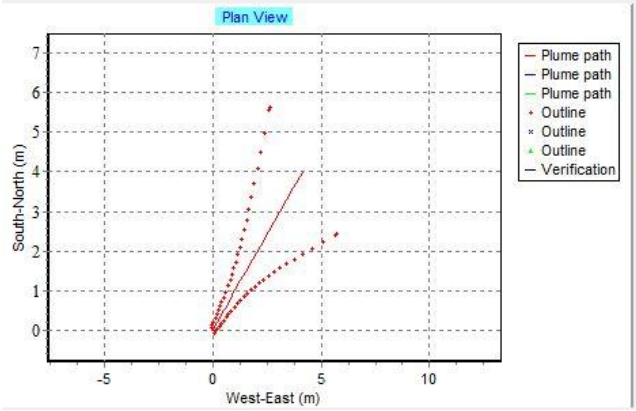


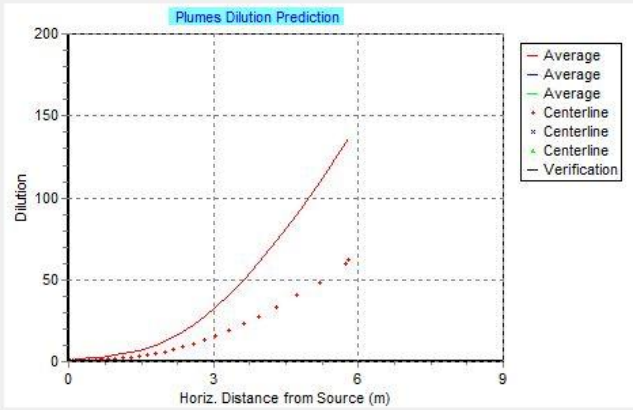
OCEAN REEF OUTLET B – INITIAL DILUTION MODELLING

```
/ Windows UM3. 2/07/2015 10:43:01 AM
Case 1; ambient file c:\plumes\VP plume 3.001.db; Diffuser table record 1: ----------------------------------
      Depth    Amb-cur    Amb-dir    Amb-sal    Amb-tem    Amb-pol       Decay    Far-spd    Far-dir    Disprsn
          m        m/s        deg        psu          C       kg/kg         s-1        m/s        deg   m0.67/s2
        0.0       0.07       44.0      35.98      22.63         0.0         0.0  2.1416E+8  2.1416E+8        0.0
       9.16      0.062       44.0      35.98       22.5         0.0         0.0  2.1416E+8  2.1416E+8        0.0
   P-dia  P-elev V-angle H-angle   Ports Spacing AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)     ()     (m)     (m)     (m)     (m)   (MLD)   (psu)     (C) (kg/kg)
    0.16    0.84     0.0    46.0    48.0     4.0   100.0   150.0    9.16   59.17    0.06    25.0     0.1
Froude number:      3.399
        Depth  Amb-cur    P-dia  Polutnt   Dilutn  CL-diln   x-posn   y-posn
Step      (m)   (cm/s)      (m)  (kg/kg)       ()       ()      (m)      (m)
   0     9.16      6.2     0.16      0.1      1.0      1.0      0.0      0.0;
 100    8.443    6.261    0.612   0.0173     5.65    2.716    0.933    0.901;
 200    4.818    6.574    2.058  0.00239    40.77    19.32    2.388    2.306;
 240    2.247    6.797    3.373  0.00108    89.99    41.03    3.402    3.285; axial vel  0.0537 max dilution reached
 254    1.163    6.891    4.009  0.00082    118.7    53.07    3.881    3.747; axial vel   0.115 merging,
 261    0.536    6.945    4.424 0.000714    136.4    62.24    4.174    4.031; surface,
 .
10:43:01 AM. amb fills: 2
```



