# PRODUCED FORMATION WATER PLAN FOR EPL57-02 CONDITION 43

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## REVISION HISTORY

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| 00 | 18/05/15 | 200 | Issued for Comments |
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| 04 | 18/05/17 | 256 | Final Issue<br>Re-issued based on NTEPA comments |

# TABLE OF CONTENTS

# TABLES



# FIGURES

# APPENDICES

# 1. EXECUTIVE SUMMARY

This document has been prepared to satisfy conditions 43 and 44 of EPL57-02, which requires a Produced Formation Water (PFW) Plan for the Blacktip Project. Its purpose is to:

- Compile all information collected on the PFW discharge to date;
- Propose an offshore mixing zone for the discharge;
- Identify marine water monitoring points around the diffuser where ANZECC water quality guidelines will be met;
- Identify a method and schedule for validating the near and far field models; and
- Identify actions and schedule for ensuring the produced water discharge achieves the trigger values specified in the EPL.

Based on PFW sampling and analysis undertaken since commencement of production and dispersion modelling, Eni proposes a circular mixing zone of radius 50 m centred on the diffuser mid-point. The dispersion models and PFW studies provide reasonable assurance that the ANZECC water quality guidelines will be met at this boundary.

Due to the scale of the discharge and assimilative capacity of the receiving waters, a field validation campaign comprised of water column sampling is considered appropriate. The dominant drivers for the plume’s behaviour within the mixing zone is tidally driven ambient current speeds and the substantially lower salinity of PFW discharge relative to the ambient marine waters (yielding a buoyant plume). An outline of a sampling and analysis plan for a 1 day field survey is provided with the objective to validate the near field modelling predictions that predict meeting the required dilution of 263 fold at the mixing zone boundary. Upon acceptance of the proposed field campaign, Eni will provide detailed sampling and analysis plan for implementation in the 2017 late dry season, subject to operational and logistical constraints. It is proposed that subject to successful validation of the dispersion modelling that marine water monitoring will be undertaken again in ~3 years when the volume of produced water (i.e. number of discharge events in a year) is expected to increase substantially in 2020 by approximately 2-fold over those predicted for 2017 with potential concomitant changes in the major factor that drives dispersion, namely PFW salinity.

# 2. ABBREVIATIONS AND DEFINITIONS

## 2.1 Abbreviations

| | |
|---|---|
| AS | Australian Standard |
| BAF | Bioaccumulation factor |
| BCF | Bio-concentration factor |
| BMF | Biomagnification factor |
| bwpd | Barrels of water per day |
| CFC | Chlorofluorocarbon |
| cfu | Colony forming units |
| CH4 | Methane |
| cm | Centimetres |
| CO | Carbon Monoxide |
| $CO_2$ | Carbon Dioxide |
| Cwlth | Commonwealth |
| °C | Degrees Celsius |
| EIF | Environmental Impact Factor |
| EIS | Environmental Impact Statement |
| EMP | Environmental Management Plan |
| Eni | Eni Australia B.V. |
| EPL | Environmental Protection Licence EPL57-02, issued by the NT EPA on 10 February 2015 |
| HDPE | High Density Polyethylene |
| HP | High Pressure |
| Hr | Hour(s) |
| HSE | Health Safety Environment |
| IGFU | Induced Gas Flotation Unit |
| K | Kelvin unit of temperature |
| kg | Kilograms |
| kJ | Kilojoules |
| km | Kilometres |
| kPa | Kilo Pascal |
| L | Litres |
| LP | Low Pressure |

| | |
|---|---|
| µ | Micro |
| m | Metres |
| $m^3$ | Cubic metres |
| mg | Milligrams |
| MGA | Map Grid of Australia |
| mL | Millilitres |
| $N_2O$ | Nitrous Oxide |
| NLC | Northern Land Council |
| NM | Not measured |
| NMHC | Non-methane hydrocarbons |
| $NO_x$ | Oxides of nitrogen |
| NORM | Naturally occurring radioactive material |
| NPI | National Pollutant Inventory |
| NT | Northern Territory |
| NT EPA | Northern Territory Environment Protection Authority (formerly NRETAS) |
| NTP | Normal temperature and pressure (i.e. at 25°C and an absolute pressure of 101.325 kPa) |
| NTU | Nephelometric turbidity units |
| $O_2$ | Oxygen |
| ODS | Open Drains System |
| OEMP | Onshore Environmental Management Plan |
| OIW | Oil in water |
| P&ID | Process and Instrumentation Diagram |
| PEC | Predicted Environmental Concentration |
| PFW | Produced Formation Water |
| PNEC | Predicted No Effect Concentration |
| POS | Plant Operations Superintendent |
| PPE | Personal Protective Equipment |
| psu | Practical Salinity Units |
| PWFD | Produced Water Flash Drum |
| QA/QC | Quality Assurance/Quality Control |
| $SO_x$ | Oxides of Sulphur |
| SPM | Single point mooring |

| | |
|---|---|
| STP | Standard temperature and pressure (i.e. at 0°C and an absolute pressure of 101.325 kPa) |
| UTM | Universal Transverse Mercator coordinate system |
| VOC | Volatile Organic Compounds |
| WHP | Wellhead Platform |
| WMPC Act | Waste Management and Pollution Control Act (NT) |
| YGP | Yelcherr Gas Plant |

## 2.2 Definitions

| | |
|---|---|
| Emission limit | A limit defined by EPL57-02 for contaminant levels which must not be exceeded in emissions. |
| Trigger value | Trigger values stated in EPL57-02 represent best practice targets. Exceedance of a trigger value does not represent a non-compliance unless specifically stated. |

# 3. INTRODUCTION

## 3.1 Background

Eni Australia B.V. (Eni) is operator of the Blacktip Project in the Northern Territory. The project consists of a small unmanned offshore wellhead platform, a subsea pipeline bringing whole well stream fluid (i.e. gas, condensate and produced water) to Yelcherr Beach and the onshore Yelcherr Gas Plant (YGP) near Wadeye (see Figure 3.1 and Figure 3.2). The processed gas is exported via an onshore export pipeline, by Australian Pipeline Trust, to the customer, Power and Water Corporation.

Produced Formation Water (PFW) is pumped to sea via a subsea outfall pipeline, which is piggybacked to the Condensate Export Pipeline. The end of the outfall pipe is located 2 km offshore in approximately 12 m of water (relative to Lowest Astronomic Tide (LAT)) (Figure 4.3)

Blacktip YGP commenced production on 26 August 2009. The operation of the YGP is licensed under the Environmental Protection Licence (EPL), EPL57, issued by the former Department of Natural Resources, Environment, The Arts and Sport (NRETAS) (now Northern Territory Environment Protection Authority (NT EPA)) on 11 August 2009.

EPL57-01 was issued to Eni on 16 December 2010 as an amendment to EPL57.

EPL57-02 (the current licence) was issued to Eni as an amendment to EPL57-01.

## 3.2 Purpose

The purpose of this report is to satisfy conditions 43 and 44 of EPL57-02.

Under these conditions, the EPL stipulates:

*43. The Licensee must provide a Produced Formation Water Plan to the NT EPA by 1 May 2015.**

*44. The Produced Formation Water Plan required under condition 43 must:*

*44.1. propose a mixing zone in accordance with the NT EPA Guidelines on Mixing Zones, Version 1.2, available from: http://www.ntepa.nt.gov.au/__data/assets/pdf_file/0017/160631/guidelines_mixing_zones.pdf;*

*44.2. assess whether the risks posed by management of Produced Formation Water are as low as reasonably practicable (ALARP);*

*44.3. include a proposed dilution factor (including methodology used to derive the dilution factor) based on results from produced water chemical characterisation, ecotoxicity and biodegradation studies undertaken in accordance with EPL 57-01;*

*44.4. include summary and interpretation of the results for all historical studies, including:*

- *chemical composition of Produced Formation Water;*
- *biodegradation and bioaccumulation potential of Produced Formation Water contaminants;*
- *toxicity testing of Produced Formation Water; and*
- *marine surveys;*

*44.5. identify surface water monitoring points where the 99% level of species protection trigger values specified in Table 3.4.1 of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000) will be applied;*

*44.6. identify a schedule for monitoring of the surface water monitoring points identified as part of condition 44.5;*

*44.7. identify a methodology for validating the near and far field Produced Formation Water dispersion modelling predictions that have been included in the document Eni Blacktip Project Produced Water Management Plan (document number 00036_DV_EX.HSE.0381.000_A03);*

*44.8. identify a schedule for implementation and completion of validation activities.*

*44.9. identify actions that will be completed to ensure that wastewater discharged from authorised discharge point PW-01 achieves the trigger value specified in Table 3, when measured at monitoring side code PW-02; and*

*44.10. identify a schedule for completion of actions identified as part of condition 44.9.*

* This report was submitted to NT EPA for review in accordance with EPL57-02 condition 43 on 29 May 2015, within the revised timeframe agreed with NT EPA. NT EPA responded on 8 April 2016, notifying Eni that it found the Produced Formation Water Plan did not meet the requirements of Condition 44 of EPL57-02. NT EPA requested the Plan be amended and resubmitted, which it was on 15 July 2016. The amended produced water plan was reviewed and in the NT EPA letter on 27 December 2016 further clarifications were sought. This plan addresses the comments from the latest review.

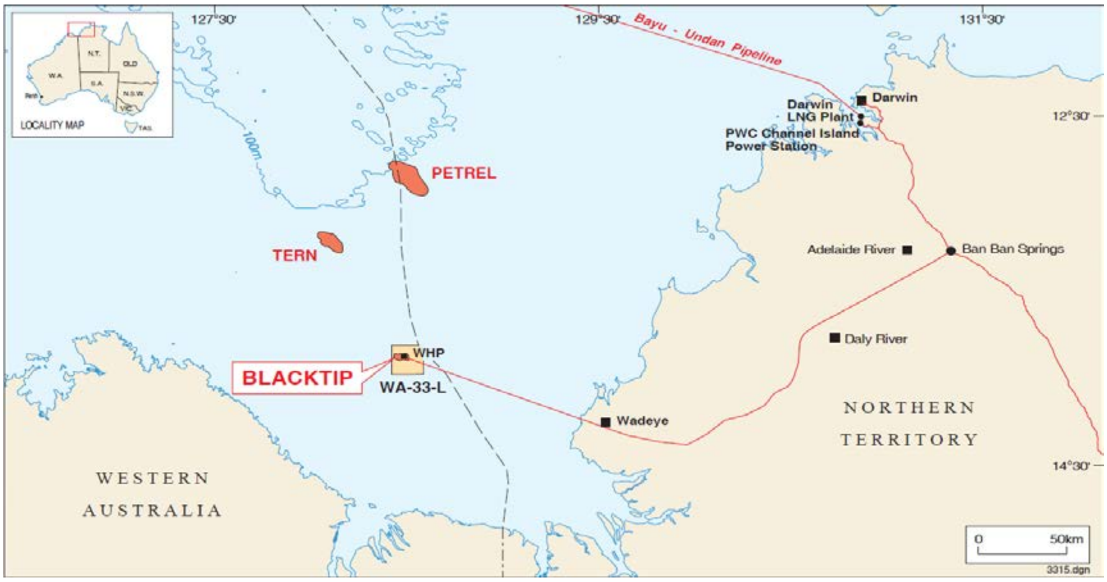



**Figure 3.1: Blacktip Field Location**

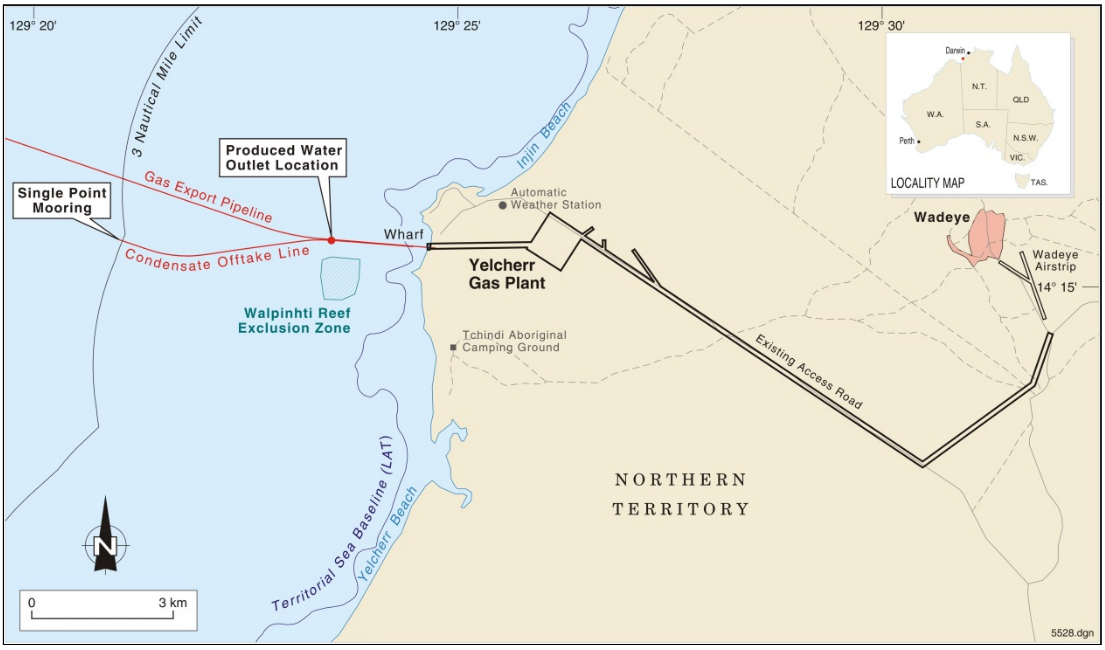



**Figure 3.2: Yelcherr Gas Plant and pipeline location**

## 3.3 Scope of this report

Table 3.1 summarises the scope of this report, and how it meets the requirements that are specified under EPL57-02 condition 44.

**Table 3.1: Requirements of this report**

| EPL57-02 condition | Requirement | Section reference in this report |
|---|---|---|
| 44.1 | Propose a mixing zone in accordance with the NT EPA Guidelines on Mixing Zones, Version 1.2; | Section 7.9 *Mixing zone assessment* |
| 44.2 | Assess whether the risks posed by management of Produced Formation Water are as low as reasonably practicable (ALARP); | Section 7.10 *ALARP and Acceptability assessment* |
| 44.3 | Include a proposed dilution factor (including methodology used to derive the dilution factor) based on results from produced water chemical characterisation, ecotoxicity and biodegradation studies undertaken in accordance with EPL 57-01; | Predicted No Effect Concentration (PNEC) of 0.38%PFW (263) dilutions proposed in Section 6.2.2 and 7.8. |
| 44.4 | Include summary and interpretation of the results for all historical studies, including:<br>• chemical composition of Produced Formation Water;<br>• biodegradation and bioaccumulation potential of Produced Formation Water contaminants;<br>• toxicity testing of Produced Formation Water; and<br>• marine surveys; | Section 6 *Historical PFW monitoring* and Appendices A and B. |
| 44.5 | Identify surface water monitoring points where the 99% level of species protection trigger values specified in Table 3.4.1 of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000) will be applied; | Section 8.4 *Surface water monitoring*. |
| 44.6 | Identify a schedule for monitoring of the surface water monitoring points identified as part of condition 44.5; | |
| 44.7 | Identify a methodology for validating the near and far field Produced Formation Water dispersion modelling predictions that have been included in the document Eni Blacktip Project Produced Water Management Plan (document number 000036_DV_EX.HSE.0381.000_A03); | Section 8.2 *Dispersion model validation* |
| 44.8 | Identify a schedule for implementation and completion of validation activities; | |
| 44.9 | Identify actions that will be completed to ensure that wastewater discharged from authorised discharge point PW-01 achieves the trigger value specified in Table 3, when measured at monitoring site code PW-02; | Section 8.4 *Performance improvement* |
| 44.10 | Identify a schedule for completion of actions identified as part of condition 44.9. | |

## 3.4 Related documentation

The following documents set out the approval conditions and operational commitments for the Blacktip YGP:

- *Blacktip Operations Onshore Gas Plant Environmental Management Plan* (EMP) (000036_DV_EX.HSE.0684.000) (Ref. [8]);
- NRETAS Assessment Report No. 50 (Ref. [33]);
- Environmental Impact Statement (Ref. [37], [38], [39]);
- EPBC approval 1180/2003;
- Environmental Protection Licence (EPL57-02); and
- Eni Blacktip Project Produced Water Management Plan (document number 00036_DV_EX.HSE.0381.000_A03) (Ref. [7]).

# 4. FACILITY DESCRIPTION

Infrastructure at the YGP includes:

- a gas processing plant consisting of slug catcher and pig receiver, separation, gas dehydration, compression, condensate storage and PFW treatment facilities
- the onshore portion of an 18“ carbon steel, multi-phase pipeline bringing produced fluids from the offshore gas field to the YGP, starting from the shore crossing
- the onshore portion of a condensate export pipeline from the condensate storage facilities at the YGP to the shore crossing
- a portion of the onshore gas export pipeline that runs from the gas processing plant to a custody transfer meter at the boundary of the YGP site.
- PFW and condensate are pumped to sea via subsea outfall pipelines, whereby the PFW pipe is piggybacked to the Condensate Export Pipeline. The end of the PFW outfall pipe is located 2 km offshore in approximately 12 m of water

An overview of the process is presented in Figure 4.1. After processing, un-odorised natural gas at agreed specifications is delivered to the customer via an onshore export pipeline to a custody transfer meter at the boundary of the YGP, at a maximum delivery rate of 191 TJ/day. Stabilised condensate is also stored on site at the YGP before being exported to the SPM for offload via tankers.

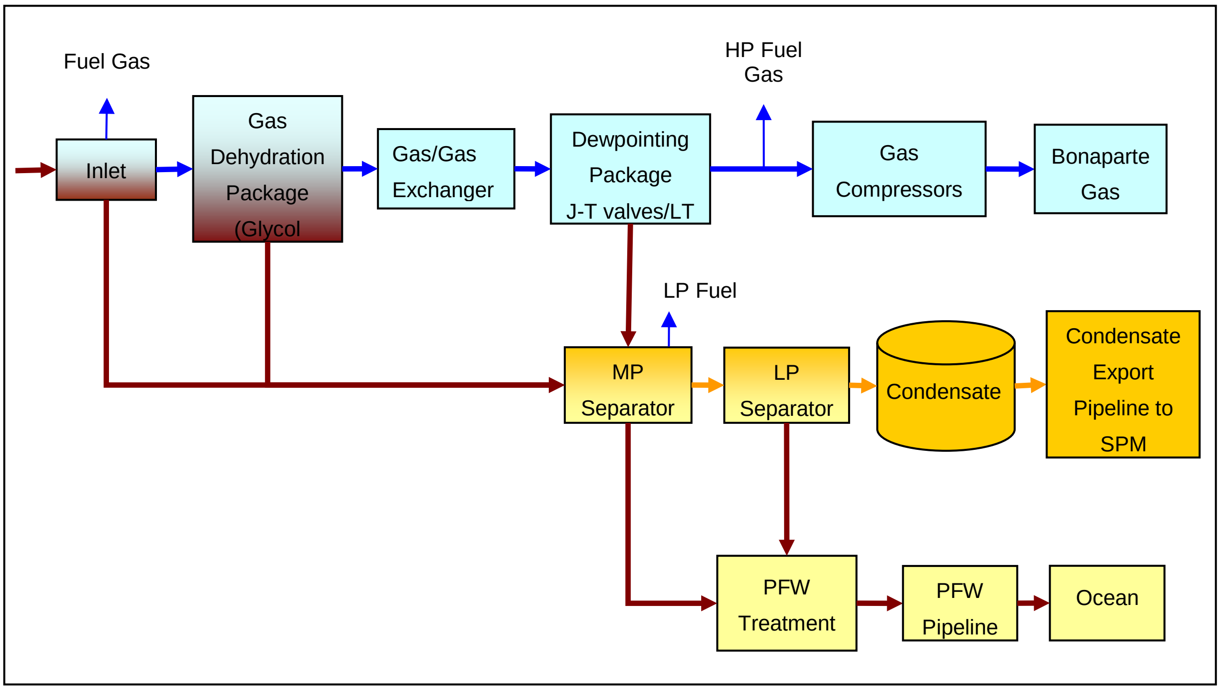



**Figure 4.1: YGP process block diagram**

## 4.1 Produced water treatment system

Produced Formation Water (PFW) or produced water (PW) separated from the liquids stream is further processed in the PFW system to remove free oil prior to disposal at sea. The key design functions of the PFW Treatment System are to:

- handle a maximum flow rate of 9,400 bwpd (1,500 $m^3$/day) (50% more than the anticipated water production rate); and
- reduce the oil in water concentration to below 30 ppm.

Figure 4.2 shows a schematic for the system. The main components include:

- Produced Water Degasser;
- Induced Gas Flotation (IGF) Units;
- Produced Water Break Tank; and
- CETCO unit.

Water flows to the Degasser Vessel from the MP Separator and is pumped in from the LP Separator. The Degasser provides bulk separation of dissolved light hydrocarbons, oil and condensate, and removes any dissolved gasses to the LP flare. Water is sent to the IGF package and skimmed hydrocarbons are pumped to the Closed Drains Drum.

Water enters the IGF vessels which remove traces of finely dispersed oil by bubbling nitrogen gas through the water. Small oil droplets attach to the surface of the bubbles and rise and accumulate on the surface of the water. Any accumulated oil in the IGF is continuously skimmed and directed to the corrugated plate interceptor (CPI) condensate bucket. Hydrocarbons from the CPI unit are pumped using low shear pumps to the closed drains drum. Water from the IGF units is pumped to the produced water tank (PWT).

The PWT ensures that sampling can be performed and compliance with regulations confirmed prior to discharge to sea. Water can be diverted through a dual set of CETCO units, which can be run in series or parallel, and can utilize a variety of filter elements (e.g. 10 micron filters) to assist in further polishing of oil in water (OIW) measurements. It is noted the CETCO unit is a temporary component to assist during major process upsets.

The PFW tank has a volume of 889 $m^3$. Any hydrocarbons that separate in the tank will be skimmed and directed to the CPI unit. Prior to discharge, the water in the tank is sampled and tested on site. Should the water not meet the discharge criteria, it will be recirculated back through the treatment system for further treatment. The storage capacity of the tank allows sufficient time to rectify any performance issues in the PFW system and ensure adequate treatment prior to discharge. The process utility flow diagrams (PFD, UFD) are provided in Appendix D.

The pump is controlled manually. The tank level is kept low to ensure adequate buffer volume exists to store water in case of a performance upset. The pump will discharge at a fixed rate of 63 $m^3$/hr.

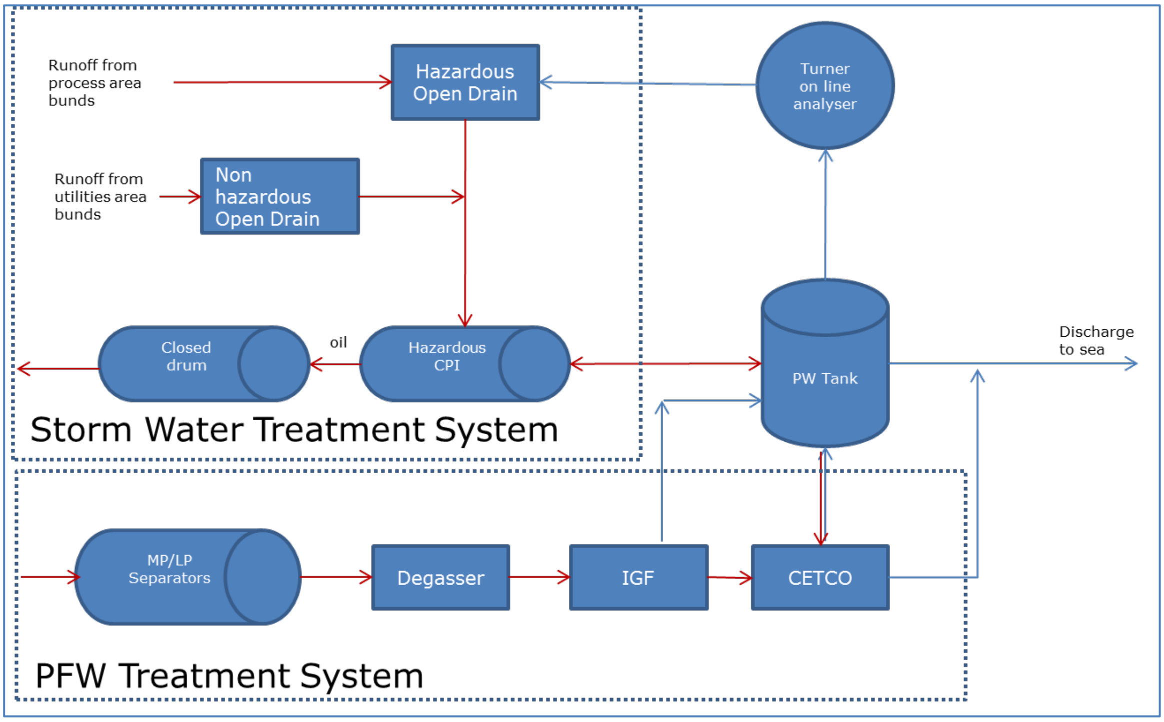



**Figure 4.2: Schematic of Produced Water Treatment System**

## 4.2 Discharge and release conditions

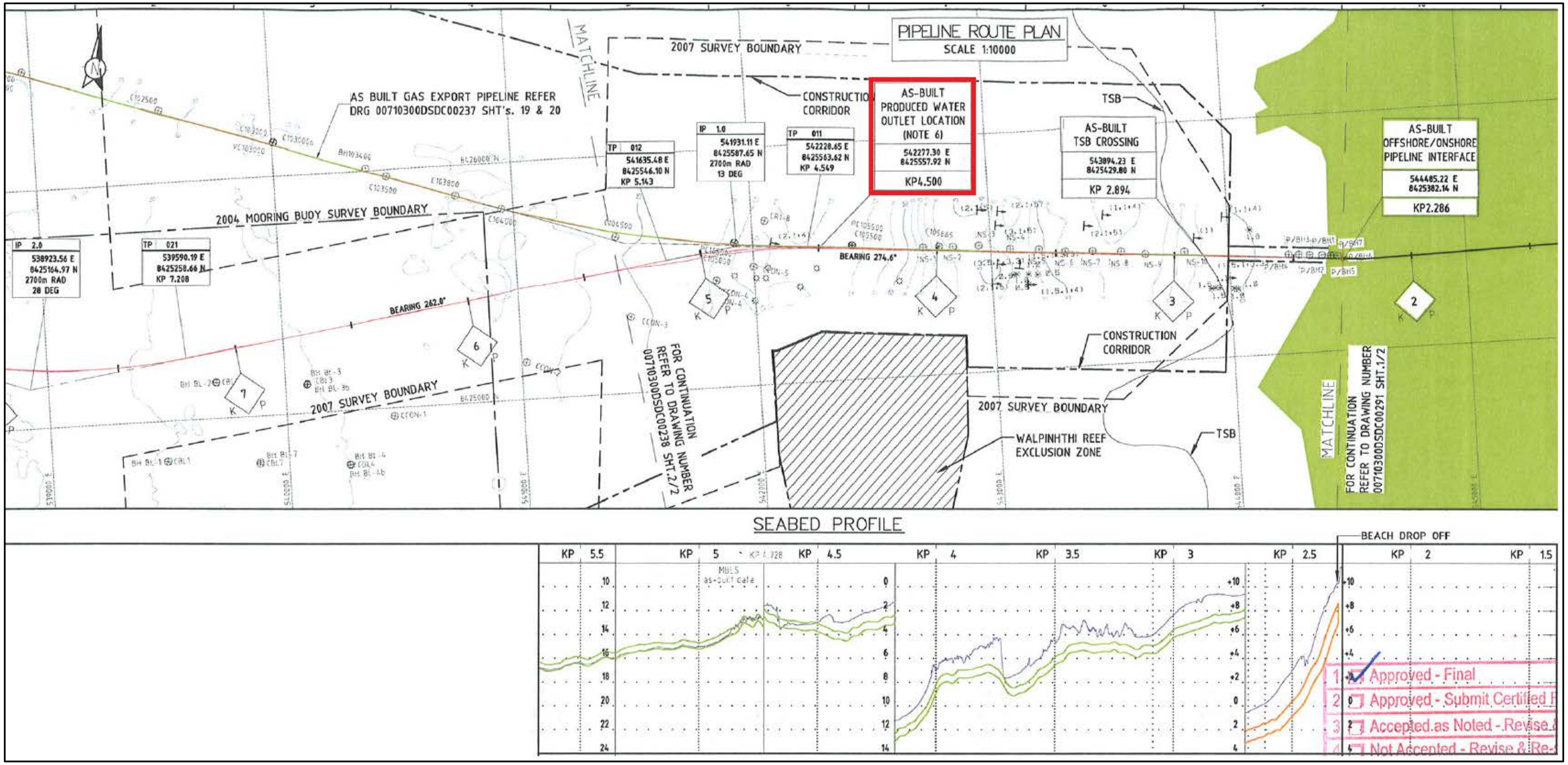
PFW is pumped from the break tank to sea via a 160 mm outer diameter, 123 mm internal diameter PE100 grade High Density Polyethylene (HDPE) subsea outfall pipeline (Ref. P&ID 00710100DPFM00291.364, Note 5). The offshore section is piggybacked to the Condensate Export Pipeline using a block and strap clamping arrangement. A typical block and strap arrangement purpose is illustrated in Figure 4.4.

The end of the outfall pipe is located 2 km offshore in approximately 12 m of water (relative to Lowest Astronomic Tide (LAT)) (Figure 4.3). Effluent is discharged through a four port diffuser, which is designed to enhance mixing of the PFW with the receiving waters upon release, as shown in Figure 4.5. The density of the PFW is less than the receiving waters and on release it rises to the surface under its own buoyancy. It then mixes horizontally and vertically with the surrounding waters whilst being advected away from the discharge location by ambient currents.

Table 4.1 summarises the discharge and release conditions associated with Blacktip PW.

**Table 4.1: Summary of discharge and release conditions**

| Condition | Value |
|---|---|
| Outfall location | 14.241506S, 129:385128E<br>(2 km offshore – refer to ) |
| Outfall type | Horizontal, four port diffuser |
| Outfall pipeline | 160 mm outer diameter, 123 mm internal diameter, PE100 grade High Density Polyethylene (HDPE) subsea outfall pipeline |
| Port diameter | 60 mm |
| Discharge rate | Maximum of 562 $m^3$/day in a single discharge event over calendar year 2016 , with an average volume of 282 $m^3$ per discharge |
| Number of days discharging | 22 events during the 2016 calendar year |
| Discharge flowrate | 63 $m^3$/hr |
| **Ambient conditions** | |
| Depth | 12 m below LAT |
| Ambient velocity | 0.05-1 m/s |
| Stratified condition | Unstratified. Refer to Section 5.4.4. |
| Ambient temperature | 28°C |
| Ambient salinity | 34 psu |




Notes: (1) Produced Formation Water Outfall Coordinates (542277E, 842557N)

**Figure 4.3: Produced water discharge location**

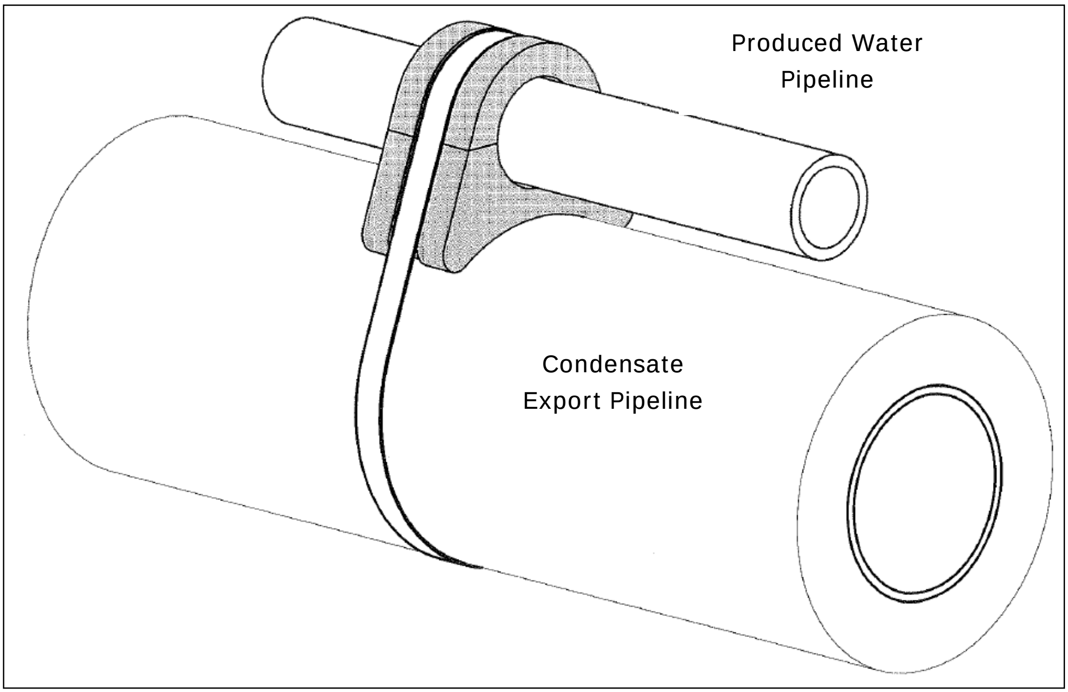



**Figure 4.4: Piggyback Block and Strap Clamping Arrangement**

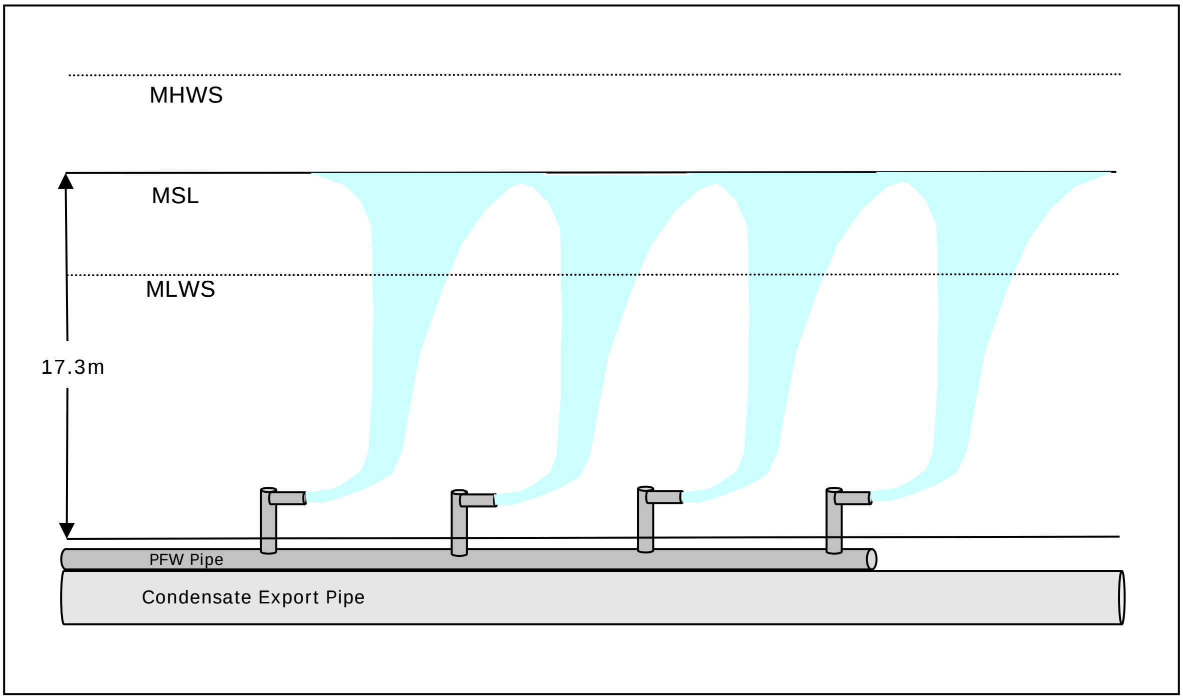



**Figure 4.5: Illustration of four port discharge diffuser**

## 4.3 Water production

### 4.3.1 Historical production

Table 4.2 and Figure 4.6 summarise the historical produced formation water volume and volume discharged from Blacktip field since commencement of production. The volume discharged includes stormwater from the process skids.

**Table 4.2: Annual volumes discharged**

| Calendar year | Produced formation water ($m^3$) | Volume discharged ($m^3$) |
|---|---|---|
| 2010 | 1,248 | 0[1] |
| 2011 | 31 | 0[1] |
| 2012 | 2,787 | 893 |
| 2013 | 26,483 | 27,764[2] |
| 2014 | 3,776 | 1,754 |
| 2015[3] | 1,875 | 6,179 |
| 2016 | 2,138 | 6,206 |

[1] At the start of operations, produced water was trucked offsite for discharge because the water did not meet the discharge criteria.
[2] Volume discharged exceeds produced formation water volume in 2013 because the discharge stream includes wastewater from the shutdown and maintenance and campaign in mid-2013.
[3] Since 2015, 100% of stormwater from the process skids is routed into the produced water system and no longer discharged to the ground, hence the increase in volume discharged from the produced water system.

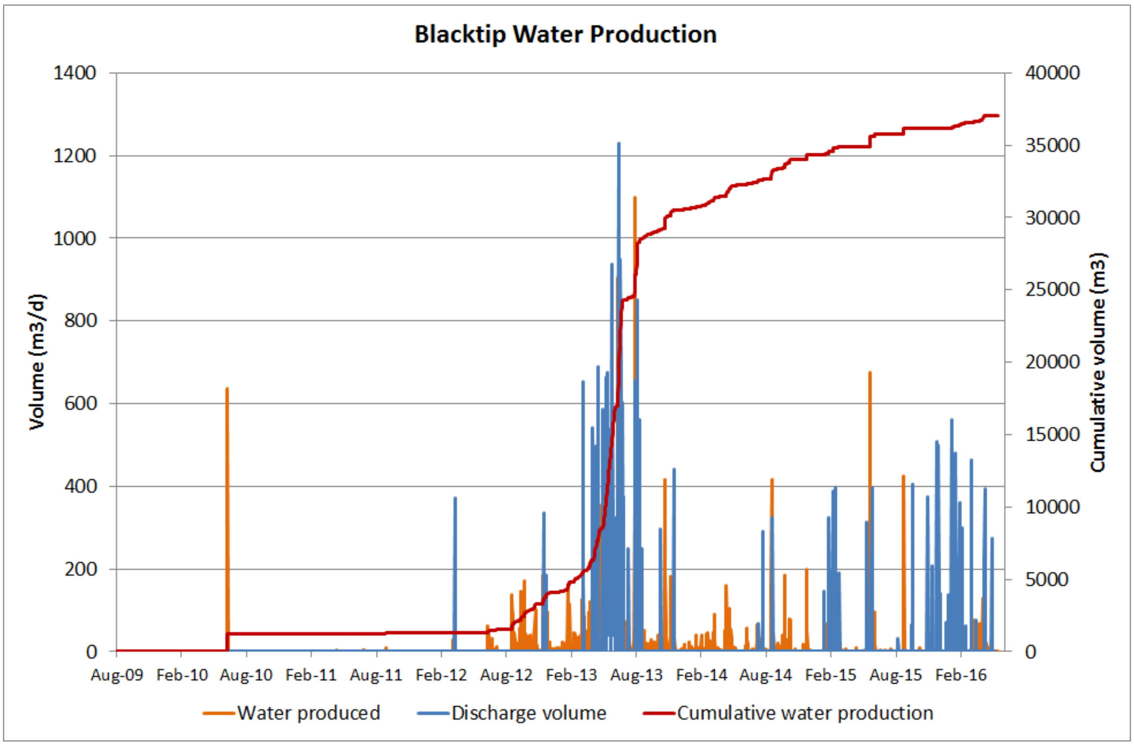



**Figure 4.6: Blacktip historical produced formation water volume**

### 4.3.2 Current production

Currently, produced water predominantly consists of condensate water from gas dehydration. Over the past calendar year (1 January 2016 – 31 December 2016), the total PFW production volume and average daily rate were 2,138 $m^3$ and 5.9 $m^3$/day, respectively. However, the average produced formation water production is projected to increase to 40 $m^3$/day in 2017 (Section 4.3.3).

The total volume discharged over the 2016 calendar year is shown in Table 4.3 and was approximately 6,206 $m^3$ over 22 separate days. The average discharge volume was approximately 282 $m^3$ per discharge event at an average frequency of about once per sixteen days.

**Table 4.3: Discharges during 2016**

| Date | Volume discharged ($m^3$) | Oil in water (mg/L) |
|---|---|---|
| 17 January 2016 | 71.0 | 19 |
| 24 January 2016 | 138.6 | 7.7 |
| 1 February 2016 | 562.4 | 18.5 |
| 13 February 2016 | 480.7 | 3.9 |
| 24 February 2016 | 361.4 | 3.6 |
| 2 March 2016 | 300.0 | 9.2 |
| 12 March 2016 | 62.0 | 22 |
| 28 March 2016 | 463.6 | 9.6 |
| 10 April 2016 | 75.0 | 10.2 |
| 4 May 2016 | 232.8 | 19 |
| 5 May 2016 | 393.5 | 24.6 |
| 24 May 2016 | 273.6 | 10.4 |
| 25 May 2016 | 257.2 | 11.7 |
| 8 June 2016 | 212.0 | 9.7 |
| 22 July 2016 | 405.0 | 12.8 |
| 6 September 2016 | 473.0 | 20.6 |
| 23 September 2016 | 446.2 | 13.6 |
| 13 October 2016 | 395.4 | 8.8 |
| 15 October 2016 | 170.5 | 2.8 |
| 25 November 2016 | 88.0 | 7.8 |
| 28 November 2016 | 189.0 | 7.67 |
| 6 December 2016 | 155.0 | 1.54 |
| TOTAL | 6205.9 | 12.03(1) |

[1]Weighted average

### 4.3.3 Future production

The daily production over the remaining life of the field is projected to range from 0 $m^3$/day to 314 $m^3$/day (Figure 4.7 and Table 4.4). The produced formation water is expected to increase from 5.9 $m^3$/day (2016 rates) to 30-35 $m^3$/day from 2017-2019, then increase to 79 $m^3$/day in 2020 and in the range of 133-159 $m^3$/day from 2021-2023, before decreasing to 15-36 $m^3$/day from 2024-2028.

It is noted that produced formation water production is variable and projections vary with well performance, as evidenced by the historical discharge volumes summarised in Table 4.2, Table 4.3 and Figure 4.6.

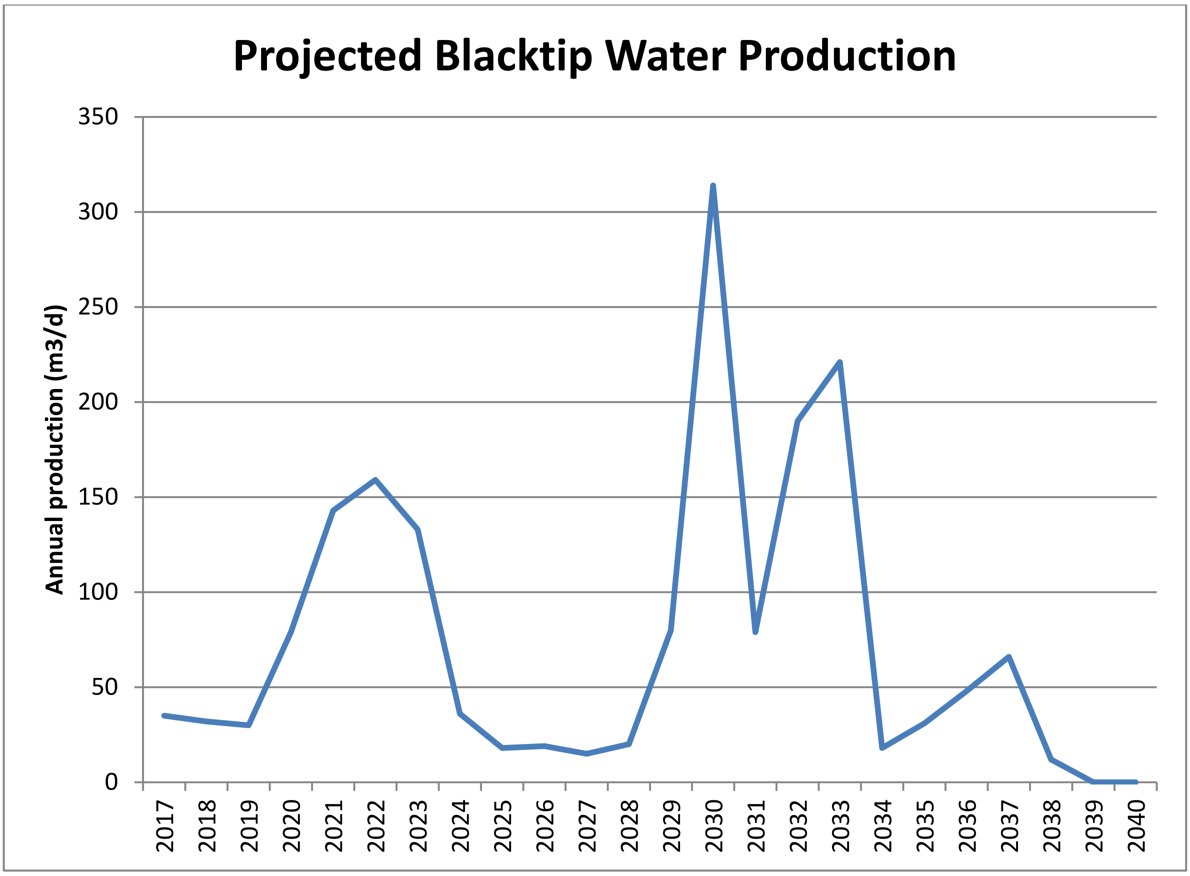



**Figure 4.7: Projected PFW flow rate over the remaining life of the field**

**Table 4.4: Projected PFW rates over the remaining life of the field**

| Year | Projected daily PFW rates ($m^3$/day) | Projected annual PFW volumes ($m^3$) | Projected number of 600 $m^3$ discharge events |
|---|---|---|---|
| 2017 | 35 | 12,775 | 21 |
| 2018 | 32 | 11,680 | 19 |
| 2019 | 30 | 10,950 | 18 |
| 2020 | 79 | 28,835 | 48 |
| 2021 | 143 | 52,195 | 87 |
| 2022 | 159 | 58,035 | 97 |
| 2023 | 133 | 48,545 | 81 |
| 2024 | 36 | 13,140 | 22 |
| 2025 | 18 | 6,570 | 11 |
| 2026 | 19 | 6,935 | 12 |
| 2027 | 15 | 5,475 | 9 |
| 2028 | 20 | 7,300 | 12 |
| 2029 | 80 | 29,200 | 49 |
| 2030 | 314 | 114,610 | 191 |
| 2031 | 79 | 28,835 | 48 |
| 2032 | 190 | 69,350 | 116 |
| 2033 | 221 | 80,665 | 134 |
| 2034 | 18 | 6,570 | 11 |
| 2035 | 31 | 11,315 | 19 |
| 2036 | 48 | 17,520 | 29 |
| 2037 | 66 | 24,090 | 40 |
| 2038 | 12 | 4,380 | 7 |
| 2039 | 0 | 0 | 0 |
| 2040 | 0 | 0 | 0 |

# 5. RECEIVING ENVIRONMENT

## 5.1 Bathymetry

Joseph Bonaparte Gulf is a large embayment on the north-western continental margin of Australia (Figure 5.1). It is approximately 300 km east-west and 120 km north-south with a broad continental shelf to seaward. Maximum width from the southernmost shore of Joseph Bonaparte Gulf to the edge of the continental shelf is 560 km. Several large rivers enter the gulf along its shoreline.

The offshore facility is located on the Sahul Shelf in 50 m of water (Figure 5.1). Depths along the pipeline route generally decrease shoreward. There are no reefs or emergent banks along the gas export pipeline route although it does pass through a dune field in the nearshore region.

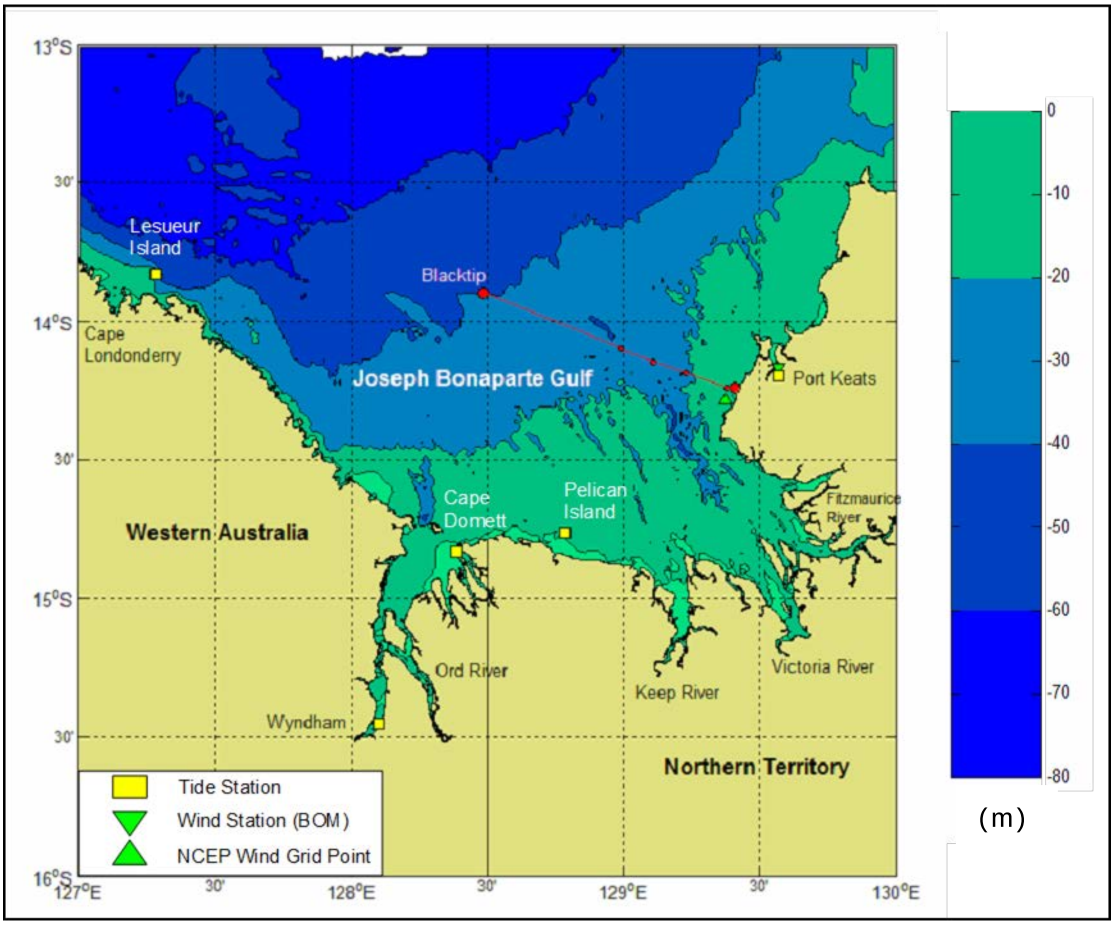



**Figure 5.1: The Joseph Bonaparte Gulf**

## 5.2 Climate

The climate of the Timor Sea is monsoonal with a wet "summer" and a dry "winter". The wet season commences between September and November as the southeast (SE) Trade winds weaken over Northern Australia and land temperatures rise. This results in two or more semi-permanent heat lows forming over central Australia, one over the Kimberley Great Sandy Desert, and often another just south of the Gulf of Carpentaria.

The early part of the season is marked by frequent thunderstorms. As the season progresses moist ocean air from the north and northwest streams into the lows and several days of heavy rain may occur. Occasionally one of the lows may strengthen and move southeast over the interior. When this happens widespread rains follow and under exceptional circumstances the cloud may effect as far south as New South Wales. The general atmospheric circulation for the wet season is illustrated in Figure 5.2(a).

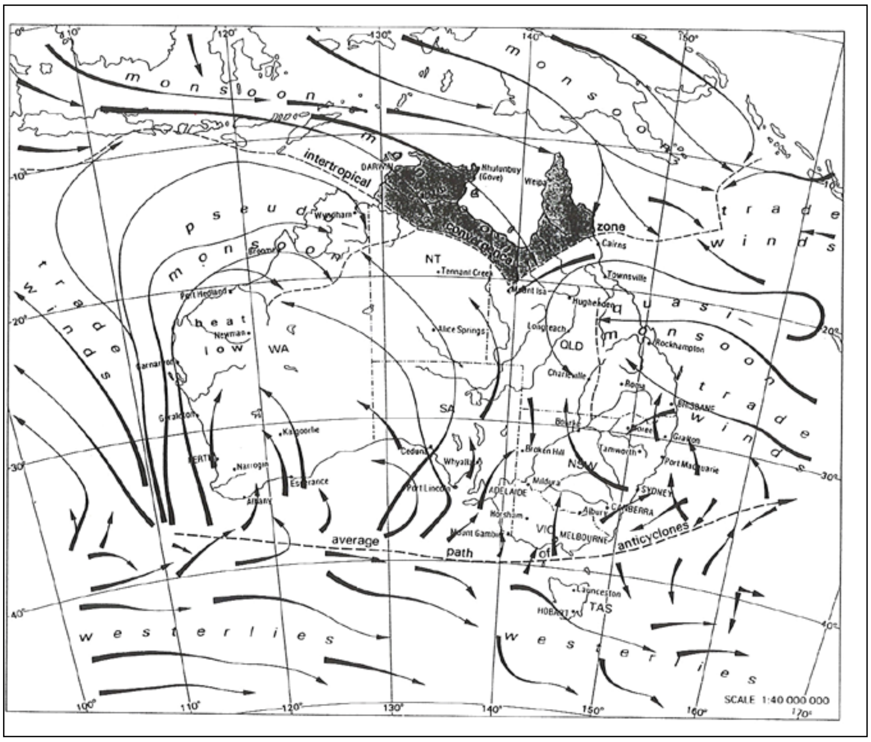
As winter approaches large highs centre over the southern part of the continent, the trade winds become re-established over Northern Australia and the monsoon retreats. The SE Trades are dry winds that bring no moisture. Figure 5.2(b) illustrates the typical atmospheric circulation for the dry season.

Mean daily maximum temperatures for Port Keats range from about 30 to 34°C, and minima from 14.5°C to 25°C. Annual rainfall is 750 to 900 mm. Almost all rainfall occurs between November and April, the greatest falls being in January and February. The frequency and severity of the thunderstorms produce a large variation in the monthly rainfall. Rainfall during the dry months is sporadic and light.

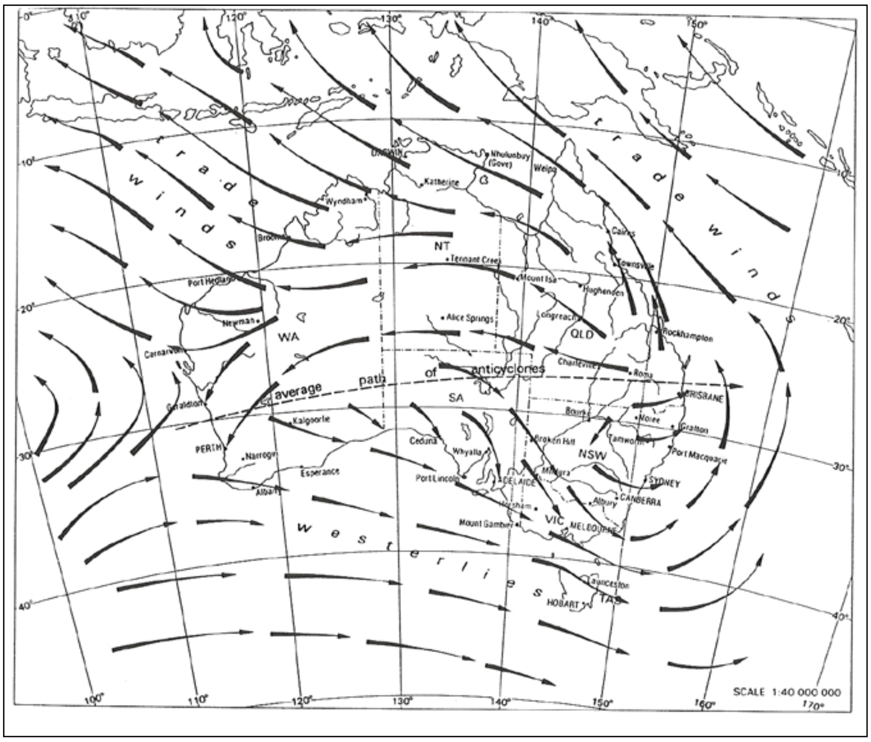
## 5.3 Winds

Monthly wind roses for Port Keats are shown in Figure 5.3. Winds are predominantly from the northwest between September and February and from the southeast between April and July. During the transition periods between the two seasons in March and August, winds are more variable. Tropical cyclones can develop between November and April resulting in short lived, severe storm events often with strong but variable winds.

(a) Summer




(b) Winter




Source: Ref. [6]

**Figure 5.2: Generalised atmospheric circulation over Australia in Winter (July) and Summer (January)**

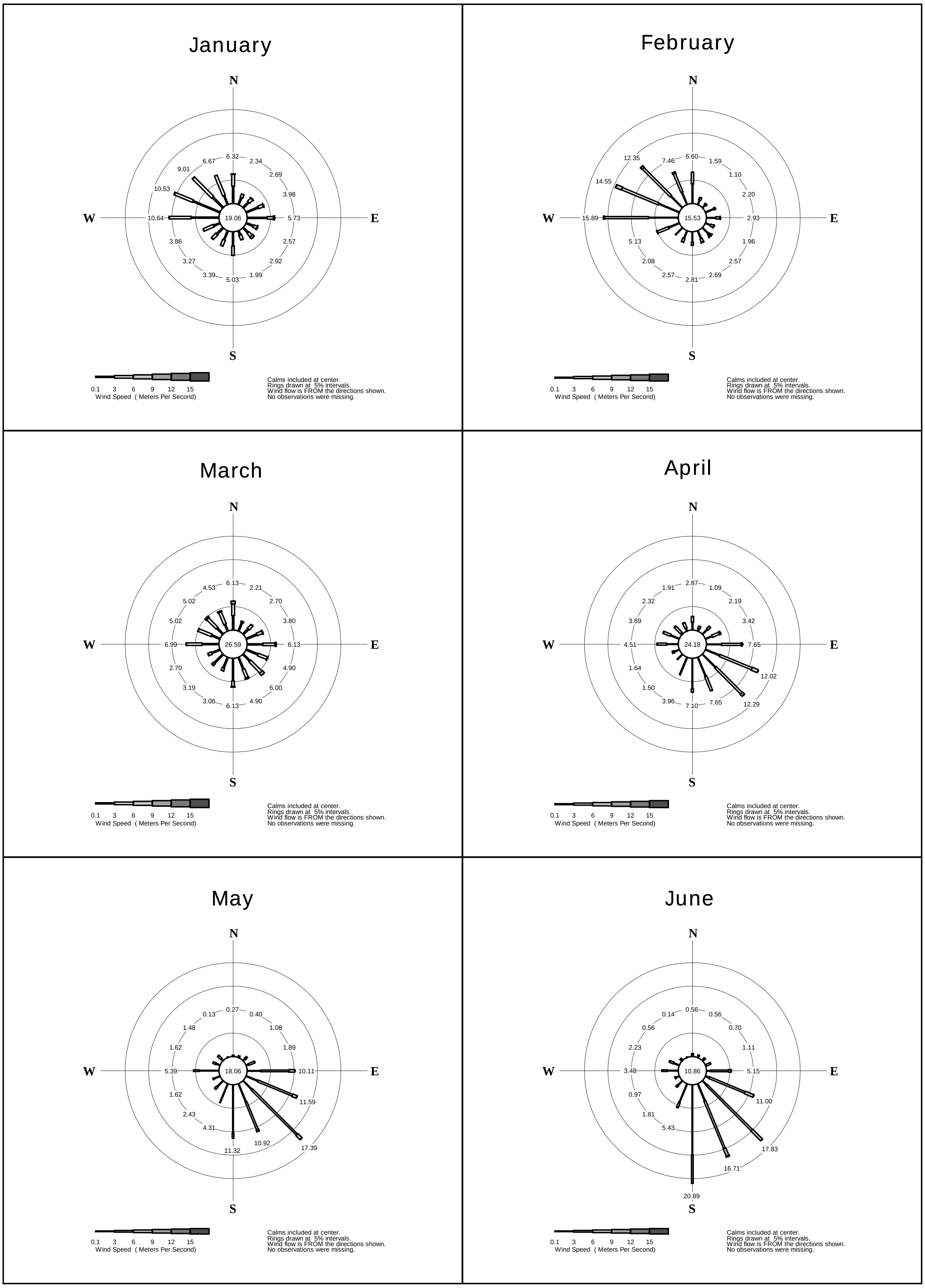



**Figure 5.3: Monthly wind roses for Port Keats (2000-2003)**

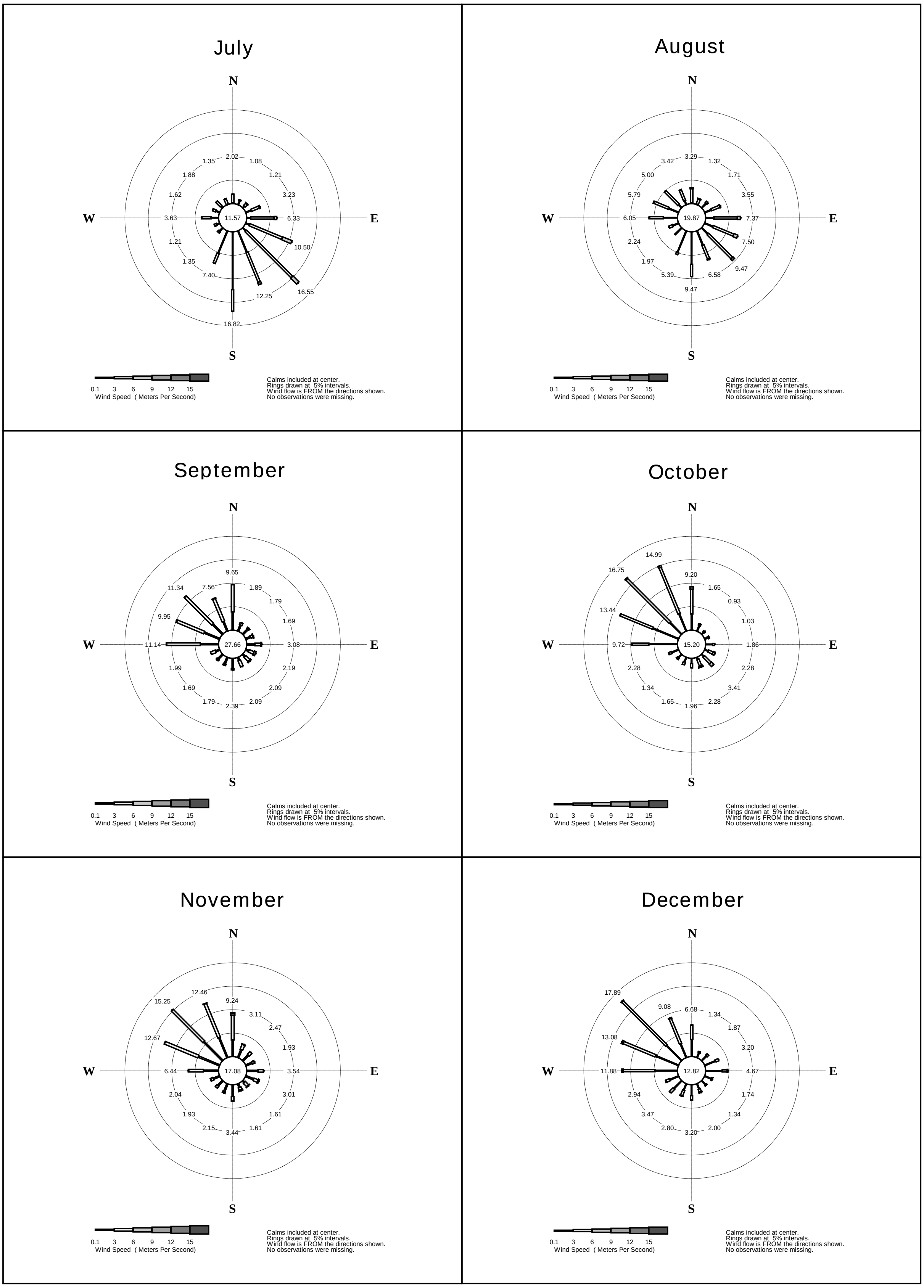



**Figure 5.3 (cont.)**

## 5.4 Oceanography

### 5.4.1 Water Levels

***Astronomical tides***

The tides in the Joseph Bonaparte Gulf propagate in from the Timor Sea and circulate around an Amphidromic Point located offshore from Cape Londonderry in the northwest. Tidal ranges increase shorewards with maximum tidal ranges exceeding 8 m along the shoreline between Wyndham and Darwin. The closest tidal station to the Blacktip shore crossing is Port Keats. This is a secondary port located between the two standard ports of Darwin and Cape Domett.

Figure 5.4 shows a typical tidal record from Darwin. The tides are semidiurnal (two highs and lows each day) with a slight diurnal inequality (difference in heights between successive highs and low). There is a well-defined spring-neap lunar cycle, with spring tides occurring two days after the new and full moon. Table 5.1 provides the standard levels for Port Keats. Highest Astronomical Tide (HAT) exceeds 8 m and the mean ranges for spring and neap tides are 5.6 m and 1.9 m, respectively. Tidal ranges will reduce offshore transport towards the Blacktip facility.

**Table 5.1: Standard tide levels for Port Keats**

| Tide level | Level (m) |
|---|---|
| Highest Astronomic Tide (HAT) | 8.2 |
| Mean High Water Springs (MHWS) | 7.2 |
| Mean High Water Neaps (MHWN) | 5.3 |
| Mean Sea Level (MSL) | 4.4 |
| Mean Low Water Neaps (MLWN) | 3.4 |
| Mean Low Water Springs (MLWS) | 1.6 |

(Ref. [1])

***Meteorological tides***

Superimposed on the astronomical tide are ‘meteorological’ tides resulting from changes in atmospheric pressure and strong onshore or offshore winds. Storm surges during cyclones, in particular, can appreciably raise sea levels above the predicted astronomical tidal height and inundate low-lying areas.

### 5.4.2 Circulation

***Tidal currents***

Circulation in the Joseph Bonaparte Gulf is dominated by the large tidal currents. Currents along the Blacktip pipeline were measured at eight locations in May 2004 (Ref. [25]; see also Appendix C for a comparison between modelled and measured data). At the WHP, current speeds range from 0.9 m/s during spring tides and up to 0.2 m/s during neaps. The currents rotate in a clockwise direction with the major flood and ebb directions towards the southeast and northwest, respectively. Shoreward, current speeds increase (1.15 m/s on a spring tide; 0.6 m/s on neap) with tidal range and become more rectilinear longshore. These large currents are responsible for the generation of dune forms on the seabed as noted in Admiralty Charts for the region. Very nearshore currents are influenced by the coastal topography with an anticlockwise gyre forming in the landfall Bay on the flood tide and a clockwise gyre on the ebb (Figure 5.5)

***Non-tidal currents***

Non-tidal current drift might be associated with:

- local winds;
- river inflow along the coastal boundary;
- large scale ocean circulation in the Timor Sea;
- continental shelf waves; and
- meteorological effects.

***Local winds***

The typical “rule of thumb” for surface current flow is 2% to 4% of the wind speed. Surface currents are expected to reflect seasonal wind regimes with flows towards the southeast during summer and westerly flows during winter. Local wind-driven surface currents may attain maximum speeds of 0.7 m/s during extreme monsoonal or Trade Wind surges. More typically speeds would be in the range of 0.2 m/s to 0.4 m/s.

***River inflow***

Four major rivers flow into the Joseph Bonaparte Gulf:

- Ord River;
- Victoria River;
- Fitzmaurice River; and
- Daly River.

The influence of these rivers on circulation within the Gulf will be greatest during periods of high flow that may occur during the wet season and minimal during the dry.

***Large scale ocean circulation***

Large scale ocean circulations are forced by synoptic scale winds. The SE Trade Winds drive a mean westerly of up to 0.2 m/s in the Timor Sea. In the wet season, currents reverse to flow towards the east. The influence of these large scale circulations in the Joseph Bonaparte Gulf is unknown.

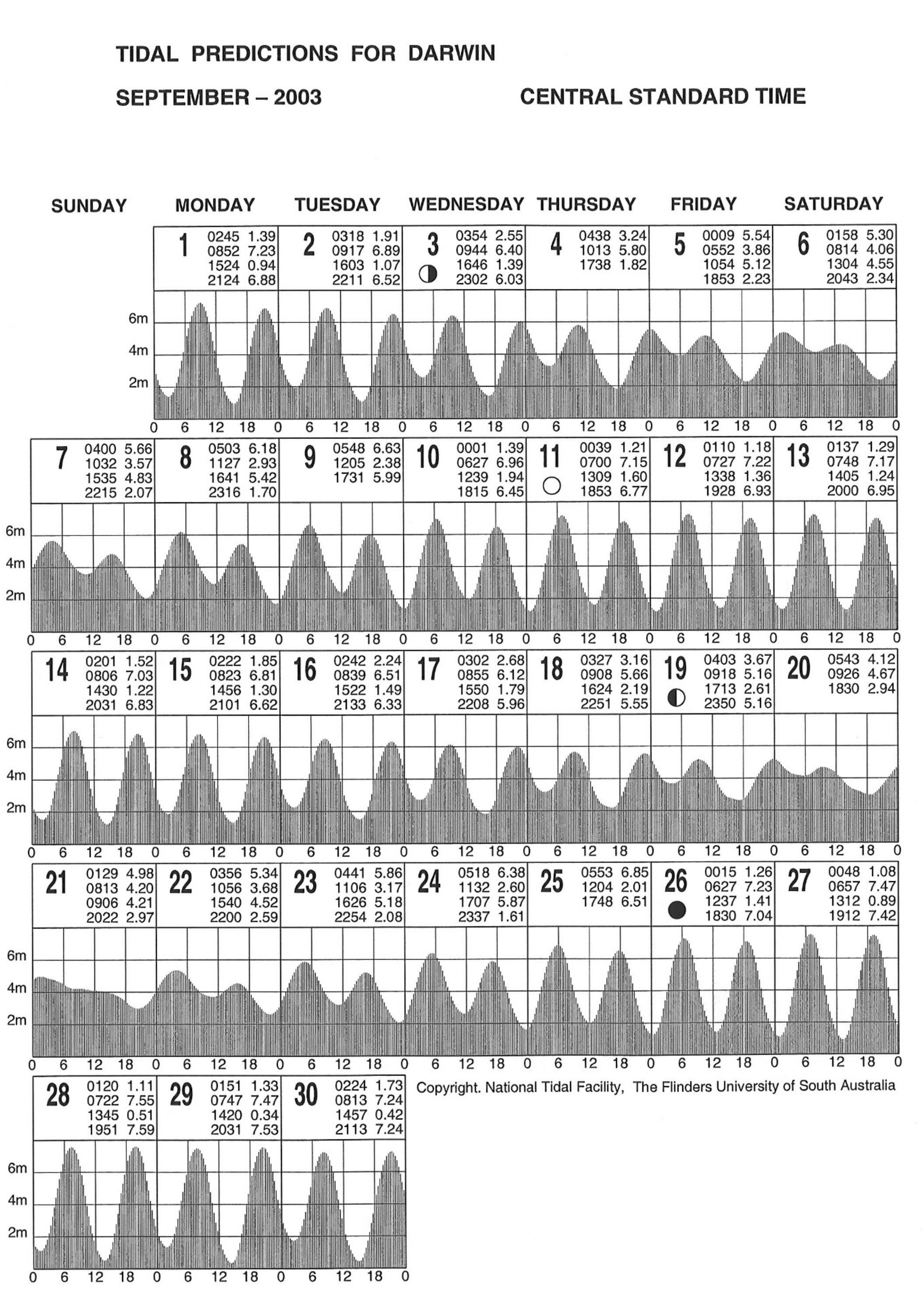
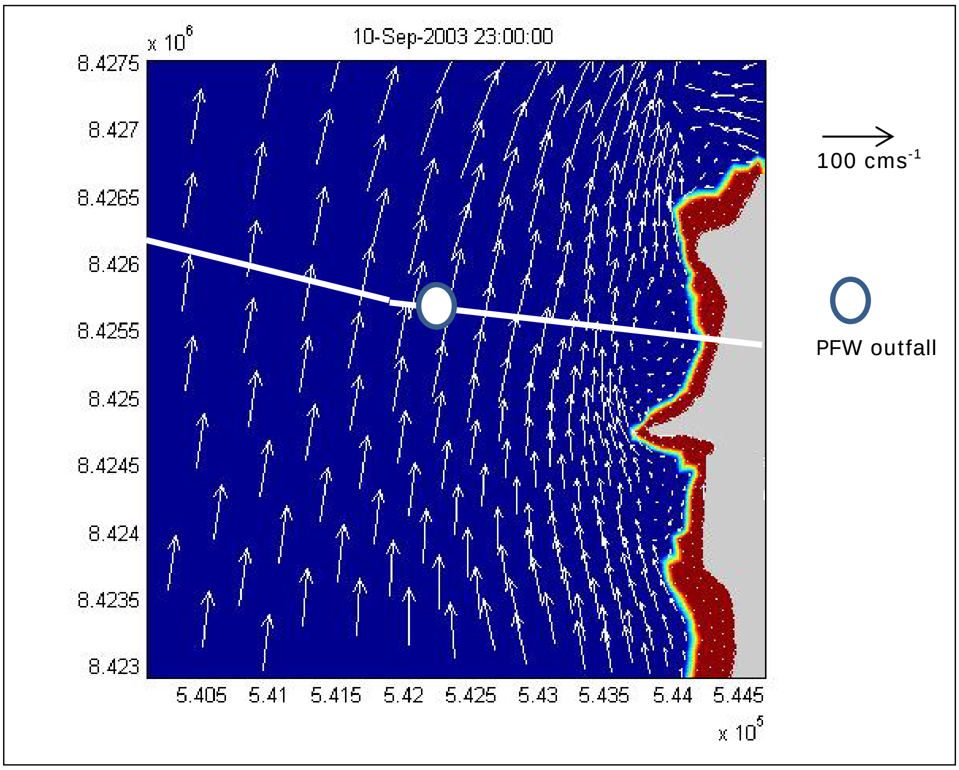



**Figure 5.4: Darwin tide curve for September 2003**

**(a) Ebb Tide**




**(b) Flood Tide**

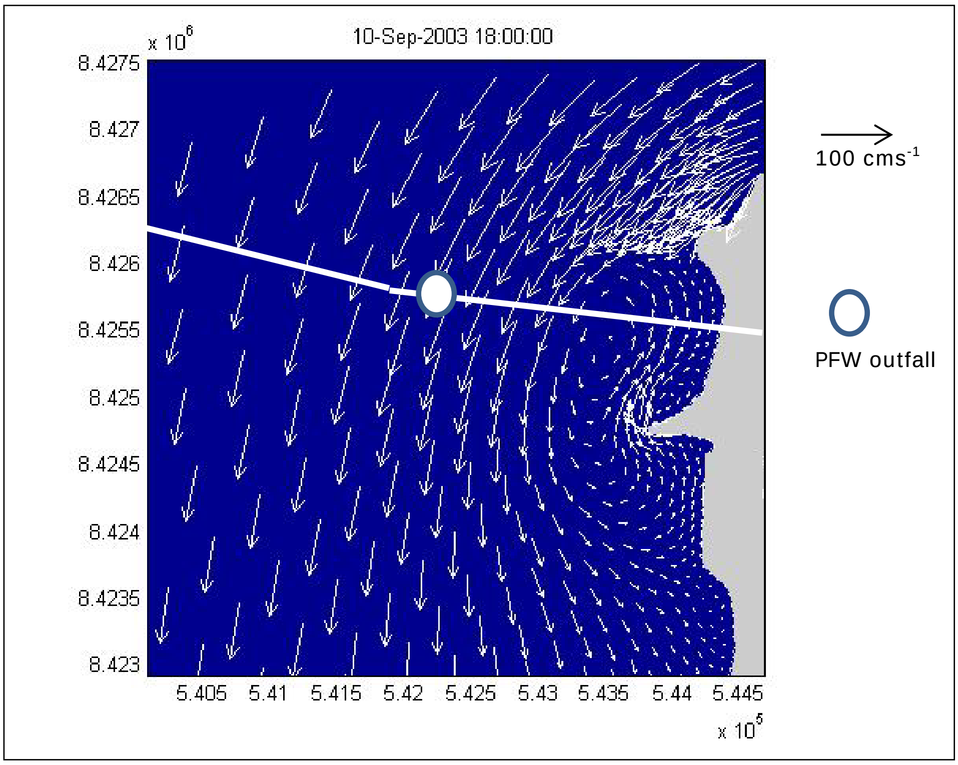



**Figure 5.5: Predicted spring tide vector fields in the vicinity of the landfall for the Blacktip pipeline (Ref. [24])**

### 5.4.3 Waves

Wave data were derived from a two degree global database constructed from a combination of remotely sensed satellite and modelled data (Ref. [40]). The monthly mean significant wave heights (Hs), spectral periods (Tm) and directions for the nearest grid point (approximately 100 km to the north northeast) are plotted in Figure 5.6. Note that wave heights are likely to be overestimated as the database location will be more exposed to westerly swell than Blacktip and have greater fetches from the south and southeast.

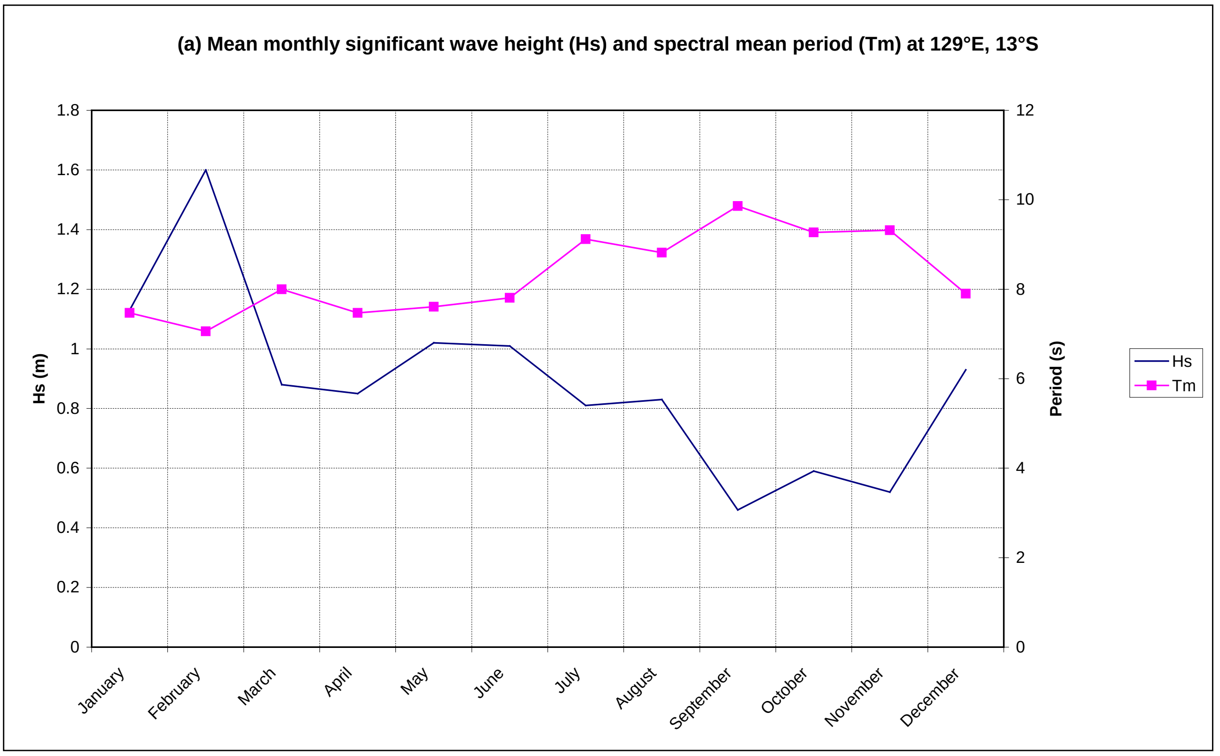
During the winter season, the ambient wave climate at Blacktip will be composed of waves generated from the prevailing south and south-easterly trade winds. Wave generation will be fetch limited and mean monthly significant wave heights are predicted to be fairly constant, ranging between 0.8 m and 1.0 m with mean period of between eight and nine seconds. Wave height and period will decrease shoreward along the pipeline route. Longer period swell waves from the Indian Ocean are unlikely to diffract around into the Joseph Bonaparte Gulf.

During the summer season, Blacktip is exposed to both sea and swell generated from the prevailing north-westerly monsoon winds blowing across the Timor Sea. As such the predominant swell direction at Blacktip is from the northwest with mean monthly periods of between seven and 10 seconds. Monthly mean significant wave heights range from a minimum of 0.45 m in September to a maximum of 1.6 m during February. As prevailing winds are onshore, wave heights in the summer will increase shoreward along the pipeline route.

Extreme waves are generated by cyclones during the summer season. The 100 year return period wave will be of the order 5 m.

### 5.4.4 Water temperatures

Mean monthly temperatures in the vicinity of the Blacktip field vary between about 25.8°C in August and 30.5°C in December (Ref. [1]). Due to the large tidal range and high currents, the water column is expected to be well mixed all year around with respect to temperature. During heavy rainfall, there may be some salinity stratification in the south of the Gulf.



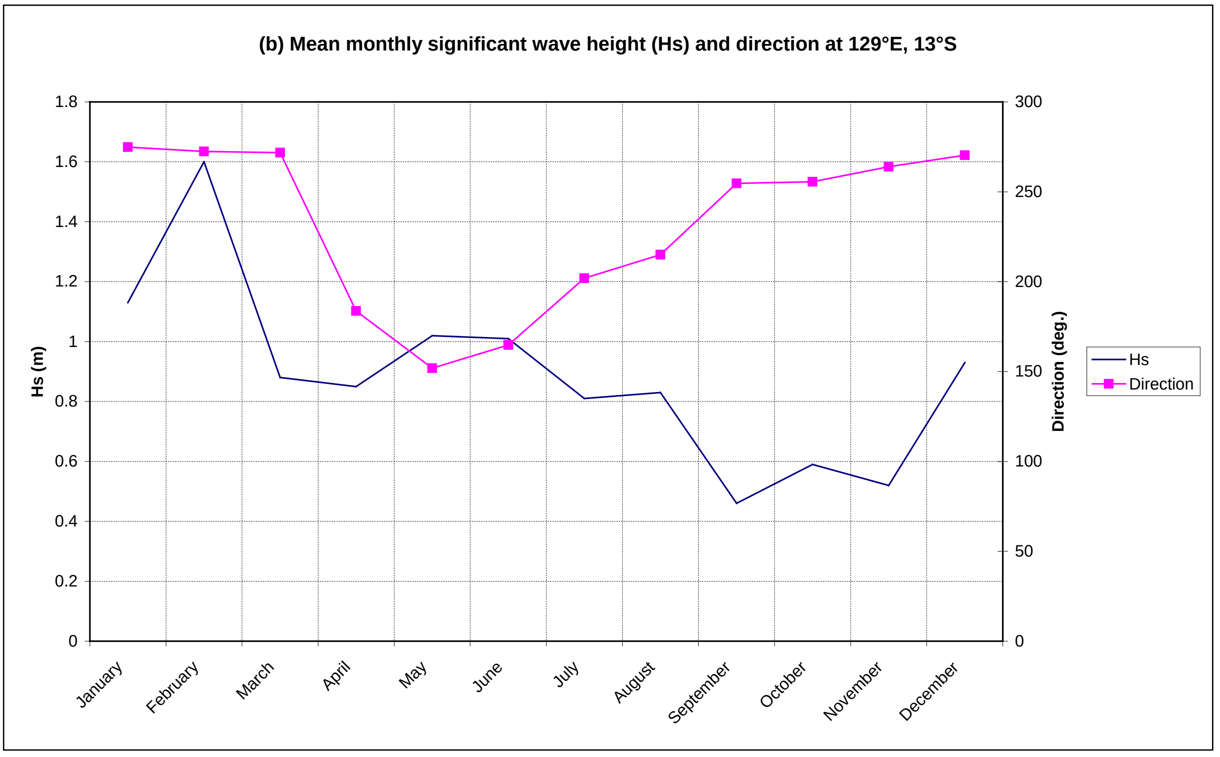




**Figure 5.6: Monthly mean wave parameters for grid location129°E, 13°S (approximately 100 km NNE of Blacktip)**

### 5.4.5 Marine habitats

Coastal habitats in the vicinity of the discharge include:

- pelagic;
- benthic; and
- intertidal zones.