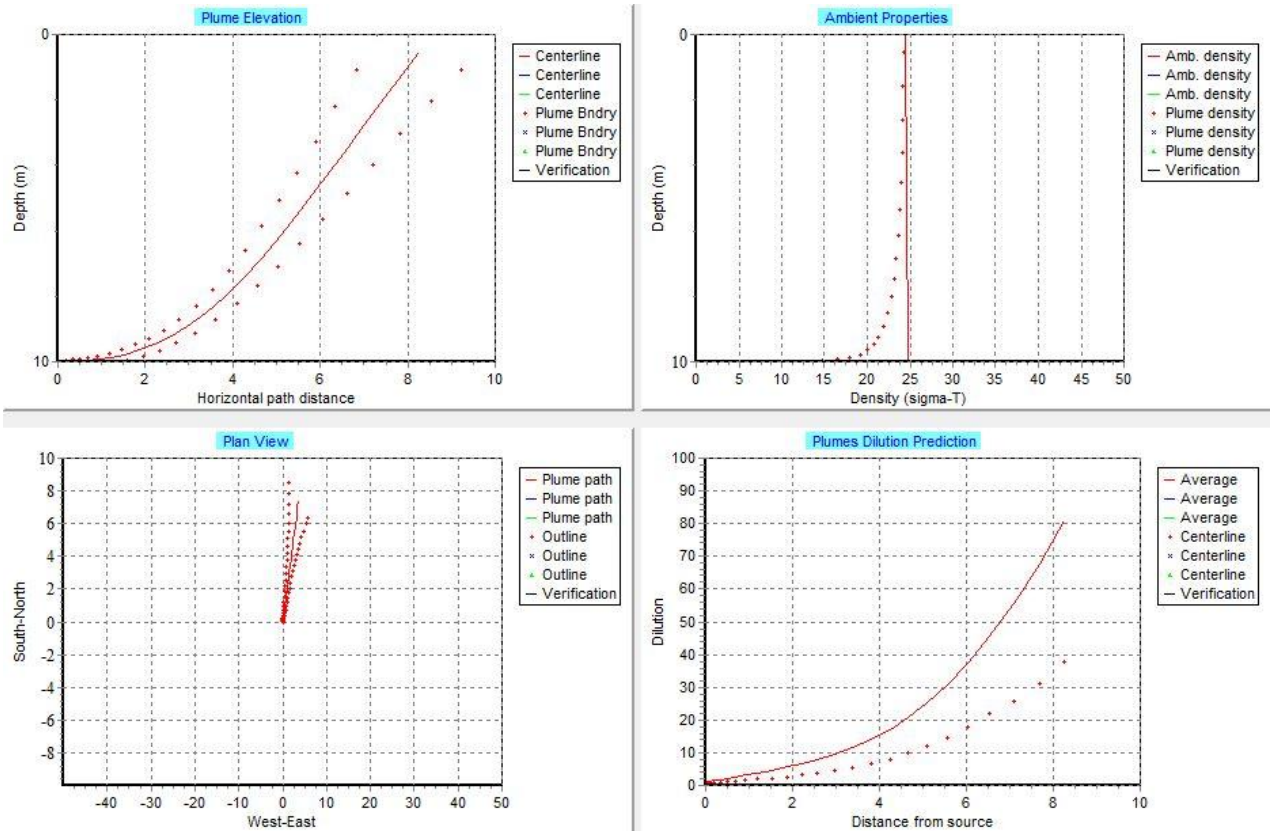






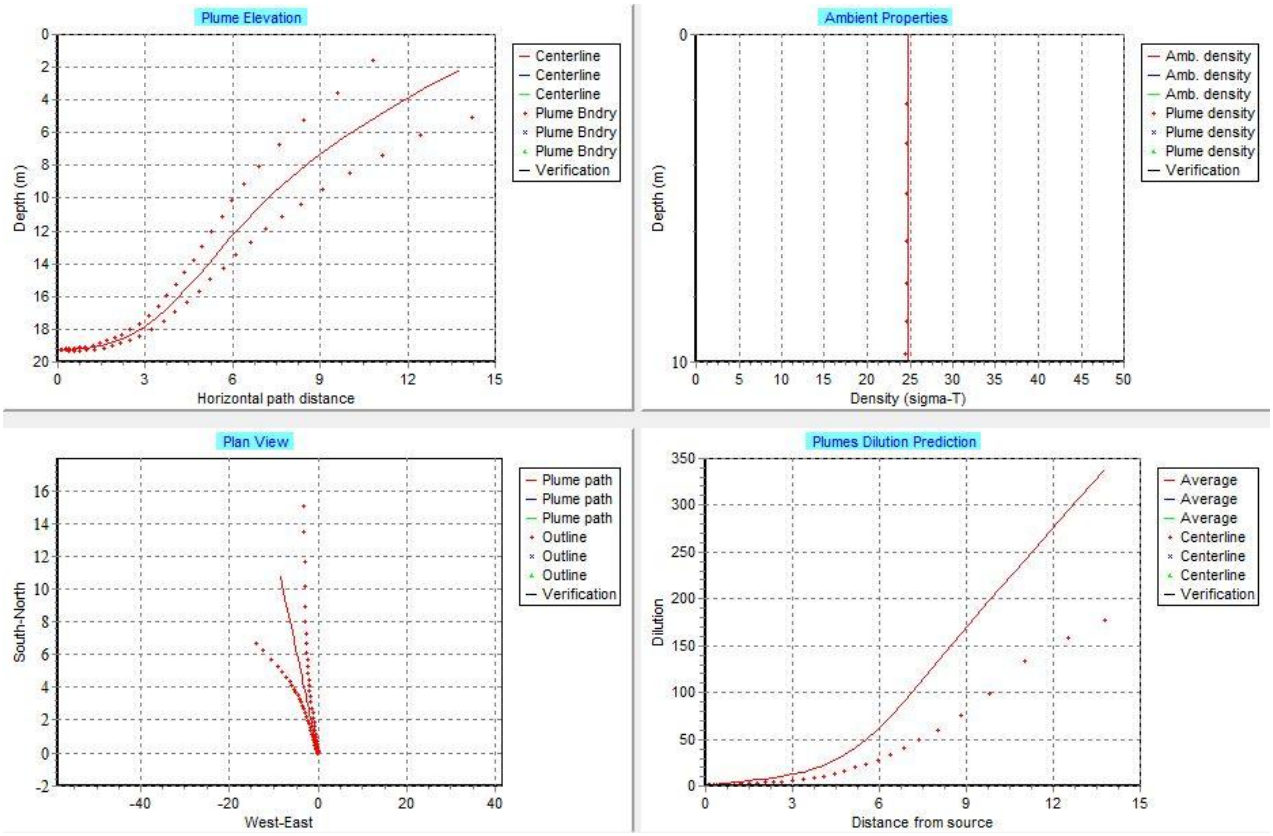
SWANBOURNE – INITIAL DILUTION MODELLING

```
/ Windows UM3. 4/06/2015 1:13:53 PM
Case 1; ambient file c:\plumes\VP plume 3.001.db; Diffuser table record 1: ----------------------------------
      Depth     Amb-cur     Amb-dir     Amb-sal     Amb-tem     Amb-pol       Decay     Far-spd     Far-dir     Disprsn
          m         m/s         deg         psu           C       kg/kg         s-1         m/s         deg    m0.67/s2
        0.0        0.07        64.0        36.09        24.1         0.0         0.0  2.1416E+8  2.1416E+8         0.0
       10.0       0.062        64.0        36.1         23.3         0.0         0.0  2.1416E+8  2.1416E+8         0.0
   P-dia  P-elev V-angle H-angle   Ports Spacing AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal     Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)     (m)   (MLD)   (psu)     (C) (kg/kg)
    0.17     1.0     0.0    26.0    20.0     5.0   100.0   150.0    10.0    65.0     0.7    24.0     0.1
Froude number:       7.83
        Depth  Amb-cur    P-dia  Polutnt   Dilutn  CL-diln   x-posn   y-posn
Step      (m)   (cm/s)      (m)  (kg/kg)       ()       ()      (m)      (m)
   0     10.0      6.2     0.17      0.1      1.0      1.0      0.0      0.0;
 100    9.467    6.241    0.965   0.0146    6.685    3.194    0.966    1.981; axial vel  0.0087
 200    3.621    6.703    3.262  0.00213    45.66    21.82    2.867    5.879; axial vel   0.046
 229    0.537    6.948    4.758   0.0012    81.07    37.75    3.623    7.427; axial vel   0.377 surface,
 ;
1:13:53 PM. amb fills: 2
```