Section 7 and Appendix B of the EIS (Ref. [37], [38], [39]) provide a detailed description of the various habitats. A summary is provided below.

**Pelagic zone**

The pelagic habitat support: marine mammals, fish, reptiles invertebrates; phyto- and zooplankton. Whales and dugongs are not expected to be common inhabitants of the Joseph Bonaparte Gulf. Dugongs are patchily distributed throughout tropical and subtropical waters of the Indian and Pacific Oceans with major concentrations of dugongs coinciding with sizeable seagrass beds, on which they feed. The lack of seagrass in Joseph Bonaparte Gulf is expected to limit the distribution of dugong's, though anecdotal evidence reported by local Aboriginals suggests that dugongs can occur between Cape Hay and Point Pearce. A number of dolphins have wide distributions and are expected to occur within the Joseph Bonaparte Gulf including the Irrawaddy dolphin, the spotted bottlenose dolphin, Risso's dolphin, Indo-Pacific humpback dolphin and pantropical spotted dolphin.

Reptiles in the Joseph Bonaparte Gulf include: turtles, saltwater crocodiles, the mangrove snake; and the mangrove monitor. Flatback turtle breeding and nesting sites are documented on the north side of Cape Domett in the inner, western Joseph Bonaparte Gulf and anecdotal evidence suggests that they may historically have nest on sandy beaches to the north of the pipeline landfall.

Generally high densities of crocodiles occur in tidal portions of mangrove-lined rivers, particularly those associated with extensive freshwater wetlands or floodplains. However, studies on crocodile populations in the Victoria and Fitzmaurice Rivers suggest that the project area is not significant for crocodile populations. Nesting sites are limited and recruitment rates are generally low. Crocodiles are however reported to be in the upper reaches of most rivers and creeks around the Wadeye area.

Sea snakes are very common in subtropical and tropical Australian waters and occupy a wide range of habitats and water depths, extending offshore from the coast to the reefs and banks of the Sahul Shelf. Although there are no records of their specific occurrence in the Joseph Bonaparte Gulf, sea snakes are expected to be very common, with as many as fifteen species known to occur in the Northern Territory.

**Benthic zone**

In the vicinity of the PFW outfall, the seabed consists of coarse sand and gravel. Further inshore and offshore the seabed contains weakly indurated patches of gravel and coralline debris. A variety of benthos are supported in the area including crustaceans, bryazoans, hydroids, polychaetes, molluscs, exchinoderms, sponges, sea cucumbers and scattered coral colonies. Large terrigenous inputs and resuspension by large tides limit the development of significant coral reefs, large seagrass beds or macroalgal beds. The coarse sediment also limits the development of a deposit feeding community.

**Intertidal zone**

- The intertidal zone includes:
  - beaches;
  - rocky coastlines; and
  - mangroves.

Northern Yelcher Beach is fringed with a steep sand dune to 2 m high. Below the beach dune but above the high spring tide level the beach is gently sloping and composed of very coarse sand with coral fragments and rock. Timber, mangrove leaves and other flotsam and jetsam are abundant in this habitat, though no drift seagrass or macroalgae have been observed. These flotsam and jetsam provide shelter for high densities of the terrestrial hermit crab *Coenobita variabilis* (up to 80 hermit crabs per square metre). This species is known to extend up to 100 m or so from the beach.

The Yulow Point rock platform at the south of Northern Yelcher Beach comprises a flat lateritic point that extends approximately 400 m from the beach. It is relatively steep sided and flanked with an extensive area of lateritic boulders, up to 100 m wide to the north and standing water and mangroves to the south. The distribution of the biota is highly variable reflecting microtopography. However, visual assessments indicate that the more seaward section of the rock platform supports a higher diversity and abundance of invertebrate fauna, including sparse corals, anemones, chitons and larger crustaceans than the nearshore sections. No macroalgae has been observed.

The Yulow Point mangroves to the south of Northern Yelcher Beach form a strip less than 700 m long and between 100 to 300 m wide. The mangrove habitat at this location is extremely sandy with muds only occurring in the most seaward zone. The mangrove forest is quite sparse with well-spaced trees and a relatively open canopy. This contrasts with the extremely dense mangroves to the north of the shore crossing, which have a muddy to gravely substrate.

The mangroves occurring on Maninh Point, to the north of northern Yelcher Beach, have a substrate comprising firm, root-structured marine muds. The muddy substrate becomes gravelly to rocky where it abuts the surrounding intertidal rocky habitat. It contrasts markedly with the sandy mangrove habitat at the southern end of northern Yelcherr Beach. The mangrove forest at Maninh Point is taller and more dense. The mud mangrove substrate supports a different invertebrate fauna with several species recorded in the northern mangrove area (including the large molluscs *Terebralia palustris*, and *T. semistriata*) not observed in the southern forest.

The closest spawning or nursery are the Victoria River to the east of the Gulf and tidal creek systems, which acts as nursery grounds for juvenile Penaeid species, namely tiger prawn (*Penaeus esculentus*), banana prawn (*P. merguiensis*) and red-legged banana prawn (*P. indicus*) (Ref. [37], [38], [39]).

## 5.5 Cultural heritage

A summary of the Aboriginal sacred and significant sites in the vicinity of the Blacktip YGP, as communicated to Eni by the NLC, is provided in Table 5.2 and Table 5.3. The sites are specific to the different Aboriginal groups, and sites sacred to the Yak Maninh People are shown separately from those sacred to the Yak Diminhin people. The indicative locations of these sacred sites are shown on Figure 5.8. Archaeological sites are shown in Figure 5.7.

**Table 5.2: Yak Maninh Sacred Sites**

| Name | Description |
|---|---|
| Maninh | Coastal point covered by distinctive black rocks. |
| Kurlangor trees near Maninh | Two Woollybutts (Eucalyptus miniata) standing on eastern side of coastal track |
| Karrinthanmoi stone | A stone located among rocks on northern side of Maninh Point, exposed at low tide. |
| Mamut trees | A cluster of seven or eight Cheesefruit trees (Morinda citrifolia) with pungent smelling fruit, located on northern side of Maninh point. |
| Walpinhthi reef | A submerged reef located approximately 1.5 km west of Yulow Point, the headland south of the pipeline landfall. |

**Table 5.3: Yak Diminhin Sacred Sites**

| Name | Description |
|---|---|
| Restricted Men's Area 4869-27 | A ceremonial ground near a creek crossing south of Wadeye/Port Keats airstrip. |
| Restricted Women's Area | A ceremonial ground located west of the Wadeye/Port Keats airstrip, and immediately south of Wadeye/Port Keats community. A tributary of Sandfly Creek runs through the site area. |
| Thawytkam (Air Force Hill) 4869-28 | Airforce Hill (Mt Goodwin) recorded by AAPA as MIKUMILU, but locally known as Thawytkam. |


Blacktip Project
*DRIMS-#1572636*

ARCHAEOLOGICAL AND HISTORIC HERITAGE SITES IN PROJECT AREA

Figure 9.9

**Figure 5.7: Archaeological sites**

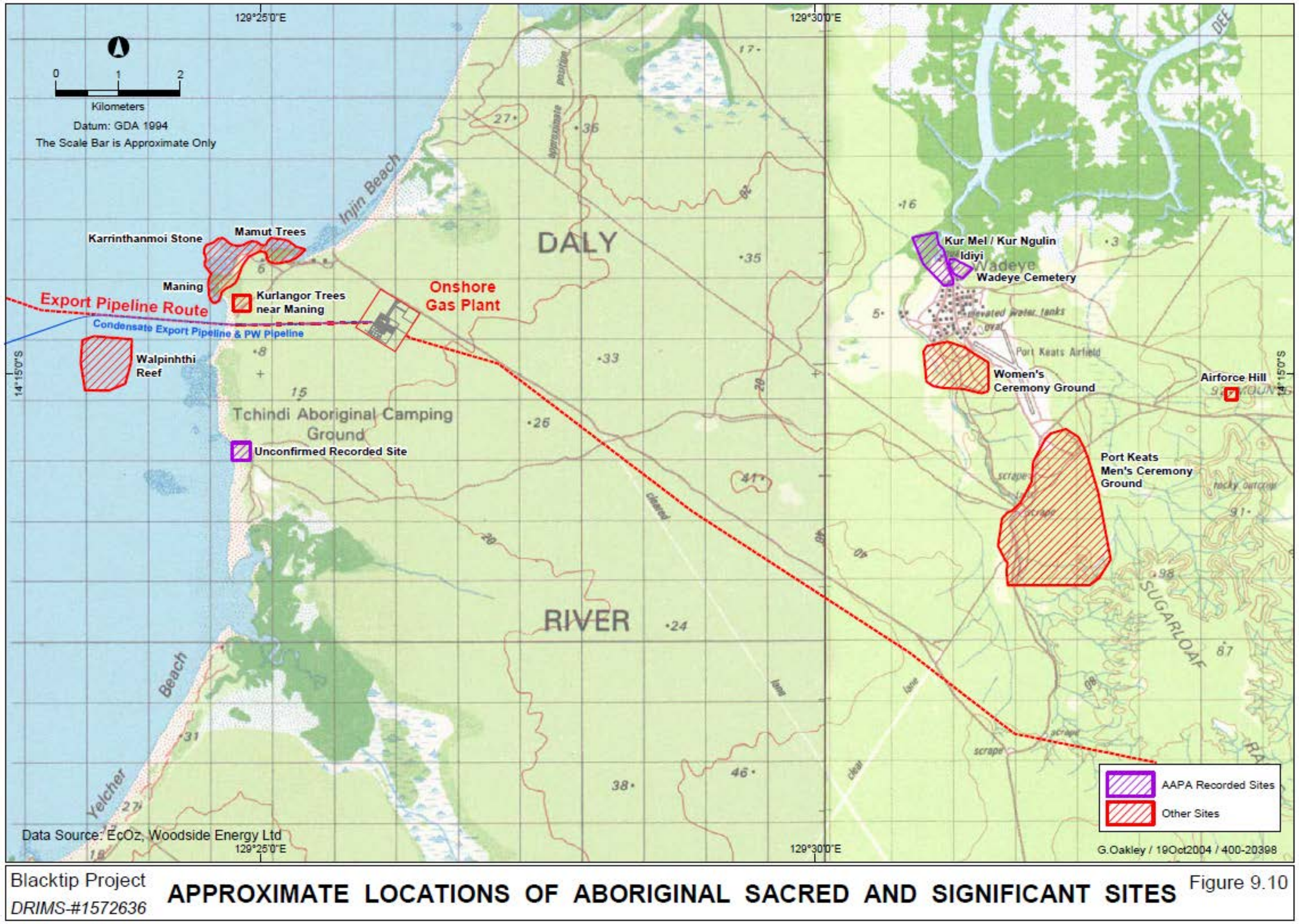



**Figure 5.8: Approximate locations of aboriginal sacred and significant sites**

# 6. HISTORICAL PFW MONITORING

## 6.1 Discharge Monitoring

The historical discharge over time and oil in water levels, measured by sampling and analysis prior to discharge, are shown in Figure 6.1, below.

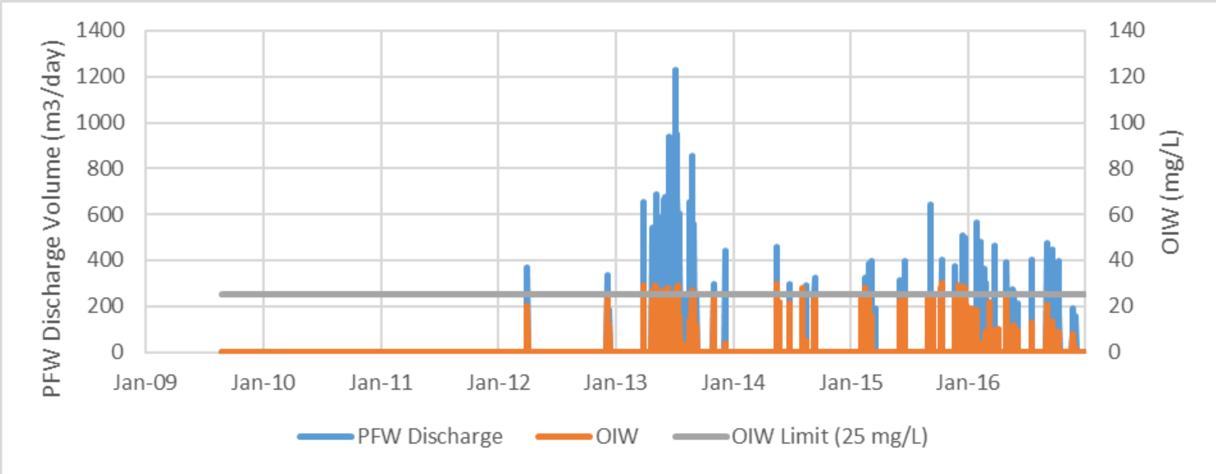



**Figure 6.1: PFW volume and OIW discharged**

## 6.2 Produced Water Studies

Produced water studies conducted under EPL57-01 include:

- Chemical characterisation;
- Ecotoxicology;
- Biodegradation;
- Bioaccumulation potential;

Produced water studies were conducted in October 2010 (Ref. [12]), February 2012 (Ref. [21]) and September 2013 (Ref. [22]). The latter three analyses are no longer required under the revised EPL57-02.

Annual marine monitoring is also undertaken, whereby sediment and shellfish samples are collected at strategic points along the coastline and analysed for a variety of common contaminants. The *Produced Water Management Plan* (Ref. [7]) describes the methodology for these studies.

Overall the minimum safe dilution factor ranged between 52 and 263 in the mixing zone to achieve 99% level of species protection in accordance with the ANZECC/ARMCANZ (2000) marine water quality guideline trigger values. The results of the biodegradation studies indicated significant reductions in BTEX and TPH within several days. The results also indicated no risk of bioaccumulation. A summary and comparison of the results are outlined below.

### 6.2.1 Chemical Composition

Blacktip PFW contains trace concentrations of:

- Dissolved oil, composed of predominantly aliphatics, benzene, toluene, ethylene and xylene (BTEX) compounds, low molecular weight Polycyclic Aromatic Hydrocarbons (PAHs);
- Organic acids;
- Heavy metals; and
- Residual process chemicals.

The results of the chemical analyses from the annual PFW studies in 2010, 2012, 2013 and 2015, and two monitoring events in 2016 (May and December) are presented in Table A.1 in Appendix A. The chemical composition shows considerable variation between years, which reflects the change in the nature of the water being produced. This is particularly the case in 2013 when the well began producing considerable volumes of formation water, as indicated by the increase in salinity, until a well intervention and a different layer of the reservoir was accessed. Since late 2013, produced water is generally composed of condensation from gas processing with much lower salinities well below those of marine waters.

Chemical characterisation of the treated produced water samples typically identified dissolved metals (including barium, cobalt, copper, iron, lead, manganese, mercury, nickel and zinc), ammoniacal nitrogen, phenol and benzene at concentrations exceeding ANZECC/ARMCANZ (2000) (hereafter referred to as ANZECC) default toxicant trigger values for a 99% level of species protection. Additionally, pH was always below and total nitrogen and turbidity above the default ANZECC guideline values for slightly disturbed tropical inshore marine waters. However since the revision of the EPL, PFW is treated to at least pH 6.5 prior to discharge. This may have contributed to a reduction in the ammoniacal nitrogen levels in 2015. Hydrocarbon concentrations were in the order of 2 mg/L and largely made up of the low molecular weight BTEX compounds.

In 2013, total dissolved solids (TDS), barium (Ba) and manganese (Mn) were particularly elevated with TDS at 94,600 mg/L, three times greater than seawater (typically ~35,000 mg/L). TDS values during recent routine fortnightly testing[1] of produced water has been often been <1,000 mg/L and no greater than 14,500 mg/L, which indicates that recently the discharge stream has been buoyant relative to seawater when discharge into the marine environment.

An elevated level of surfactants was measured in 2013 , which was likely indicative of residual corrosion inhibitor in the PFW. Ba and Mn remained elevated in 2015. There are no default ANZECC toxicant marine trigger values for TDS, Ba, Mn or surfactants.

### 6.2.2 Toxicity

Whole effluent toxicity (WET) testing was also undertaken in 2010, 2012 and 2013, and the results were used to derive PNEC values and associated dilution factors for Blacktip produced water. Each ecotoxicity test involved five chronic and two acute marine bioassays to determine the EC10, EC50, NOEC and LOEC levels. The bioassays typically included:

[1] This routine fortnightly testing is for process integrity purposes only and does not measure discharge water quality. Therefore the full results are not presented in this document.

- Microtox;
- Microalgae cell division;
- Sea urchin fertilisation;
- Mussel larvae development;
- Copepod development;
- Fish larvae development; and
- Prawn survival.

The dilution factors for 99% marine species protection are shown in Table 6.1, determined based on the EC10 results (effect concentration for 10% of population tested) for each bioassay. The dilution factors show the toxicity increased in 2012, and was the lowest in 2013. The ecotoxicity results and laboratory reports are provided in Appendix A.

**Table 6.1: Required dilution factors to achieve 99% marine species protection**

| Year | PNEC (%PFW) | Dilution Factor Required |
|---|---|---|
| 2010 | 1.1 | **91** |
| 2012 | 0.38 | **263** |
| 2013 | 1.9 | **52** |

*Based on EC10 ecotoxicity results (Ref. [19], [21], [22]).

In the absence of toxicity data for Blacktip PFW at the time, the *Blacktip Produced Water Management Plan* (Ref. [7]) previously adopted a default PNEC of 0.1%PFW based on earlier Woodside results. The ecotoxicology studies conducted on Blacktip PFW determined the required dilution factors to achieve 99% species protection ranged between 52 (1.9%PFW) and 263 (0.38%PFW). Based on the Blacktip toxicity results, the lowest determined PNEC of 0.38%PFW has been adopted for Blacktip PFW.

### 6.2.3 Bioaccumulation Potential

The 2010 investigation observed zinc in mussel tissues of the 1% produced water treatments at slightly elevated concentrations compared to the seawater control. However, considering the concentration of zinc was only slightly elevated and no observation of acute toxicity, the results suggested a low likelihood of adverse biological effects from bioaccumulation of zinc where produced water is diluted by a factor >100 in the seawater mixing zone.

The 2012 investigation observed manganese in mussel tissues in the 1% produced water treatments at slightly elevated concentrations compared to the seawater control. Little environmental risk was determined from this observation as manganese is an essential trace element actively regulated by several marine organisms and there were no observations of acute toxicity. The study concluded no risk of bioaccumulation at a dilution factor >100.

The 2013 study found elevated levels of barium and manganese in mussel tissues at the 0.1% (barium only ) and 1% (both barium and manganese) treatments. As per the 2012 investigation, little environmental risk was determined from the observed bioaccumulation of manganese. Similarly, barium is most likely bioaccumulated as barite which is considered to have low toxicity and low bioaccumulation potential, and therefore the observed barium levels are deemed not of concern.

Overall, the above studies indicate no evidence of bioaccumulation.

### 6.2.4 Biodegradation Potential

Results from the 2010 biodegradation study indicated that statistically significant toxicity from the produced water (based on Microtox results) will not persist in the marine receiving environment for more than 6 days. Considerable reductions in BTEX (>93%) and TPHs (>65%) were observed at the 24-hour time interval, followed by almost complete evaporation and/or biodegradation of BTEX and TPH by Day 6.

The 2012 biodegradation study observed similarly significant reductions in BTEX (>99%) and TPHs (81%) at the 24-hour time interval, followed by almost complete evaporation and/or biodegradation by Day 14. However Microtox showed relatively high EC50 of 19.5% compared to the initial EC50 of 5.9%. Thus the study indicated toxicity would potentially persist in the produced water for more than 14 days, however it was believed the copper was contributing to toxicity in the sample. Furthermore, the produced water would be subject to dilution of >700 in the marine receiving environment.

The 2013 biodegradation study indicated that the toxicity from the produced water (based on Microtox results) will potentially under environmental conditions exist for more than 14-days if undiluted. As the toxicity observed did not match the reduction in BTEX, the toxicity is most likely due to the metals or TPH which remained after 5 days. Despite the low degradation potential of the sample, the study concluded if the sample is diluted to the recommended 99% species protection dilution factor, the environmental risk should be low.

## 6.3 Baseline Marine Monitoring

The Environment Protection Licence also specified annual marine monitoring of the area in the vicinity of the PFW discharge outfall (Condition P.4.6 and P.4.11). This involves taking sediment and shellfish samples from along the coast and testing for metals and hydrocarbons, to determine whether the PFW is impacting the environment and biota.

Baseline marine monitoring was conducted in 2010 to characterise the marine sediments and biota in the vicinity of the outfall prior to first release of PFW. Annual marine monitoring was conducted thereafter to allow a comparison with the original 2010 baseline survey data, to provide an indication of any build-up of contamination in the marine environment as a result of the PFW discharge.

Overall, annual marine monitoring measured some increases in the presence of heavy metals in the sediment and shellfish between 2012 and 2013; however, these increases were also reflected in control samples. All TPH, BTEX, PAH and phenol concentrations in shellfish were below detection limit and therefore considered acceptable.

Although no longer a requirement in EPL57-02, annual marine monitoring remains a commitment under the *Produced Water Management Plan* (Ref. [7]).

### 6.3.1 2010 Baseline Marine Monitoring

The baseline monitoring (Ref. [9]) was conducted on 18-19 May 2010 and consisted of the following:

- Ten offshore samples collected on two radial transects situated over the PFW discharge;
- Onshore samples of Echinolittorina trochoides and Rhizophore stylosa collected from rocky headlands and mangrove forests either side of Yelcherr beach. Approximately 6-8 shellfish were collected from each site.

Sample and control locations are shown in Figure 6.2 and Figure 6.3. The control station is approximately 7-8 km from the PFW outfall and sample sites. Sediment and shellfish were analysed for hydrocarbons and heavy metals, the contaminants of concern for PFW.

Sediment sampling found the seabed in the vicinity of the PFW outfall is rocky and all samples consisted of coarse sand, gravel, cobble and shell fragments. There was insufficient material available to analyse for hydrocarbons in the offshore sediments, although concentrations of arsenic, chromium, nickel and vanadium were measured in excess of ANZECC/ARMCANZ trigger values. Concentrations of silver, chromium, copper and mercury were also measured in mangrove sediments in excess of ANZECC/ARMCANZ trigger values.

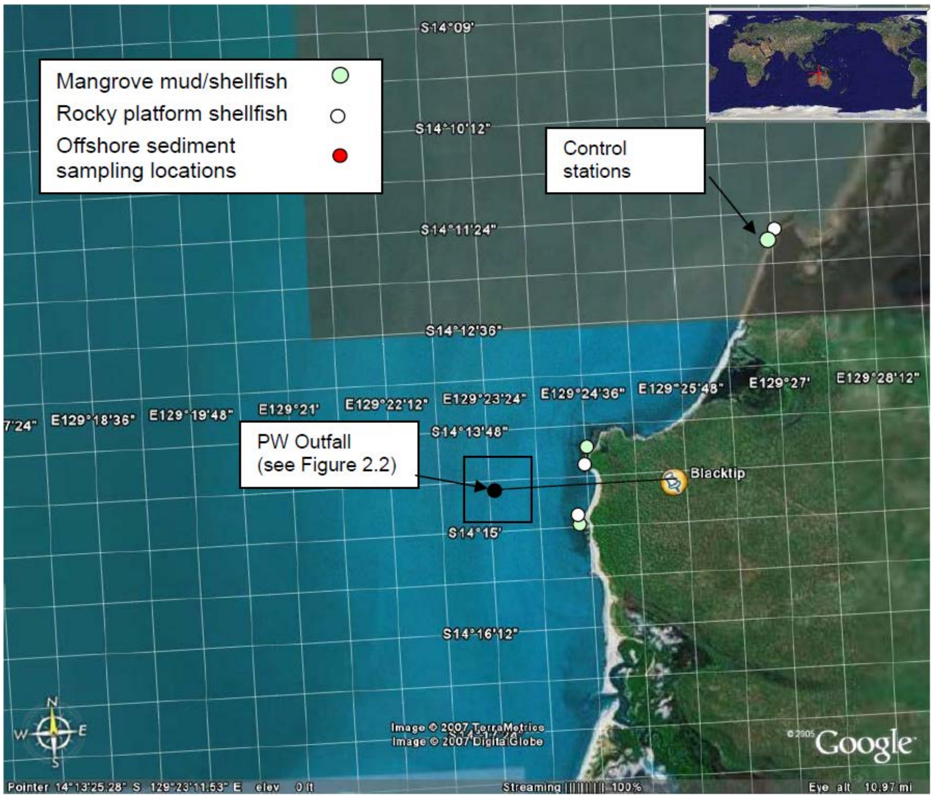



**Figure 6.2: 2010 baseline marine monitoring sampling locations**

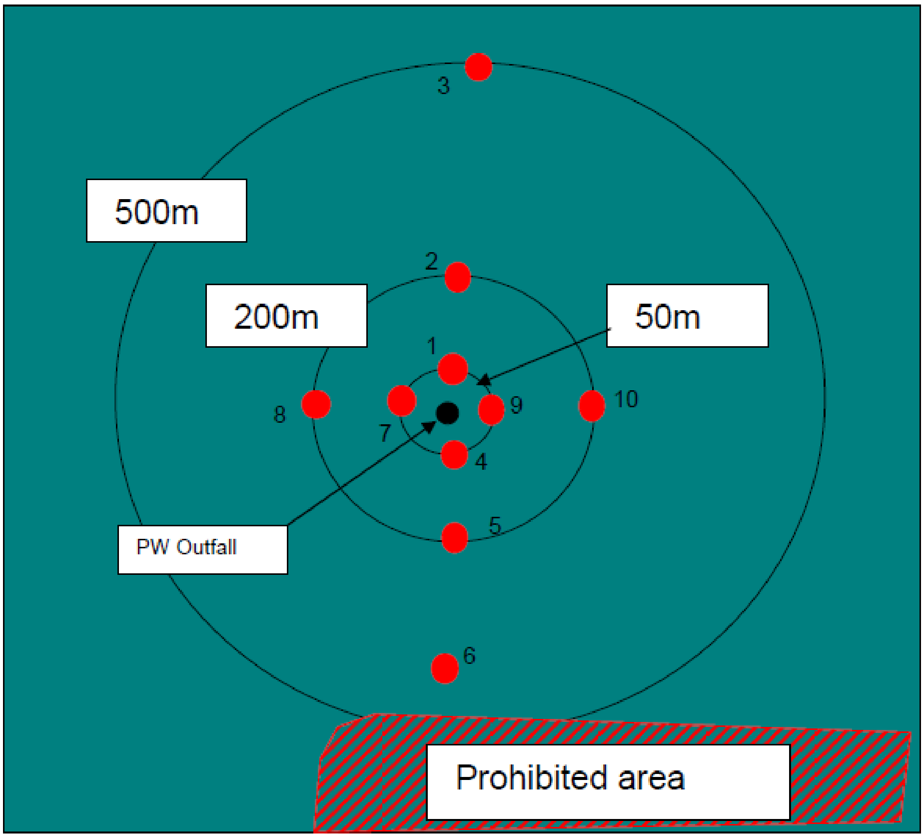



**Figure 6.3: 2010 offshore marine monitoring sampling locations**

### 6.3.2 2011 Marine Monitoring

The 2011 marine monitoring (Ref. [10]) was conducted on 6 June 2011 and consisted of the following:

- Three onshore samples of sediment (mangrove mud), including one control sample taken from an area north of the beach (Figure 6.4);
- Onshore samples of *Echinolittorina trochoides* and *Rhizophore stylosa* collected from rocky headlands and mangrove forests either side of Yelcherr beach. 7 shellfish were collected for analysis.

The mangrove sediment sample from location 1 (south end of Yelcherr Beach) had a reading for arsenic of 22 mg/kg sediment, which narrowly exceeds the trigger value of 20 mg/kg (ANZECC 2000). This is most likely attributed to the naturally high arsenic levels in the area as indicated in the EIS (Ref. [37], [38]). All other readings were below the trigger values.

Comparison with the 2010 baseline survey showed Arsenic, Cobalt and Lead readings in sediment were slightly higher in 2011 at one of the two sample points. Aluminium, Iron, Manganese and Vanadium readings were slightly higher in 2011 at both sample points in comparison with the baseline survey. Metal concentrations measured in shellfish samples were slightly higher in 2011 (Al, Ar, Cd, Cu, Pb, Hg, Ag, Zn). All TPH, BTEX, PAH and phenol concentrations in shellfish were below detection limit and therefore considered acceptable.

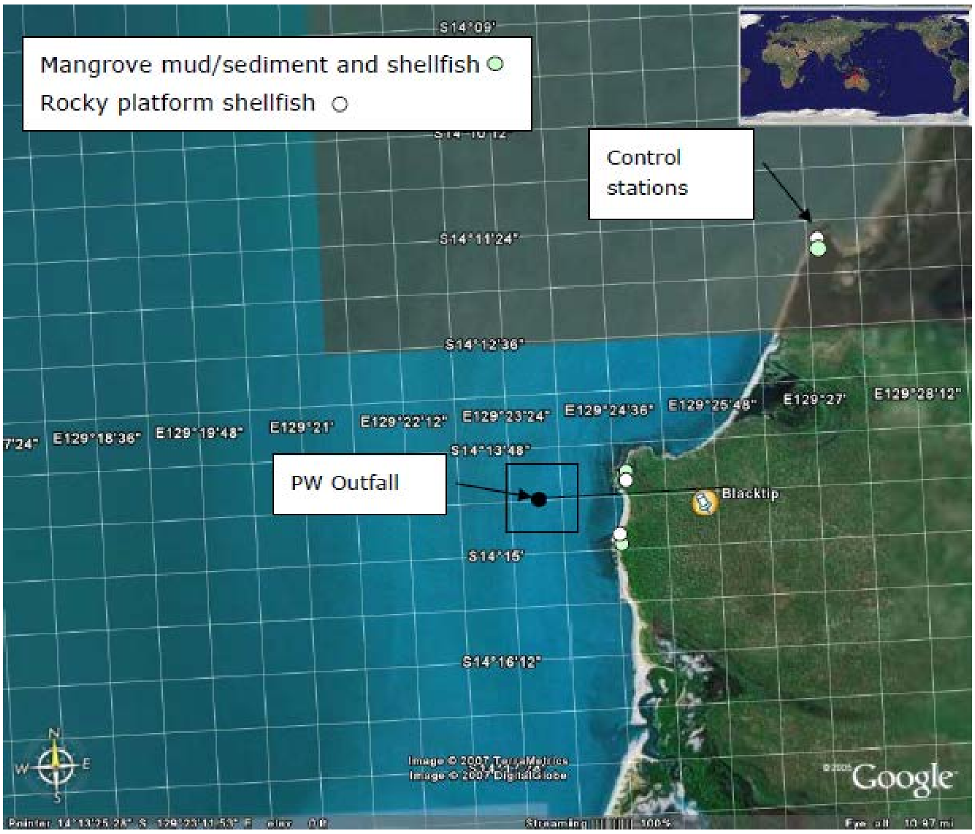



**Figure 6.4: 2011 marine monitoring sampling locations**

### 6.3.3 2012 Marine Monitoring

The 2012 marine monitoring (Ref. [11]) was conducted on 20 June 2012 consisted of the following:

- Three onshore samples of sediment (mangrove mud), including one control sample taken from an area north of the beach (Figure 6.5);
- Onshore samples of *Echinolittorina trochoides* and *Rhizophore stylosa* collected from rocky headlands and mangrove forests either side of Yelcherr beach. 7 shellfish were collected for analysis.

The following metals were measured in the sediment samples at higher levels than baseline:

- Arsenic in the mangrove sediment sample from location 1 (south end) was slightly higher in 2012, although the same as the mangrove control sample reading;
- Iron (both samples);
- Manganese (both samples), although the 2012 control sample was also higher than the original baseline 2010 readings; and
- Vanadium (both samples).

All concentrations of hydrocarbons in sediment (except pentachlorophenol) were found to be below detection limits and therefore satisfactory. Pentachlorophenol levels were slightly higher in 2012 compared to the 2010 baseline survey.

The following metals were measured in the shellfish samples at higher levels than baseline:

- Cadmium readings were higher in one of the 2012 mangrove shellfish samples, however the control sample had a higher reading.
- Cobalt readings were higher in 2012 than 2010 and 2011 for the two rocky headland shellfish samples and the mangrove shellfish sample. Note that only the rocky headland 2012 (south end) sample was higher than the respective control sample.
- Copper readings were higher in 2012 than 2010 and 2011 for the two rocky headland shellfish samples and the mangrove shellfish sample. Note that the rocky headland shellfish readings were lower than the control sample, and the mangrove shellfish reading was only slightly higher than the mangrove control.
- Lead readings were higher in 2012 than 2010 and 2011 for the two rocky headland shellfish samples and the mangrove shellfish sample. Note that the readings were lower than the control samples for all.
- Mercury readings were higher in 2012 than 2010 and 2011 for the two rocky headland shellfish samples and the mangrove shellfish sample. Note that the readings were lower than the control samples.
- Silver readings were higher in 2012 than 2010 and 2011 for the two rocky headland shellfish samples and the mangrove shellfish sample. Note that the readings were lower than the control samples.

- Vanadium readings were higher in 2012 than 2011 for the two rocky headland shellfish samples and the mangrove shellfish sample. Note that the readings were lower than the control samples.
- Zinc readings were higher in 2012 than 2010-2011 for the two rocky headland shellfish samples and the mangrove shellfish sample. Note that the readings were lower than the control samples for rocky headland samples, and only marginally higher for the mangrove sample.

TPH, BTEX, PAH and phenol concentrations in shellfish were below detection limit and therefore considered satisfactory. The total organic carbon reading for the mangrove shellfish sample was slightly higher than the mangrove control.

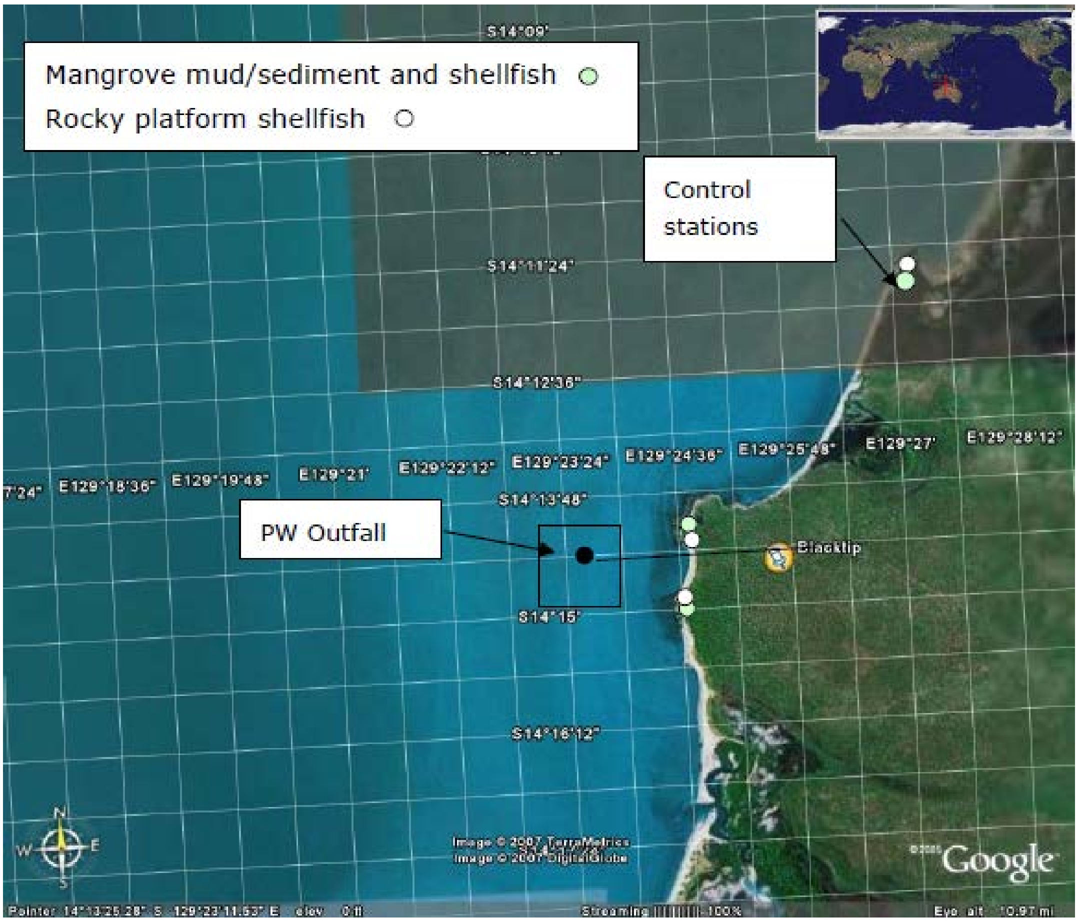



**Figure 6.5: 2012 marine monitoring sampling locations**

### 6.3.4 2014 Marine Monitoring

Monitoring was conducted on 30 April 2014 and the results are detailed in *Blacktip Operations Marine Survey 2014* (000036_DV_PR.HSE.1035.000). The majority of the readings from the mangrove monitoring sites were lower than from the control sites and within the range of measurements previously recorded. All hydrocarbon readings in sediment and shellfish were below the detection limit, with the exception of $C_{15}$-$C_{28}$ hydrocarbons which was measured at low levels, and therefore considered satisfactory. The results shows variation from previous years, however most of the increases were observed in sediment and shellfish samples collected from the control site. The reason for the increase is unknown and it is possible the control site may be impacted by new activities.

### 6.3.5 2015 Marine Monitoring

Monitoring was conducted on 5 and 9 June 2015 and the results are detailed in *Blacktip Operations Marine Survey 2015* (000036_DV_PR.HSE.1066.000), attached in Appendix B. The sampling locations are shown in Figure 6.6. The survey found all metal and hydrocarbon readings were below the Interim Sediment Quality Guideline (ISQG) trigger values (ANZECC 2000) or consistent with, and in many cases lower than, readings from the control site and previous surveys. The only exception was arsenic, which was measured slightly above the lower ISQG trigger value at Location 2, consistent with the naturally high arsenic levels reported during baseline surveys. Overall, the survey results provide no indication of adverse impact from produced water discharge.

### 6.3.6 2016 Marine Monitoring

The survey was conducted in May 2016 and the results are detailed in *Blacktip Operations Marine Survey 2016* (000036_DV_PR.HSE.1104.000), attached in Appendix B. The survey found all metal and hydrocarbon readings in sediment were below the Interim Sediment Quality Guideline (ISQG) trigger values (ANZECC 2000) or consistent with, and in many cases lower than, readings from the control site and previous surveys. The only exception was arsenic, which was measured slightly above the lower ISQG trigger value at Location 2, consistent with the naturally high arsenic levels reported during baseline surveys. All hydrocarbon readings in sediment were below the detection limit.

The majority of metal readings were slightly higher than the 2015 readings across all sites, but much lower than the historical maximums and within the range measured previously. The exceptions are barium, chromium and nickel, which were measured higher across all sites, particularly Location 1 – south end (mangroves only), Location 2 – north end (mangroves and rocky headlands), and the Control site (mangroves only). Hydrocarbons, C10-C28, were also detected in shellfish across all sites, suggesting a natural or regional source. Further advice will be sought with respect to the hydrocarbon, nickel and chromium results. No other hydrocarbons were detected in shellfish.

Overall, the results were consistent across the sampling sites, with little variation between the control and monitoring sites, providing confidence that there are no adverse impacts from produced water discharge.