SEPIA DEPRESSION – INITIAL DILUTION MODELLING

```
/ Windows UM3. 4/06/2015 1:43:39 PM
Case 1: ambient file c:\plumes\VP plume 3.001.db; Diffuser table record 1: ----------------------------------
      Depth    Amb-cur    Amb-dir    Amb-sal    Amb-tem    Amb-pol      Decay    Far-spd    Far-dir    Disprsn
          m        m/s        deg        psu          C      kg/kg        s-1        m/s        deg   m0.67/s2
        0.0       0.14     -232.0      36.04      23.19        0.0        0.0  2.1416E+8  2.1416E+8        0.0
      19.25      0.034     -232.0       36.1       23.0        0.0        0.0  2.1416E+8  2.1416E+8        0.0
   P-dia  P-elev V-angle H-angle   Ports Spacing AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)     ()     (m)     (m)     (m)     (m)   (MLD)   (psu)     (C) (kg/kg)
   0.135    0.75     0.0   322.0    68.0    4.65   100.0   150.0   19.25  145.26    0.47    29.7      0.1
Froude number:      8.853
        Depth  Amb-cur    P-dia  Polutnt   Dilutn  CL-diln    x-posn    y-posn
Step      (m)   (cm/s)      (m)  (kg/kg)       ()       ()       (m)       (m)
   0    19.25      3.4    0.135      0.1      1.0      1.0       0.0       0.0;
 100    18.87    3.601    0.803   0.0147    6.633    3.272    -1.094       1.4;
 200     14.0    6.251    2.487  0.00239    40.69    19.74    -3.173     4.061;
 246    10.11    8.386    4.467 0.000961    101.1    45.45    -4.397     5.628; max dilution reached
 250     9.75    8.582    4.701 0.000888    109.5    48.77    -4.529     5.796; axial vel   0.0187 merging,
 300    3.303    12.09     11.8  0.00033    294.6    158.9    -7.712     9.871; axial vel    0.119
 307    2.136    12.73    13.56 0.000287    338.4    176.5    -8.485     10.86; surface,
 ;
1:43:39 PM. amb fills: 2
```



Appendix D – Water Quality Sampling Sites and Data

OCEAN REEF - SAMPLING SITES, 03 FEBRUARY 2015

Site	Latitude GDA94 S (actual)	Longitude GDA94 E (actual)	UTM50, GDA94 actual Easting	Northing
1	31° 47' 45.51" S	115° 42' 30.74" E	377740.68	6481452.43
2	31° 47' 15.85" S	115° 41' 37.97" E	376341.92	6482349.14
18	31° 46' 5.17" S	115° 42' 14.68" E	377281.43	6484537.07
20	31° 46' 5.32" S	115° 42' 37.47" E	377881.05	6484539.62
22	31° 46' 5.57" S	115° 43' 0.24" E	378479.98	6484538.95
25	31° 45' 55.44" S	115° 42' 26.05" E	377576.91	6484840.42
26	31° 45' 55.73" S	115° 42' 48.90" E	378178.24	6484838.52
27	31° 45' 51.24" S	115° 41' 4.80" E	375437.96	6484944.08
28	31° 45' 50.75" S	115° 42' 37.55" E	377877.87	6484988.44
30	31° 45' 45.50" S	115° 42' 18.61" E	377377.64	6485144.11
31	31° 45' 45.81" S	115° 42' 31.91" E	377727.66	6485138.80
32	31° 45' 45.87" S	115° 42' 37.78" E	377882.09	6485138.52
33	31° 45' 46.00" S	115° 42' 43.31" E	378027.62	6485136.27
34	31° 45' 46.04" S	115° 42' 56.74" E	378381.04	6485139.25
36	31° 45' 46.28" S	115° 43' 30.86" E	379278.74	6485142.63
37	31° 45' 40.91" S	115° 42' 37.66" E	377877.21	6485291.50
38	31° 45' 36.06" S	115° 42' 26.43" E	377579.94	6485437.06
39	31° 45' 36.12" S	115° 42' 49.28" E	378181.19	6485442.51
40	31° 45' 25.96" S	115° 42' 0.04" E	376881.95	6485739.88
41	31° 45' 26.06" S	115° 42' 11.44" E	377181.97	6485740.33
43	31° 45' 26.28" S	115° 42' 26.63" E	377581.67	6485738.24
44	31° 45' 26.27" S	115° 42' 37.94" E	377879.15	6485742.20
45	31° 45' 26.42" S	115° 42' 49.40" E	378180.65	6485741.20
47	31° 45' 26.63" S	115° 43' 4.54" E	378579.12	6485739.32
48	31° 45' 26.81" S	115° 43' 15.86" E	378877.11	6485737.32
52	31° 44' 59.77" S	115° 41' 41.23" E	376377.25	6486540.36
53	31° 44' 59.95" S	115° 42' 0.31" E	376879.34	6486540.81
54	31° 45' 0.22" S	115° 42' 19.30" E	377379.08	6486538.65
55	31° 45' 0.40" S	115° 42' 38.29" E	377878.79	6486539.00
56	31° 45' 0.59" S	115° 42' 57.41" E	378382.02	6486539.05
57	31° 45' 0.79" S	115° 43' 16.29" E	378878.82	6486538.75
60	31° 44' 40.57" S	115° 42' 8.12" E	377077.79	6487139.98
61	31° 44' 41.11" S	115° 43' 8.83" E	378675.41	6487142.32
63	31° 44' 14.15" S	115° 41' 41.84" E	376376.67	6487945.32
64	31° 44' 14.58" S	115° 42' 38.78" E	377875.23	6487949.98
Drogue1	31° 45' 45.86" S	115° 42' 37.54" E	377875.66	6485138.75
Drogue2	31° 45' 45.41" S	115° 42' 50.46" E	378215.48	6485156.81
Drogue3	31° 45' 41.71" S	115° 42' 52.46" E	378266.70	6485271.18
Drogue4	31° 45' 38.03" S	115° 42' 57.83" E	378406.59	6485386.21
Drogue5	31° 45' 30.51" S	115° 42' 56.96" E	378381.13	6485617.56
A	31° 48.560' S	115° 43.882' E	379908	6480928
B	31° 47.164' S	115° 43.210' E	380108	6482579
C	31° 46.362' S	115° 43.906' E	379910	6484058
D	31° 45.943' S	115° 43.759' E	379669	6484830
E	31° 45.579' S	115° 43.612' E	379429	6485500
F	31° 45.167' S	115° 43.548' E	379319	6486260
G	31° 44.760' S	115° 43.452' E	379158	6487010
H	31° 44.160' S	115° 43.159' E	378680	6488335
I	31° 43.215' S	115° 42.631' E	377828	6489877