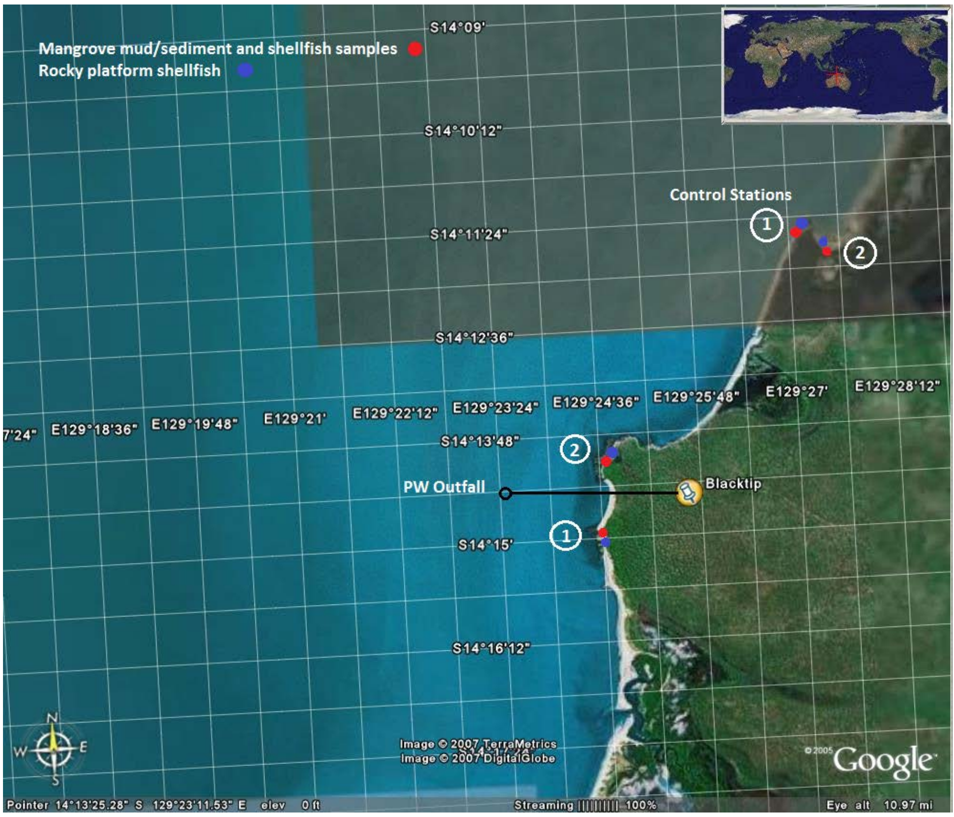



**Figure 6.6: 2016 marine monitoring sampling locations**

# 7. ENVIRONMENTAL IMPACT ASSESSMENT

The ratio of the Predicted Environmental Concentration (PEC) to the PNEC (PEC/PNEC ratio) is an established technique to screen chemicals in offshore discharges. It forms the basis of the OSPAR Harmonised Notification Scheme (Reference [12] ) and is used in the Environmental Impact Factor (EIF) tool (Ref. [19]). The PNEC relies upon the assumption that a single value captures the concentration at which no toxic response (acute or chronic) is expected in the target population of marine biota. Dispersion models provide spatially and temporally varying PECs for either the whole effluent of individual compounds.

The below risk assessment examines the:

- Fate of PFW in the marine environment;
- Predicted PECs determined by the near field and far field dispersion models;
- Exposure pathways between source and receptor;
- PFW composition and characteristics determined by historical monitoring; and
- Appropriate mixing zone.
- An ALARP and acceptability assessment is also provided.

## 7.1 Fate of PFW in the marine environment

Upon discharge into the marine environment, contaminants in the PFW undergo a number of processes to reduce their concentrations, including:

- dilution;
- evaporation of volatile components;
- adsorption to particles and sedimentation;
- biodegradation; and
- photodegradation.

Collectively, these processes tend to decrease the concentration of chemicals in the PFW plume and thereby decrease its toxicity to marine organisms. However, fate processes (e.g. weathering, degradation) are complex and difficult to predict with accuracy. For example, weathering may produce new chemicals or result in speciation of chemicals into forms that are more bioavailable and toxic than the original chemicals. Therefore, it is possible that PFW may not decrease in toxicity and could even increase in toxicity during the weathering process (Neff, 2002). Furuholt (1996) suggests that these transformation processes are more likely to cancel each other out for mixtures with more than five toxicants.

Adsorption of dispersed oil and heavier chemical components onto particles is not likely to be an issue for Blacktip as the PFW should contain mainly low molecular weight compounds. Sedimentation of hydrocarbon compounds from PFW is not generally thought to be a problem as suspended particles would be spread over a wide area meaning that concentration build up in the sediments is likely to be extremely low and probably of no significance (Furuholt, 1996). Biodegradation will occur over longer time scales (greater than one day) and is important for reducing possible chronic toxicity effects.

## 7.2 Dilution

Dilution is divided into two phases: the jet phase which is the initial, rapid dilution; and, the ambient phase which is the slower, far-field dilution (North Sea PFW and Effect Task Force 1994). PFW discharges are generally less dense than seawater. Unless there is adequate dilution at the point of discharge, a surface slick will form providing visual evidence of the discharge.

Slick prevention requires adequate dilution for the discharge and initial dilution standards apply to marine outfalls. Initial dilution is defined as the number of dilutions received by an effluent from the time it leaves the diffuser port to the time it makes impact with either a submerged or surface field. Two forces are responsible for the enhanced dilution in the near field:

- the momentum of the discharge; and
- the buoyancy resulting from the density difference between the effluent and the receiving waters.

## 7.3 Biodegradation

A wide range of marine micro-organisms are able to utilise organic matter as an energy source in the natural environment. Low molecular weight, soluble hydrocarbons and organic acids are utilised particularly rapidly, as these classes of compounds occur ubiquitously in the environment and micro-organisms have evolved to degrade them efficiently. The importance of biodegradation in the destruction of organic chemicals in PFW plumes depends primarily on the persistence of elevated concentrations of the organic chemicals in the plume and the pre-adaptation of the local microbial community for resistance to and biodegradation of PFW chemicals (Neff, 2002). As a general rule, linear hydrocarbons are more easily biodegraded than aromatic hydrocarbons (Neff, 2002).

## 7.4 Biochemical Oxygen Demand

Biological oxygen demand (BOD) is a measure of the rate at which oxygen is consumed by bacterial activity in the water and thus is an indirect measure of the organic content of wastewater. BOD concentrations in PFW can be high. However, in the ocean where dissolved oxygen is abundant, demand is met quickly. It is estimated that in any area where BOD levels deviate by <1.5 $mgL^{-1}$ from background levels, the resulting impact on dissolved oxygen levels will be <0.5 $mgL^{-1}$ (CSTT, 1993). A change of 0.5 $mgL^{-1}$ can be assumed to cause no adverse effect. The Australian guidelines (ANZECC, 2000) are slightly less conservative stating that that dissolved oxygen (DO) should not normally be permitted to fall below 90% saturation, this being determined over at least one diurnal cycle.

## 7.5 Bioaccumulation

A contaminant can have no effect on an organism unless it is bioavailable, i.e. in a form that can move through or bind to a surface coating (e.g. skin, gill epithelium, gut lining, cell membrane) to prevent it from functioning properly. As a general rule, hydrocarbons in solution are most bioavailable followed by those in tissues of marine organisms or associated with liquid oil droplets (Neff, 2002). The bioavailability of hydrocarbons decreases sharply with increasing carbon chain length and molecular weight.

Aquatic biota do not only degrade pollutant chemicals, they may also accumulate them. Bioaccumulation is the uptake and retention of bioavailable chemicals from any one of, or all possible external sources (water, food, substrate, air). For bioaccumulation to occur, the rate of uptake from all sources must be greater than the rate of loss of the chemical from the tissues of the organism. The bioaccumulation factor (BAF) is the ratio of the concentration of the chemical in the tissues of the organism ($C_t$) to its concentration in all ambient environmental compartments in equilibrium with the organism ($C_e$):

$$BAF = \frac{C_t}{C_e}$$

Bio-concentration is a special case of bioaccumulation as it is defined as uptake and retention of a chemical from water alone as opposed to all possible external sources. It is measured by the bio-concentration factor (BCF), which is the ratio at equilibrium of the concentration of a chemical in the tissues of the organism ($C_t$) to the concentration of the chemical in solution in the water ($C_w$) to which the organism was exposed.

Marine animals are able to bioaccumulate most bioavailable forms of metals and organic contaminants from their food. Bioaccumulation of chemicals from food is called trophic transfer. Biomagnifcation is the process whereby a chemical, as it is passed through a food chain or food web by trophic transfer, reaches increasingly higher concentrations in the tissues of animals at each higher trophic level. The biomagnification factor (BMF) can be defined as the ratio of the concentration of a contaminant in the tissues of the consumer ($C_t$) to its concentration in the diet ($C_d$):

$$BMF = \frac{C_t}{C_d}$$

## 7.6 Dispersion modelling

The original numerical models used to predict the fate and effects of the discharge are presented in Appendix J, Volume 2 of the EIS (Ref. [38]) and the produced water management plan (Ref. [7]). Due to the different scales of motion, both near and far field models were used to predict the fate and effects of the PFW discharge. Near field modelling predicts the initial dilution received from momentum and buoyancy driven flows from each diffuser. Far field models predict mixing due to passive (i.e. natural) dispersion. Both modelling approaches use site specific discharge (flow rate, density, diffuser orifice dimensions and orientation) and receiving water parameters (depth, current speed, density).

### 7.6.1 Near field modelling for the EIS

The objectives of the near field modelling conducted as part of the EIS were:

- To compute the initial dilution and to demonstrate the effectiveness of the diffuser design; and
- To provide near field dimensions for input into the far field model.

Initial dilution was simulated using Cornell Buoyant Jet Integral Model (CORJET). This model is part of the Cornell Mixing Zone Expert System (CORMIX), a USEPA recommended analysis tool for industrial, municipal, thermal, and other point source discharges to receiving waters. The current speed was set at 0.05 m/s, which is considered conservatively low for the area where circulation is dominated by strong tidal currents superimposed on lower frequency residual currents associated with wind, oceanic drift and river discharges (during wet season). The model was based on a daily discharge volume of 7,000 bbl/day (1,100 $m^3$/day) continuously over 16 hours each day. The model assumes steady state conditions.

**Table 7.1: CORMIX near field model inputs**

| Parameter | Value |
|---|---|
| **Discharge flows** | 7,000 bbl/day (1,100 $m^3$/day), discharged over 16 hours each day |
| **Ambient conditions** | |
| Average depth | 15 m |
| Depth at discharge | 15 m below LAT |

| Parameter | Value |
|---|---|
| Ambient velocity (CORJET) | 0.05 m/s |
| Stratified condition | Unstratified |
| Ambient temperature | 28°C |
| Ambient salinity | 34 psu |
| **Discharge parameters** | |
| Discharge orientation | Horizontal (co-flowing) |
| Port diameter | 60 mm |
| Discharge flowrate | 63 $m^3$/hr (fixed) |
| Temperature | 28°C |
| Salinity | 10 psu |
| Concentration | 100% |
| Coefficient of decay | 0 $s^{-1}$ |

Under such conditions, the model predicted the discharge to rise under its own buoyancy. Within the first 5 m, 100 dilutions would be achieved and by the time the plume reaches the surface the surface, it would have received at least 700 dilutions as shown in Figure 7.1. The predicted cumulative travel time is 224 seconds. During this time it would have travelled 19 and 12 m in the X and Y directions, respectively, and the resulting plume width would be in the order of ~6 m. It is noted that the current average discharge volumes (280 $m^3$ every two weeks) is less than half of the modelled discharge volume and would therefore likely undergo more dilution. The maximum projected PFW production rate (~450 $m^3$/day) is also much lower than the modelled discharge volume and thus there is sufficient allowance for additional flow due to storm water.

The CORMIX1 inputs are provided below in Table 7.1 and outputs are provided in Appendix E.

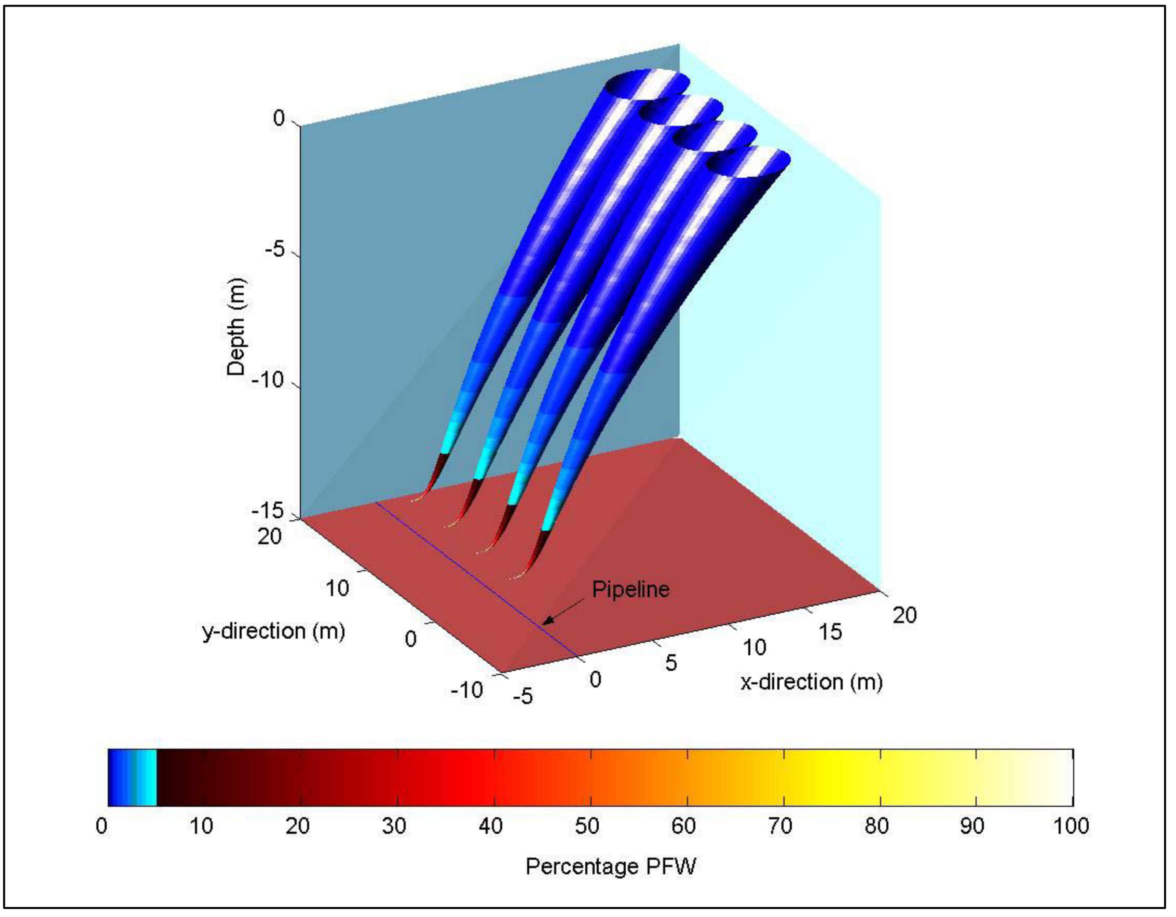



**Figure 7.1: Near field modelling results: initial dilution at diffuser**

### 7.6.2 Updated near field modelling for this PFW plan

The objectives of the updated near field modelling for this PFW plan are:

- To model the initial dilution from jet- and buoyancy-driven mechanisms and to demonstrate the effectiveness of the diffuser design over a larger range of salinities and ambient current conditions than were considered in the EIS;
- To confirm the appropriateness of the proposed mixing zone spatial boundaries (i.e. 50 m); and
- To inform the design of an appropriate mixing zone compliance and/or model validation monitoring methodology.

Initial dilution of the PFW injected into the marine environment was predicted with the United States Environmental Protection Agency (USEPA) Updated Merge near-field model (UM3). As with CORMIX, this is a USEPA recommended analysis tool for industrial, municipal, thermal, and other point source discharges to receiving waters.

Figure 7.6 shows the current speeds at BT7 near the PFW diffuser over a spring-neap tidal cycle in 2004. The lines on Figure 7.6 represent the following range of ambient current conditions that were modelled with UM3:

- Low currents of 0.05 m/s (as modelled in the EIS near-field modelling with CORMIX);

- Moderately low currents of 0.1 m/s;
- Moderate currents of 0.3 m/s;
- High neap tide currents of 0.6 m/s; and
- High spring tide currents of 1.0 m/s.

Predictions over this range of ambient currents provides a holistic characterisation of the degree of PFW dilution within the mixing zone that occurs at the diffuser.

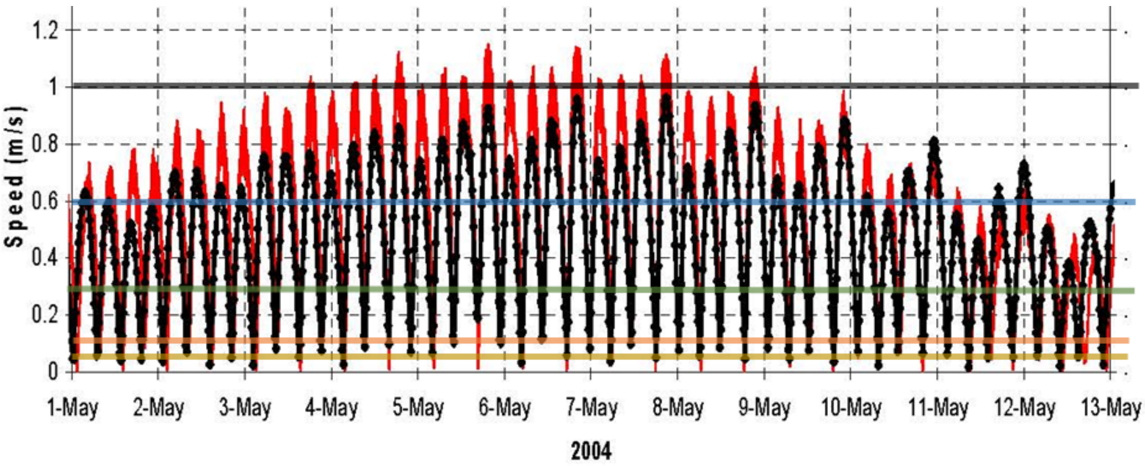



**Figure 7.2: 2004 measured (red) and far-field model simulated (black) current speeds at BT7 in proximity to the PFW diffuser where lines demarcate current speed that served as inputs into the UM3 near-field modelling**

Another important influence on the degree and manner of dilution in the mixing zone is the TDS (or salinity) of the PFW discharge. TDS measurements of PFW are shown in Figure 7.7, which can be characterised as:

- Recent 2016 measurements have been predominately comprised of levels representative of freshwater (~0.4 g/L);
- Low TDS (~5 g/L) has typically occurred from 2010-2014;
- Moderate TDS (~20 g/L) has occurred over several periods in late 2013 and early 2014; and
- Hypersaline TDS (65 g/L) has occurred in mid-2013 when a hydrocarbon reservoir was intersected with a high amount of produced water over a relatively brief period of months.

A freshwater to moderate range of TDS (0.5-20 g/L) is anticipated over the next several years based on the projected PFW volumes. However, for completeness, hypersaline discharges are also considered in the UM3 modelling presented here.

Salinity stratification conditions were assumed to be primarily well-mixed (34 psu) given that the high tidally induced currents likely lead to well mixed conditions in the relatively shallow waters (~12 m at lowest astronomical tide to 20 m at highest astronomical tide, Table 5.1). Because of the elevated tidally induced currents, salinity and thermal stratification are not likely; nonetheless, evaluation of PFW dilution under strong salinity stratification conditions was investigated for thoroughness. The idealised strong salinity stratification case was defined with a 5 m mixed layer depth of 32 psu, a halocline from 5 to 7 m of 32 to 34 psu, and a homogeneous salinity profile from 7 m to the sediment-water interface.

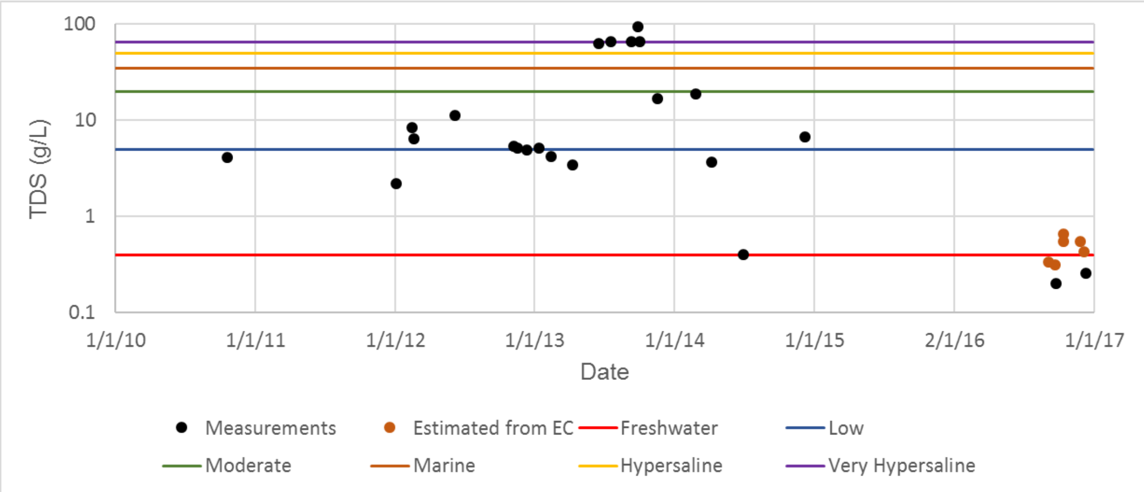



**Figure 7.3: 2010-2016 measurements of PFW TDS where lines demarcate TDS inputs into the UM3 near-field model**[2]

Twelve cases were evaluated with the UM3 near-field model across a range of PFW salinities (Figure 7.3), ambient current speeds (Figure 7.2) and salinity stratification conditions. Each case considered three salinities so a total of 36 simulations were carried out. All other inputs were similar to those carried out for the previous EIA CORMIX near-field modelling, which are summarised in

[2] There is a high correlation (97.8%) between TDS (g/L) and EC (µS/cm) (TDS=0.52385 EC, n=23) over the range of 0-95 g/L and 0-150 µS/cm, which was used to convert sampling dates with only EC measurements to TDS.

Table 7.2.

As a conservative measure all of the cases were modelled with the minimum water depth possible, namely the lowest astronomical tide with a 12 m water column depth. Further, the diffuser ports were modelled to be approximately 1 m above the seabed. A conservative far-field dilution coefficient of 0.0003 $m^{0.67}/s^2$ was applied to the UM3's Brookes far-field algorithm to estimate the dilution from the 'natural ambient background' mixing rates once jet- (i.e. arrest of initial momentum from the diffuser nozzle) and buoyancy-driven mechanisms (i.e. once the plume intersects the surface) were simulated to be exhausted prior to the mixing zone edge.

**Table 7.2: UM3 near field model inputs**

| *Parameter* | *Case 1 Low (0.05 m/s), Well-mixed* | *Case 2 Medium (0.3 m/s), Well-mixed* | *Case 3 High Neap (0.6 m/s), Well-mixed* | *Case 4 High Spring (1 m/s), Well-mixed* | *Case 5 Low (0.05 m/s), Strati-fied* | *Case 6 Medium (0.3 m/s), Strati-fied* | *Case 7 Medium Low (0.1 m/s), Well-mixed* | *Case 8 Medium Low (0.1 m/s), Strati-fied* | *Case 9 Brine High Neap (0.6 m/s), Well-mixed* | *Case 10 Brine Medium (0.3 m/s), Well-mixed* | *Case 11 Brine Medium (0.05 m/s), Well-mixed* | *Case 12 Brine Medium (0.1 m/s), Well-mixed* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PFW discharge ($m^3/s$) | 0.0175 | | | | | | | | | | | |
| PFW salinity (psu) | 0.4, 5, 20 | | | | | | | | 35, 50, 65 | | | |
| PFW temperature (°C) | 28 | | | | | | | | | | | |
| Port diameter (m) | 0.06 | | | | | | | | | | | |
| Port elevation (m) | 1 | | | | | | | | | | | |
| Port depth (m) | 11 | | | | | | | | | | | |
| Port vertical angle (°) | 0 | | | | | | | | | | | |
| Port horizontal angle (°) | 0 | | | | | | | | | | | |
| Number of ports | 4 | | | | | | | | | | | |
| Port spacing (m) | 10 | | | | | | | | | | | |
| Current speed (m/s) | 0.05 | 0.3 | 0.6 | 1 | 0.05 | 0.3 | 0.1 | 0.1 | 0.6 | 0.3 | 0.05 | 0.1 |
| Current direction (°) | 90 | | | | | | | | | | | |

A 263-fold dilution is adopted as the minimum requirement at the mixing zone edge at a horizontal distance of 50 m from the diffusers to meet the 99$^{th}$ percent level of species protection as described in section 7.9.

UM3 modelling output for case 1 is illustrated in Figure 7.4, which clearly shows that for three PFW salinities (0.4, 5.0 and 20.0 psu, which are well below the ambient salinity of 34 psu), the resultant plume rises through the water column. Because of the low current speeds, the plume rises to the surface within a horizontal distance of 10 m from the diffuser and undergoes a 460-480 fold average dilution during its ascent, well above the minimum 263-fold dilution requirement. Given that the PFW discharge velocity immediately upon exiting the diffuser nozzle is only 1.5 m/s, jet-induced mixing is limited to the immediate vicinity (~1-2 m) of the diffuser (note optimal port exit velocities are ~6-7 m/s). The majority of the simulated dilution is driven primarily by buoyancy driven mixing as the plume rises through the water column over a horizontal distance within 10 m of the diffuser. Once the plume intersects the surface, subsequent dilution by UM3 is simulated via the Brookes far-field algorithm to the 50 m boundary of the proposed mixing zone, which clearly occurs at a much lower rate from 'natural ambient' mixing processes than jet- and buoyancy- driven mixing mechanisms.

Case 1 contrasts with the UM3 predictions for case 3 during high neap tide currents (0.6 m/s). The high current speeds result in the centreline of the plume only rising from 11 m depth upon exiting the diffuser to 9-10 m over the 50 m horizontal distance to reach the edge of mixing zone in ~1 minute. However, over this short duration the plume is predicted to undergo vigorous mixing associated with the elevated tidally-induced current speeds with an average predicted plume dilution of 720-1,120 fold at the mixing zone edge.

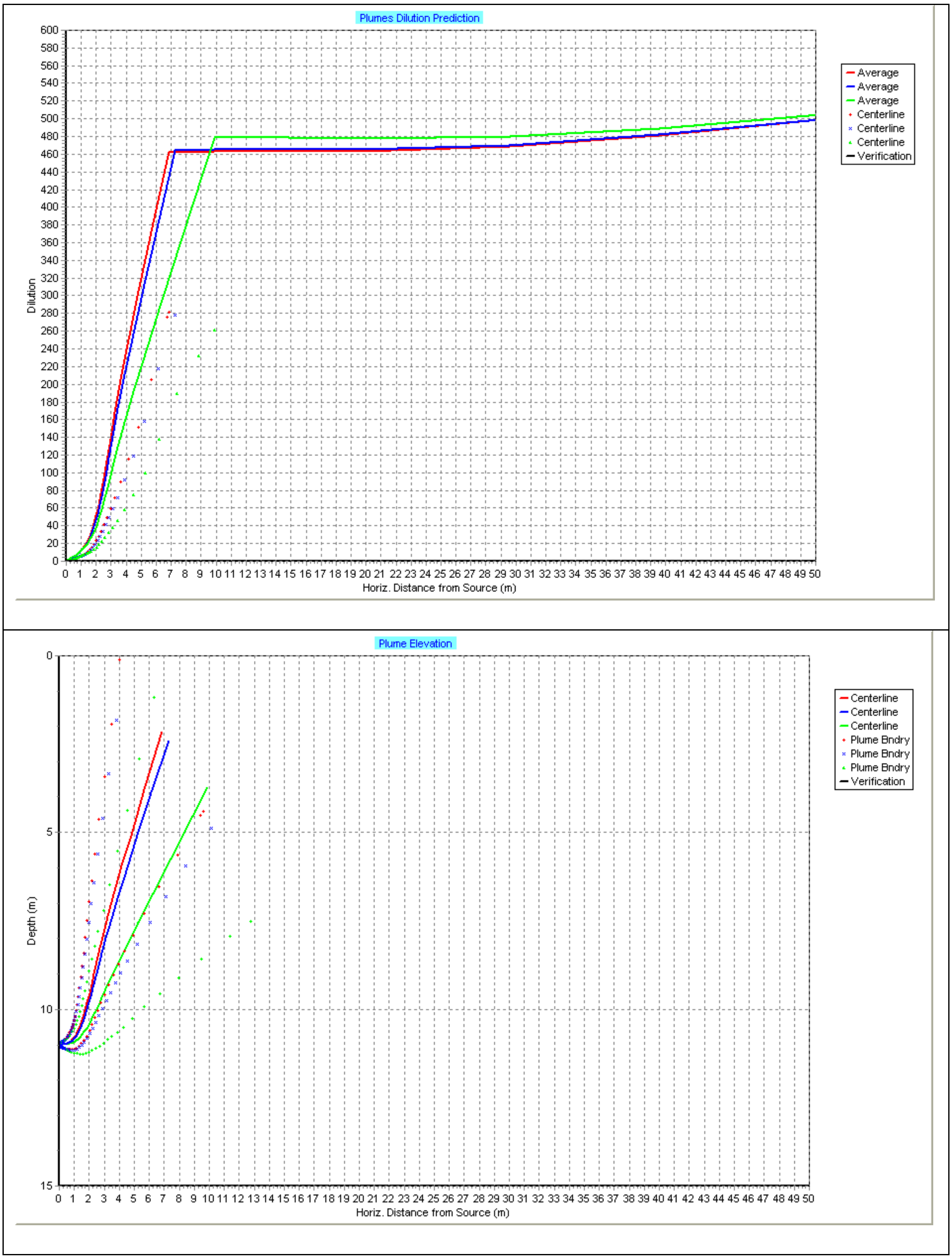



**Figure 7.4: Case 1 (low 0.05 m/s currents under well mixed conditions) UM3 predictions where the red, green and blue line demarcate PFW salinities of 0.4, 5.0 and 20.0 psu**

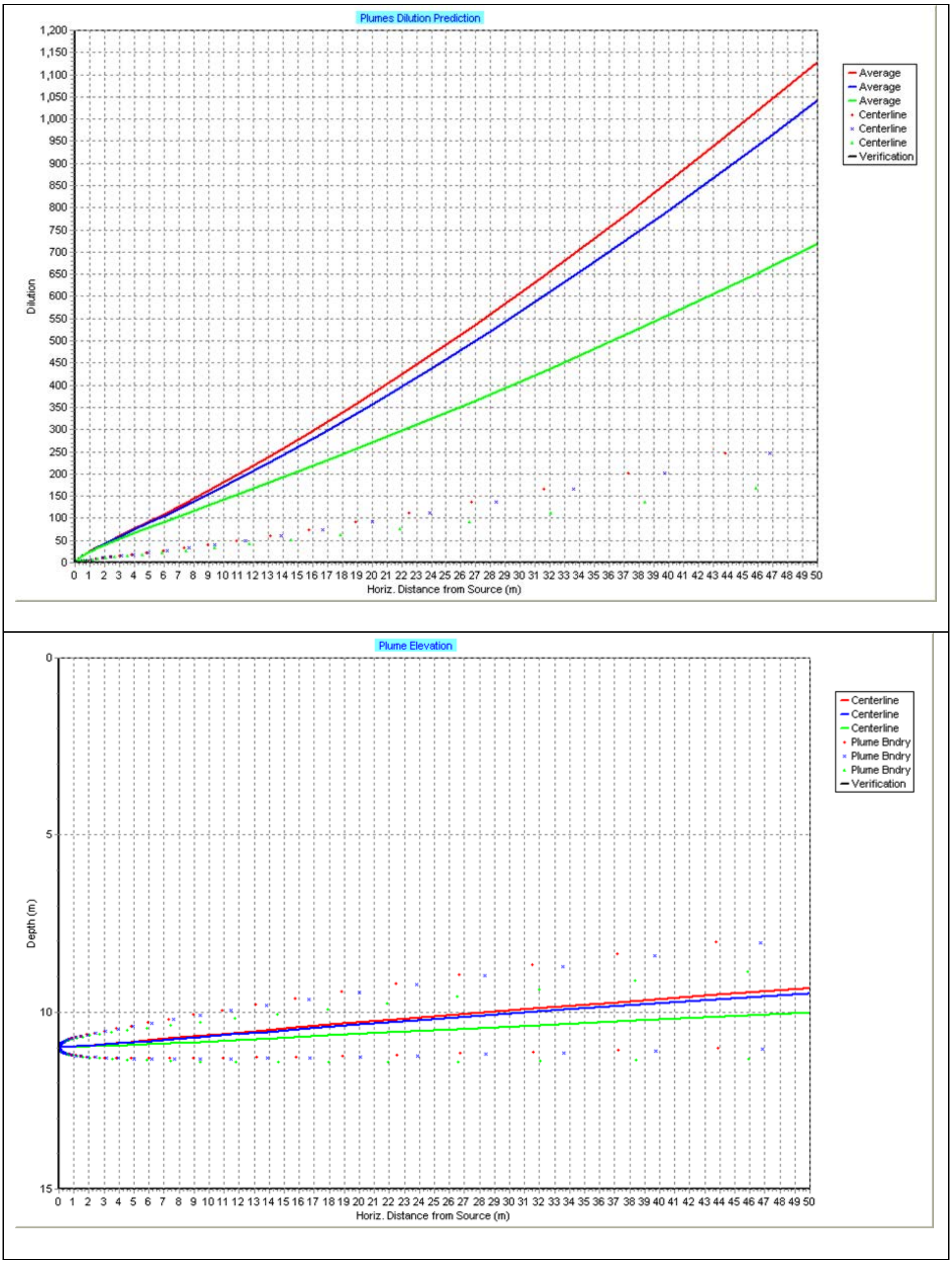



**Figure 7.5: As Figure 7.2 for case 3 (moderately high 0.6 m/s currents under well mixed conditions) UM3 modelling predictions**

A summary of the twelve modelled cases (36 simulations) is provided in Table 7.3 for the following parameters:

- The horizontal distance from the diffuser where a 263 fold average plume dilution is achieved;
- The plume centreline height above the diffuser at which a 263 fold average plume dilution is achieved;
- The average plume dilution at the mixing zone edge (i.e. 50 m down-current from diffuser);
- The plume centreline height above the diffuser at the mixing zone edge; and
- The width of a single plume from one of the diffuser nozzles at the at the mixing zone edge not accounting for any merging between adjacent plumes.

For cases 1-8 with PFW salinities (0.4, 5, 20 psu) considerably lower than the ambient salinity (34 psu), the following was predicted by the UM3 near-field model:

- All low (cases 1 and 5 at 0.05 m/s) and moderately low (case 7 at 0.1 m/s) current speeds achieved a 263-fold dilution within a 10 m horizontal distance of the diffuser. Moderate current speeds (cases 2 and 6 at 0.3 m/s) were predicted to achieve an average plume dilution within a 15 m horizontal distance of the diffuser. The high current speeds (cases 3 and 4 at 0.6 and 1 m/s respectively) attained an average plume dilution within a 15 to 35 m horizontal distance of the diffuser.
- For well mixed conditions the vertical height above the diffuser of the plume centrelines at an average dilution of 263-fold tended to be greater for low current speed (case 1 at 6-7 m for 0.05 m/s) than under salinity stratification where the plume was predicted to be trapped below the halocline (case 5 at 3-4 m for 0.05 m/s).
- The average plume dilution at the mixing zone edge (50 m horizontal distance from the diffuser) ranged from 340 to 1,750.
- The plume centreline heights above the diffuser at the mixing zone edge ranged from intersecting the surface for the lowest current speed with well-mixed conditions (case 1) and trapped below the halocline for strong salinity stratification conditions (case 5) to near the seabed for higher current speeds (i.e. insufficient time for the plume to rise through the water column within the mixing zone).
- Lastly, the cross-current width of a plume form a single nozzle ranged from 2 m for the high spring tide currents (case 4) to ~10 m for lower current speeds.

For cases 9-12 with PFW salinities (35, 50, 65 psu) greater than the ambient salinity (34 psu), application of the UM3 near-field model was hampered. The UM3 model does not account for the seabed (i.e. the dense saline plume are predicted to mix assuming no seabed impingement). Hence, the following dilution estimates are based when the denser than seawater plume was predicted to strike the seabed:

- For the high neap tide (0.6 m/s) current speed (case 9) the average plume dilution of 263 fold was achieved within 40, 20 and 15 m for PFW salinities of 35, 50 and 65 psu, respectively. The average plume dilutions at the mixing zone edge could not be predicted by UM3 for the 65 psu PFW salinity because the plume struck the seabed beforehand. The 35 and 50 psu PFW salinities had average plume dilution from 350-770 fold at the edge of the mixing zone.

- For a moderate (0.3 m/s) current speed (case 10) the average plume dilution of 263 fold was achieved within 30, 15 and 10 m for PFW salinities of 35, 50 and 65 psu, respectively. The average plume dilutions at the mixing zone edge could not be predicted by UM3 for the 50 and 65 psu PFW salinities because the plume struck the seabed beforehand. For the 35 psu PFW salinity the average plume dilution was 490 fold at the edge of the mixing zone.
- The model could not be used to predict the 263-fold dilution for the low current speed case (0.05 m/s, case 11) for any of the higher PFW salinities (35, 50, 65 psu) because the plume struck the seabed prior to achieving this dilution. The UM3 model predicted the following:
    - For a 35 psu PFW salinity the seabed was intersected at ~10 m from the diffuser and achieved a 200 fold average plume dilution;
    - For a 50 psu PFW salinity the seabed was intersected at ~2.5 m from the diffuser and achieved a 75 fold average plume dilution;
    - For a 65 psu PFW salinity the seabed was intersected at ~2 m from the diffuser and achieved a 50 fold average plume dilution;
- All of the predicted plumes for the case 12 moderately low current (0.1 m/s) runs intersected the seabed prior to the edge of the mixing zone at 50 m. The UM3 model predicted the following:
    - For a 35 psu PFW salinity the seabed was intersected at ~20 m from the diffuser and achieved at least a 263 fold average plume dilution;
    - For a 50 psu PFW salinity the seabed was intersected at ~5 m from the diffuser and achieved at least a 263 fold average plume dilution;
    - For a 65 psu PFW salinity the seabed was intersected at ~2.5 m from the diffuser and achieved a 150 fold average plume dilution;

In summary, the UM3 near-field model predicts that for PFW salinities (0.4, 5 and 20 psu, cases 1-8) substantially lower than the ambient salinity (34 psu), the 263 fold dilution requirement at the edge of the mixing zone (50 m horizontal distance from the diffuser) is readily achieved. However, for those cases (9-12) with salinities (35, 50, 65 psu) greater than the ambient salinity, the required dilution is generally predicted to be achieved for higher current speeds (>0.3 m/s), but not for the lower current speeds (0.05 and 0.1 m/s) prior to the plume striking the seabed. In these cases, the additional mixing that the plumes will undergo after striking the seabed with the overlying water is likely to achieve the 263-fold dilution requirement at the edge of the mixing zone.

**Table 7.3: UM3 near field model inputs**

| Case | Horizontal Distance at 263 fold Dilution (m) | Plume Centreline Height above Diffuser at 263 fold Dilution (m) | Average Dilution at Mixing Zone Edge | Plume Centreline Height above Diffuser at Mixing Zone Edge (m) | Single Plume Width at Mixing Zone Edge (m) |
|---|---|---|---|---|---|
| 1 | 5-7 | 6-7 | 500 | surface | 10 |
| 2 | 10-15 | 1 | 1,150-1,750 | 2.5-4 | 7-8 |
| 3 | 15-25 | 0.5-1 | 700-1,150 | 1-2 | 5 |
| 4 | 25-35 | 0-0.5 | 490-720 | 0.5-1 | 2 |
| 5 | 6-8 | 3-4 | 340-450 | trapped below halocline (~4) | 10 |
| 6 | 10-15 | 0.5-1 | 1,150-1,750 | 2.5-4 | 7-8 |
| 7 | 5-8 | 3 | 880-920 | surface | 10 |
| 8 | 5-8 | 3 | 920-1,090 | trapped below halocline (~4) | 10 |
| 9 | 15-40 | -1 to 0 (65 psu may intersect seabed[3]) | 350-770 (65 psu not valid, intersect seabed) | -1 to 0 (65 psu not valid, intersect seabed) | 3-5 (65 psu not valid, intersect seabed) |
| 10 | 10-30 | -1 to 0 (65 psu may intersect seabed) | 490 (50 and 65 psu not valid, intersect seabed) | -0.5 (50 and 65 psu not valid, intersect seabed) | 5 (50 and 65 psu not valid, intersect seabed) |
| 11 | Model cannot predict, intersect seabed | Model cannot predict, intersect seabed | Model cannot predict, intersect seabed | Model cannot predict, intersect seabed | Model cannot predict, intersect seabed |
| 12 | 35 psu @ 20 m<br>50 psu @ 5 m<br>65 psu, model cannot predict, intersect seabed | 35 psu @ -1 m<br>50 psu @ -1 m<br>65 psu, model cannot predict, intersect seabed | Model cannot predict | Model cannot predict | Model cannot predict |

### 7.6.3 Far field model

The objectives of the far field modelling conducted as part of the EIS were:

- To derive an effective disposal strategy by predicting the fate of PFW discharged from different locations; and
- To predict the environmental risk associated with the discharge.

The far field model used spatially and temporally varying currents predicted from a detailed hydrodynamic model for the area, computed using the Advanced CIRCulation model (ADCIRC). This model is a system of computer programs for solving time dependent, free surface circulation and transport problems in two and three dimensions (Westerink et al., 1994). The algorithms that comprise ADCIRC utilise the finite element (FE) method in space and the model can be applied to computational domains encompassing the Deep Ocean, continental shelves, coastal seas and small scale estuarine systems.

3

Standard particle tracking dispersion algorithms and diffusion coefficients were applied in the model. These are detailed in the produced formation water assessment conducted as part of the EIS (Ref. [24], [38]). The model was also validated against tidal stations around the coastline. Comparisons with measured data compare favourably with modelled hydrodynamics (see Appendix C), giving confidence that the hydrodynamic model is fit for purpose. Model inputs are provided in Table 7.4. The far field model was run over a two day period with batch releases over 16 hours (8 hour period of no release between these two daily discharge events) of 6,000 bbl/day (900 $m^3$/day, total release over 2 days of 1,800 $m^3$) and 200 bbl/day (30 $m^3$/day, total release over 2 days of 60 $m^3$) for high and low discharges, respectively.

**Table 7.4: Far field model inputs**

| **Parameter** | **Value** |
|---|---|
| **Discharge parameters** | As per Table 7.1 |
| Minimum | 200 bbl/day (30 $m^3$/day) |
| Maximum | 6,000 bbl/day (900 $m^3$/day)<br>Batch release assumed to occur 16 hours every 24 hours, with a break of 8 hours between releases. |
| **Ambient conditions** | As per Table 7.1 |
| **Metereological conditions** | |
| Season | Transitional |
| Wind | Light onshore winds |
| Tide | Neap |

The far field modelling results for 200 bbl/day (30 $m^3$/day) discharge are shown in Figure 7.6, Figure 7.8, and Figure 7.9. Plume concentrations are in the range 0.01–0.1%PFW. The far field modelling results for 6,000 bbl/day (900 $m^3$/day) discharge are shown in Figure 7.7, Figure 7.10 and Figure 7.11. As the current discharge events are on average 280 $m^3$ (Section 4.3.1), only the latter scenario will be discussed here. Again, the modelled discharge volumes are much higher than the current average discharge volumes and nearly two-fold greater than the projected maximum PFW volume of 450 $m^3$/day (Section 4.3.3). Therefore the modelling is considered representative of worst case conditions in terms of PFW discharge.

The dispersion predictions at 50 m from the discharge location show slightly higher peak concentrations (0.4%PFW (250 dilutions)) than the near field initial dilution model. This is attributed to the plume recirculating over the discharge location at the turn of tide, which is not simulated in the near field model. Figure 7.11 shows predicted concentrations further afield along the coastline. The model predicts intermittent peaks at concentration of less than 0.02%PFW (5,000 dilutions). This equates to oil concentrations of below 6 ppb, which is well below concentrations that could possibly cause environmental harm.

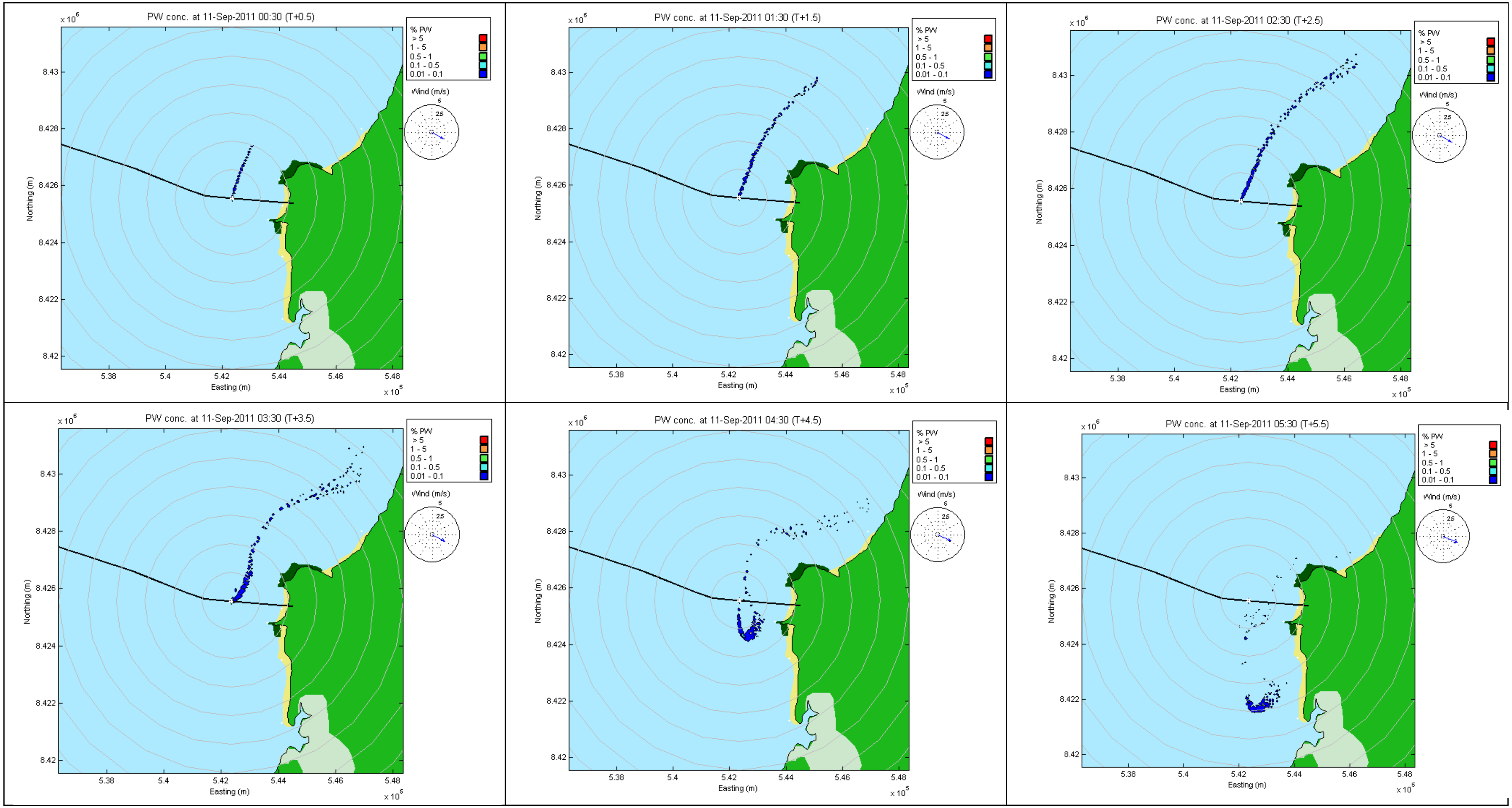



**Figure 7.6: Predicted PFW concentrations during neap tide and light onshore winds for water production of 200 bbl/d ($30\ m^3/d$)**

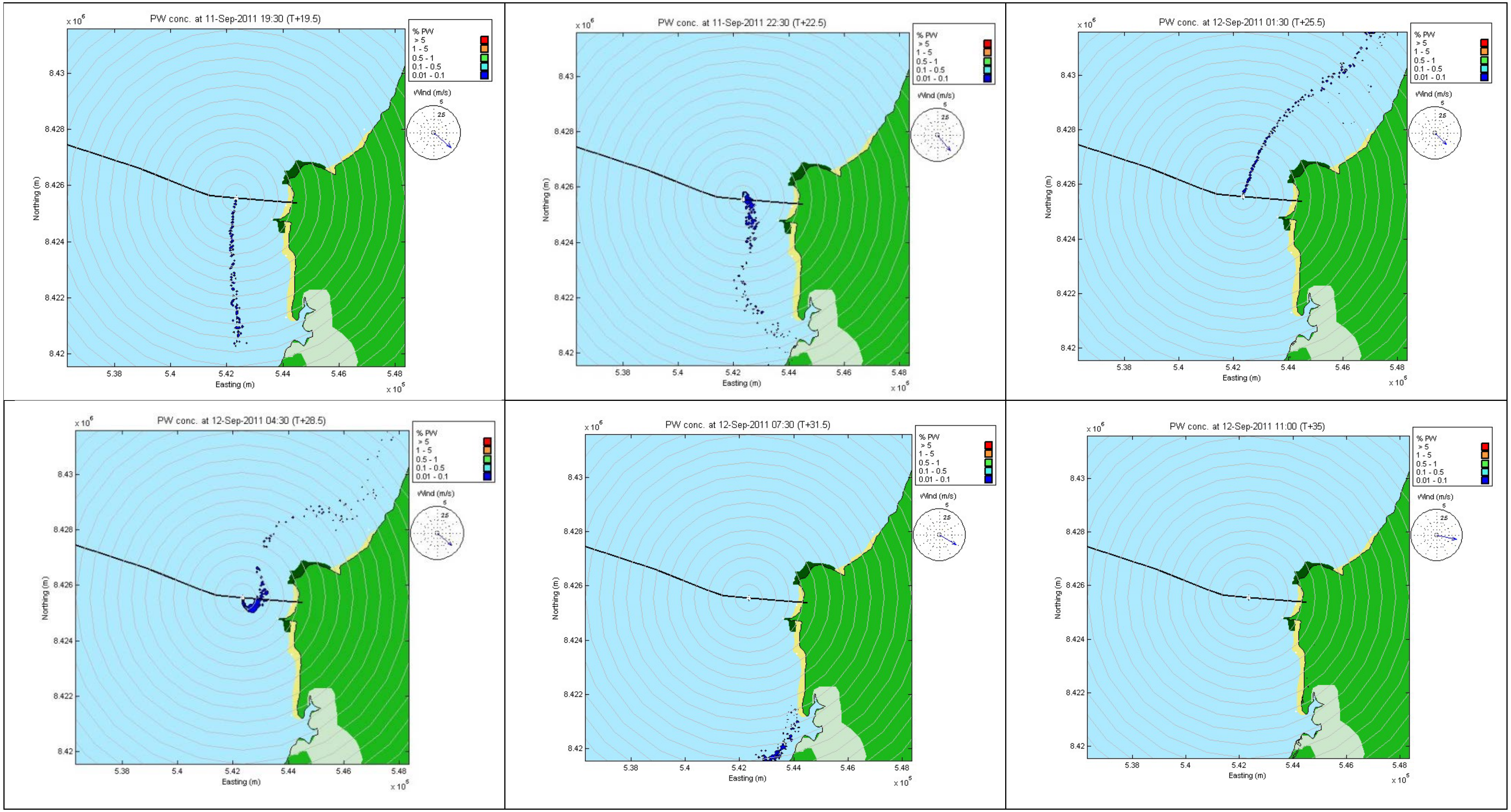



**Figure 7.7: Predicted PFW concentrations during neap tide and light onshore winds for water production of 6000 bbl/d (900 $m^3$/d)**

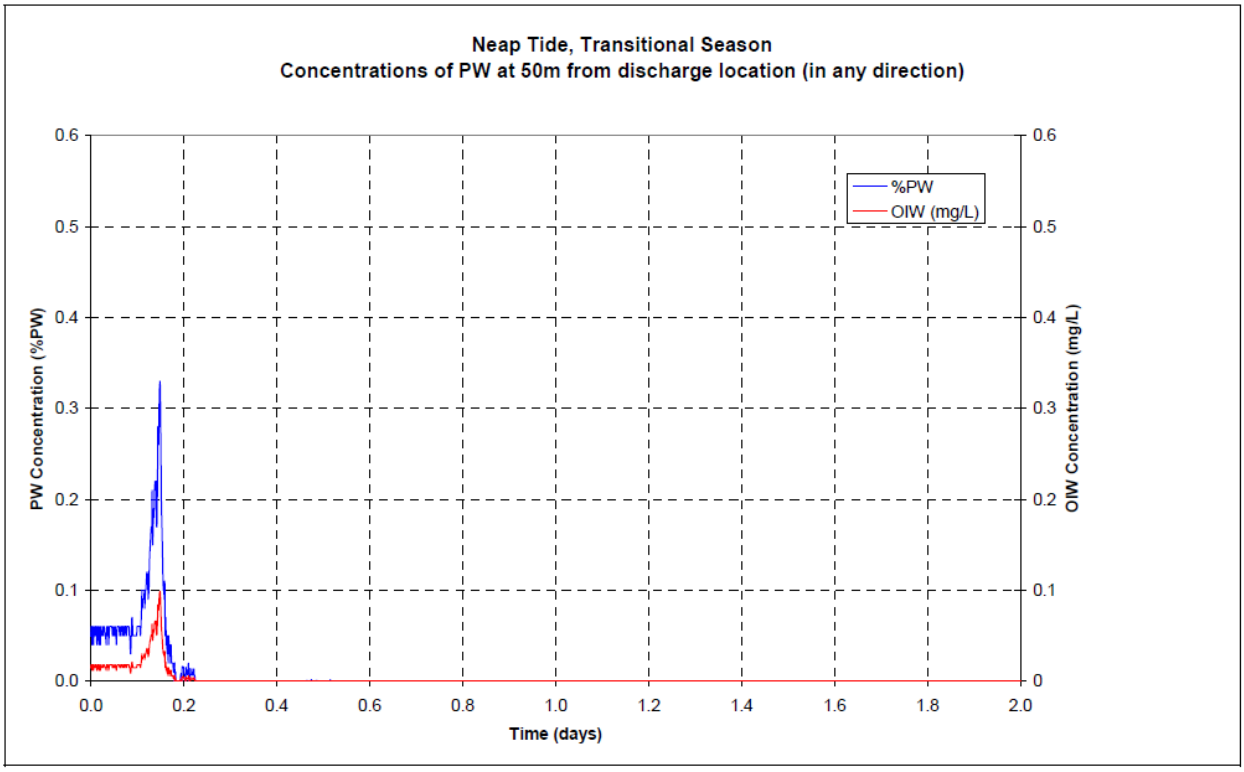



**Figure 7.8: Time series of predicted PFW concentrations at 50 m from the discharge location for water production of 200 bbl/d (30 $m^3$/d)**

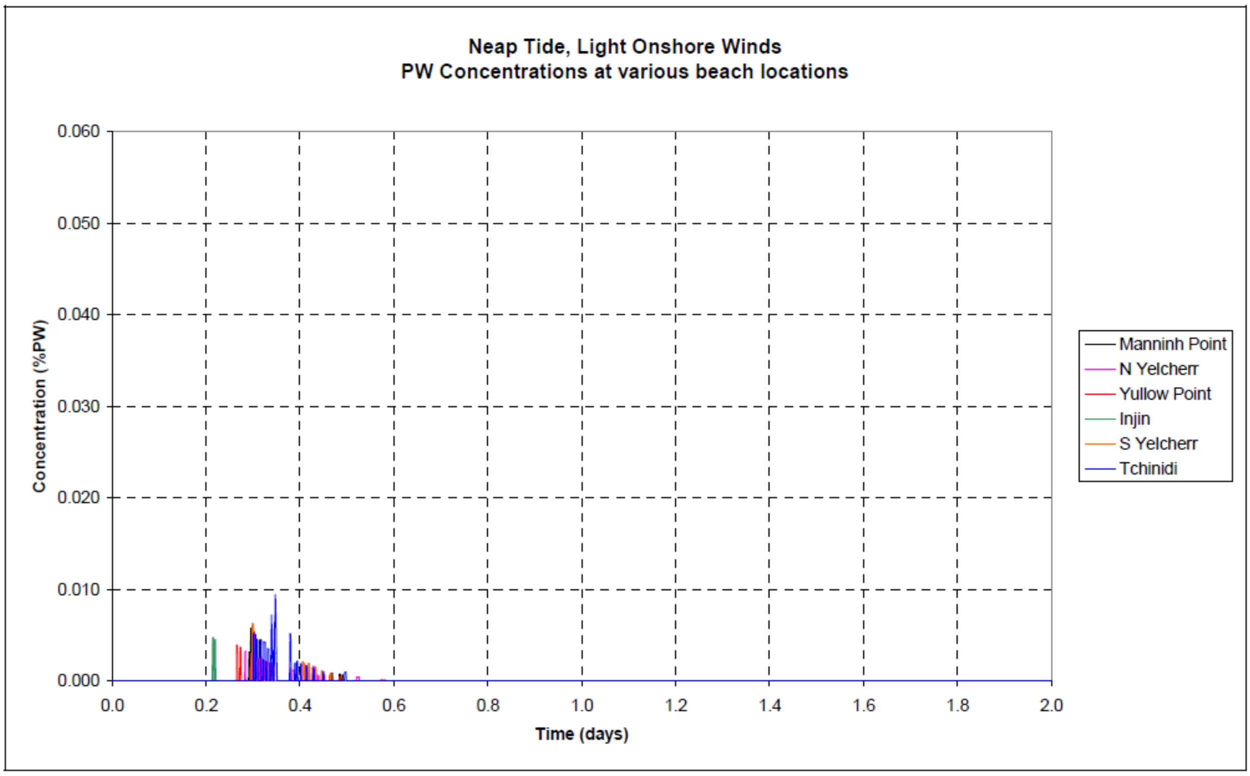



**Figure 7.9: Time series of predicted PFW concentrations at various beach locations for water production of 200 bbl/d (30 $m^3$/d)**

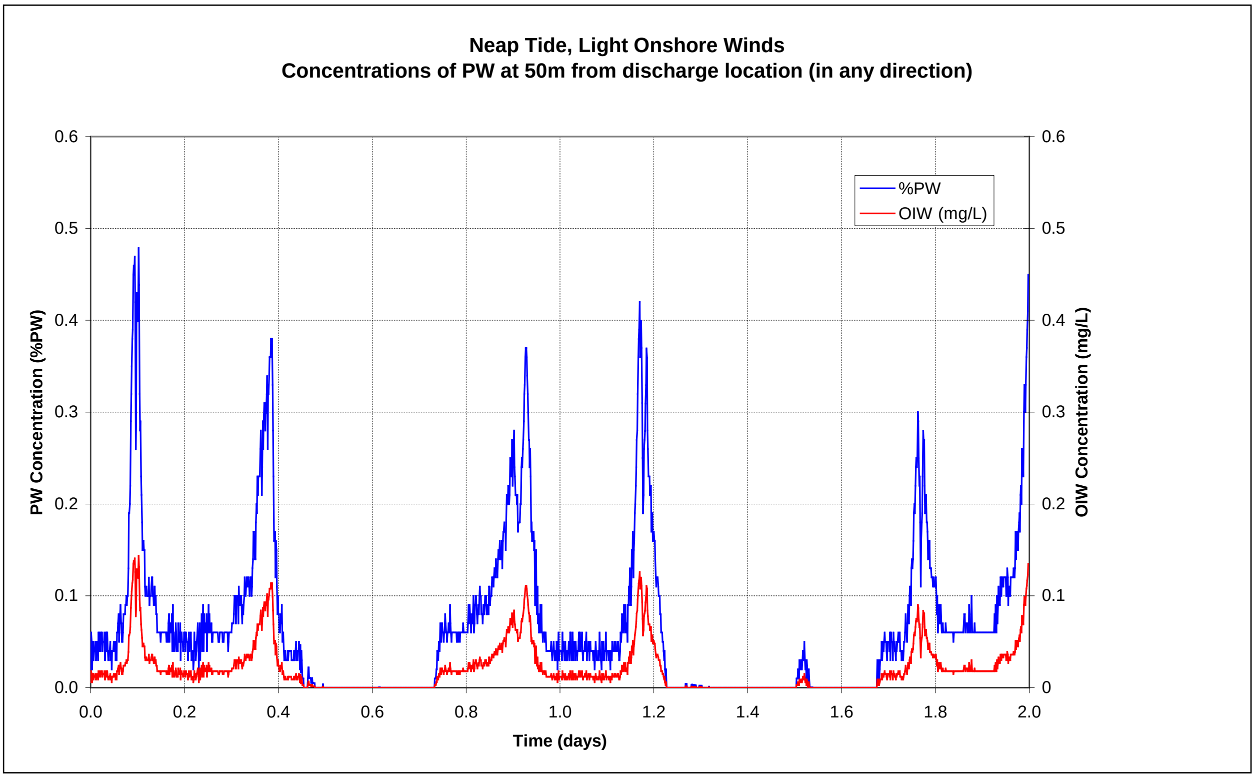



**Figure 7.10: Time series of predicted PFW concentrations at 50 m from the discharge location for water production of 6000 bbl/d (900 $m^3$/d)**

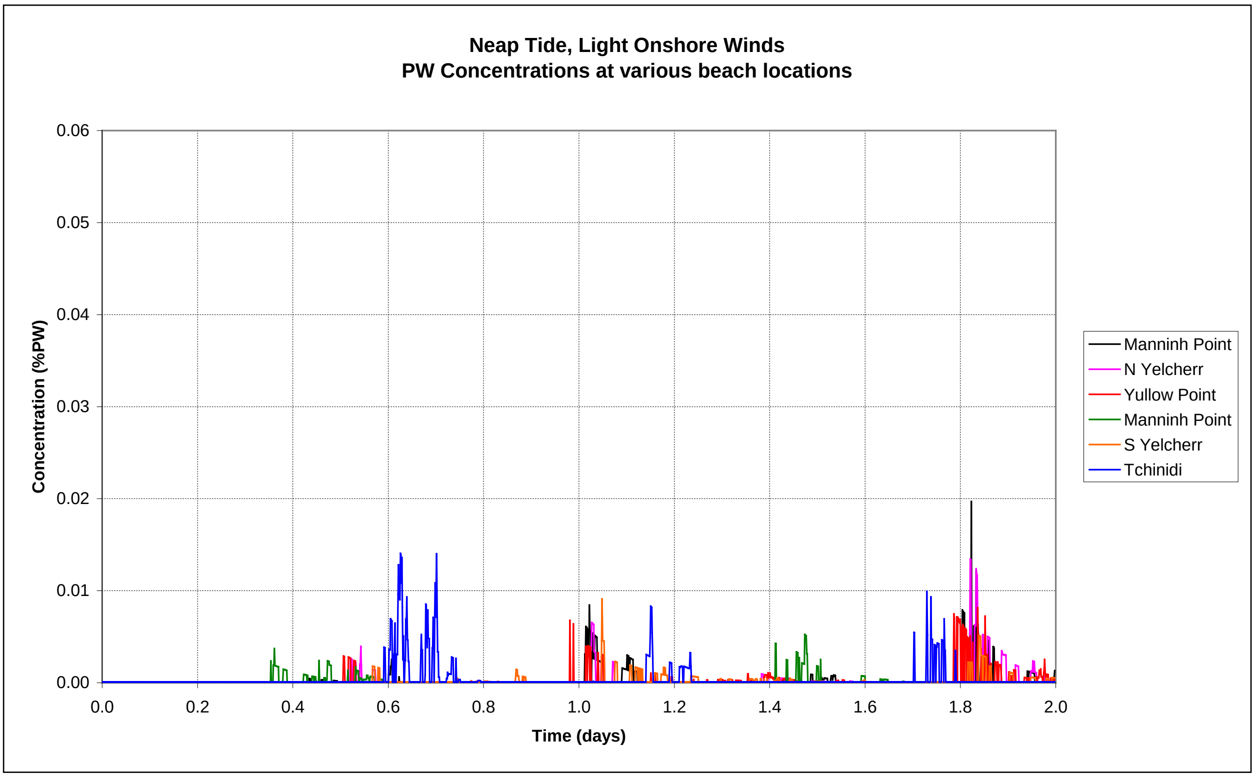



**Figure 7.11: Time series of predicted PFW concentrations at various beach locations for water production of 6000 bbl/d (900 $m^3$/d)**

## 7.7 Exposure pathways between source and receptor

Biological communities that could potentially be affected by the PFW discharge include:

- plankton;
- sessile marine invertebrates (shellfish, seaweeds, seagrass etc.);
- benthos;
- fish;
- marine mammals; and
- sea birds.

Planktonic organisms live freely in the water column and drift with the water currents. Plankton may also include the early stages (e.g. egg, larva and spores) of non-planktonic species (fish, benthic invertebrates and algae). Figure 7.12 illustrates the typical exposure periods for passive floating organisms. Once discharged to the receiving environment, dilution reduces the concentration of toxic chemicals in the PFW, as described in Sections 7.1 *Fate of PFW in the marine environment* and 7.6 *Dispersion modelling*. The worst-case scenario would be chronic exposure of an organism to PFW concentrations above the PNEC value, e.g. chronic exposure over several days. Outside of the modelled 50 m radius around the outfall, exposure times for PFW concentrations above the PNEC would likely be in the order of minutes, as illustrated by Figure 7.10. There is therefore the potential for exposure; however, the concentration will be continually diluting and only organisms residing directly in the plume would be impacted, which constitutes a small proportion of the community.

The produced water studies discussed in Section 6.2 indicated that following mixing, concentrations of the PFW in the receiving environment will not be acutely toxic to fish and there were no chemical components that would bio-accumulate or magnify. Moreover, vertebrates including fish have detoxification mechanisms that break hydrocarbon compounds down (Ref. [16], [27]). The typical exposure periods for fish is conceptually similar to that for motile organisms shown in Figure 7.12. In addition, fish have the ability to swim and might move in and out of the plume. Exposure periods are therefore sporadic and unlikely to be at levels which would harm or taint the organism.

Benthos communities are found in or around the seabed. There is some potential for metals, such as barium, iron and manganese precipitates, and higher molecular weight aromatic and saturated hydrocarbons to accumulate in sediments. The high level of mixing and dispersion suggests accumulation of saturated hydrocarbons and PAHs in the seabed is unlikely. Studies have shown unfiltered produced water samples containing metal precipitates generally had higher toxicity than filtered samples (Ref. [4], [27]), although data from environmental effects monitoring programs generally show natural dispersion processes appear to limit the concentrations of toxic metals in the water column and sediments to just above background levels (Ref. [27]). Furthermore, the coarse sediments in the vicinity of the outfall limit the development of a deposit feeding community (Ref. [7], [37], [38]). Therefore, impacts to the benthos communities are expected to be limited and unlikely.

As marine mammals feed on fish and/or plankton, they could potentially be affected by trophic transfer (i.e. bioaccumulation of chemicals from food) and potential biomagnification. However, vertebrates are able to metabolise and excrete the type of chemicals that contribute most to the risk (Ref. [16], [27]). They are also generally migratory so individuals are not likely to be affected by any localised contamination that may occur.

Seabirds are harmed mainly by the physical properties of floating oil and not the toxicity (Ref. [14]). As with marine mammals, there is the potential for trophic transfer and indirect effects such as changes in the availability of food sources. As the food source is not likely to be impacted, the risk to sea birds is low.

In summary, it is possible that there could be a localised impact to the sessile marine communities attached to the outlet, however, contamination would be mitigated by continual flushing of the receiving waters and the spatial and temporal variability of the PFW plume. Beyond the immediate vicinity of the discharge, dilution alone will be sufficiently high to reduce contaminant concentrations to a level below which there could possibly be any adverse environmental impact.

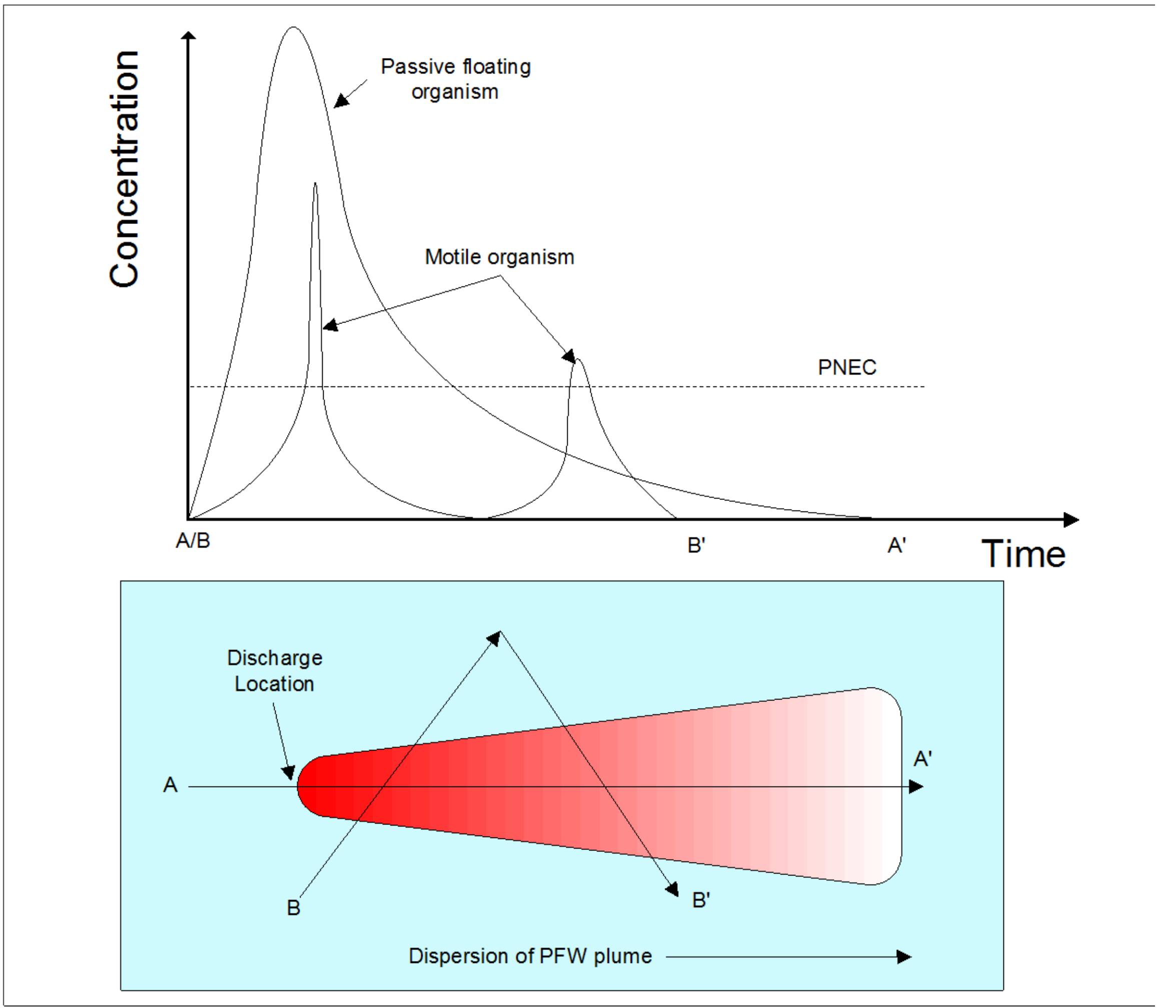



**Figure 7.12: Exposure times to the PFW plume for passive and motile organisms**

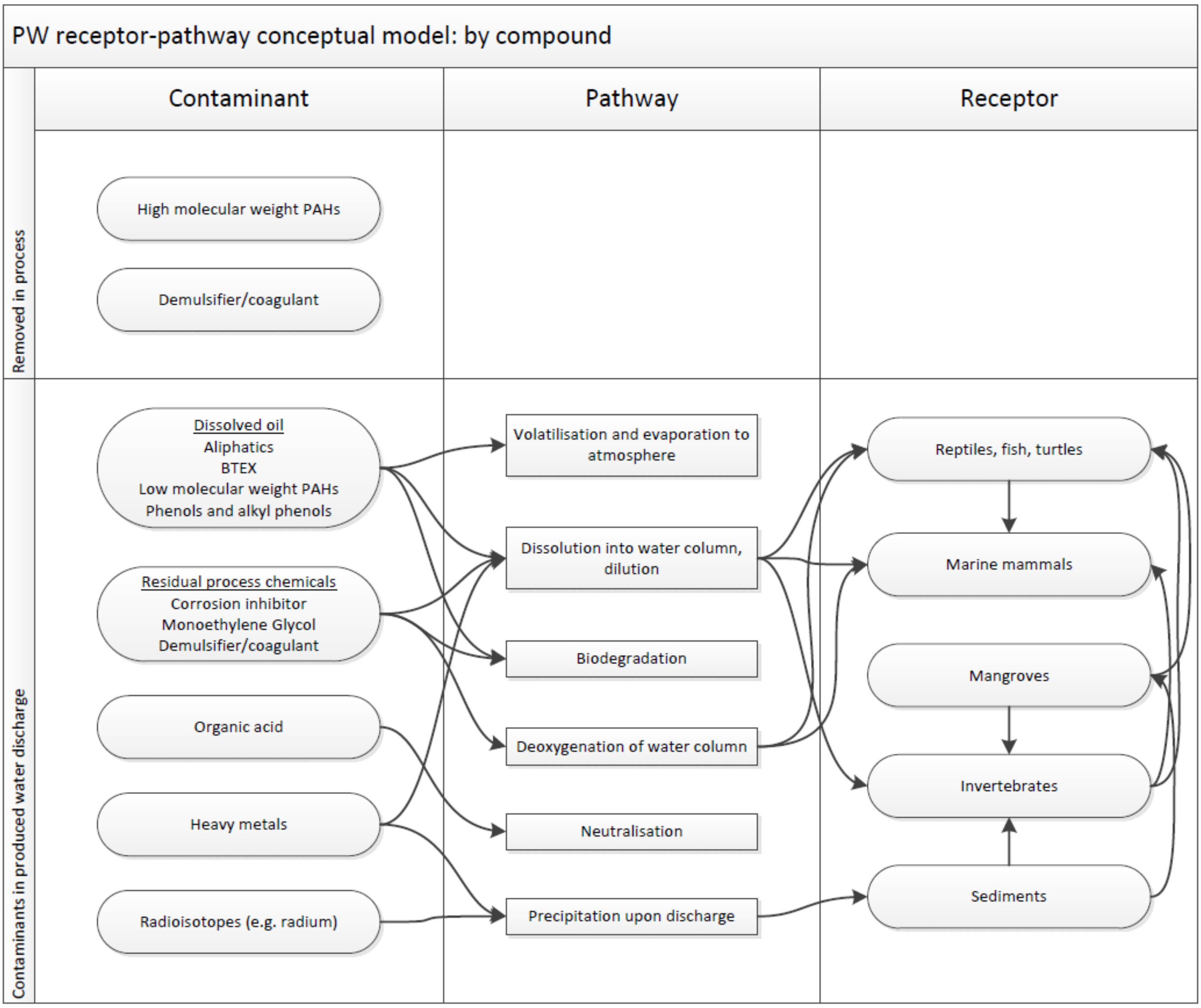



**Figure 7.13 Receptor-pathway conceptual model by compound**

## 7.8 Blacktip PFW Characteristics

Produced water studies undertaken include characterisation of the chemical composition, biodegradation potential, bioaccumulation potential and toxicity. The results of the studies are detailed in Section 6 and Appendix A.

Chemical characterisation of the treated produced water samples typically identified dissolved metals (including barium, cobalt, copper, iron, lead, manganese, mercury, nickel and zinc), total nitrogen, ammoniacal nitrogen, turbidity, phenol and benzene at concentrations exceeding ANZECC/ARMCANZ (2000) marine water quality guideline trigger values for 99% protection of slightly to moderately disturbed ecosystems.

Barium is known precipitate upon contact with seawater to form barium sulfate, which has low solubility and commonly indicated to have low toxicity potential (Ref. [27]). Dissolved iron and manganese also rapidly precipitate as oxyhydroxides upon contact with oxygen rich sea water. These particulate metals tend to slowly settle out of the water column and accumulate in sediments over a large area around the discharge (Ref. [4], [26], [27], [30]).

Based on the ANZECC toxicant trigger values for a 99% level of species protection and the chemical characterisation studies, the required dilution was determined for all relevant parameters and are presented in Table A.1 in Appendix A. The key parameters requiring a higher level of dilution are summarised in Table 7.5. All other parameters were always within 100 dilutions of the ANZECC 99% level of species protection default trigger value.

**Table 7.5: Required dilution factors to achieve ANZECC 2000 toxicant trigger values for a 99% level of species protection**

| Parameter | Oct 2010 | Feb 2012 | Sep 2013 | 2015 | May 2016 | Dec 2016 |
|---|---|---|---|---|---|---|
| pH[4] | 1,451 | 633 | 178 | 8.4 | 14.2 | 4.1 |
| Ammoniacal nitrogen | 10 | 22 | 141 | 5 | 1 | 0 |
| Cobalt | 1,000 | No data | 0 | 400 | 0 | 200 |
| Zinc | 407 | No data | 6 | 4 | 287 | 6 |
| Direct Toxicity Assessment | 91 | 263 | 52 | - | - | - |

Also presented in Table 7.5 are the direct toxicity assessments (i.e. ecotoxicology studies) performed on PFW samples during October 2010, February 2012 and September 2013. These direct toxicity assessments are the preferred manner to derive the relevant concentrations for a particular level of species protection by ANZECC. Hence, though the required dilutions for pH[5] (1,451 fold dilution), cobalt (1,000 fold dilution)and zinc (407 fold dilution) are greater than the direct toxicity assessment (91 fold dilution), it is adopted as the most reliable value to achieve a 99% level of species protection for this sample as per ANZECC. Similarly, for the February 2012 and September 2013 PFW samples the direct toxicity assessment dilutions of 263 and 52 fold are adopted for those respective samples, even though higher dilutions are calculated from ANZECC toxicant trigger values on the basis of the same rationale.

[4] Note that upon release of PFW discharge into the marine environment, the buffering capacity via chemical process well also act in a rapid manner to equilibrate the pH to ambient marine water values. Further, the recommended pH range for slightly disturbed tropical marine inshore waters is a default guideline value and not a 99% level of species protection value per se.

[5] PFW is now treated to pH >6.5 prior to discharge, and therefore minimal dilution will be required to achieve the guideline pH value of 8 (ANZECC, 2000).

Though no direct toxicity assessments were carried out the 2015 and 2016 samples, only cobalt and zinc levels of these three PFW samples require substantive dilution to meet the default toxicant trigger values for a 99% level of species protection. Given that the dilution estimates from the direct toxicity assessments for the 2010, 2012 and 2013 samples were at least 2-3 fold less than the worst case default toxicant trigger values of these analytes, it follows that the dilution estimates on the basis of the concentrations of these analytes and toxicant trigger values is overestimated.

***Hence, a conservative required dilution at the edge of the mixing zone has been adopted as 263 fold, on the basis of direct toxicity assessments of 2010, 2012 and 2013.***

We note that the 99% and 95% species protection trigger levels for cobalt are 0.005 µg/L and 1 µg/L, respectively, a large 200 fold difference. Importantly, the ANZECC guidelines are only indicative of the possibility of effects from chronic exposure to a single toxicant, and do not reflect the complex interaction of multiple components in produced water. For example, pH affects the availability of many heavy metal ions in solution. At higher pH values, metals will precipitate out as salts, thus reducing their toxicity (Ref [2], [4], [25], [27]). Hence, the whole effluent toxicity (WET) testing (or direct toxicity assessments) in 2010, 2012 and 2013 (Section 6.2.2) are considered the more robust data in which to set the mixing zone dilution requirement (i.e. a PNEC of 0.38%PFW or 263 dilutions).

Biodegradation and bioaccumulation studies confirmed that hydrocarbon concentrations and the ecotoxicity in the PFW degrade rapidly, and a low potential for bioaccumulation of hydrocarbon compounds or heavy metals in laboratory shellfish. The annual sampling and analysis of shellfish around the coastline has shown no evidence of hydrocarbon accumulation. There was a slight increase in heavy metal concentrations; however, these increases were also found in the control samples and can be considered a regional phenomenon.

## 7.9 Mixing Zone Assessment

A mixing zone is defined in the *NT EPA Mixing Zone Guidelines* (Ref. [32]) as ‘a specifically defined area or volume of water around a waste water discharge where the water quality may be below that required to protect environmental values and beneficial uses’.

The combination of near field and far field modelling results provides reasonable assurance that the PFW will achieve a dilution of 263 fold prior to edge of the mixing zone. Figure 7.6 and Figure 7.7 show the plume transport predicted by the far field model and that the plume concentrations will be in the range 0.01-0.1% PFW. Although the far field model predicted peak concentrations of 0.4% PFW (250 dilutions, for a 900 $m^3$/day discharge) at 50 m radius from the diffuser over a two-day period, it also predicted concentrations above 0.1% PFW (1,000 dilutions) would only occur 19% of the time and concentrations above 0.38%PFW (263 dilutions) were predicted to occur 0.94% of the time, as illustrated in Figure 7.10. Therefore, 50 m radius mixing zone centred on the outfall diffuser is considered a practical and reasonable to achieve 99% species protection. The mixing zone is illustrated in Figure 7.14.

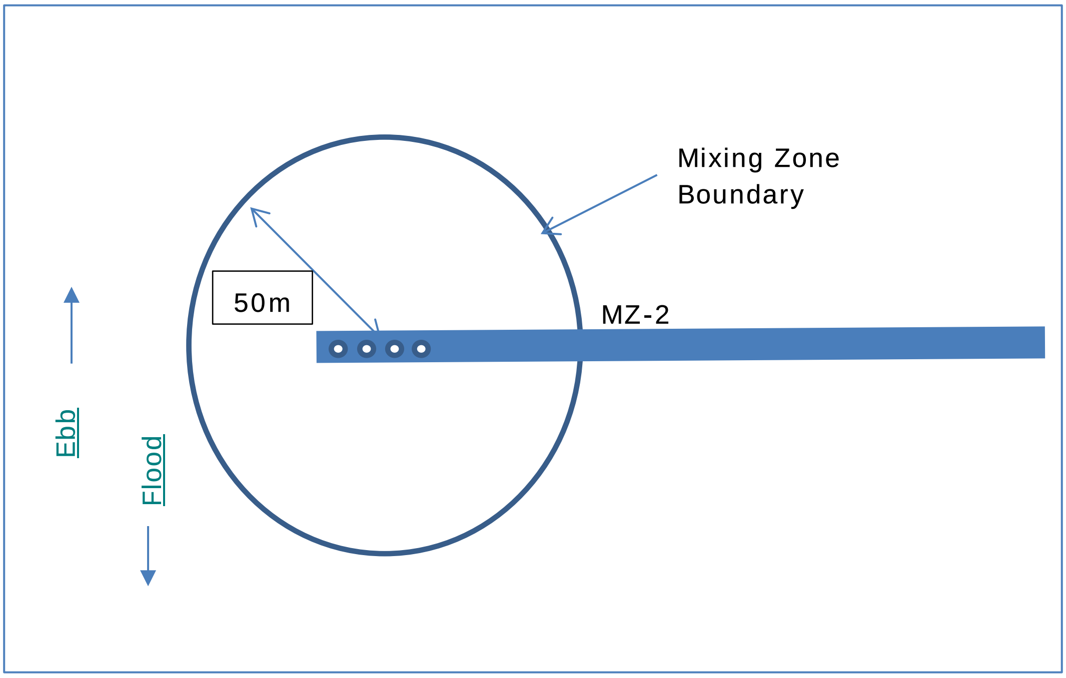



**Figure 7.14: Proposed produced water mixing zone for Blacktip**

Table 7.6 summarises the information provided in this document to support the mixing zone application. The basic assessment is summarised in Table 7.7.