OCEAN REEF - SURFACE AND SHORELINE WATER QUALITY, 03 FEBRUARY 2015

Site	Ammonia µg.N/L (<3)	Ortho-phosphate µg.P/L (<2)	Nitrate + Nitrite µg.N/L (<2)	Total Phosphorus µg.P/L (<5)	Total Nitrogen µg.N/L (<50)	Chlorophyll *a* (flurometry) µg/L (<0.1)	Chlorophyll *a* (acetone) µg/L (<0.1)	Phaeophytin *a* µg/L (<0.2)	Thermalolerant Coliforms CFU/100mL (<10)	Enterococci MPN/100mL (<10)
1A	<3	14	12	25	120	0.5	0.6	0.3	<10	<10
1B	<3	13	13	24	120	0.5	0.6	0.3	<10	<10
1C	<3	13	12	24	120	0.4	0.6	0.3	<10	<10
2	<3	10	11	19	100	0.3			<10	<10
18	<3	18	21	29	110	0.6			<10	<10
20	5	23	28	36	140	0.4			160	<10
22	9	31	26	42	120	0.6			<10	<10
25	6	23	23	36	130	0.5			470	41
26	17	60	58	73	170	0.5			1300	63
27	<3	8	15	16	100	0.2	0.3	<0.2	<10	<10
28	10	38	34	52	140	0.6			660	20
30	8	30	24	43	130	0.6			310	31
31	6	25	20	36	120	1.0			330	41
32	9	43	45	58	170	0.4			450	<10
33	13	58	64	68	180	0.5			380	20
34	9	39	37	51	160	0.3			150	<10
36	4	14	6	26	120	0.4	0.4	<0.2	<10	<10
37	13	56	54	68	170	0.6			200	30
38	12	48	42	62	180	0.6			40	<10
39	8	41	40	53	160	0.5			91	10
40	<3	16	9	26	100	0.6			<10	<10
41	4	22	14	32	100	0.6			<10	<10
43	4	31	27	44	120	0.5			<10	<10
44	11	47	42	61	160	0.7	0.5	<0.2	<10	<10
45	7	34	31	43	140	0.6			<10	<10
47	4	22	14	32	110	0.5			<10	<10
48	4	17	10	28	120	0.5			<10	<10
52	<3	9	8	18	100	0.4			<10	<10
53	<3	7	4	17	100	0.6			<10	<10
54	<3	8	<2	18	90	0.7			<10	<10
55	<3	16	9	28	100	0.6			<10	<10
56	<3	12	3	24	110	0.5			<10	<10
57	<3	14	9	24	110	0.4			<10	<10
60	<3	6	<2	16	110	0.9	0.6	<0.2	<10	<10
61	<3	12	3	24	120	0.7			<10	<10
63	<3	6	3	16	90	0.7			<10	<10
64	<3	7	<2	18	100	0.6	0.5	0.2	<10	<10
A	18	13	10	39	290		0.7	0.4	<10	20
B	7	14	68	33	260		1.0	0.8	<10	<10
C	23	10	9	24	200		0.8	0.7	20	<10
D	19	16	40	33	250		1.2	2.9	20	<10
E	13	10	160	26	380		2.4	4.0	<10	<10
F	7	11	18	25	180		0.5	2.5	10	63
G	13	14	24	26	210		0.3	1.7	<10	<10
H	9	12	36	23	190		0.7	1.8	<10	<10
I	13	13	64	28	260		1.1	1.4	<10	<10

Notes:

1. Numbers in parenthesis after the units indicate the detection limit for each water quality parameter
2. Chlorophyll *a* (flurometry) was not measured on shoreline sites

Site	Ammonia µg.N/L (<3)	Ortho-phosphate µg.P/L (<2)	Nitrate + Nitrite µg.N/L (<2)	Total Phosphorus µg.P/L (<5)	Total Nitrogen µg.N/L (<50)	Chlorophyll *a* (flurometry) µg/L (<0.1)	Chlorophyll *a* (acetone) µg/L (<0.1)	Phaeophytin *a* µg/L (<0.2)	Thermalolerant Coliforms CFU/100mL (<10)	Enterococci MPN/100mL (<10)
1A	<3	13	13	25	120	0.5			<10	<10
1B	5	13	12	25	120				<10	<10
1C	<3	13	11	24	120				<10	<10
2	<3	9	13	19	100	0.2			<10	<10
18	<3	16	13	26	110	0.4			<10	<10
20	3	16	10	28	120	0.4			<10	<10
22	3	15	7	26	100	0.5			<10	<10
25	<3	12	9	24	110	0.4			<10	<10
26	3	16	10	30	130	0.5			<10	<10
27	<3	8	16	16	100	0.2			<10	<10
28	<3	13	10	26	120	0.3			<10	<10
30	<3	9	8	20	100	0.4			<10	<10
31	<3	11	10	22	110	0.5			<10	<10
32	11	53	57	61	170	0.5			<10	<10
33	3	16	15	26	130	0.4			<10	<10
34	<3	8	4	19	110	0.6			<10	<10
36	4	15	5	27	120	0.4			<10	<10
37	<3	9	5	19	110	0.6			<10	<10
38	<3	7	3	16	110	0.6			<10	<10
39	<3	12	7	22	120	0.8			<10	<10
40	<3	8	5	18	100	0.6			<10	<10
41	<3	7	2	17	80	0.9			<10	<10
43	<3	6	<2	18	90	0.7			<10	<10
44	<3	9	<2	21	100	0.6			<10	<10
45	<3	12	<2	24	130	0.5			<10	<10
47	<3	13	<2	25	110	0.5			<10	<10
48	<3	14	2	26	110	0.5			<10	<10
52	<3	10	5	20	90	0.5			<10	<10
53	<3	6	5	16	100	0.8			<10	<10
54	<3	6	3	15	80	0.8			<10	<10
55	<3	8	<2	18	100	0.7			<10	<10
56	<3	7	<2	18	100	0.8			<10	<10
57	<3	14	<2	26	100	0.6			<10	<10
60	<3	5	3	16	90	0.9			<10	<10
61	<3	12	<2	23	120	0.8			<10	<10
63	<3	6	2	16	90	0.9			<10	<10
64	<3	7	2	16	110	0.7			<10	<10

Notes:

1. Numbers in parenthesis after the units indicate the detection limit for each water quality parameter
2. Chlorophyll *a* (acetone) and Phaeophytin *a* were not measured in bottom waters

SWANBOURNE - SAMPLING SITES, 20 JANUARY 2015

Site	Latitude GDA94 S (actual)	Longitude GDA94 E (actual)	UTM50, GDA94 actual Easting	Northing
2	31° 58' 40.52" S	115° 44' 34.89" E	381239.21	6461321.48
3	31° 58' 23.79" S	115° 43' 37.97" E	379739.21	6461819.11
9	31° 58' 7.92" S	115° 44' 16.30" E	380739.75	6462319.56
10	31° 58' 8.02" S	115° 44' 35.30" E	381238.59	6462322.39
11	31° 58' 8.36" S	115° 44' 54.11" E	381732.34	6462317.58
18	31° 57' 51.62" S	115° 43' 57.36" E	380236.71	6462815.87
19	31° 57' 52.00" S	115° 44' 35.54" E	381239.12	6462815.86
20	31° 57' 52.34" S	115° 45' 2.17" E	381938.16	6462813.36
22	31° 57' 38.59" S	115° 44' 12.86" E	380638.78	6463221.59
24	31° 57' 38.83" S	115° 44' 35.76" E	381240.09	6463221.30
26	31° 57' 39.01" S	115° 44' 58.54" E	381838.10	6463222.87
27	31° 57' 29.07" S	115° 44' 24.53" E	380941.89	6463518.35
28	31° 57' 29.30" S	115° 44' 47.33" E	381540.31	6463518.38
29	31° 57' 24.31" S	115° 44' 35.93" E	381239.46	6463668.51
30	31° 57' 18.71" S	115° 43' 19.95" E	379242.77	6463817.69
32	31° 57' 19.14" S	115° 43' 57.88" E	380238.56	6463816.18
33	31° 57' 19.33" S	115° 44' 16.93" E	380738.82	6463816.09
34	31° 57' 19.39" S	115° 44' 30.24" E	381088.23	6463818.41
35	31° 57' 19.41" S	115° 44' 36.02" E	381240.04	6463819.33
36	31° 57' 19.52" S	115° 44' 41.62" E	381387.06	6463817.86
37	31° 57' 19.72" S	115° 44' 55.01" E	381738.61	6463815.53
38	31° 57' 14.70" S	115° 44' 35.73" E	381230.67	6463964.46
39	31° 57' 9.67" S	115° 44' 24.56" E	380935.67	6464115.73
40	31° 57' 9.90" S	115° 44' 47.67" E	381542.41	6464115.81
42	31° 56' 59.82" S	115° 44' 13.21" E	380634.07	6464415.58
44	31° 57' 0.04" S	115° 44' 36.25" E	381239.03	6464416.00
46	31° 57' 0.25" S	115° 44' 59.02" E	381837.03	6464416.41
47	31° 56' 46.62" S	115° 43' 58.51" E	380243.38	6464817.57
48	31° 56' 46.89" S	115° 44' 36.55" E	381242.33	6464821.09
49	31° 56' 47.28" S	115° 45' 3.13" E	381940.31	6464817.15
57	31° 56' 30.67" S	115° 44' 17.57" E	380738.18	6465314.73
58	31° 56' 30.73" S	115° 44' 36.61" E	381238.19	6465318.68
59	31° 56' 30.89" S	115° 44' 55.65" E	381737.95	6465319.33
60	31° 56' 13.94" S	115° 43' 39.69" E	379737.43	6465818.24
65	31° 55' 58.31" S	115° 44' 37.21" E	381242.31	6466316.94
Drogue1	31° 57' 19.37" S	115° 44' 37.41" E	381276.53	6463821.02
Drogue2	31° 57' 21.30" S	115° 44' 36.67" E	381257.85	6463761.28
Drogue3	31° 57' 22.59" S	115° 44' 37.72" E	381285.83	6463722.08
Drogue4	31° 57' 22.68" S	115° 44' 39.12" E	381322.57	6463719.62
Drogue5	31° 57' 22.00" S	115° 44' 42.05" E	381399.33	6463741.52
Drogue6	31° 57' 17.87" S	115° 44' 45.01" E	381475.45	6463869.50
Drogue7	31° 57' 12.75" S	115° 44' 48.47" E	381564.46	6464028.16
Drogue8	31° 57' 6.26" S	115° 44' 50.72" E	381621.15	6464228.79
Drogue9	31° 57' 1.03" S	115° 44' 51.99" E	381652.58	6464390.27
Drogue10	31° 56' 55.00" S	115° 44' 53.12" E	381680.25	6464576.28
Drogue11	31° 56' 49.49" S	115° 44' 53.96" E	381700.29	6464746.27
A	31° 57.980' S	115° 45.264' E	382299	6462619
B	31° 57.763' S	115° 45.273' E	382309	6463020
C	31° 57.547' S	115° 45.263' E	382289	6463419
D	31° 57.330' S	115° 45.274' E	382259	6463819
E	31° 57.114' S	115° 45.256' E	382268	6464218
F	31° 57.897' S	115° 45.247' E	382250	6464619
G	31° 57.681' S	115° 45.256' E	382259	6465018
H	31° 57.464' S	115° 45.233' E	382218	6465419
I	31° 56.248' S	115° 45.281' E	382289	6465819