**Table 7.6: Information provided for mixing zone application**

| | Requirement | Section reference in this report |
|---|---|---|
| 1 | Detailed information on the site and facility | Section 4 |
| 2 | Discharge and release conditions | Section 4 |
| 3 | Receiving environment | Section 5 |
| 4 | Exposure pathway between source and receptor | Section 7.7 |
| 5 | Monitoring plan for the discharge, consistent with the NT EPA's Guidelines for Consultants Reporting environmental Issues | Section 8 |
| 6 | Continuous improvement plan for managing waste discharge over time so as to reduce the extent and impact of the mixing zone | Section 8.4 |
| 6 | A conceptual site model should be developed to support the application. The model should consider the extent of a mixing zone's impact based on:<br>• Representation of the source of the discharge<br>• All flow scenarios, inclusive of:<br>o Wet and dry season;<br>o Catchment flows; and<br>o Variation of the discharge volume due to waste water reuse, reduction;<br>• Release and transport mechanism for nutrients/toxicants ay from the discharge and in and away from the mixing zone; and<br>• A review of potential and actual receptors. | Section 7 |

**Table 7.7: Summary of basic assessment**

| Aspect | Criteria | Assessment |
|---|---|---|
| Acute toxicity | No acute or chronic effects after initial dilution and at the boundary of the mixing zone, respectively. | Results from three rounds of ecotoxicology studies (both acute (lethal end point) and chronic (sub-lethal end points) tests) found that the required dilution factors to achieve 99% species protection ranged between 52 and 263 (Appendix A). This is below the initial dilution factor of 700 predicted by the near field model for the outfall and within the dilution predicted by the far field model. |
| Harm to humans | No harm to humans | Both near and far field modelling (Section 7.1) has demonstrated that mixing in the receiving waters would rapidly reduce concentrations of any contaminant to concentrations well below thresholds that could possibly have any effect to humans or flora and fauna (including migratory aquatic organisms). This is supported by the annual marine monitoring which have provided no indication of adverse impact from produced water discharge. |
| Impacts to flora and fauna (including migratory organisms) | No unacceptable impacts on flora and fauna | |
| Odours | No odours from the discharge that could adversely affect the use of the surrounding area | No odours have been recorded, and mixing would rapidly dilute any hydrocarbon concentrations to below odour threshold. |
| Migratory Fish or other aquatic organisms | No adverse impact on migratory fish or other aquatic organisms (i.e. the zone should not extend over the breadth, depth or length of a waterway) | The mixing zone does not overlap with any sensitive marine habitats. Due to the relatively low discharge volumes, intermittent frequency of discharges and rapid mixing in the area, no adverse impacts are expected on migratory fish or other aquatic organisms. |
| Bioaccumulation | No persistent or potentially bioaccumulative substances or chemicals in the discharge | As described in Section 6.2, Blacktip PFW contains low level hydrocarbons and heavy metals at or slightly above ANZECC trigger values. PAH compounds have the potential to bioaccumulate; however, in the chemical analysis undertaken as part of the licence requirements, these compounds were found to be consistently below detection limits (Appendix A). Specific bioaccumulation studies in the laboratory also demonstrate a low potential for bioaccumulation of hydrocarbon compounds or heavy metals in |

| Aspect | Criteria | Assessment |
|---|---|---|
| | | shellfish. Moreover, the sampling and analysis of shellfish around the coastline has shown no evidence of hydrocarbon accumulation. |
| Non-Indigenous Marine Species | No undesirable aquatic life or dominance of a nuisance species | Blacktip PFW is abiotic. The PFW contains total nitrogen and ammoniacal nitrogen at levels above the ANZECC 2000 guideline values; however the dispersion models suggest there sufficient mixing at the outfall and within the first 50 m to reduce levels to below the 99% species protection trigger value. See Section 7.8. |
| Primary contact recreation | Mixing zones will not generally be designated in areas containing these activities or environmental values | Waters in the vicinity of outfall are not used for recreation |
| Cultural values | | The only area of cultural value is Walpinhthi Reef, a submerged reef, which is located approximately 500 m to the south the outfall (Section 5.5). Although the plume may encounter the reef, given the mixing predicted within the first 50 m of the outfall, it is likely to be highly diluted by the time it reaches the reef (0.01-0.1%PFW) and to be of no harm to the reef. |
| Spawning or nursery habitats | | The proposed mixing zone is remote from spawning or nursery habitats. The closest being the river and tidal creek systems, which acts as nursery grounds for juvenile Penaeid species, namely tiger prawn (*Penaeus esculentus*), banana prawn (*P. merguiensis*) and red-legged banana prawn (*P. indicus*). Figure 7.9 shows that PFW concentration would be less than 0.02%PFW at coastal sites and that elevated concentrations would be sporadic. Therefore, PFW discharge at the outfall will have no impact on spawning or nursery habitats. |
| Aquaculture | | There are no aquaculture operations in the vicinity of the outfall. |
| Important food gathering sites for Traditional Owners | | There are no significant food gathering sites for traditional owners in the vicinity of the proposed mixing zone. |
| Potable water supply | | Potable water is extracted from the onshore groundwater aquifer, which will not be impacted. No potable water is sourced from the Joseph Bonaparte Gulf. |
| Conservation value | | No other specific conservation values have been identified in the vicinity. |

## 7.10 ALARP and Acceptability Assessment

The risks posed by the management of Produced Formation Water have been assessed as low as reasonably practicable (ALARP) and acceptable. An overview of the assessment is provided below.

### 7.10.1 ALARP

For risks to be considered ALARP, the following criteria must apply:

- there are no reasonable practicable alternatives to the activity; or
- the cost (i.e. sacrifice) for implementing further measure is disproportionate to the reduction in risk.

ALARP is demonstrated against the risk reduction hierarchy:

- Eliminate;
- Substitute
- Engineering
- Isolate the risk; and
- Administration (development of procedures or training).

ALARP may also be determined by referring to existing 'good practice'. Table 7.8 provides the ALARP demonstrates in relation to the management of PFW.

**Table 7.8: Demonstration of ALARP**

| Demonstration of ALARP | |
|---|---|
| Eliminate | Alternatives for PFW disposal, to eliminate or substitute the risk, were considered during the design phase of the project. Alternatives to ocean discharge include:<br>1. trucking back to Darwin for treatment; and<br>2. installation of evaporation ponds within the boundary of the gas plant.<br>Trucking out is prohibitively expensive and not possible during the wet season as the road between Wadeye and Darwin is impassable. Trucking would also unnecessarily increase emissions to atmospheric and increase |

| Demonstration of ALARP | |
|---|---|
| Substitute | the risk of road accidents. Trucking out water was considered a last resort and temporary solution only, in circumstances where the discharge limits cannot be met.<br>Evaporation ponds were considered a viable alternative; however, there were concerns about:<br>• land and/or aquifer contamination;<br>• animals drinking from the ponds;<br>• low evaporation rate, particularly if there is an oily film;<br>• emission of VOCs; and<br>• residue disposal.<br>Of the above options, ocean discharge with appropriate engineering and administrative controls was considered the most acceptable solution for PFW disposal. |
| Engineering | Engineering controls presently employed to treat the PFW include:<br>• CPI separators;<br>• GFU;<br>• CETCO filters;<br>• Long sea outfall; and<br>• Diffusers at the end of the outfall.<br><br>In addition, Eni is continuously seeking to improve the produced water treatment process from an engineering perspective, an example of this is evidenced in the Technical Deviation Request Or Query #00193 (attached in Appendix F: TDRQ #00193 - Produced Water Treatment)<br>Further to the existing infrastructure, the Blacktip plant will be trialling Hi-Flow Filters with upstream Spiral Wound Filters and Hydro cyclone technology to further improve the performance of the produced water treatment package. This package is planned to be tested in 4Q 2017, any further actions will be dependent upon the outcomes of this testing. |
| Isolate the risk | This is not relevant for PFW discharge and is not considered further. |
| Administration (development of procedures or training) | Administrative arrangements for PFW discharge include:<br>• *Blacktip Operations Environmental Monitoring Requirements* (Doc No. 000036_DV_PR.HSE.1020.000);<br>• Competent onsite operators aware of EPL57-02 requirements as they apply to PFW;<br>• *Blacktip Operations Yelcherr Gas Plant Oil in Water Sampling and Testing Procedure* (Doc No. 000036_DV_PR.DPM.1053.000); and<br>• *Blacktip Operations Water Sampling Procedure* (Doc No. 000036_DV_PR.HSE.1013.000). |

### 7.10.2 Acceptability

Table 7.9 summarises the criteria against which acceptability is assessed.

**Table 7.9: Eni acceptability factors**

| **Demonstration of Acceptability** | |
|---|---|
| Compliance with Legal Requirements/Laws/Standards | *Considers the legal aspect, particularly compliance with applicable legislative prescriptions and/or regulations in force which imply specific procedures to be carried out by the Operator to control the environmental aspect.*<br>Eni has strict legal requirements and conditions associated with PFW discharge, specified in the:<br>• EPL57-02; and<br>• EPBC Approval 1180/2003 conditions. |
| Policy Compliance | *The risk or impact must be compliant with the objectives of Eni policies.*<br>Engineering and procedural controls are in place to ensure the residual risk posed by discharging PFW to the ocean is ALARP. The environmental aspects of PFW discharge are therefore compliant with Eni's Australia's HSE Statement. |
| Social Acceptability | *Considers the 'social' aspects that can alter stakeholder perception on the Operator's commitment regarding the safeguard and protection of the environment and that can cause serious harm to the Operator's public image.*<br>An Environmental Impact Assessment was prepared for the project and involved extensive stakeholder consultation (Ref. [37], [38], [39]). This continued in the execution of the project, in particular with consultation with: NT and commonwealth government departments; the Northern Lands Council, the Traditional Owners of the land and the fishing industry. There were no objections to the PFW discharge. |
| Area Sensitivity/Biodiversity | *The proposed risk or impact controls, environmental performance objectives and standards must be consistent with the nature of the receiving environment.*<br>• Receiving waters are well flushed with strong tidal currents and no environmentally sensitive areas nearby (see Section 5).<br>• Water production is variable resulting in an intermittent discharge of low volume.<br>• Engineering controls have been put in place to reduce oil in water concentrations, including a diffuser to enhance initial dilution upon discharged. |
| Environmentally Sustainable Development Principles | Gas from Blacktip provides a clean energy source to Darwin. The development is therefore consistent with environmentally sustainable development principles. |
| ALARP | The risks have been assessed to ALARP (see Section 7.10.1). |

# 8. MONITORING

## 8.1 Ongoing PFW chemical characterisation

The chemical characteristics of the PFW shall continue to be monitored in accordance with EPL57-02 (Table 8.1). Table 8.2 defines each of the test suites and lists the parameters included within each suite.

**Table 8.1: Summary of produced water discharge monitoring**

| Frequency | Sample location | Parameter | Analysis | EPL57-02 discharge limit |
|---|---|---|---|---|
| Prior to every discharge | PW-02 | *Enviro parameters 1 suite, including the following:* | - | - |
| | | pH | PC700 | Between 6.5-8.5 |
| | | Electrical conductivity | PC700 | - |
| | | Temperature | PC700 | - |
| | | Oil in water | TD500 | 25 mg/L (~30 ppm) |
| | | Dissolved oxygen | tba | - |
| | | Turbidity | tba | - |
| Quarterly | PW-02 | *Environment parameters 1*[1] | External laboratory analysis | As above |
| | | *Environment parameters 2*[1] | | 50 mg/L TSS |
| | | *Metals and metalloids*[1] | | 10 µg/L Cu |
| | | *Hydrocarbons*[1] | | 25 mg/L OIW |
| | | *Speciated phenols*[1] | | - |
| | | *Nutrient indicators*[1] | | - |
| Annually | PW-02 | *NORMS*[1] | External laboratory analysis | - |

[1]Test suites as defined in Table 8.2.
Source: EPL57-02

**Table 8.2: Test suites and parameters**

| Parameter | Abbrev | Unit | Analysis type | Test method[1] |
|---|---|---|---|---|
| *Environmental parameters 1* | | | | |
| pH | pH | pH | In situ *(or by external laboratory where site equipment is not yet available or as requested)* | APHA 4500-H+ B, EPA 150.1, 150.2, HACH 8156 |
| Electrical conductivity | EC | µs/cm | | APHA 2510B |
| Dissolved oxygen | DO | % saturation | | APHA 4500-O G, HACH 10360, HACH 8157, HACH 8229, HACH 8215 |
| Temperature | T | °C | | Thermometer |
| Turbidity | NTU | NTU | | 40 CFR 141 |
| Oil in Water | OIW | mg/L | | Turner TD500 (fluorescence with hexane extraction) |
| *Environmental parameters 2* | | | | |
| Biological Oxygen Demand | BOD | mg/L | | APHA 5210B, HACH 8043 |

| Parameter | Abbrev | Unit | Analysis type | Test method[1] |
|---|---|---|---|---|
| Chemical Oxygen Demand | COD | mg/L | | 40 CFR 136.3, HACH 8000 |
| Total Suspended Solids | TSS | mg/L | | APHA 2540D, AS3550.4–1990, HACH 8277 |
| Total Dissolved Solids | TDS | mg/L | | APHA 2540C, HACH 8158 |
| Total Organic Carbon | TOC | mg/L | | APHA 5310B |
| *Metals and metalloids* | | | | |
| Aluminium | Al | µg/L | Total and filtered (0.45 µg) | APHA 3111/3500 |
| Arsenic | As | µg/L | | APHA 3500-AS B or C, HACH 8013 |
| Barium | Ba | µg/L | | APHA 3111/3500 |
| Beryllium | Be | µg/L | | APHA 3111/3500 |
| Boron | B | µg/L | | APHA 3111/3500 |
| Cadmium | Cd | µg/L | | APHA 3111/3500 |
| Cobalt | Co | µg/L | | APHA 3111/3500 |
| Copper | Cu | µg/L | | 40 CFR 136, HACH 8160 |
| Chromium III | Cr III | µg/L | | APHA 3111/3500 |
| Chromium VI | Cr VI | µg/L | | APHA 3500-CR B or D |
| Iron | Fe | µg/L | | ICP-AES or ASTM D1068-method 2 |
| Lead | Pb | µg/L | | APHA 3500-Pb B or D |
| Magnesium | Mg | mg/L | | ICP-AES |
| Manganese | Mn | µg/L | | 40 CFR 136 |
| Mercury | Hg | µg/L | | UOP 938 |
| Molybdenum | Mo | µg/L | | APHA 3111/3500 |
| Nickel | Ni | µg/L | | APHA 3500-Ni D |
| Selenium | Se | µg/L | | APHA 3111/3500 |
| Tin | Sn | µg/L | | APHA 3111/3500 |
| Zinc | Zn | µg/L | | 40 CFR 136.3 or HACH 8009 |
| *Nutrient indicators* | | | | |
| Total Phosphorous | TP | µg/L | Total and filtered (0.45µm) | APHA 4500-P B.5, 4500-P F, HACH 8190, EPA 365.1, 365.3 |
| Total Nitrogen | TN | µg/L | | HACH 10208 |
| Oxidised Nitrogen | NOx | µg/L | Filtered (0.45µm) | APHA 4500-$NO_3$ F |
| Nitrate | $NO_3^-$ | µg/L | | EPA 353.2, HACH 8507 |
| Nitrite | $NO_2^-$ | µg/L | | EPA 353.2, HACH 8507 |
| Ammoniacal Nitrogen | $NH_3^-N$ | µg/L | | APHA 4500-$NH_3$ G |
| *Hydrocarbons* | | | | |
| Total Petroleum Hydrocarbons | TPH | µg/L | Total | USEPA 3510B, 8015 B |
| Polycyclic Aromatic Hydrocarbons | PAH | µg/L | | USEPA 3550B, 8270 |
| Benzene | | µg/L | | APHA 6200, 6040C, USEPA 8021B, 8260B |

| Parameter | Abbrev | Unit | Analysis type | Test method[1] |
|---|---|---|---|---|
| Toluene | | µg/L | | |
| Ethyl benzene | | µg/L | | |
| Xylene | | µg/L | | |
| Aliphatic / Aromatic Split (%) | | µg/L | | EPA (Massachusetts) 1998 |
| *Speciated phenols* | | | | |
| Phenol | | mg/L | Total | USEPA 8270 modified, EPA 420.1, HACH 8047 |
| 2-Chlorophenol | | mg/L | | |
| 2-Methylphenol | | mg/L | | |
| 4-Methylphenol | | mg/L | | |
| 2-Nitrophenol | | mg/L | | |
| Ethyl/Dimethylphenols | | mg/L | | |
| Benzoic acid | | mg/L | | |
| 2,4-Dichlorophenol | | mg/L | | |
| 2,6-Dichlorophenol | | mg/L | | |
| 4-Chloro-3-methylphenol | | mg/L | | |
| 2,4,6-Trichloropheno | | mg/L | | |
| 2,4,5-Trichlorophenol | | mg/L | | |
| 2,4-Dinitrophenol | | mg/L | | |
| 4-Nitrophenol | | mg/L | | |
| 2,3,4,5-Tetrachlorophenol | | mg/L | | |
| 4,6-Dinitro-o-cresol | | mg/L | | |
| Methyl Blue Active Substances (anionic surfactants) | MBAS | ug/L | Total | APHA 5540 |
| *NORMS* | | | | |
| Radium isotopes | | - | | APHA 7500-Ra |

[1]Source: Government of Western Australia Department of Water 2000. *Surface water sampling methods and analysis — technical appendices.* Perth, WA.
Department of Environment and Conservation (NSW) 2004. *Approved Methods for the Sampling and Analysis of Water Pollutants in New South Wales*. Sydney, NSW.

## 8.2 Dispersion Model Validation

EPL57-02 requires Eni to:

*44.7. identify a methodology for validating the near and far field Produced Formation Water dispersion modelling predictions that have been included in the document Eni Blacktip Project Produced Water Management Plan (document number 00036_DV_EX.HSE.0381.000_A03);*

*44.8. identify a schedule for implementation and completion of validation activities.*

Due to the scale of the discharge and assimilative capacity of the receiving waters, a field survey to validate the dispersion modelling within and in proximity to the mixing zone over a range of ambient current conditions has been developed. Water samples will be collected around the diffuser location during a PFW discharge event over a range of ambient current conditions. Specifically, the objective of the survey will be to validate the near field modelling predictions that the required dilution of 263 fold is achieved prior to the edge of the mixing zone over a range of ambient currents speeds.

An outline of the sampling and analysis plan for the survey is provided in this section. Upon NT EPA approval of this outline, a separate comprehensive sampling and analysis plan document will be developed that specifies detailed logistics, survey and quality control/assurance procedures, data analysis methods and reporting.

### 8.2.1 Methodology Outline

The purpose of the field survey is to:

- Validate the near field and far field dispersion models, discussed in Section 7.1; and
- Demonstrate a 50 m mixing zone radius around the diffuser will reasonably assure a 99% species protection level outside of this nominated area.

The objective is to demonstrate that a minimum dilution of 263 fold is achieved within a 50 m radius of the diffuser, although it is anticipated that on average a greater degree of dilution will be observed.

Spatial estimates of dilution during the survey will be determined through analysis of the water quality concentrations of selected analyses of water samples at multiple sites within and proximal to the mixing zone and the undiluted produced water.

In order to ensure the objectives of the survey are met, key characteristics of the receiving environment and produced water have been considered as outlined in Table 8.3. To the greatest practicable degree possible, the survey will be collected under the conditions outlined in Table 8.3. No provision has been made to monitor during stratified conditions because the water column is expected to be well mixed all year around with respect to temperature due to the large tidal range and high currents (see Section 5.4.4). Additionally, the produced water discharge events has TDS lower than seawater, and are therefore expected to be buoyant plumes upon injection into the marine waters (see Section 6.2.1). On the basis of the routine TDS monitoring since 2014 (see Figure 7.3), the produced water salinity is expected to continue to have low TDS (or salinity) relative to the ambient receiving marine waters.

**Table 8.3: Targeted characteristics for survey**

| Characteristic | Condition | Rationale |
|---|---|---|
| Produced Water | 500 $m^3$ of PFW in discharge event | A 500 $m^3$ discharge event over 7 hours is needed to carry out the survey design in 1 day over the desired range of tides and currents to meet the model validation objective. |
| Tides and Currents | Low, moderately low and high currents during a neap tide | Slack tides with low currents (~0.05-0.1 m/s) allow easiest validation of the predicted dilution from buoyancy driven dilution mechanism of both the EIS (Section 7.6.1) and this PFW Plan (Section 7.6.2) near-field modelling. It is predicted that the plume will surface within the mixing zone under low currents.<br>Moderately low currents (0.1-0.2 m/s) to validate near-field modelling predictions in terms of a mid-water column plume intersection of the mixing zone edge (Section 7.6.2).<br>Relatively high currents (~0.4-0.6 m/s) to validate near-field modelling predictions of a plume near the seabed (Section 7.6.2). |
| Season | Transitional/dry season | Seasonality and wind climate are not dominant factors in this setting. Rather tidally induced currents and the salinity differences between the produced water and the receiving ambient marine waters are the primary drivers in the plume's behaviour. However, alignment with the far field simulation inputs, namely the September transitional seasonal conditions, will be targeted (see Section 7.6.3). |

### 8.2.2 Sampling Sites

The spatial design of the field survey is comprised of the following sites and depths to be carried out during three sampling events (low, moderately low, high current speeds), as depicted in Figure 8.1:

- PFW discharge pump at the YGP on an hourly basis over the 7 hours discharge of ~500 m3 to accurately characterise the PFW discharge over the entire event;
- At an up-current reference site ~1-3 km from the diffuser to characterise the ambient background marine water quality immediately prior to or after each of the 3 monitoring events in the vicinity of the mixing zone;
- At the boundary of the mixing zone, 50 m up-current of the outfall to confirm the veracity of the up-current reference site and to make any required adjustment to derived dilution calculation at the down-current measurement sites;
- At a down-current location within the mixing zone that is dependent on tidal current speeds, whereby for a current speed of:
    - o 0.05 m/s at ~ 5-10 m down-current of the diffuser;

- o 0.1 m/s at ~15 m down-current of the diffuser;
- o 0.3 and 0.6 m/s at ~30 m down-current of the diffuser;

- At the boundary of the mixing zone, 50 m down-current of the outfall; and
- 100 m downstream of the outfall to allow estimation of further dilution beyond the mixing zone.

Targeted site locations have been identified in Table 8.4 and Figure 8.1 for different current speed scenarios on the basis of the near field modelling.

**Table 8.4: Indicative surface water sampling points**

| Location ID | Easting | Northing |
|---|---|---|
| MZ-1 (north 50 m) | 542277 | 8425607 |
| MZ-2 (east 50 m) | 542327 | 8425557 |
| MZ-3 (south 50 m) | 542277 | 8425507 |
| MZ-4 (west 50 m) | 542227 | 8425557 |
| MZ-5 (north 100 m) | 542277 | 8425657 |
| MZ-6 (south 100 m) | 542277 | 8425457 |
| IMZ- 1 (north 7 m, ~0.05 m current speed) | 542277 | 8425550 |
| IMZ- 2 (south 7 m, ~0.05 m current speed) | 542277 | 8425564 |
| IMZ- 3 (north 15 m, ~0.2 m current speed) | 542277 | 8425542 |
| IMZ- 4 (south 15 m, ~0.2 m current speed) | 542277 | 8425572 |
| IMZ- 5 (north 30 m, ~0.6 m current speed) | 542277 | 8425527 |
| IMZ- 6 (south 30 m, ~0.6 m current speed) | 542277 | 8425587 |
| PW outfall | 542277 | 8425557 |
| PW-02 – Discharge Pump (at YGP) | 546947 | 8425312 |
| Ref-1 (default 3 km north) | 542277 | 8428557 |
| Ref-2 (default 3 km south) | 542277 | 8422557 |

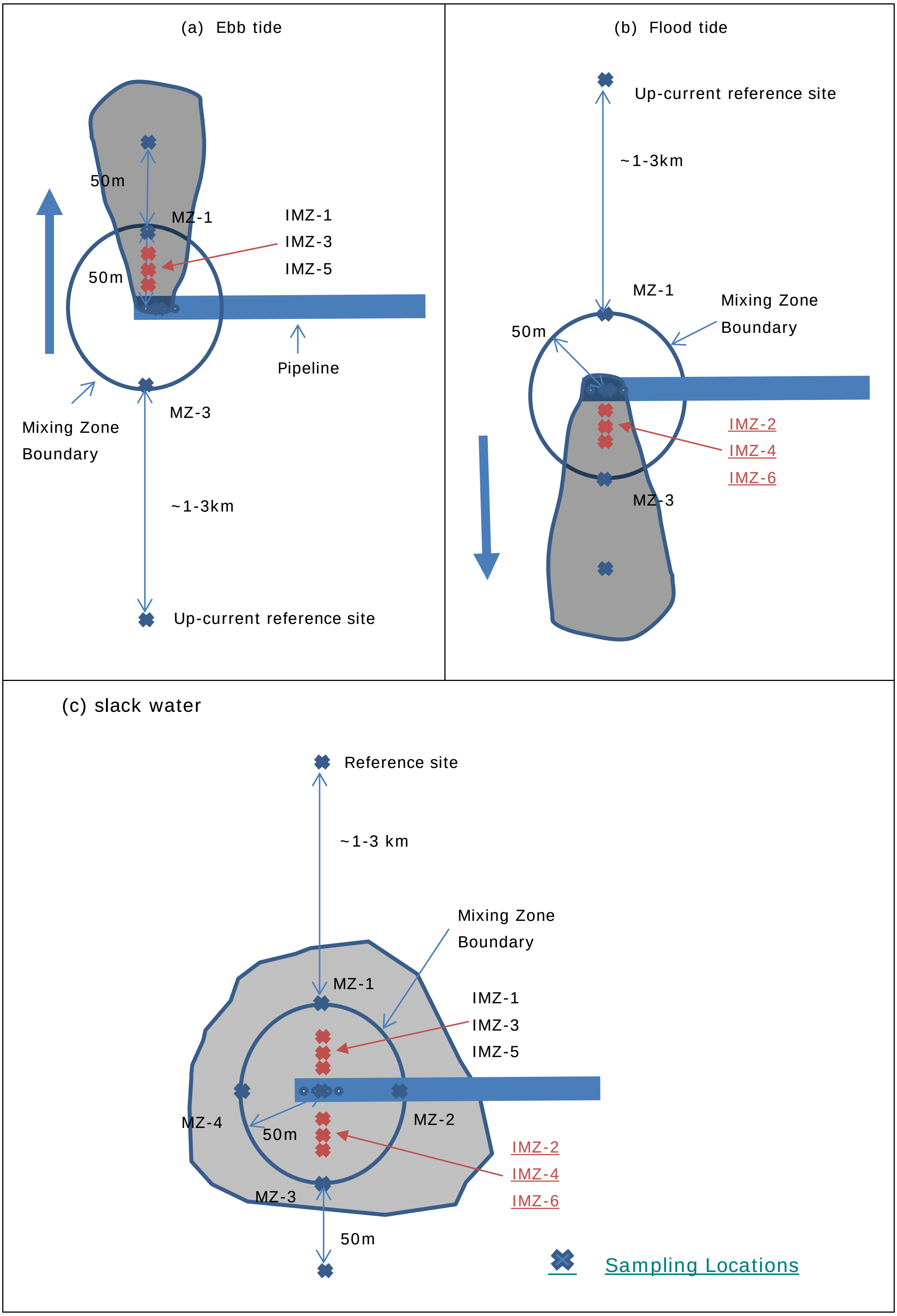



**Figure 8.1 Indicative surface water sampling sites**

The plume depth will vary as a function of the tidal current speeds with surfacing well within the mixing zone predicted for low current speeds (0.05 m/s) and the plume near the seabed for higher current speeds (0.6 m/s) (see Sections 7.6.1 and 1.1.1). To ensure samples are collected from within the plume, ideally a small vessel (<10 m) will be used to allow accurate positioning to collect meaningful samples. To facilitate accurate positioning, on the day prior to the field survey, markers will be deployed at key locations (down- and up-stream boundary of mixing zone, diffuser location). A GPS will be used to precisely locate the outfall, mixing zone boundary and sampling sites during the survey in addition to the surface markers.

## 8.3 Sample Collection Overview

All sites will have water samples collected from the surface, mid-depth and 1 m above the seabed with a niskin bottle type sampler. Hence, for the three sampling events of the 1 day field campaign the following number of samples are anticipated:

- 8 samples at the YGP discharge pump;
- 3 samples from the reference sites per sampling event, or 9 samples for the field survey; and
- 3 samples from the 4 sites in the proximity of the mixing zone (2 sites up- and down-current mixing zone boundary sites, 1 site 50 m down-current of the mixing zone edge site and 1 site within mixing zone site) yielding a total of 12 samples per sampling event (4 sites x 3 samples = 12 samples/event) or 36 samples over the survey.

Hence, a total of 53 samples will be collected across the three monitoring events of the 1 day survey. For QA/QC purposes, 5 field spits (i.e. dividing 1 sample into three portions) and 5 field triplicates (i.e. collecting three samples from 1 site and 1 depth) will also be collected. Hence, QA/QC samples will comprise 20 additional samples across the 1 day field campaign.

Additionally, a sonde or CTD with a high precision and accuracy temperature and conductivity probes will be used to collect fine scale profiles through the water column. It is anticipated that additional sites will be profiled with this instrument to provide a finer vertical and horizontal spatial characterisation the PFW plume through the mixing zone.

Indicative timing for the field survey is summarised in Table 8.5

**Table 8.5: Indicative schedule on field survey day**

| Site | Hour 0 | Hour 1 | Hour 2 | Hour 3 | Hour 4 | Hour 5 | Hour 6 | Hour 7 | Hour 8 |
|---|---|---|---|---|---|---|---|---|---|
| YGP - PFW WQ | | | | | | | | | |
| Up-Current Reference Site | | | | | | | | | |
| Mixing Zone | | | | | | | | | |
| Cumulative PFW (m3) | 0 | 63 | 126 | 189 | 252 | 315 | 378 | 441 | |
| Time of September 1 2017 | 837 | 937 | 1037 | 1137 | 1237 | 1337 | 1437 | 1537 | 1637 |
| Tidal State (Catfish Island) | | | Low Tide (4.6 m) | | | | | High Tide (6.4 m) | |
| **Monitoring Legend** | | | | | | | | | |
| PFW flow ceases | | | | | | | | | |
| PFW discharge & hourly sampling | | | | | | | | | |
| Marine water sampling - Morning #1 (low currents) | | | | | | | | | |
| Marine water sampling - Mid-day #2 (high currents) | | | | | | | | | |
| Marine water sampling - Afternoon #3 (moderate currents) | | | | | | | | | |

### 8.3.1 Analytes And Other Measurements

As the objective of the field survey is to validate the dispersion modelling, specifically to verify that the predicted required dilution of 263 fold is met within the 50 m radius mixing zone, water samples will be analysed for a subset of the analytes in Table 8.2. The analyte selection criteria was based on whether a particular analyte has the potential to allow estimation of the dilution of the PFW discharge with ambient waters in the vicinity of the mixing zone. Very conservative criteria were used to filter the list of potential analytes and other measurements, specifically:

- The PFW concentration was based on maximum concentrations measured from 2015-2016 (CPFW);
- The ambient concentration in the marine waters was assumed to be zero, except for salinity, total dissolved solids and conductivity, thereby giving an elevated dilution (CAmb); and
- The lowest analytical limits of reporting were assumed (CLoR).

The maximum dilution with these assumptions for the analytes in Table 8.2 is shown in Table 8.6 and those to be used in the field survey are noted.

**Table 8.6: Maximum potential dilution that can be estimated from analytes**

| Analyte | Units | LoR | $C_{PFW}$ | $C_{AMB}$ | Maximum D Estimate | Include in Survey |
|---|---|---|---|---|---|---|
| Physico-Chemical | | | | | | |
| Salinity | psu | 0.1 | 5 | 34 | 289 | Yes |
| Conductivity | mS/cm | 0.1 | 3 | 25 | 219 | Yes |
| Total Dissolved Solids | mg/L | 5 | 1,000 | 35,000 | 6,799 | Yes |
| Total Suspended Solids | mg/L | 1 | 1,000 | 0 | 999 | Yes |
| Turbidity | NTU | 0.1 | 30 | 0 | 299 | Yes |
| Nutrients | | | | | | |
| Total Organic Carbon | mg/L | 1 | 1,500 | 0 | 1,499 | Yes |
| Total Oxidised Nitrogen | mg/L | 0.01 | 0.01 | 0 | 0 | No |
| Ammoniacal Nitrogen | mg/L | 0.01 | 2.5 | 0 | 249 | Yes |
| Total Nitrogen | mg/L | 0.05 | 3 | 0 | 59 | No |
| Metals | | | | | | |
| Antimony (Sb) | µg/L | 0.5 | 1 | 0 | 1 | No |
| Arsenic (As) | µg/L | 0.5 | 2 | 0 | 3 | No |
| Barium (Ba) | µg/L | 1 | 1,5000 | 0 | 14,999 | Yes |
| Beryllium (Be) | µg/L | 0.1 | 0.5 | 0 | 4 | No |
| Boron (B) | µg/L | 100 | 300 | 0 | 2 | No |
| Cadmium (Cd) | µg/L | 0.2 | 0.5 | 0 | 1.5 | No |
| Chromium (Cr) | µg/L | 0.5 | 10 | 0 | 19 | No |
| Cobalt (Co) | µg/L | 0.2 | 2 | 0 | 9 | No |
| Copper (Cu) | µg/L | 1 | 2 | 0 | 1 | No |
| Iron | µg/L | 5 | 44,000 | 0 | 8799 | Yes |
| Lead (Pb) | µg/L | 0.2 | 10 | 0 | 49 | No |
| Manganese (Mn) | µg/L | 0.5 | 11,000 | 0 | 21,999 | Yes |

| Analyte | Units | LoR | $C_{PFW}$ | $C_{AMB}$ | Maximum D Estimate | Include in Survey |
|---|---|---|---|---|---|---|
| Mercury (Hg) | µg/L | 0.04 | 1 | 0 | 24 | No |
| Molybdenum (Mo) | µg/L | 0.1 | 3 | 0 | 29 | No |
| Nickel (Ni) | µg/L | 0.5 | 100 | 0 | 199 | Yes |
| Selenium (Se) | µg/L | 2 | 3 | 0 | 0.5 | No |
| Tin (Sn) | µg/L | 5 | 8 | 0 | 0.6 | No |
| Zinc (Zn) | µg/L | 5 | 2,000 | 0 | 399 | Yes |
| Other | | | | | | |
| Phenol | ug/L | 0.1 | 500 | 0 | 4,999 | Yes |
| Total Petroleum Hydrocarbons | µg/L | 50 | 35,000 | 0 | 699 | Yes |
| Volatile TPH C6 to C9 | µg/L | 20 | 12,000 | 0 | 599 | Yes |
| Benzene | µg/L | 1 | 1,000 | 0 | 999 | Yes |
| Toluene | µg/L | 2 | 2,500 | 0 | 1,249 | Yes |
| Ethylbenzene | µg/L | 2 | 500 | 0 | 249 | Yes |
| Xylene | µg/L | 2 | 2500 | 0 | 1249 | Yes |
| Polycyclic Aromatic Hydrocarbons | µg/L | 2 | 60 | 0 | 29 | No |

### 8.3.2 Near-Field Model Validation Method

Analyte concentrations of the produced water at the YPG sampling point ($C_{PFW}$), background ambient concentrations at the reference site(s) ($C_{Amb}$) and down-current measurements within, at the boundary and 50 m downstream of the boundary of the mixing zone ($C_{DC}$) will be used to detect the presence of the plume within the water column (surface, mid-depth, near-bottom). If analytes are detected above background concentrations due to the PFW discharge (except for TDS, conductivity and salinity which will be lower than ambient), then the dilution at that location and depth will be estimated as $D=(C_{PFW}-C_{DC})/(C_{DC}-C_{Amb})$. The resultant dilution estimates will be compared across the various analytes and measurements for reconciliation across these various parameters at each location and depth. Particular emphasis will be placed on reconciling the dilution estimates from the salinity profiles, as it is anticipated that this measurement will provide the greatest spatial granularity of dilution estimates both vertically and horizontally.

The dilution estimates from each of the three sampling events will then be directly compared to the near-field modelling predictions in Section 1.1.1 for validation.

### 8.3.3 Other Constraints

In addition to planning for the appropriate environmental conditions, there are also a number of operational and logistical constraints that have been considered:

- The field campaign will be carried out by a marine scientist with at least 5 years' experience.
- Ideally, the survey will be conducted with a full batch of water to increase the probability of achieving steady state discharge and ensure sufficient duration to collect all samples (>450 $m^3$ discharge event, >7 hours). This must also coincide with produced water within the discharge limits. Currently, produced water is discharged on average several times per month. The availability of a full batch of water is difficult to predict, and to retain spare capacity to handle plant fluctuations, operators rarely allow the produced water tank to fill completely. It is also possible for a slug of water to unexpectedly enter the system and cause the entire batch to require further treatment. However, once a date has been identified based on environmental variables and vessel availability, in the lead up to the survey date it is possible for the plant to maintain a minimum level in the tank.
- Monitoring will be targeted after at least 1 hour of discharge, with the aim to discharge over a period of time to characterise a range of current speeds.
- The personnel on the vessel be fully aware of when the discharge occurs in order to collect all required samples while the PFW is exiting the outfall. Satellite phones will be used to maintain communications between the vessel and the YGP.
- The volume of the outfall pipeline from YGP to the outfall is estimated as 22 $m^3$. Given the discharge rate of 63 $m^3$/hr, the produced water is expected to reach the outfall within 30 minutes.
- Inclement weather can preclude vessel activity, however this should not be a problem in the transition season slated for the field campaign around September 2017.

Table 8.7 ranks environmental and operational constraints according to their ability to predict and control.

**Table 8.7: Environmental and operational constraints**

| | Predictability | Ability to control/change |
|---|---|---|
| **Environmental considerations** | | |
| Tide | High | Low |
| Currents | Medium/High | Low |
| Season | High | Low |
| **Operational considerations** | | |
| Water production | Low | Low |
| Tank level | Medium | Medium |
| Communications | High | High |
| Vessel availability | High | Medium |
| Inclement weather | Medium/High | Low |

### 8.3.4 Schedule

Once this report is accepted by NT EPA, a detailed sampling and analysis plan will be developed and sampling undertaken in the 2017 late dry – transition season, subject to operational and logistical constraints. Laboratory results should be available within 2-4 weeks. A survey report will follow in a further 4 weeks.

Following availability of the model validation results and agreement of the mixing zone, Eni will review its PW monitoring regime.

**Table 8.8: Sampling schedule**

| Activity | Indicative timeframe |
|---|---|
| Development of a detailed sampling and analysis plan | 4 weeks from acceptance |
| Sample collection | 1 day |
| Laboratory analysis and reporting | 2-4 weeks |
| Submission of survey report and confirmation of mixing zone. | 4 weeks |
| Completion of validation exercise | 31 December 2017 |

## 8.4 Ongoing Surface Water Monitoring

EPL57-02 requires Eni to:

*44.5. identify surface water monitoring points where the 99% level of species protection trigger values specified in Table 3.4.1 of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000) will be applied;*

*44.6. identify a schedule for monitoring of the surface water monitoring points identified as part of condition 44.5;*

As described in Section 4.3.3, the projected produced water production is relatively constant from 2017-2019. Hence, on the provision of success field validation campaign and resultant validation of the model predictions, the next field campaign is proposed for 2020 when the PFW production volumes are projected to increase substantially. The monitoring campaign and model validation for the 2020 campaign will be conducted with the same methodology described in this plan. See Section 8.2 for monitoring locations.

Should the volumes discharged, water quality or discharge regime change substantially from current projections, the ongoing surface water monitoring and mixing zone will be reviewed.

## 8.5 Performance Improvement

EPL57-02 requires Eni to:

*44.9. identify actions that will be completed to ensure that wastewater discharged from authorised discharge point PW-01 achieves the trigger value specified in Table 3 (6 mg/L), when measured at monitoring site code PW-02; and*

*44.11. identify a schedule for completion of actions identified as part of condition 44.9.*

Eni has implemented the following measures to improve water quality:

- Installation of the CETCO filter system for water polishing;
- Reduced injection of corrosion inhibitor at the WHP. Corrosion Inhibitor is necessary for protecting the pipeline, however, as it is a surfactant chemical it also contributes to the formation of an oil in water emulsion which reduces the effectiveness of the treatment system. In the past, acid has been added to break up the emulsion and enable separation of hydrocarbons from water. A reduction in corrosion inhibitor injection should reduce the formation of emulsion and lead to more effective removal of oil and lower the oil in water content of PFW discharge.
- Eni also undertakes ongoing monitoring for impacts from produced water discharge, which has detected no impacts to sediments or biota. Refer to the marine monitoring results discussed in Section 6.3 and latest results attached in Appendix B.
- In addition to the above, Eni will undertake validation of the 50 m mixing zone as outlined in Section 8.2.1 and as per the schedule presented in Section 8.3.4. If the predicted PEC at the 50 m radius around the diffuser is not satisfied, then additional measures will be recommended.
- While the TDS in the past 12 months has remained at 189-2,866 mg/L, it is noted that in the past the TDS has been measured at 94,600 mg/L. At current PFW volumes, the TDS is not expected to increase significantly and therefore the salinity used in the current models are considered appropriate. However, should the TDS increase above 20,000 mg/L on a regular basis, then re-modelling of the initial dilution and a field campaign to validate the updated prediction will be carried out (see Section 6.2.1). Similarly, should the chemical composition of the PFW change in a manner that increase the risk of non-compliance of the mixing zone, then Eni will evaluate technical preventative controls (e.g. treatment) and/or mitigation measures (e.g. timing of discharges) at that time.