Site	Ammonia µg.N/L (<3)	Ortho-phosphate µg.P/L (<2)	Nitrate + Nitrite µg.N/L (<2)	Total Phosphorus µg.P/L (<5)	Total Nitrogen µg.N/L (<50)	Chlorophyll *a* (flurometry) µg/L (<0.1)	Chlorophyll *a* (acetone) µg/L (<0.1)	Phaeophytin *a* µg/L (<0.2)	Thermalolerant Coliforms CFU/100mL (<10)	Enterococci MPN/100mL (<10)
2A	<3	3	<2	12	100	0.2	0.1	<0.2	<10	<10
2B	<3	2	<2	12	90	0.2	0.1	<0.2	<10	<10
2C	<3	3	<2	12	100	<0.1	0.1	<0.2	<10	<10
3	<3	<2	<2	11	90	0.2			<10	<10
9	<3	2	<2	12	90	0.1			<10	<10
10	<3	2	<2	11	100	0.1			<10	<10
11	<3	2	<2	12	90	0.2			<10	<10
18	8	<2	4	11	110	0.4			<10	<10
19	<3	2	<2	13	90	0.1			<10	<10
20	<3	3	<2	12	100	0.2	0.2	<0.2	<10	<10
22	60	17	3	28	190	0.2			160	62
24	<3	3	<2	14	130	0.2			<10	<10
26	<3	3	<2	13	120	0.3			<10	<10
27	80	35	3	46	200	0.2			120	30
28	<3	3	<2	12	120	0.3			<10	<10
29	110	50	5	62	240	0.3			2100	52
30	<3	2	<2	11	90	0.1	0.2	<0.2	<10	<10
32	46	10	4	21	160	0.4			<10	<10
33	56	20	3	31	170	0.3			<10	<10
34	96	48	4	62	210	0.2			90	20
35	140	64	5	76	260	0.2			1800	75
36	41	14	3	24	150	0.2			540	<10
37	56	14	3	24	170	0.2			<10	<10
38	260	120	9	130	390	0.2			6200	140
39	170	70	7	84	290	0.3			10	10
40	68	31	3	42	190	0.2			73	20
42	140	32	10	44	280	0.3			10	10
44	160	67	6	77	270	0.3			<10	10
46	83	28	4	39	190	0.2			<10	20
47	28	3	5	12	140	0.4			<10	<10
48	140	51	7	62	260	0.3			<10	<10
49	52	22	2	32	160	0.2	0.2	<0.2	<10	<10
57	77	6	12	16	190	0.3			<10	<10
58	130	28	9	40	250	0.4			<10	<10
59	100	38	6	49	210	0.3			<10	<10
60	10	<2	7	11	110	0.4			<10	<10
65	99	11	8	21	210	0.4	<0.1	<0.2	<10	<10
A	4	8	14	18	140		0.2	0.3	<10	<10
B	<3	5	4	15	140		0.3	0.4	<10	<10
C	3	5	4	15	120		0.4	0.3	<10	<10
D	5	7	10	18	140		0.5	0.3	<10	<10
E	12	6	6	17	150		0.4	0.3	<10	<10
F	3	5	6	15	130		0.4	0.3	<10	<10
G	4	5	8	16	130		0.4	0.4	<10	<10
H	7	4	4	16	130		0.5	0.2	<10	<10
I	5	6	2	16	120		1.1	0.4	<10	<10

Notes:

1. Numbers in parenthesis after the units indicate the detection limit for each water quality parameter
2. Chlorophyll *a* (flurometry) was not measured on shoreline sites

SWANBOURNE - BOTTOM WATER QUALITY, 20 JANUARY 2015

Site	Ammonia µg.N/L (<3)	Ortho-phosphate µg.P/L (<2)	Nitrate + Nitrite µg.N/L (<2)	Total Phosphorus µg.P/L (<5)	Total Nitrogen µg.N/L (<50)	Chlorophyll *a* (flurometry) µg/L (<0.1)	Chlorophyll *a* (acetone) µg/L (<0.1)	Phaeophytin *a* µg/L (<0.2)	Thermalolerant Coliforms CFU/100mL (<10)	Enterococci MPN/100mL (<10)
2A	<3	3	<2	12	100	0.1			<10	<10
2B	<3	3	<2	13	90				<10	<10
2C	<3	3	<2	12	100				<10	<10
3	<3	<2	<2	12	100	0.5			<10	<10
9	<3	3	<2	14	110	0.2			<10	<10
10	<3	2	<2	13	110	0.2			<10	<10
11	<3	3	<2	13	100	0.4			<10	<10
18	<3	2	<2	14	100	0.3			<10	<10
19	<3	3	<2	12	100	0.2			<10	<10
20	<3	3	<2	14	120	0.5			<10	<10
22	<3	2	<2	14	110	0.1			<10	<10
24	<3	3	<2	15	120	0.2			<10	<10
26	<3	<2	<2	12	110	0.2			<10	<10
27	<3	3	<2	12	100	0.2			<10	<10
28	<3	2	<2	14	130	0.2			<10	<10
29	<3	3	<2	13	110	0.2			<10	<10
30	<3	3	4	12	100	0.2			<10	<10
32	3	3	2	12	110	0.2			<10	<10
33	<3	3	<2	14	110	0.3			<10	<10
34	<3	3	<2	12	100	0.2			<10	<10
35	<3	4	<2	14	110	0.2			<10	<10
36	<3	3	<2	13	110	0.2			10	<10
37	<3	3	<2	12	100	0.2			<10	<10
38	<3	4	<2	16	100	0.2			<10	<10
39	<3	3	<2	14	120	0.1			<10	<10
40	<3	4	<2	14	110	0.2			45	<10
42	<3	3	<2	14	130	0.2			<10	<10
44	<3	2	<2	15	120	0.2			<10	<10
46	<3	4	<2	14	120	0.2			<10	<10
47	<3	3	<2	12	100	0.2			<10	<10
48	<3	3	<2	12	100	0.2			<10	<10
49	<3	3	<2	14	120	0.3			<10	<10
57	<3	3	<2	11	90	0.2			<10	<10
58	3	4	2	15	110	0.2			<10	<10
59	<3	3	<2	11	100	0.3			10	<10
60	<3	3	<2	13	100	0.2			<10	<10
65	<3	3	<2	12	100	0.3			<10	<10