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# APPENDICES

# APPENDIX A:

# SUMMARY OF PRODUCED WATER MONITORING RESULTS 2010-2016

**Table A.1: Chemical composition determined by annual produced water studies (Ref. [19], [21], [22], [23])**

| | | | Concentration | | | | | | ANZECC trigger value (99% protection)* | Dilution to achieve ANZECC values | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chemical Parameter** | **LOD** | **Units** | **Oct 2010** | **Feb 2012** | **Sep 2013** | **2015** | **May 2016[6]** | **Dec 2016[6]** | | **Max[7]** | **2015[8]** |
| pH | 0.1 | - | 5.14 | 5.5 | 6.05 | 7.33 | 7.12 | 7.59 | 8-8.4[9] [10] | **1451**[11] | 4.5 |
| Conductivity | 0.1 | mS/cm 18°C | 8.3 | 14.1 | 148.6 | 3.37 | 0.42 | 0.81 | - | - | - |
| Total Dissolved Solids | 5 | mg/L | 4,122 | 6,480 | 94,600 | 1,090 | 201 | 259 | - | - | - |
| Total Suspended Solids | 5 | mg/L | 6 | 121 | 166 | 91 | 48 | 844 | - | - | - |
| Turbidity | 0.1 | NTU | 15 | 1,900 | 0.1 | 6.5 | 28 | 9.5 | 1-20[12] | 95 | 0.3 |
| Total Organic Carbon | 1 | mg/L | 460 | 170 | 1,100 | 1,500 | 130 | 940 | - | - | - |
| Total Oxidised Nitrogen | 0.01 | mg/L | - | - | <LoD | <0.005 | <0.005 | 0.007 | 0.08[9] | - | - |
| Ammoniacal Nitrogen | 0.01 | mg/L | 5 | 11 | 69 | 2.2 | 0.65 | 0.01 | 0.5[313] | **138** | 4.4 |
| Total Nitrogen | 0.05 | mg/L | 5 | 16 | 69 | 7.7 | 1.2 | 0.2 | 0.1[9] | | |
| Soluble Metals | | | | | | | | | - | - | - |
| Antimony (Sb) | 1 | µg/L | - | - | 1 | - | - | - | ID | - | - |
| Arsenic (As) | 1 | µg/L | 1 | 1 | 2 | <1 | <1 | <1 | ID | - | - |
| Barium (Ba) | 10 | µg/L | 18,450 | 37,000 | 170,000 | 15,000 | 260 | 580 | - | - | - |
| Beryllium (Be) | 10 | µg/L | - | - | <LoD | <0.5 | <0.5 | <0.5 | ID | - | - |
| Boron (B) | 10 | µg/L | 781 | 1,000 | 10,000 | 270 | 86 | 100 | ID | - | - |
| Cadmium (Cd) | 2 | µg/L | - | - | <LoD | <0.1 | 0.4 | 0.4 | 0.70[13] | - | - |
| Chromium (Cr) | 10 | µg/L | - | - | <LoD | 1 | <1 | 9 | 7.70[13] | 1.2 | 0.1 |
| Cobalt (Co) | 10 | µg/L | 5 | - | <LoD | 2 | <1 | 1 | 0.005[13] | **1000** | 400 |
| Copper (Cu) | 10 | µg/L | 1 | 10 | <LoD | <1 | <1 | <1 | 0.30[13] | 33 | - |
| Iron | 10 | µg/L | - | - | - | 44,000 | 2,500 | 4,000 | ID | - | - |
| Lead (Pb) | 10 | µg/L | - | - | <LoD | 7 | <1 | <1 | 2.20[13] | 3.3 | 3.2 |
| Manganese (Mn) | 10 | µg/L | 2,200 | 1,900 | 520,000 | 11,000 | 67 | 150 | ID | - | - |
| Mercury (Hg) | 0.1 | µg/L | - | - | <LoD | 0.84 | 0.6 | 0.6 | 0.10[13] | 8.4 | 8.4 |
| Molybdenum (Mo) | 1 | µg/L | - | - | <LoD | <LoD | 1 | 3 | ID | - | - |
| Nickel (Ni) | 10 | µg/L | 47 | - | 20 | 39 | <1 | 81 | 7.00[13] | 11.6 | 5.6 |
| Selenium (Se) | 1 | µg/L | - | - | <LoD | <LoD | <LoD | <LoD | ID | - | - |
| Tin (Sn) | 10 | µg/L | 52 | - | <LoD | <1 | <1 | <1 | ID | - | - |

[6] From quarterly 2016 PFW monitoring programme.

[7] The dilution required to achieve ANZECC trigger values based on the maximum concentration measured across the four years except for pH which is based on the minimum. Values highlighted in light red shading.

[8] The dilution required to achieve ANZECC trigger values based on the concentration measured in 2015.

[9] From Table 3.3.4 of the ANZECC 2000 guidelines Volume 1. Not a toxicant trigger value, for information only.

[10] Note that dilution calculation for pH do not consider the high buffering capacity of seawater that acts rapidly in a chemical manner (not dilution manner) to equilibrate the pH of PFW discharge to ambient marine pH levels.

[11] Red bold demarcates a maximum dilution in excess of 100 fold required and warrants further consideration in section 7.8.

[12] From Table 3.3.5 of the ANZECC 2000 guidelines Volume 1. Not a toxicant trigger value, for information only.

[13] From Table 3.4.1 of the ANZECC 2000 guidelines Volume 1. Toxicant trigger values for consideration in mixing zone analysis.

| | | | Concentration | | | | | | ANZECC trigger value (99% protection)* | Dilution to achieve ANZECC values | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chemical Parameter** | **LOD** | **Units** | **Oct 2010** | **Feb 2012** | **Sep 2013** | **2015** | **May [6]2016** | **Dec 2016[6]** | | **Max[7]** | **2015[8]** |
| Zinc (Zn) | 1 | µg/L | 2,850 | - | 40 | 29 | 2,006 | 42 | 7.00[13] | **407** | 4.1 |
| Speciated Phenols | - | | - | - | - | | | | - | - | - |
| Phenol | 0.1 | mg/L | 4 | - | <LoD | 0.44 | 0.089 | 0.25 | 0.27[13] | 14.8 | 1.6 |
| 2-Chlorophenol | 0.1 | mg/L | - | - | <LoD | <0.01 | <0.001 | <0.01 | - | - | - |
| 2-Methylphenol | 0.1 | mg/L | 3 | - | <LoD | 0.78 | <0.005 | <0.05 | - | - | - |
| 4-Methylphenol | 0.1 | mg/L | 3 | - | <LoD | <0.02 | 0.14 | 0.54 | - | - | - |
| 2-Nitrophenol | 0.1 | mg/L | - | - | <LoD | <0.01 | 0.14 | 0.43 | - | - | - |
| Ethyl/Dimethylphenols | 0.1 | mg/L | 2 | - | <LoD | <0.01 | <0.001 | <0.01 | - | - | - |
| Benzoic acid | 0.1 | mg/L | - | - | <LoD | - | | | - | - | - |
| 2,4-Dichlorophenol | 0.1 | mg/L | - | - | <LoD | <0.01 | <0.001 | <0.01 | - | - | - |
| 2,6-Dichlorophenol | 0.1 | mg/L | - | - | <LoD | <0.01 | <0.001 | <0.01 | - | - | - |
| 4-Chloro-3-methylphenol | 0.1 | mg/L | - | - | <LoD | 0.78 | <0.001 | <0.01 | - | - | - |
| 2,4,6-Trichlorophenol | 0.1 | mg/L | - | - | <LoD | <0.01 | <0.001 | <0.01 | - | - | - |
| 2,4,5-Trichlorophenol | 0.1 | mg/L | - | - | <LoD | <0.01 | <0.001 | <0.01 | - | - | - |
| 2,4-Dinitrophenol | 0.1 | mg/L | - | - | <LoD | <0.1 | <0.02 | <0.01 | - | - | - |
| 4-Nitrophenol | 0.1 | mg/L | - | - | <LoD | <0.2 | <0.02 | <0.2 | - | - | - |
| 2,3,4,5-Tetrachlorophenol | 0.1 | mg/L | - | - | <LoD | <0.01 | <0.001 | <0.2 | - | - | - |
| 4,6-Dinitro-o-cresol | 0.1 | mg/L | - | - | <LoD | - | - | - | - | - | - |
| Total Petroleum Hydrocarbons | 100 | µg/L | 1,647 | 2,000 | 1,000 | - | 8,700 | 33,120 | ID | - | - |
| Volatile TPH C6 to C9 | 100 | µg/L | - | 1,600 | 2 | 12,000 | 4,400 | 5,500 | - | - | - |
| BTEX (µg/L) | | | | | | | | | - | - | - |
| Benzene | 0.25 | µg/L | 1,560 | 600 | 160 | 860 | 420 | 460 | 500[13] | 3.1 | 1.7 |
| Toluene | 0.25 | µg/L | 1,623 | 710 | 160 | 2,400 | 1,000 | 1,000 | ID | - | - |
| Ethylbenzene | 0.25 | µg/L | 97 | 42 | 7.6 | 410 | 140 | 140 | ID | - | - |
| Xylene | 0.25 | µg/L | 587 | 250 | 3 | 2,350 | 670 | 920 | ID | - | - |
| Polycyclic Aromatic Hydrocarbons | 7 | µg/L | - | - | <LoD | - | 53 | 19 | 50[13] | 1.0 | - |
| Aliphatic / Aromatic Split (%) | 1 | % | 29% Aliphatic / 71% Aromatic | 60% Aliphatic / 40% Aromatic | 100% Aliphatic | - | - | - | - | - | - |
| Surfactants - MBAS | 50 | µg/L | - | - | 2100 | <0.1 | <0.1 | <0.5 | - | - | - |

*LOD = Limit of Detection, ID = Insufficient Data, NM = Not measured.*

**Table A.2: Ecotoxicity determined by annual produced water studies (Ref. [19], [21], [22])**

| Bioassay | Protocol | Reference | Test Species | Temperature | Year | EC10 (%) | EC50 (%) | NOEC (%) | LOEC (%) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Microtox | WIENV-30 | Microbics 1992 | *V. fischeri* | 25°C | 2010 | 17.5 | 54.6 | 6.3 | 12.5 |
| | | | | | 2012 | 0.9 | 5.9 | <1.6 | 1.6 |
| | | | | | 2013 | 21.8 | 37.3 | 12.5 | 25 |
| Microalgae Cell Division | WIENV-45 | Stauber et al. 1994 | *I. galbana* | 25°C | 2010 | 1.6 | 4.8 | 0.8 | 1.6 |
| | | | | | 2012 | 2.9 | 14.6 | <3.1 | 3.1 |
| | | | | | 2013 | 8.3 | 14.3 | 6.3 | 12.5 |
| Sea Urchin Fertilisation | WIENV-99 | Simon et al. 1997 | *H. erythrogramma* | 25°C | 2010 | 3.0 | 8.0 | 3.1 | 6.3 |
| | | | | | 2012 | 2.1 | 6.5 | <3.1 | 3.1 |
| | | | | | 2013 | 3.4 | 5.1 | 0.8 | 1.6 |
| Mussel Larvae Development | WIECX-23 | ASTM E724-98 | *M. edulis* | 25°C | 2010 | 4.3 | 11.2 | 3.1 | 6.3 |
| | | | | | 2012 | 2.6 | 4.8 | 1.6 | 3.1 |
| | | | | | 2013 | 5.1 | 7.8 | 3.1 | 6.3 |
| Copepod Development | WIENV-62 | USEPA 1002.0 | *G. imparipes* | 25°C | 2010 | 1.9 | 4.7 | 1.2 | 3.7 |
| | | | | | 2012 | 3.4 | 4.7 | 3.1 | 6.3 |
| | | | | | 2013 | 3.2 | 7.9 | 3.1 | 6.3 |
| Fish Larvae Development | WIENV-64 | USEPA 1004.0 | *P. auratus* | 25°C | 2010 | 5.6 | 24.8 | 3.7 | 11 |
| | | | | | 2012 | 1.5 | 4.6 | <1.6 | 1.6 |
| | | | | | 2013 | 3.5 | 11.5 | 6.3 | 12.5 |
| Prawn Survival | WIENV-00 | USEPA 1004.0 | *P. monodon* | 25°C | 2010 | 16.9 | 33.1 | 12.5 | 25 |
| | | | | | 2012 | 2.6 | 11.2 | 6.3 | 12.5 |
| | | | | | 2013 | 3.0 | 11.1 | 3.1 | 6.3 |

**Table A.3: Bioaccumulation results from annual produced water studies (Ref. [19], [21], [22])**

| | Chemical Parameter | | | | Chemical Parameter | Concentration of Contaminant in Mussel Tissue after 28 days exposure and 28 days depuration (mg/kg, dry weight) 1 | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Control (seawater) | 0.1% Treatment 2 | 1% Treatment 3 |
| **2010** | - | - | - | - | Arsenic | 13 ± 0 | 13 ± 0 | 13 ± 1 |
| | - | - | - | - | Barium | 0.2 ± 0.1 | 0.2 ± 0.1 | 0.3 ± 0.1 |
| | - | - | - | - | Cobalt | 0.4 ± 0.1 | 0.5 ± 0.1 | 0.5 ± 0.1 |
| | - | - | - | - | Copper | 5 ± 1 | 5 ± 1 | 5 ± 2 |
| | - | - | - | - | Manganese | 4 ± 1 | 5 ± 1 | 5 ± 1 |
| | - | - | - | - | Nickel | 1.1 ± 0.6 | 0.7 ± 0.1 | 0.7 ± 0.1 |
| | - | - | - | - | Tin | 0.6 ± 0.1 | 0.6 ± 0.1 | 0.4 ± 0.1 |
| | - | - | - | - | Zinc | 267 ± 25 | 280 ± 0 | 303 ± 6 |
| | **Chemical Parameter** | **Concentration of Contaminant in Mussel Tissue after 30 days exposure (mg/kg, dry weight) 1** | | | **Chemical Parameter** | **Concentration of Contaminant in Mussel Tissue after 30 days exposure and 30 days depuration (mg/kg, dry weight) 1** | | |
| | | **Control (seawater)** | **0.1% Treatment 2** | **1% Treatment 3** | | **Control (seawater)** | **0.1% Treatment 2** | **1% Treatment 3** |
| **2012** | Arsenic | 2.6 ± 0.35 | 2.6 ± 0.30 | 3.0 ± 0.25 | Arsenic | 2.2 ± 0.17 | 2.5 ± 0.15 | 2.5 ± 0.51 |
| | Barium | 0.023 ± 0.006 | 0.073 ± 0.011 | 0.49 ± 0.025 | Barium | 0.027 ± 0.006 | 0.05 ± 0 | 0.033 ± 0.006 |
| | Copper | 1.12 ± 0.18 | 0.93 ± 0.25 | 1.00 ± 0.17 | Copper | 0.93 ± 0.15 | 1.40 ± 0.46 | 1.54 ± 0.69 |
| | Manganese | 1.53 ± 0.76 | 2.17 ± 1.03 | 4.10 ± 1.06 | Manganese | 0.76 ± 0.30 | 1.93 ± 0.21 | 1.36 ± 0.38 |
| | **Chemical Parameter** | **Concentration of Contaminant in Mussel Tissue after 30 days exposure (mg/kg, dry weight) 1** | | | **Chemical Parameter** | **Concentration of Contaminant in Mussel Tissue after 30 days exposure and 30 days depuration (mg/kg, dry weight) 1** | | |
| | | **Control (seawater)** | **0.1% Treatment 2** | **1% Treatment 3** | | **Control (seawater)** | **0.1% Treatment 2** | **1% Treatment 3** |
| **2013** | Antimony | <LoD | <LoD | <LoD | Antimony | <LoD | <LoD | <LoD |
| | Arsenic | 3.1 ± 0.06 | 2.9 ± 0.15 | 2.9 ± 0.15 | Arsenic | 2.9 ± 0.1 | 2.67 ± 0.21 | 2.9 ± 0.17 |
| | Barium | 0.08 ± 0.02 | 0.31 ± 0.04 | 9.8 ± 1.1 | Barium | 0.06 ± 0.02 | 0.09 ± 0.03 | 6.47 ± 0.95 |
| | Beryllium | <LoD | <LoD | <LoD | Beryllium | <LoD | <LoD | <LoD |
| | Boron | 5.17 ± 0.38 | 4.9 ± 0.1 | 4.7 ± 0 | Boron | 4.73 ± 0.21 | 4.7 ± 0.1 | 4.83 ± 0.06 |
| | Cadmium | 0.23 ± 0.12 | 0.20 ± 0.02 | 0.19 ± 0.02 | Cadmium | 0.24 ± 0.03 | 0.24 ± 0.02 | 0.24 ± 0.04 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2013 | Chromium | 0.12 ± 0.02 | 0.12 ± 0.03 | 0.08 ± 0.02 | Chromium | 0.11 ± 0.01 | 0.13 ± 0.02 | 0.13 ± 0.01 |
| | Cobalt | 0.07 ± 0.01 | 0.07 ± 0.01 | 0.05 ± 0.01 | Cobalt | 0.08 ± 0.01 | 0.08 ± 0.01 | 0.09 ± 0.02 |
| | Copper | 0.79 ± 0.01 | 0.76 ± 0.6 | 0.72 ± 0.13 | Copper | 0.75 ± 0.11 | 0.67 ± 0.05 | 0.70 ± 0.05 |
| | Lead | 0.15 ± 0.07 | 0.11 ± 0.04 | 0.07 ± 0.015 | Lead | 0.10 ± 0.04 | 0.10 ± 0.02 | 0.07 ± 0 |
| | Manganese | 0.83 ± 0.09 | 1.05 ± 0.18 | 1.97 ± 0.05 | Manganese | 0.68 ± 0.12 | 0.65 ± 0.04 | 1.43 ± 0.21 |
| | Mercury | 0.01 ± 0.01 | 0.01 ± 0 | 0.01 ± 0 | Mercury | 0.01 ± 0.01 | 0.02 ± 0.01 | 0.01 ± 0 |
| | Molybdenum | 0.16 ± 0.01 | 0.14 ± 0.01 | 0.11 ± 0.02 | Molybdenum | 0.13 ± 0.01 | 0.13 ± 0.02 | 0.13 ± 0.01 |
| | Nickel | 0.21 ± 0.03 | 0.18 ± 0.02 | 0.18 ± 0.05 | Nickel | 0.23 ± 0.02 | 0.23 ± 0.04 | 0.28 ± 0.05 |
| | Selenium | 1.13 ± 0.06 | 1.1 ± 0 | 1.00 ± 0.08 | Selenium | 0.98 ± 0.02 | 0.96 ± 0.05 | 0.96 ± 0.13 |
| | Tin | 0.08 ± 0.04 | 0.05 ± 0.02 | 0.04 ± 0 | Tin | 0.07 ± 0.01 | 0.05 ± 0.02 | 0.05 ± 0.01 |
| | Zinc | 42.3 ± 8.5 | 39.7 ± 2.5 | 32.3 ± 8.5 | Zinc | 39.7 ± 5.1 | 37.3 ± 5.1 | 50.0 ± 3.6 |

Note: BTEXs and TPH were below limit of detection

**Table A.4: Biodegradation results from annual produced water studies (Ref. [19], [21], [22])**

| | Chemical Parameter | Sampling Interval | | | | | |
|---|---|---|---|---|---|---|---|
| | | Initial | Day 0 | Day 1 | Day 2 | Day 6 | Day 10 |
| 2010 | **Microtox EC10 (%)** | 17.4 | 29.6 | 51.0 | 67.1 | 77.2 | >80.0 |
| | **BTEX (µg/L)** | | | | | | |
| | Benzene | 1560 | 1142 | 70 | 6 | 1 | - |
| | Toluene | 1623 | 1641 | 105 | 13 | 3 | - |
| | Ethylbenzene | 97 | 134 | 9 | 2 | 1 | - |
| | Xylenes | 587 | 862 | 52 | 5 | - | - |
| | Relative BTEX remaining (%) | 100.0 | 97.7 | 6.1 | 0.7 | 0.1 | - |
| | **Volatile TPH C6 to C9 (µg/L)** | - | - | - | - | - | - |
| | Relative C6 to C9 remaining (%) | - | - | - | - | - | - |
| | **TPH - gravimetric (µg/L)** | 1647 | 900 | 570 | 120 | - | - |
| | Relative TPH remaining (%) | 100.0 | 54.6 | 34.6 | 7.3 | - | - |
| | **TPH - speciated (µg/L)** | | | | | | |
| | Undecane | 6.0 | 2.3 | - | - | - | - |
| | Dodecane | 16.1 | 6.6 | - | - | - | - |
| | Tridecane | 26.8 | 11.6 | - | - | - | - |
| | Tetradecane | 34.0 | 15.3 | - | - | - | - |
| | Pentadecane | 28.0 | 13.1 | - | - | - | - |
| | Hexadecane | 27.5 | 13.1 | - | - | - | - |
| | Heptadecane | 26.1 | 12.4 | - | - | - | - |
| | Pristane | 9.7 | 4.8 | - | - | - | - |
| | Octadecane | 21.9 | 11.0 | - | - | - | - |
| | Phytane | 5.2 | 2.7 | - | - | - | - |
| | Nonadecane | 19.6 | 9.8 | - | - | - | - |
| | Eicosane | 17.0 | 9.0 | - | - | - | - |
| | Heneicosane | 15.5 | 8.4 | 0.1 | - | - | - |
| | Docosane | 13.6 | 7.4 | 0.3 | - | - | - |
| | Tricosane | 11.5 | 6.2 | 0.8 | - | - | - |
| | Tetracosane | 7.8 | 4.3 | 1.0 | - | - | - |
| | Pentacosane | 6.2 | 3.4 | 1.0 | - | - | - |
| | Hexacosane | 3.8 | 2.1 | 0.9 | - | - | - |
| | Heptacosane | 2.5 | 1.4 | 0.7 | - | - | - |
| | Octacosane | 1.1 | 0.6 | 0.5 | - | - | - |
| | Nonacosane | 0.9 | 0.4 | 0.4 | - | - | - |
| | Relative n-alkane remaining (%) * | 100.0 | 48.5 | 1.8 | - | - | - |

| | Chemical Parameter | Sampling Interval | | | | | |
|---|---|---|---|---|---|---|---|
| | | Day 0 | Day 1 | Day 2 | Day 5^ | Day 7 | Day 14 |
| 2012 | **Microtox EC50 (%)** | 5.88 | 8.95 | 13.2 | 7.96 | 16.55 | 19.46 |
| | **BTEX (µg/L)** | | | | | | |
| | Benzene | 600 | 0.00 | - | - | - | - |
| | Toluene | 710 | 1.1 | - | - | - | - |
| | Ethylbenzene | 42 | 0.1 | - | - | - | - |
| | Xylenes | 250 | 1.8 | 1 | 1.1 | - | - |
| | Relative BTEX remaining (%) | 100% | 0.19% | 0.06% | 0.06% | 0% | 0% |
| | **TPH - gravimetric (µg/L)** | 2000 | 380 | 380 | 630 | 400 | 200 |
| | Relative TPH remaining (%) | 100% | 19% | 19% | 31.5% | 20% | 10% |
| | **TPH - speciated (µg/L)** | | | | | | |
| | Undecane | 44.0 | - | - | - | - | - |
| | Dodecane | 141.8 | - | - | - | - | - |
| | Tridecane | 179.7 | 19.6 | 12.9 | 18.6 | 9.4 | 3.7 |
| | Tetradecane | 201.7 | 28.9 | 22.5 | 31.3 | 24.9 | 12.1 |
| | Pentadecane | 232.5 | 35.5 | 28.6 | 39.7 | 37.7 | 19.1 |
| | Hexadecane | 197.5 | 38.0 | 35.5 | 43.5 | 46.0 | 24.5 |
| | Heptadecane | 183.8 | 40.1 | 43.0 | 49.8 | 51.3 | 27.8 |
| | Octadecane | 159.1 | 35.2 | 38.5 | 45.5 | 49.2 | 26.4 |
| | Nonadecane | 150.1 | 32.6 | 34.1 | 43.4 | 43.9 | 24.3 |
| | Eicosane | 124.7 | 28.8 | 31.5 | 43.6 | 38.9 | 21.3 |
| | Heneicosane | 111.9 | 26.5 | 26.4 | 44.2 | 32.6 | 18.5 |
| | Docosane | 91.5 | 24.0 | 25.4 | 50.7 | 29.6 | 15.9 |
| | Tricosane | 75.1 | 21.8 | 23.2 | 54.4 | 25.7 | 13.9 |
| | Tetracosane | 46.0 | 17.0 | 19.6 | 53.2 | 23.1 | 11.8 |
| | Pentacosane | 31.7 | 13.3 | 14.5 | 43.6 | 23.8 | 10.3 |
| | Hexadecane | 18.1 | 8.5 | 9.0 | 31.6 | 19.8 | 7.3 |
| | Tetracosane | 8.8 | 3.7 | 6.5 | 19.6 | 24.1 | 6.8 |
| | Nonadecane | 1.9 | 1.5 | 3.6 | 12.2 | 19.9 | 6.2 |
| | Relative n-alkane remaining (%) * | 100% | 18.8% | 18.8% | 31.3% | 25% | 12.5% |
| | **PAHs** | | | | | | |
| | Total PAH | - | - | - | - | - | - |

| | Chemical Parameter | Sampling Interval | | | | | |
|---|---|---|---|---|---|---|---|
| | | Day 0 | Day 1 | Day 2 | Day 5^ | Day 7 | Day 14 |
| 2013 | **Microtox EC50 (%)** | 37.3 | 43.8 | 49.1 | 47.8 | 55.4 | 58.1 |
| | **BTEX (µg/L)** | | | | | | |
| | Benzene | 160 | 0.6 | <LoD | <LoD | - | - |
| | Toluene | 160 | 160 | 1 | <LoD | - | - |
| | Ethylbenzene | 7.6 | <LoD | <LoD | <LoD | - | - |
| | Xylenes | 38 | <LoD | <LoD | <LoD | - | - |
| | Relative BTEX remaining (%) | 100% | 43.9% | 0.3% | 0% | - | - |
| | **TPH - gravimetric (µg/L)** | 1000 | 930 | 730 | 930 | - | - |
| | Relative TPH remaining (%) | 100% | 93% | 73% | 93% | - | - |
| | **TPH - speciated (µg/L)** | | | | | | |
| | < C13 hydrocarbons | <LoD | <LoD | <LoD | <LoD | - | - |
| | C13 hydrocarbons | 21 | <LoD | <LoD | <LoD | - | - |
| | C14 hydrocarbons | 79 | 12 | 38 | <LoD | - | - |
| | C15 hydrocarbons | 126 | 36 | 98 | 3 | - | - |
| | C16 hydrocarbons | 145 | 64 | 104 | 16 | - | - |
| | C17 hydrocarbons | 149 | 85 | 65 | 37 | - | - |
| | C18 hydrocarbons | 126 | 77 | 52 | 44 | - | - |
| | C19 hydrocarbons | 99 | 68 | 51 | 45 | - | - |
| | C20 hydrocarbons | 79 | 73 | 50 | 53 | - | - |
| | C21 hydrocarbons | 83 | 80 | 47 | 67 | - | - |
| | C22 hydrocarbons | 36 | 78 | 51 | 78 | - | - |
| | C23 hydrocarbons | 21 | 70 | 50 | 82 | - | - |
| | C24 hydrocarbons | 13 | 66 | 51 | 88 | - | - |
| | C25+ hydrocarbons | 22 | 220 | 75 | 417 | - | - |
| | Relative n-alkane remaining (%) * | | | | | | |
| | **PAHs** | | | | | | |
| | Total PAH | <LoD | <LoD | <LoD | <LoD | - | - |

**Table A.5: Species sensitivity determined by annual produced water studies**

| Year | Level of Species Protection | Produced Water (%) | Dilution Factor Required |
|---|---|---|---|
| 2010[1] | 99% | 1.1 | 91 |
| | 95% | 1.4 | 71 |
| | 90% | 1.7 | 59 |
| | 80% | 2.3 | 44 |
| 2012[2] | 99% | 0.38 | 263 |
| | 95% | 0.82 | 122 |
| | 90% | 1.13 | 88 |
| | 80% | 1.59 | 63 |
| 2013[3] | 99% | 1.9 | 52 |
| | 95% | 2.2 | 45 |
| | 90% | 2.4 | 42 |
| | 80% | 2.7 | 37 |

[1]Intertek Geotechnical Services Pty Ltd (Intertek), 2011. Ecotoxicology Laboratory Test Report, Blacktip Produced Water Studies, Updated 21st March 2011. Lab Id No: ECX10/2510. Perth, WA.
[2]Intertek Geotechnical Services Pty Ltd (Intertek), 2012. Ecotoxicology Laboratory Test Report, Final Report, Report Date: 28 September 2012. Lab Project Id No: ECX12-2002. Perth, WA.
[3]Intertek Geotechnical Services Pty Ltd (Intertek), 2014. Ecotoxicology Laboratory Test Report, Final Report, Report Date: 27 February 2014. Lab Project Id No: ECX13-2709. Perth, WA.

## Produced water laboratory report 2010

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# Ecotoxicology Laboratory Test Report

## Blacktip Produced Water Studies

### Updated 21st March 2011

**Sample Details**

| | | | |
|---|---|---|---|
| **Client** | ENI Australia Limited | **Lab ID No** | ECX10-2510 |
| **Attention** | Rob Phillips<br>40 Kings Park Road<br>West Perth WA 6005 | **Sampled By** | ENI Australia Limited |
| | | **Date Sampled** | 21/10/10 |
| | | **Date Received** | 25/10/10 |
| **Phone No** | (08) 9320 1541 | **Project Start** | 25/10/10 |
| **Order No** | ZF2010 102079 | **Project Finish** | 18/03/11 |

### Produced Water Studies Overview

This report outlines results from the chemical characterisation, ecotoxicity, biodegradation and bioaccumulation studies undertaken in partial fulfilment of the licensing conditions (Licence No. EPL57) for discharge of produced water under the ENI Australia Produced Water Management Plan for the Blacktip Project.

The objectives for the produced water studies include:

- Determining the chemical composition of the produced water relative to the ANZECC/ARMCANZ (2000) Fresh and Marine Water Quality Guidelines,
- Determining the ecotoxicity of the whole produced water to a range of marine organisms to predict a 99% Species Protection Trigger Value,
- Monitoring changes in the toxicity and chemical composition of the produced water with biodegradation,
- Determining the bioaccumulative potential of the produced water to a representative marine bivalve.

All results contained in this revised summary report have been finalised and apply to the sample as received by Intertek-Geotech. Specific methodologies for all produced water studies may be provided in an interpretive report on request.

### Disclaimer

Intertek-Geotech has endeavoured to achieve high accuracy results and information using certified techniques and equipment. All data and information contained in this summary report will remain proprietary to ENI Australia Limited and regarded as strictly confidential by all Intertek-Geotech personnel. Intertek-Geotech shall not be held responsible or liable for the results of any actions taken on the basis of the information contained in this document. Moreover, this report should not be the sole reference when considering issues that may have commercial implications. Any queries related to this report may be directed to David Strom at Intertek-Geotech.

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## Chemical Characterisation

| Chemical Parameter | Practical Quantitation Limit (PQL) | Concentration |
|---|---|---|
| pH (units) | 0.1 | 5.14 |
| Conductivity (mmho/cm at 25°C) | 0.1 | 8.3 |
| Total Dissolved Solids (mg/L) | 5 | 4122 |
| Total Suspended Solids (mg/L) | 5 | 6 |
| Turbidity (NTU) | 0.1 | 15 |
| Total Organic Carbon (mg/L) | 1 | 460 |
| Total Oxidised Nitrogen (mg/L) | 0.01 | - |
| Ammoniacal Nitrogen (mg/L) | 0.01 | 5 |
| Total Nitrogen (mg/L) | 0.05 | 5 |
| Soluble Metals (µg/L) | | |
| Antimony (Sb) | 1 | - |
| Arsenic (As) | 1 | 1 |
| Barium (Ba) | 1 | 18450 |
| Beryllium (Be) | 1 | - |
| Boron (B) | 5 | 781 |
| Cadmium (Cd) | 0.2 | - |
| Chromium (Cr) | 1 | - |
| Cobalt (Co) | 1 | 5 |
| Copper (Cu) | 1 | 1 |
| Lead (Pb) | 1 | - |
| Manganese (Mn) | 1 | 2200 |
| Mercury (Hg) | 0.1 | - |
| Molybdenum (Mo) | 1 | - |
| Nickel (Ni) | 1 | 47 |
| Selenium (Se) | 1 | - |
| Tin (Sn) | 1 | 52 |
| Zinc (Zn) | 5 | 2850 |
| Speciated Phenols (µg/L) | | |
| Phenol | 0.91 | 4 |
| 2-Chlorophenol | 0.91 | - |
| 2-Methylphenol | 0.91 | 3 |
| 4-Methylphenol | 0.91 | 3 |
| 2-Nitrophenol | 0.91 | - |
| Ethyl/Dimethylphenols | 0.91 | 2 |
| Benzoic acid | 0.91 | - |
| 2,4-Dichlorophenol | 0.91 | - |
| 2,6-Dichlorophenol | 0.91 | - |
| 4-Chloro-3-methylphenol | 0.91 | - |
| 2,4,6-Trichlorophenol | 0.91 | - |
| 2,4,5-Trichlorophenol | 0.91 | - |
| 2,4-Dinitrophenol | 0.91 | - |
| 4-Nitrophenol | 0.91 | - |
| 2,3,4,5-Tetrachlorophenol | 0.91 | - |
| 4,6-Dinitro-o-cresol | 0.91 | - |
| Total Petroleum Hydrocarbons (µg/L) | 100 | 1647 |
| Volatile TPH C6 to C9 (µg/L) | 100 | - |
| BTEX (µg/L) | | |
| Benzene | 0.23 | 1560 |
| Toluene | 0.23 | 1623 |
| Ethylbenzene | 0.23 | 97 |
| Xylene | 0.23 | 587 |
| Polycyclic Aromatic Hydrocarbons (µg/L) | 0.16 | - |
| Aliphatic / Aromatic Split (%) | 1 | 29 / 71 |
| Surfactants - MBAS (µg/L) | 50 | - |

- Denotes the concentration as being below the Practical Quantitation Limit (PQL)

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## Ecotoxicity Testing

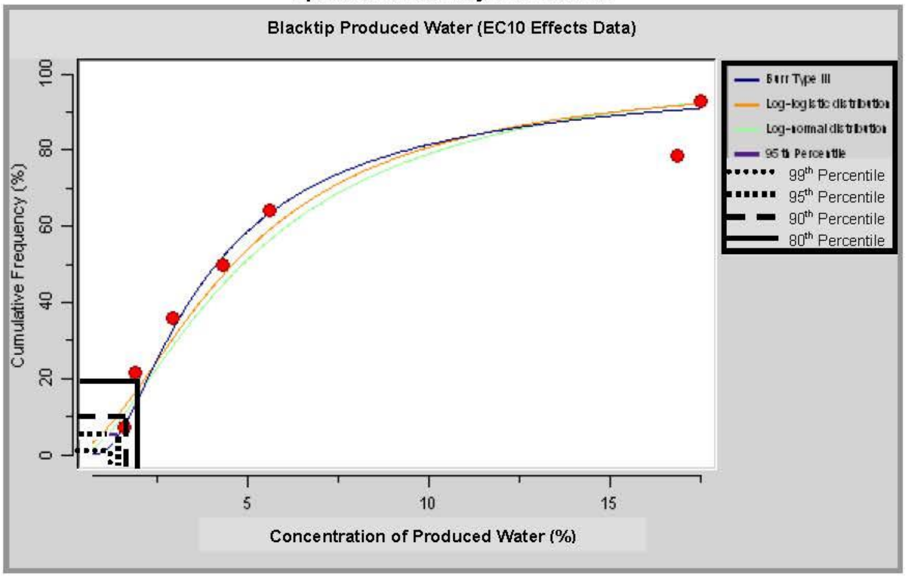
### Bioassay Details

| Bioassay | Protocol | Reference | Test Species | Temperature |
|---|---|---|---|---|
| Microtox | WIENV-30 | Microbics 1992 | *V. fischeri* | 25°C |
| Microalgae Cell Division | WIENV-45 | Stauber et al. 1994 | *I. galbana* | 25°C |
| Sea Urchin Fertilisation | WIENV-99 | Simon et al. 1997 | *H. erythrogramma* | 25°C |
| Mussel Larvae Development | WIECX-23 | ASTM E724-98 | *M. edulis* | 25°C |
| Copepod Development | WIENV-62 | USEPA 1002.0 | *G. imparipes* | 25°C |
| Fish Larvae Development | WIENV-64 | USEPA 1004.0 | *P. auratus* | 25°C |
| Prawn Survival | WIENV-00 | USEPA 1004.0 | *P. monodon* | 25°C |

### Statistical Effects Data

| Bioassay | EC50 (%) | EC10 (%) | LOEC (%) | NOEC (%) |
|---|---|---|---|---|
| Microtox | 54.6 | 17.5 | 12.5 | 6.3 |
| Microalgae Cell Division | 4.8 | 1.6 | 1.6 | 0.8 |
| Sea Urchin Fertilisation | 8.0 | 3.0 | 6.3 | 3.1 |
| Mussel Larvae Development | 11.2 | 4.3 | 6.3 | 3.1 |
| Copepod Development | 4.7 | 1.9 | 3.7 | 1.2 |
| Fish Larvae Development | 24.8 | 5.6 | 11 | 3.7 |
| Prawn Survival | 33.1 | 16.9 | 25 | 12.5 |

### Species Sensitivity Distribution




| Level of Species Protection | Produced Water (%) | Dilution Factor Required |
|---|---|---|
| 99% | 1.1 | 91 |
| 95% | 1.4 | 71 |
| 90% | 1.7 | 59 |
| 80% | 2.3 | 44 |

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## Biodegradation Potential

| Chemical Parameter | Sampling Interval | | | | | |
|---|---|---|---|---|---|---|
| | Initial | Day 0 | Day 1 | Day 2 | Day 6 | Day 10 |
| **Microtox EC10 (%)** | 17.4 | 29.6 | 51.0 | 67.1 | 77.2 | >80.0 |
| **BTEX (µg/L)** | | | | | | |
| Benzene | 1560 | 1142 | 70 | 6 | 1 | - |
| Toluene | 1623 | 1641 | 105 | 13 | 3 | - |
| Ethylbenzene | 97 | 134 | 9 | 2 | 1 | - |
| Xylenes | 587 | 862 | 52 | 5 | - | - |
| Relative BTEX remaining (%) | 100.0 | 97.7 | 6.1 | 0.7 | 0.1 | - |
| **Volatile TPH C6 to C9 (µg/L)** | - | - | - | - | - | - |
| Relative C6 to C9 remaining (%) | - | - | - | - | - | - |
| **TPH - gravimetric (µg/L)** | 1647 | 900 | 570 | 120 | - | - |
| Relative TPH remaining (%) | 100.0 | 54.6 | 34.6 | 7.3 | - | - |
| **TPH - speciated (µg/L)** | | | | | | |
| Undecane | 6.0 | 2.3 | - | - | - | - |
| Dodecane | 16.1 | 6.6 | - | - | - | - |
| Tridecane | 26.8 | 11.6 | - | - | - | - |
| Tetradecane | 34.0 | 15.3 | - | - | - | - |
| Pentadecane | 28.0 | 13.1 | - | - | - | - |
| Hexadecane | 27.5 | 13.1 | - | - | - | - |
| Heptadecane | 26.1 | 12.4 | - | - | - | - |
| Pristane | 9.7 | 4.8 | - | - | - | - |
| Octadecane | 21.9 | 11.0 | - | - | - | - |
| Phytane | 5.2 | 2.7 | - | - | - | - |
| Nonadecane | 19.6 | 9.8 | - | - | - | - |
| Eicosane | 17.0 | 9.0 | - | - | - | - |
| Heneicosane | 15.5 | 8.4 | 0.1 | - | - | - |
| Docosane | 13.6 | 7.4 | 0.3 | - | - | - |
| Tricosane | 11.5 | 6.2 | 0.8 | - | - | - |
| Tetracosane | 7.8 | 4.3 | 1.0 | - | - | - |
| Pentacosane | 6.2 | 3.4 | 1.0 | - | - | - |
| Hexacosane | 3.8 | 2.1 | 0.9 | - | - | - |
| Heptacosane | 2.5 | 1.4 | 0.7 | - | - | - |
| Octacosane | 1.1 | 0.6 | 0.5 | - | - | - |
| Nonacosane | 0.9 | 0.4 | 0.4 | - | - | - |
| Relative n-alkane remaining (%) * | 100.0 | 48.5 | 1.8 | - | - | - |

- Denotes concentration as being below the Practical Quantitation Limits (PQL) listed in *Chemical Characterisation*

* Relative n-alkane calculations based on $C_{11}$ to $C_{29}$

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## Bioaccumulation Potential

| Chemical Parameter | Concentration of Contaminant in Mussel Tissue (mg/kg, dry weight) [1] | | |
|---|---|---|---|
| | Control (seawater) | 0.1% Treatment [2] | 1% Treatment [3] |
| **Metals** | | | |
| Arsenic | 13 ± 0 | 13 ± 0 | 13 ± 1 |
| Barium | 0.2 ± 0.1 | 0.2 ± 0.1 | 0.3 ± 0.1 |
| Cobalt | 0.4 ± 0.1 | 0.5 ± 0.1 | 0.5 ± 0.1 |
| Copper | 5 ± 1 | 5 ± 1 | 5 ± 2 |
| Manganese | 4 ± 1 | 5 ± 1 | 5 ± 1 |
| Nickel | 1.1 ± 0.6 | 0.7 ± 0.1 | 0.7 ± 0.1 |
| Tin | 0.6 ± 0.1 | 0.6 ± 0.1 | 0.4 ± 0.1 |
| Zinc | 267 ± 25 | 280 ± 0 | 303 ± 6 |
| **BTEX** | | | |
| Benzene | - | - | - |
| Toluene | - | - | - |
| Ethylbenzene | - | - | - |
| Xylenes | - | - | - |
| **TPH - Speciated** | | | |
| Undecane | - | - | - |
| Dodecane | - | - | - |
| Tridecane | - | - | - |
| Tetradecane | - | - | - |
| Pentadecane | - | - | - |
| Hexadecane | - | - | - |
| Heptadecane | - | - | - |
| Pristane | - | - | - |
| Octadecane | - | - | - |
| Phytane | - | - | - |
| Nonadecane | - | - | - |
| Eicosane | - | - | - |
| Heneicosane | - | - | - |
| Docosane | - | - | - |
| Tricosane | - | - | - |
| Tetracosane | - | - | - |
| Pentacosane | - | - | - |
| Hexacosane | - | - | - |
| Heptacosane | - | - | - |
| Octacosane | - | - | - |
| Nonacosane | - | - | - |

[1] Mean concentration (n=3) ± 1 standard deviation
[2] Equivalent to a dilution factor of 1000
[3] Equivalent to a dilution factor of 100
- Denotes concentration as being below the Practical Quantitation Limit (PQL) of 0.1 mg/kg, dry weight

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## General Comments

The produced water sample appeared to precipitate when mixed with natural seawater. This observation was consistent with the formation iron-oxyhydroxide phases (e.g. Fe-OOH), often occurring when soluble iron ($Fe^{2+}$) present in lower pH waters (pH 5.14 for the produced water) oxidises and precipitates following an increase to pH 8.20 (naturally buffered seawater). It is advised that precipitation may occur when the produced water is discharged into the marine receiving environment.