Notes:

1. Numbers in parenthesis after the units indicate the detection limit for each water quality parameter
2. Chlorophyll *a* (acetone) and Phaeophytin *a* were not measured in bottom waters

SEPIA DEPRESSION - SAMPLING SITES, 17 FEBRUARY 2015

Site	Latitude GDA94 S (actual)	Longitude GDA94 E (actual)	UTM50, GDA94 actual Easting	Northing
14	32° 18' 11.21" S	115° 38' 43.91" E	372480.75	6425159.96
15	32° 18' 11.67" S	115° 39' 22.07" E	373478.81	6425158.28
16	32° 18' 12.10" S	115° 40' 0.40" E	374481.52	6425157.83
26	32° 17' 35.83" S	115° 39' 3.62" E	372982.41	6426256.00
28	32° 17' 36.17" S	115° 39' 22.73" E	373482.53	6426251.98
30	32° 17' 36.14" S	115° 39' 41.78" E	373980.61	6426259.05
31	32° 17' 27.82" S	115° 39' 22.67" E	373477.69	6426509.00
34	32° 17' 22.53" S	115° 38' 52.20" E	372678.61	6426661.91
36	32° 17' 22.89" S	115° 39' 17.04" E	373328.55	6426658.98
37	32° 17' 22.79" S	115° 39' 23.00" E	373484.30	6426663.86
38	32° 17' 23.02" S	115° 39' 28.44" E	373626.75	6426658.69
40	32° 17' 23.24" S	115° 39' 53.23" E	374275.33	6426659.86
43	32° 17' 18.02" S	115° 39' 22.73" E	373475.51	6426810.80
44	32° 17' 9.93" S	115° 39' 3.99" E	372982.19	6427053.68
45	32° 17' 9.96" S	115° 39' 15.40" E	373280.56	6427056.49
46	32° 17' 10.00" S	115° 39' 23.04" E	373480.48	6427057.80
47	32° 17' 9.94" S	115° 39' 30.69" E	373680.67	6427062.13
48	32° 17' 10.09" S	115° 39' 42.16" E	373980.62	6427061.43
53	32° 16' 50.09" S	115° 38' 44.91" E	372475.35	6427658.44
54	32° 16' 50.37" S	115° 39' 7.85" E	373075.47	6427657.36
55	32° 16' 50.41" S	115° 39' 23.23" E	373477.89	6427661.30
56	32° 16' 50.44" S	115° 39' 38.52" E	373877.77	6427665.13
57	32° 16' 50.80" S	115° 40' 1.57" E	374481.03	6427661.67
61	32° 16' 23.65" S	115° 38' 14.85" E	371678.62	6428462.72
62	32° 16' 24.14" S	115° 38' 45.44" E	372479.07	6428457.86
63	32° 16' 24.33" S	115° 39' 8.52" E	373083.06	6428459.56
64	32° 16' 24.58" S	115° 39' 23.70" E	373480.31	6428456.82
65	32° 16' 24.62" S	115° 39' 39.04" E	373881.46	6428460.52
66	32° 16' 24.97" S	115° 40' 1.89" E	374479.42	6428457.18
67	32° 16' 25.35" S	115° 40' 32.54" E	375281.59	6428455.39
70	32° 15' 44.90" S	115° 38' 26.84" E	371977.18	6429660.05
71	32° 15' 45.55" S	115° 39' 24.52" E	373486.50	6429658.87
72	32° 15' 46.16" S	115° 40' 21.55" E	374979.18	6429658.76
74	32° 15' 13.07" S	115° 39' 24.90" E	373483.91	6430659.19
Drogue1	32° 17' 22.86" S	115° 39' 22.69" E	373476.14	6426661.60
Drogue2	32° 17' 10.36" S	115° 39' 14.09" E	373246.57	6427043.73
Drogue3	32° 16' 56.05" S	115° 38' 58.51" E	372833.45	6427479.39
Drogue4	32° 16' 51.30" S	115° 38' 53.95" E	372712.24	6427624.03
A	32° 22.192' S	115° 42.791' E	378939	6417838
B	32° 21.105' S	115° 44.502' E	381599	6419879
C	32° 18.559' S	115° 43.722' E	380320	6424568
D	32° 18.670' S	115° 42.154' E	377848	6425448
E	32° 17.228' S	115° 42.160' E	377839	6426998
F	32° 16.167' S	115° 41.156' E	376239	6428939
G	32° 16.300' S	115° 41.974' E	377519	6429258
H	32° 14.949' S	115° 42.161' E	377789	6431209
I	32° 14.643' S	115° 40.859' E	375738	6431749

Site	Ammonia µg.N/L (<3)	Ortho-phosphate µg.P/L (<2)	Nitrate + Nitrite µg.N/L (<2)	Total Phosphorus µg.P/L (<5)	Total Nitrogen µg.N/L (<50)	Chlorophyll *a* (flurometry) µg/L (<0.1)	Chlorophyll *a* (acetone) µg/L (<0.1)	Phaeophytin *a* µg/L (<0.2)	Thermalolerant Coliforms CFU/100mL (<10)	Enterococci MPN/100mL (<10)
14	<3	<2	<2	10	70	0.4			<10	<10
15A	<3	<2	<2	11	80	0.3	0.3	<0.2	<10	<10
15B	<3	<2	<2	10	70	0.4	0.4	<0.2	<10	<10
15C	<3	<2	<2	10	80	0.4	0.4	<0.2	<10	<10
16	<3	<2	<2	9	80	0.2			10	<10
26	<3	<2	<2	10	80	0.4			<10	<10
28	57	17	8	27	140	0.3			96	230
30	<3	<2	1	11	90	0.3			<10	<10
31	51	17	11	29	170	0.4			3600	150
34	<3	<2	<2	10	80	0.5			<10	<10
36	64	18	9	30	170	0.4			4900	260
37	81	24	14	35	180	0.3			4900	3900
38	97	27	9	39	200	0.4			<10	<10
40	34	13	13	24	140	0.3			420	110
43	140	36	5	48	240	0.3	0.3	<0.2	24000	1800
44	78	22	3	34	180	0.4			3000	590
45	110	30	3	42	200	0.3			4700	1100
46	90	25	3	37	190	0.3			30000	1900
47	44	13	<2	24	140	0.4			5600	3400
48	73	20	3	30	180	0.4			450	380
53	76	22	6	32	160	0.5			50	120
54	98	26	4	37	180	0.3			500	400
55	100	28	3	38	190	0.3			500	630
56	44	13	6	23	140	0.3			<10	41
57	13	5	6	16	100	0.3			<10	10
61	22	9	8	17	120	0.4	0.5	<0.2	<10	<10
62	35	12	6	22	120	0.3			<10	10
63	13	6	3	15	110	0.3			<10	10
64	7	3	2	14	100	0.4			<10	<10
65	19	8	6	18	110	0.4			<10	<10
66	7	3	4	13	100	0.4			<10	<10
67	<3	<2	2	10	100	0.6	0.5	<0.2	<10	<10
70	12	5	4	15	100	0.6			<10	<10
71	8	3	2	15	160	0.4			<10	<10
72	<3	<2	<2	10	100	0.4	0.5	<0.2	<10	<10
74	8	4	4	14	100	0.5	0.4	<0.2	<10	<10
A	32	5	3	20	240		1.4	0.6	<10	10
B	4	3	3	17	150		0.9	0.5	<10	<10
C	8	2	2	15	190		0.7	0.5	<10	<10
D	<3	<2	4	13	130		0.3	0.4	<10	<10
E	32	5	<2	19	200		0.8	0.4	<10	<10
F	7	<2	2	13	160		0.4	0.6	10	10
G	<3	2	<2	22	210		1.9	0.6	10	<10
H	18	6	<2	20	250		0.5	0.6	<10	<10
I	10	2	3	11	160		0.1	0.6	<10	<10

Notes:

1. Numbers in parenthesis after the units indicate the detection limit for each water quality parameter
2. Chlorophyll *a* (flurometry) was not measured on shoreline sites

SEPIA DEPRESSION - BOTTOM WATER QUALITY, 17 FEBRUARY 2015

Site	Ammonia µg.N/L (<3)	Ortho-phosphate µg.P/L (<2)	Nitrate + Nitrite µg.N/L (<2)	Total Phosphorus µg.P/L (<5)	Total Nitrogen µg.N/L (<50)	Chlorophyll *a* (flurometry) µg/L (<0.1)	Chlorophyll *a* (acetone) µg/L (<0.1)	Phaeophytin *a* µg/L (<0.2)	Thermalolerant Coliforms CFU/100mL (<10)	Enterococci MPN/100mL (<10)
14	<3	<2	<2	10	80	0.3			<10	<10
15A	<3	<2	<2	11	80	0.5			<10	<10
15B	<3	<2	<2	11	80				<10	<10
15C	<3	<2	<2	10	90				<10	<10
16	<3	<2	<2	11	100	0.3			<10	<10
26	<3	<2	<2	10	80	0.5			<10	<10
28	<3	<2	<2	10	70	0.3			20	<10
30	<3	<2	<2	10	100	0.4			<10	<10
31	<3	<2	<2	11	80	0.4			10	<10
34	<3	<2	<2	10	80	0.4			<10	<10
36	<3	<2	<2	10	80	0.3			64000	1200
37	56	16	5	27	160	0.5			<10	<10
38	<3	<2	<2	10	100	0.3			91	10
40	3	2	<2	12	90	0.3			<10	<10
43	<3	<2	<2	11	80	0.3			<10	<10
44	<3	<2	<2	10	110	0.5			30	10
45	<3	<2	<2	11	80	0.5			<10	<10
46	<3	<2	<2	11	90	0.4			<10	<10
47	<3	<2	<2	10	80	0.3			<10	<10
48	<3	<2	<2	10	100	0.4			10	<10
53	<3	<2	<2	9	80	0.5			80	<10
54	5	2	<2	12	90	0.4			10	<10
55	<3	<2	<2	11	90	0.3			<10	<10
56	<3	<2	<2	10	90	0.4			<10	<10
57	<3	<2	<2	10	90	0.4			20	<10
61	<3	2	7	10	80	0.3			20	10
62	<3	<2	<2	10	80	0.6			<10	<10
63	<3	<2	<2	10	90	0.7			<10	<10
64	<3	<2	<2	10	90	0.5			<10	<10
65	<3	<2	<2	10	90	0.7			<10	<10
66	<3	<2	<2	11	90	0.6			20	20
67	<3	<2	7	12	110	0.4			<10	<10
70	<3	<2	<2	10	80	0.6			42	10
71	<3	<2	<2	9	90	0.6			<10	<10
72	<3	2	9	11	110	0.4				
74	<3	<2	<2	12	90	0.7				

Notes:

1. Numbers in parenthesis after the units indicate the detection limit for each water quality parameter
2. Chlorophyll *a* (acetone) and Phaeophytin *a* were not measured in bottom waters

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