*Chemical Characterisation*

Chemical characterisation of the produced water sample identified ammoniacal nitrogen, dissolved metals (including cobalt, manganese, nickel and zinc) and BTEX (benzene and xylene) at concentrations exceeding ANZECC/ARMCANZ (2000) marine water quality guideline trigger values for slightly to moderately disturbed ecosystems. Although water quality guideline trigger values were not available for barium, TPHs, toluene and ethylbenzene, elevated concentrations were noted. Quality assurance and quality control criteria were within acceptable limits for all chemical analyses.

*Ecotoxicity Testing*

The produced water concentration series was pH adjusted prior to toxicity testing. Initial Microtox testing indicated that the produced water toxicity was not altered when the sample pH was adjusted from pH 5.14 to pH 8.20. This implied that any contaminants present in the produced water were not complexed with the precipitate and the predicted bioavailability would be representative of discharge in the mixing zone.

Based on the EC10 data from five chronic and two acute marine bioassays, the dilution factors required to achieve 99, 95, 90 or 80% species protection in seawater were determined to be 91, 71, 59 and 44 (respectively). The Northern Territory Environmental Protection Licence (Licence No. EPL57) stipulates a 99% level of species protection be achieved in the mixing zone. Therefore, a dilution factor of 91 (based on chronic effect EC10 values) will be sufficient to achieve compliance, i.e. diluting the produced water by a factor of 91 will result in only 1% of the exposed species showing a 10% reduction in growth or reproduction in the mixing zone. Quality assurance and quality control criteria were within acceptable limits for all ecotoxicity bioassays

*Biodegradation Potential*

Toxicity of the produced water to the marine bacterium *Vibrio fischeri* (15-min Microtox bioassay) had significantly decreased after 6-days, with the 15-min EC10 (i.e. the concentration at which bioluminescence is inhibited by 10% compared to the control after a 15-minute exposure) increasing from 29.6% on Day 0 to 77.2% on Day 6. The reduced toxicity was in good agreement with measurements of BTEX (benzene, toluene, ethylbenzene and xylene) and TPH (volatile, gravimetric and speciated n-alkanes). Significant reductions in BTEX (>93%) and TPHs (>65%) were observed at the 24-hour time interval, followed by almost complete evaporation and/or biodegradation of BTEX and TPH by Day 6 (<0.1% remaining). Volatile TPHs $C_6$ to $C_9$ were not detected in the produced water.

Results from the biodegradation study indicate that statistically significant toxicity from the produced water (based on Microtox results) will not persist in the marine receiving environment for more than 6-days. This estimate was conservative given the produced water was tested at 80% of the initial concentration (i.e. 20% seawater added as diluent). The safe dilution factor of 91 (99% level of species protection) is in excess of the produced water dilution used in this biodegradation study which will ensure (i) toxic effects from the produced water remain negligible and (ii) BTEX and TPHs biodegrade rapidly (<24-hours). Quality assurance and quality control criteria were within acceptable limits for all chemical analyses and ecotoxicity bioassays.

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*Bioaccumulation Potential*

The bioaccumulation study was performed to assess the uptake and retention of contaminants by the bivalve *Mytilis edulis*. The bivalves were exposed in semi-static chambers to a control treatment (seawater only) and two sublethal concentrations of the produced water, including 0.1% and 1% concentrations (equivalent to dilution factors of 1000 and 100, respectively). In accordance with OECD Test Guideline 305, a continuous exposure period of 28-days (uptake phase) was followed by an additional 28-day period of depuration in seawater. Only those contaminants identified in the produced water 'chemical characterisation' study were analysed in the whole tissues post depuration. Boron was exempted due to the naturally higher concentrations in seawater (~4 mg/L).

For the contaminants identified in produced water, only zinc was observed in the mussel tissues of the 1% produced water treatments at slightly (but significantly, $p<0.05$) elevated concentrations compared to the seawater control. All measurements for BTEX and speciated TPHs were below the limit of practical quantitation (i.e. concentrations of BTEX and TPH were negligible). Quality assurance and quality control criteria were within acceptable limits for all chemical analyses and bioassays.

Caution is advised when extrapolating environmental risk from the observed bioaccumulation of zinc in the mussel. Zinc is an essential trace element actively regulated or detoxified by several marine organisms, including bivalves. Accurately determining the extent of biological effects from internally sequestered zinc is complex and often variable. Considering that (i) the concentration of zinc was only slightly elevated in the 1% produced water treatment compared to the control, and (ii) there were no significant differences in bivalve mortality over the 56-day exposure duration (i.e. no acute toxicity), a low likelihood of adverse biological effects from the bioaccumulation of zinc is expected where the produced water is diluted by a factor >100 in the seawater mixing zone.

*Summary and Recommendations*

The produced water contained ammoniacal nitrogen, dissolved metals (cobalt, manganese, nickel and zinc) and BTEX (benzene and xylene) at concentrations exceeding ANZECC/ARMCANZ (2000) marine water quality guideline trigger values for slightly to moderately disturbed ecosystems. Elevated concentrations of barium, TPHs, toluene and ethylbenzene were also noted. Contaminants such as BTEX and TPHs were demonstrated to biodegrade rapidly on mixing with seawater and are not expected to persist in the receiving environment.

Based on results from the produced water chemical characterisation, ecotoxicity and biodegradation studies, a minimum safe dilution factor of 91 in the mixing zone will be sufficient to achieve a 99% level of species protection. With the exception of zinc, the calculated dilution factor of 91 will lower all contaminants identified in the produced water to concentrations below the ANZECC/ARMCANZ (2000) marine water quality guideline trigger values recommended for a 99% level of species protection. For zinc, a dilution factor of 408 in the mixing zone will be sufficient to achieve concentrations below the 99% species protection trigger value of 7 µg Zn/L, while ensuring the bioaccumulation of zinc in marine biota remains similar to background concentrations.

**Report Approval**

| Report by: | Reviewed by: |
|---|---|
| [signature] | [signature] |
| David Strom<br>Principal Ecotoxicologist & Divisional Manager | Neville Phillips<br>Senior Chemist |

**Produced water laboratory report 2012**

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## Ecotoxicology Laboratory Test Report

# Final Report

### Report Date: 28 September 2012

**Sample Details**

| **Client** | ENI Australia Limited | **Lab Project ID No.** | ECX12-2002 |
|---|---|---|---|
| **Attention** | Rob Phillips<br>40 Kings Park Road<br>West Perth WA 6005 | **Sampled By** | ENI Australia Limited |
| | | **Date Sampled** | 19/02/2012 |
| | | **Date Received** | 20/02/2012 |
| **Phone No.** | (08) 9320 1541 | **Project Start** | 20/02/2012 |
| **Order No.** | ZF 2012 006092 | **Project Finish** | 28/09/2012 |

### Produced Water Studies Overview

This report outlines results from ecotoxicity, chemical characterisation, biodegradation and bioaccumulation studies undertaken in partial fulfilment of the licensing conditions (Licence No. EPL57) for discharge of produced water under the ENI Australia Produced Water Management Plan for the Blacktip Project.

The objectives for the produced water studies include:

- Determining the chemical composition of the produced water relative to the ANZECC/ARMCANZ (2000) Fresh and Marine Water Quality Guidelines
- Determining the ecotoxicity of the whole produced water to a range of marine organisms to predict a 99% Species Protection Trigger Value
- Monitoring changes in the toxicity and chemical composition of the produced water with biodegradation
- Determining the bioaccumulative potential of the produced water to a representative marine bivalve

All results contained in this revised summary report have been finalised and apply to the sample as received by Intertek-Geotech. Specific methodologies for all produced water studies may be provided in an interpretive report on request.

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## Chemical Characterisation

| Chemical Parameter | Practical Quantitation Limit (PQL) | Concentration |
|---|---|---|
| pH (units) | 0.1 | 5.5 |
| Conductivity (mS/cm at 18°C) | 0.1 | 14.1 |
| Total Dissolved Solids (mg/L) | 5 | 6480 |
| Total Suspended Solids (mg/L) | 5 | 121 |
| Turbidity (NTU) | 0.1 | 1900 |
| Total Organic Carbon (mg/L) | 1 | 170 |
| Total Oxidised Nitrogen (mg/L) | 0.01 | - |
| Ammoniacal Nitrogen (mg/L) | 0.01 | 11 |
| Total Nitrogen (mg/L) | 0.05 | 16 |
| Soluble Metals (µg/L) | | |
| Antimony (Sb) | 1 | - |
| Arsenic (As) | 1 | 1 |
| Barium (Ba) | 10 | 37000 |
| Beryllium (Be) | 10 | - |
| Boron (B) | 10 | 1000 |
| Cadmium (Cd) | 2 | - |
| Chromium (Cr) | 10 | - |
| Cobalt (Co) | 10 | - |
| Copper (Cu) | 10 | 10 |
| Lead (Pb) | 10 | - |
| Manganese (Mn) | 10 | 1900 |
| Mercury (Hg) | 0.1 | - |
| Molybdenum (Mo) | 1 | - |
| Nickel (Ni) | 10 | - |
| Selenium (Se) | 1 | - |
| Tin (Sn) | 10 | - |
| Zinc (Zn) | 10 | - |
| Speciated Phenols (mg/L) | | |
| Phenol | 0.1 | - |
| 2-Chlorophenol | 0.1 | - |
| 2-Methylphenol | 0.1 | - |
| 4-Methylphenol | 0.1 | - |
| 2-Nitrophenol | 0.1 | - |
| Ethyl/Dimethylphenols | 0.1 | - |
| Benzoic acid | 0.1 | - |
| 2,4-Dichlorophenol | 0.1 | - |
| 2,6-Dichlorophenol | 0.1 | - |
| 4-Chloro-3-methylphenol | 0.1 | - |
| 2,4,6-Trichlorophenol | 0.1 | - |
| 2,4,5-Trichlorophenol | 0.1 | - |
| 2,4-Dinitrophenol | 0.1 | - |
| 4-Nitrophenol | 0.1 | - |
| 2,3,4,5-Tetrachlorophenol | 0.1 | - |
| 4,6-Dinitro-o-cresol | 0.1 | - |
| Total Petroleum Hydrocarbons (µg/L) | 100 | 2000 |
| Volatile TPH C6 to C9 (µg/L) | 100 | 1600 |
| BTEX (µg/L) | | |
| Benzene | 0.25 | 600 |
| Toluene | 0.25 | 710 |
| Ethylbenzene | 0.25 | 42 |
| Xylene | 0.25 | 250 |
| Polycyclic Aromatic Hydrocarbons (µg/L) | 7 | - |
| Aliphatic / Aromatic Split (%) | 1 | 60% Aliphatic / 40% Aromatic |
| Surfactants - MBAS (µg/L) | 50 | - |

- Denotes the concentration as being below the Practical Quantitation Limit (PQL)

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## Ecotoxicity Testing

### Bioassay Details

| Bioassay | Protocol | Reference | Test Species | Temperature |
|---|---|---|---|---|
| Microtox | WIENV-30 | Microbics 1992 | *V. fischeri* | 25°C |
| Microalgae Cell Division | WIENV-45 | Stauber et al. 1994 | *I. galbana* | 25°C |
| Sea Urchin Fertilisation | WIENV-99 | Simon et al. 1997 | *H. erythrogramma* | 25°C |
| Mussel Larvae Development | WIECX-23 | ASTM E724-98 | *M. edulis* | 25°C |
| Copepod Reproduction | WIENV-62 | USEPA 1002.0 | *G. imparipes* | 25°C |
| Fish Larvae Development | WIENV-64 | USEPA 1004.0 | *P. auratus* | 25°C |
| Prawn Survival | WIENV-00 | USEPA 1004.0 | *P. japonicus* | 25°C |

### Concentration-Response Data

| Bioassay (% Control) | Control | 1.6% | 3.1% | 6.3% | 12.5% | 25% | 50% | 100% |
|---|---|---|---|---|---|---|---|---|
| Microtox | 100 ± 6 | 83 ± 2 | 64 ± 3 | 46 ± 3 | 30 ± 4 | 15 ± 2 | 7 ± 1 | 4 ± 0 |
| Microalgae Cell Division | 100 ± 8 | - | 94 ± 10 | 76 ± 2 | 75 ± 20 | 53 ± 4 | 43 ± 4 | 5 ± 0 |
| Sea Urchin Fertilisation | 100 ± 13 | - | 67 ± 11 | 55 ± 4 | 28 ± 18 | 1 ± 2 | 1 ± 2 | - |
| Mussel Larvae Development | 100 ± 2 | 93 ± 12 | 79 ± 6 | 31 ± 15 | 0 ± 0 | 0 ± 0 | 0 ± 0 | - |
| Copepod Development | 100 ± 25 | - | 91 ± 9 | 0 ± 0 | 0 ± 0 | 0 ± 0 | 0 ± 0 | - |
| Fish Larvae Development | 100 ± 4 | 75 ± 12 | 59 ±10 | 64 ± 14 | 0 ± 0 | 0 ± 0 | 0 ±0 | - |
| Prawn Survival | 100 ± 6 | - | 83 ± 10 | 76 ± 24 | 41 ± 18 | 21 ± 18 | 10 ± 18 | - |

### Statistical Effects Data

| Bioassay | EC10 (%) | EC50 (%) | NOEC (%) | LOEC (%) |
|---|---|---|---|---|
| Microtox | 0.9 | 5.9 | <1.6 | 1.6 |
| Microalgae Cell Division | 2.9 | 14.6 | <3.1 | 3.1 |
| Sea Urchin Fertilisation | 2.1 | 6.5 | <3.1 | 3.1 |
| Mussel Larvae Development | 2.6 | 4.8 | 1.6 | 3.1 |
| Copepod Development | 3.4 | 4.7 | 3.1 | 6.3 |
| Fish Larvae Development | 1.5 | 4.6 | <1.6 | 1.6 |
| Prawn Survival | 2.6 | 11.2 | 6.3 | 12.5 |

* Results apply to the sample in the condition as received by Geotechnical Services Pty Ltd

### Quality Assurance Limits

| Bioassay | Reference Toxicant | Cusum Chart Limits | Observed EC50 | Coefficient of Variance | Control Response | Test Acceptability |
|---|---|---|---|---|---|---|
| Microtox | Phenol | 11 - 30 mg/L | 22.3 mg/L | 23.2% | >90% | YES |
| Microalgae Cell Division | Copper | 17 – 29 µg/L | 21.5 µg/L | 16.5% | > 3 x cell divisions | YES |
| Sea Urchin Fertilisation | Copper | 4 – 72 µg/L | 33.3 µg/L | 45.2% | > 70 % Fertilised | YES |
| Mussel Larvae Development | Copper | 4.6 – 6.3 µg/L | 5.6 µg/L | 10.8% | >80% Development | YES |
| Copepod Development | Copper | 6 – 34 µg/L | 14.8 µg/L | 36.2% | >8 Gravid Females | YES |
| Fish Larvae Development | Copper | 30 – 48 µg/L | 36.4 µg/L | 11.1% | >80% Survival | YES |
| Prawn Survival | - | - | - | - | >80% Survival | YES |

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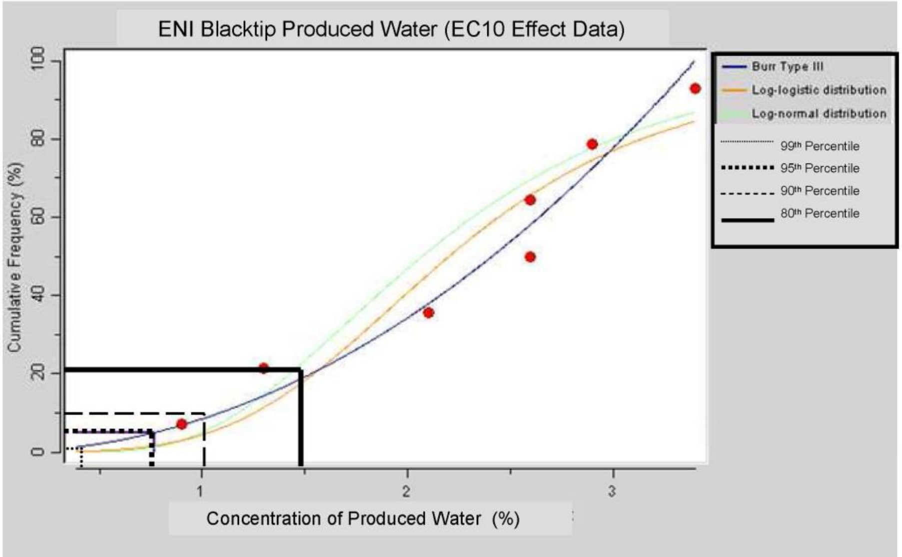
**Species Sensitivity Distribution**




| Level of Species Protection | Produced Water (%) | Dilution Factor Required |
|---|---|---|
| 99% | 0.35 | 263 |
| 95% | 0.77 | 122 |
| 90% | 1.09 | 88 |
| 80% | 1.53 | 63 |

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## Biodegradation Potential

| Chemical Parameter | Sampling Interval | | | | | |
|---|---|---|---|---|---|---|
| | Day 0 | Day 1 | Day 2 | Day 5^ | Day 7 | Day 14 |
| **Microtox EC50 (%)** | 5.88 | 8.95 | 13.2 | 7.96 | 16.55 | 19.46 |
| **BTEX (µg/L)** | | | | | | |
| Benzene | 600 | 0.00 | - | - | - | - |
| Toluene | 710 | 1.1 | - | - | - | - |
| Ethylbenzene | 42 | 0.1 | - | - | - | - |
| Xylenes | 250 | 1.8 | 1 | 1.1 | - | - |
| Relative BTEX remaining (%) | 100% | 0.19% | 0.06% | 0.06% | 0% | 0% |
| **TPH - gravimetric (µg/L)** | 2000 | 380 | 380 | 630 | 400 | 200 |
| Relative TPH remaining (%) | 100% | 19% | 19% | 31.5% | 20% | 10% |
| **TPH - speciated (µg/L)** | | | | | | |
| Undecane | 44.0 | - | - | - | - | - |
| Dodecane | 141.8 | - | - | - | - | - |
| Tridecane | 179.7 | 19.6 | 12.9 | 18.6 | 9.4 | 3.7 |
| Tetradecane | 201.7 | 28.9 | 22.5 | 31.3 | 24.9 | 12.1 |
| Pentadecane | 232.5 | 35.5 | 28.6 | 39.7 | 37.7 | 19.1 |
| Hexadecane | 197.5 | 38.0 | 35.5 | 43.5 | 46.0 | 24.5 |
| Heptadecane | 183.8 | 40.1 | 43.0 | 49.8 | 51.3 | 27.8 |
| Octadecane | 159.1 | 35.2 | 38.5 | 45.5 | 49.2 | 26.4 |
| Nonadecane | 150.1 | 32.6 | 34.1 | 43.4 | 43.9 | 24.3 |
| Eicosane | 124.7 | 28.8 | 31.5 | 43.6 | 38.9 | 21.3 |
| Heneicosane | 111.9 | 26.5 | 26.4 | 44.2 | 32.6 | 18.5 |
| Docosane | 91.5 | 24.0 | 25.4 | 50.7 | 29.6 | 15.9 |
| Tricosane | 75.1 | 21.8 | 23.2 | 54.4 | 25.7 | 13.9 |
| Tetracosane | 46.0 | 17.0 | 19.6 | 53.2 | 23.1 | 11.8 |
| Pentacosane | 31.7 | 13.3 | 14.5 | 43.6 | 23.8 | 10.3 |
| Hexadecane | 18.1 | 8.5 | 9.0 | 31.6 | 19.8 | 7.3 |
| Tetracosane | 8.8 | 3.7 | 6.5 | 19.6 | 24.1 | 6.8 |
| Nonadecane | 1.9 | 1.5 | 3.6 | 12.2 | 19.9 | 6.2 |
| Relative n-alkane remaining (%) * | 100% | 18.8% | 18.8% | 31.3% | 25% | 12.5% |
| **PAHs** | | | | | | |
| Total PAH | - | - | - | - | - | - |

^ evaporation is likely the cause of the increase in contaminant concentrations and the increase in toxicity observed
- Denotes concentration as being below the Practical Quantitation Limits (PQL) listed in *Chemical Characterisation*
* Relative n-alkane calculations based on $C_{11}$ to $C_{29}$

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**Bioaccumulation Potential**

Mussel tissue concentrations after 30 –days exposure

| Chemical Parameter | Concentration of Contaminant in Mussel Tissue (mg/kg, dry weight) [1] | | |
|---|---|---|---|
| | Control (seawater) | 0.1% Treatment [2] | 1% Treatment [3] |
| **Metals** | | | |
| Arsenic | 2.6 ± 0.35 | 2.6 ± 0.30 | 3.0 ± 0.25 |
| Barium | 0.023 ± 0.006 | 0.073 ± 0.011 | 0.49 ± 0.025 |
| Copper | 1.12 ± 0.18 | 0.93 ± 0.25 | 1.00 ± 0.17 |
| Manganese | 1.53 ± 0.76 | 2.17 ± 1.03 | 4.10 ± 1.06 |
| **BTEX** | | | |
| Benzene | - | - | - |
| Toluene | - | - | - |
| Ethylbenzene | - | - | - |
| Xylenes | - | - | - |
| **TPH - Speciated** | | | |
| $C_6 – C_9$ | - | - | - |
| $C_{10} – C_{14}$ | - | - | - |
| $C_{15} – C_{28}$ | - | - | - |
| $C_{29} – C_{36}$ | - | - | - |

[1] Mean concentration (n=3) ± 1 standard deviation, [2] Equivalent to a dilution factor of 1000, [3]Equivalent to a dilution factor of 100
- Denotes concentration as being below the Practical Quantitation Limit (PQL) of 0.1 mg/kg, dry weight

Mussel tissue concentrations after 60 days (30 day exposure, then 30 depuration)

| Chemical Parameter | Concentration of Contaminant in Mussel Tissue (mg/kg, dry weight) [1] | | |
|---|---|---|---|
| | Control (seawater) | 0.1% Treatment [2] | 1% Treatment [3] |
| **Metals** | | | |
| Arsenic | 2.2 ± 0.17 | 2.5 ± 0.15 | 2.5 ± 0.51 |
| Barium | 0.027 ± 0.006 | 0.05 ± 0 | 0.033 ± 0.006 |
| Copper | 0.93 ± 0.15 | 1.40 ± 0.46 | 1.54 ± 0.69 |
| Manganese | 0.76 ± 0.30 | 1.93 ± 0.21 | 1.36 ± 0.38 |
| **BTEX** | | | |
| Benzene | - | - | - |
| Toluene | - | - | - |
| Ethylbenzene | - | - | - |
| Xylenes | - | - | - |
| **TPH - Speciated** | | | |
| $C_6 – C_9$ | - | - | - |
| $C_{10} – C_{14}$ | - | - | - |
| $C_{15} – C_{28}$ | - | - | - |
| $C_{29} – C_{36}$ | - | - | - |

[1] Mean concentration (n=3) ± 1 standard deviation, [2] Equivalent to a dilution factor of 1000, [3]Equivalent to a dilution factor of 100
- Denotes concentration as being below the Practical Quantitation Limit (PQL) of 0.1 mg/kg, dry weight

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**General Comments**

***Chemical Characterisation***

Chemical characterisation of the produced water sample identified turbidity, ammoniacal nitrogen, dissolved metals (copper), and BTEX (Benzene) at concentrations exceeding ANZECC/ARMCANZ (2000) marine water quality guideline trigger values for slightly to moderately disturbed ecosystems. Although water quality guideline trigger values were not available for barium, boron, manganese, TPHs, and toluene, elevated concentrations were noted. Quality assurance and quality control criteria were within acceptable limits for all chemical analyses.

***Ecotoxicity Testing***

The produced water concentration series was salinity and pH adjusted prior to toxicity testing, due to low salinity (10.4‰) and low pH (5.5). Salinity was adjusted to 35‰, by the addition of Red Sea® sea salts to match that of the diluent seawater, and pH was adjusted by the addition of NaOH to match the diluent seawater pH of 8.0. The adjustments in pH and salinity resulted in precipitation of manganese and iron oxides. This observation was consistent with the formation of oxyhydroxide phases (e.g. Fe-OOH), often occurring when soluble iron and manganese (e.g. $Fe^{2+}$) present in lower pH waters (pH 5.5 for the produced water) oxidises and precipitates following an increase in pH to 8.0 (naturally buffered seawater). Thusly the sample had to be filtered through a 0.45µm filter to remove the precipitate.

Unfiltered and artificial sea salt controls were conducted to ensure that the sample modifications did not alter toxicity. This implied that any contaminants present in the produced water were not complexed with the precipitate and the predicted bioavailability would be representative of discharge in the mixing zone.

Based on the EC10 data from five chronic and two acute marine bioassays, the dilution factors required to achieve 99, 95, 90 or 80% species protection in seawater were determined to be 263, 122, 88, and 63 (respectively). The Northern Territory Environmental Protection Licence (Licence No. EPL57) stipulates a 99% level of species protection be achieved in the mixing zone. Therefore, a dilution factor of 263 (based on chronic effect EC10 values) will be sufficient to achieve compliance, i.e. diluting the produced water by a factor of 263 will result in only 1% of the exposed species showing a 10% reduction in growth or reproduction in the mixing zone.

Quality assurance and quality control criteria were within acceptable limits for all ecotoxicity bioassays.

***Biodegradation Potential***

Toxicity of the produced water to the marine bacterium *Vibrio fischeri* (15-min Microtox bioassay) only slightly decreased over 14 days, with the 15-min EC50 (i.e. the concentration at which bioluminescence is inhibited by 50% compared to the control after a 15-minute exposure) increasing from 5.9% on Day 0 to 19.5% on Day 14.

Significant reductions in BTEX (>99%) and TPHs (81%) were observed at the 24-hour time interval, followed by almost complete evaporation and/or biodegradation of BTEX (100%) and TPH (90%) by Day 14. Despite the reductions in BTEX and TPH the Microtox showed relatively high EC50 of 19.5% compared to the initial EC50 of 5.9%.

Results from the biodegradation study indicate that significant toxicity from the produced water (based on Microtox results) will potentially persist in the marine receiving environment for more than 14-days. As the toxicity observed did not match the reduction in BTEX and TPH it is most likely due to metal concentrations or other unmeasured chemicals. In particular copper exceeds the ANZECC (2000) 80% species protection trigger value at 10 µg/L. At these levels it is likely that copper is contributing to the observed toxicity.

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Quality assurance and quality control criteria were within acceptable limits for all chemical analyses and ecotoxicity bioassays.

***Bioaccumulation potential***

The bioaccumulation study was performed to assess the uptake and retention of contaminants by the bivalve *Mytilis edulis*. The bivalves were exposed in semi-static chambers to a control treatment (seawater only) and two sublethal concentrations of the produced water, including 0.1% and 1% concentrations (equivalent to dilution factors of 1000 and 100, respectively). In accordance with OECD Test Guideline 305, a continuous exposure period of 30-days (uptake phase) was followed by an additional 30-day period of depuration in seawater. Only those contaminants identified in the produced water 'chemical characterisation' study were analysed in the whole tissues post depuration.

For the contaminants identified in produced water, only manganese was observed in the mussel tissues of the 1% produced water treatments at slightly (but significantly, $p<0.05$) elevated concentrations compared to the seawater control after 30-d of exposure and in the 0.1% treatment after the depuration period (60-d). All measurements for BTEX and speciated TPHs were below the limit of practical quantitation (i.e. concentrations of BTEX and TPH were negligible). Quality assurance and quality control criteria were within acceptable limits for all chemical analyses and bioassays.

There is little environmental risk from the observed bioaccumulation of manganese in the mussel. Manganese is an essential trace element actively regulated by several marine organisms, including bivalves. Accurately determining the extent of biological effects from internally sequestered manganese is complex and often variable. As there were no significant differences in bivalve mortality over the 60-day exposure duration (i.e. no acute toxicity), and low likelihood of adverse biological effects from the bioaccumulation of manganese, there is no risk of bioaccumulation accumulation at 100x dilution.

***Summary and Recommendations***

The produced water contained turbidity, ammoniacal nitrogen, dissolved metals (copper), and BTEX (Benzene) at concentrations exceeding ANZECC/ARMCANZ (2000) marine water quality guideline trigger values for slightly to moderately disturbed ecosystems. Elevated concentrations of barium, boron, manganese, TPHs, and toluene were also noted. Contaminants such as BTEX and TPHs were demonstrated to biodegrade rapidly on mixing with seawater and are not expected to persist in the receiving environment.

Based on results from the produced water chemical characterisation, ecotoxicity and biodegradation studies, a minimum safe dilution factor of 263 in the mixing zone will be sufficient to achieve a 99% level of species protection. The dilution factor of 263 will lower all contaminants identified in the produced water to concentrations below the ANZECC/ARMCANZ (2000) marine water quality guideline trigger values recommended for a 99% level of species protection.

**Report Approval**

| | |
|---|---|
| Tristan Stringer<br>Principal Ecotoxicologist & Divisional Manager | Neville Phillips<br>General Manager |

**Produced water laboratory report 2014**

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## Ecotoxicology Laboratory Test Report

# Final Report

**Report Date: 27 February 2014**

***Updated: 9 June 2014***

**Sample Details**

| | | | |
|---|---|---|---|
| **Client** | ENI Australia Limited | **Lab Project ID No.** | ECX13-2709 |
| **Attention** | Rob Phillips<br>40 Kings Park Road<br>West Perth WA 6005 | **Sampled By** | ENI Australia Limited |
| | | **Date Sampled** | Unknown |
| | | **Date Received** | 27/09/13 |
| **Phone No.** | (08) 9320 1541 | **Project Start** | 27/09/13 |
| **Order No.** | ZF 2013 007174 | **Project Finish** | 27/02/14 |

## Produced Water Studies Overview

This report outlines results from ecotoxicity, chemical characterisation, biodegradation and bioaccumulation studies undertaken in partial fulfilment of the licensing conditions (Licence No. EPL57) for discharge of produced water under the ENI Australia Produced Water Management Plan for the Blacktip Project.

The objectives for the produced water studies include:

- Determining the chemical composition of the produced water relative to the ANZECC/ARMCANZ (2000) Fresh and Marine Water Quality Guidelines
- Determining the ecotoxicity of the whole produced water to a range of marine organisms to predict a 99% Species Protection Trigger Value
- Monitoring changes in the toxicity and chemical composition of the produced water with biodegradation
- Determining the bioaccumulative potential of the produced water to a representative marine bivalve

### Disclaimer

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## Chemical Characterisation

| Chemical Parameter | Limit of Detection | Concentration |
|---|---|---|
| pH (units) | 0.1 | 6.05 |
| Conductivity (mS/cm at 18°C) | 0.1 | 148.6 |
| Total Dissolved Solids (mg/L) | 5 | 94600 |
| Total Suspended Solids (mg/L) | 5 | 166 |
| Turbidity (NTU) | 0.1 | 0.1 |
| Total Organic Carbon (mg/L) | 1 | 1100 |
| Total Oxidised Nitrogen (mg/L) | 0.01 | <LoD |
| Ammoniacal Nitrogen (mg/L) | 0.01 | 69 |
| Total Nitrogen (mg/L) | 0.05 | 69 |
| Soluble Metals (µg/L) | | |
| Antimony (Sb) | 1 | 1 |
| Arsenic (As) | 1 | 2 |
| Barium (Ba) | 10 | 170000 |
| Beryllium (Be) | 10 | <LoD |
| Boron (B) | 10 | 10000 |
| Cadmium (Cd) | 2 | <LoD |
| Chromium (Cr) | 10 | <LoD |
| Cobalt (Co) | 10 | <LoD |
| Copper (Cu) | 10 | <LoD |
| Lead (Pb) | 10 | <LoD |
| Manganese (Mn) | 10 | 520000 |
| Mercury (Hg) | 0.1 | <LoD |
| Molybdenum (Mo) | 1 | <LoD |
| Nickel (Ni) | 10 | 20 |
| Selenium (Se) | 1 | <LoD |
| Tin (Sn) | 10 | <LoD |
| Zinc (Zn) | 1 | 40 |
| Speciated Phenols (mg/L) | | |
| Phenol | 0.1 | <LoD |
| 2-Chlorophenol | 0.1 | <LoD |
| 2-Methylphenol | 0.1 | <LoD |
| 4-Methylphenol | 0.1 | <LoD |
| 2-Nitrophenol | 0.1 | <LoD |
| Ethyl/Dimethylphenols | 0.1 | <LoD |
| Benzoic acid | 0.1 | <LoD |
| 2,4-Dichlorophenol | 0.1 | <LoD |
| 2,6-Dichlorophenol | 0.1 | <LoD |
| 4-Chloro-3-methylphenol | 0.1 | <LoD |
| 2,4,6-Trichlorophenol | 0.1 | <LoD |
| 2,4,5-Trichlorophenol | 0.1 | <LoD |
| 2,4-Dinitrophenol | 0.1 | <LoD |
| 4-Nitrophenol | 0.1 | <LoD |
| 2,3,4,5-Tetrachlorophenol | 0.1 | <LoD |
| 4,6-Dinitro-o-cresol | 0.1 | <LoD |
| Total Petroleum Hydrocarbons (µg/L) | 100 | 1000 |
| Volatile TPH C6 to C9 (µg/L) | 100 | 300 |
| BTEX (µg/L) | | |
| Benzene | 0.25 | 160 |
| Toluene | 0.25 | 160 |
| Ethylbenzene | 0.25 | 7.6 |
| Xylene | 0.25 | 3 |
| Polycyclic Aromatic Hydrocarbons (µg/L) | 7 | <LoD |
| Aliphatic / Aromatic Split (%) | 1 | 100% Aliphatic |
| Surfactants - MBAS (µg/L) | 50 | 2100 |

<LoD - Denotes concentration as being below the limit of detention

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## Ecotoxicity Testing

| Bioassay DetailsBioassay | Protocol | Reference | Test Species | Temperature |
|---|---|---|---|---|
| Microtox | WIECX-17 | Microbics 1992 | *V. fischeri* | 25°C |
| Microalgae Cell Division | WIECX-08 | Stauber et al. 1994 | *I. galbana* | 25°C |
| Sea Urchin Development | WIECX-24 | Simon et al. 1997 | *H. erythrogramma* | 25°C |
| Oyster Larvae Development | WIECX-14 | ASTM E724-98 | *S. glomerata* | 25°C |
| Copepod Reproduction | WIECX-13 | OECD 2005 | *G. imparipes* | 25°C |
| Fish Larvae Development | WIECX-16 | USEPA 1004.0 | *A. butcheri* | 25°C |
| Amphipod Survival | WIECX-00 | USEPA 1004.0 | *Corphium sp.* | 25°C |

### Concentration-Response Data

| Bioassay (% Control) | Control | 0.8% | 1.6% | 3.1% | 6.3% | 12.5% | 25% | 50% | 100% |
|---|---|---|---|---|---|---|---|---|---|
| Microtox | 100 ± 7 | - | 123 ± 13 | 141 ± 16 | 171 ± 7 | 129 ± 4 | 81 ± 11 | 24 ± 3 | 0 ± 0 |
| Microalgae Cell Division | 100 ± 2 | - | 129 ± 10 | 129 ± 22 | 105 ± 3 | 58 ± 7 | 10 ± 4 | 2 ± 3 | 0 ± 0 |
| Sea Urchin Development | 100 ± 3 | 98 ± 4 | 94 ± 2 | 91 ± 2 | 24 ± 4 | 0 ± 0 | 0 ± 0 | 0 ± 0 | 0 ± 0 |
| Oyster Larvae Development | 100 ± 11 | - | 113 ± 5 | 111 ± 4 | 72 ± 8 | 10 ± 10 | 0 ± 0 | 0 ± 0 | - |
| Copepod Development | 100 ± 16 | 112 ± 14 | 95 ± 15 | 93 ± 23 | 48 ± 14 | 43 ± 29 | 0 ± 0 | 0 ± 0 | - |
| Fish Larvae Development | 100 ± 12 | 107 ± 7 | 107 ± 7 | 93 ± 7 | 98 ± 10 | 38 ± 10 | 0 ± 0 | - | - |
| Amphipod Survival | 100 ± 0 | - | 91 ± 10 | 87 ± 12 | 76 ± 10 | 60 ± 18 | 18 ± 14 | 0 ± 0 | - |

- Concentration not used in toxicity test

### Statistical Effects Data

| Bioassay | EC10 (%) | EC50 (%) | NOEC (%) | LOEC (%) |
|---|---|---|---|---|
| Microtox | 21.8 | 37.3 | 12.5 | 25 |
| Microalgae Cell Division | 8.3 | 14.3 | 6.3 | 12.5 |
| Sea Urchin Development | 3.4 | 5.1 | 0.8 | 1.6 |
| Oyster Larvae Development | 5.1 | 7.8 | 3.1 | 6.3 |
| Copepod Development | 3.2 | 7.9 | 3.1 | 6.3 |
| Fish Larvae Development | 3.5 | 11.5 | 6.3 | 12.5 |
| Amphipod Survival | 3.0 | 11.1 | 3.1 | 6.3 |

* Results apply to the sample in the condition as received by Intertek Geotech

### Quality Assurance Limits

| Bioassay | Reference Toxicant | Cusum Chart Limits | Coefficient of Variance | Observed EC50 | Control Response | Test Acceptability |
|---|---|---|---|---|---|---|
| Microtox | Phenol | 16.1 – 30.3 mg/L | 15.3% | 23.9 mg/L | >90% | YES |
| Microalgae Cell Division | Copper | 10.9 – 50.1 µg/L | 32.0% | 38.7 µg/L | > 3 x cell divisions | YES |
| Sea Urchin Development | Copper | 10.2 – 27.1 µg/L | 22.6% | 11.2 µg/L | > 70 % Fertilised | YES |
| Mussel Larvae Development | Copper | 1.9 – 13.4 µg/L | 37.5 % | 5.4 µg/L | >80% Development | YES |
| Copepod Development | Copper | 6.1 – 16.8 µg/L | 23.4% | 8.5 µg/L | >8 Gravid Females | YES |
| Fish Larvae Development | Copper | 13.3 – 72 µg/L | 32.0% | 35.1 µg/L | >80% Survival | YES |
| Amphipod Survival | Copper | 130 – 430 µg/L | 30.3 % | 193.0 µg/L | >80% Survival | YES |

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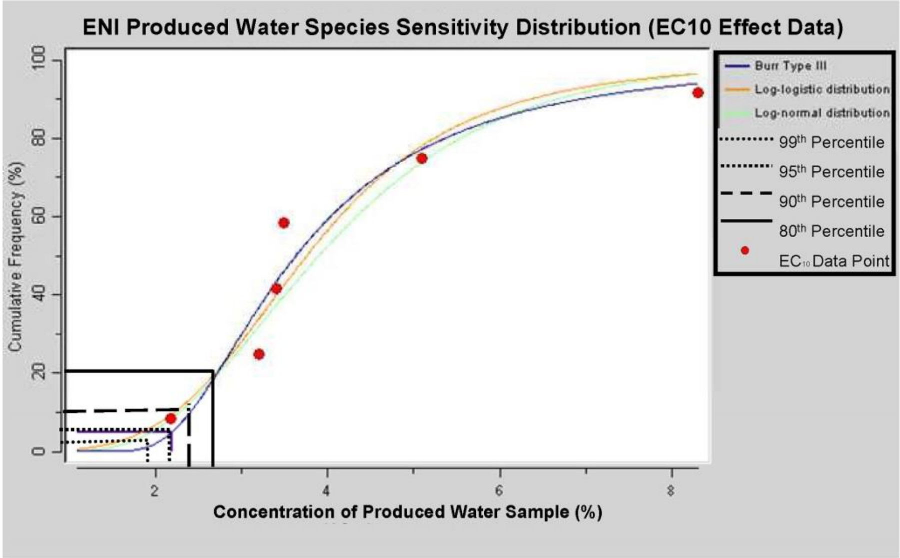
## Species Sensitivity Distribution




| Level of Species Protection | Produced Water (%) | Dilution Factor Required |
|---|---|---|
| 99% | 1.9 | 52 |
| 95% | 2.2 | 45 |
| 90% | 2.4 | 42 |
| 80% | 2.7 | 37 |

**Note: The amphipod survival test has been dropped from being included in the species sensitivity distribution as it resulted in high dilution factors that were not representative of the other bioassays in the assessment. This is due to the 10x correction factor used to convert the acute EC10 (3.0%) into a surrogate chronic EC10 value (0.3%).**

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## Biodegradation Potential

| Chemical Parameter | Sampling Interval | | | | | |
|---|---|---|---|---|---|---|
| | Day 0 | Day 1 | Day 2 | Day 5 | Day 7 | Day 14 |
| **Microtox EC50 (%)** | 37.3 | 43.8 | 49.1 | 47.8 | 55.4 | 58.1 |
| **BTEX (µg/L)** | | | | | | |
| Benzene | 160 | 0.6 | <LoD | <LoD | - | - |
| Toluene | 160 | 160 | 1 | <LoD | - | - |
| Ethylbenzene | 7.6 | <LoD | <LoD | <LoD | - | - |
| Xylenes | 38 | <LoD | <LoD | <LoD | - | - |
| Relative BTEX remaining (%) | 100% | 43.9% | 0.3% | 0% | - | - |
| **TPH - gravimetric (µg/L)** | 1000 | 930 | 730 | 930 | - | - |
| Relative TPH remaining (%) | 100% | 93% | 73% | 93% | - | - |
| **TPH - speciated (µg/L)** | | | | | | |
| < C13 hydrocarbons | <LoD | <LoD | <LoD | <LoD | - | - |
| C13 hydrocarbons | 21 | <LoD | <LoD | <LoD | - | - |
| C14 hydrocarbons | 79 | 12 | 38 | <LoD | - | - |
| C15 hydrocarbons | 126 | 36 | 98 | 3 | - | - |
| C16 hydrocarbons | 145 | 64 | 104 | 16 | - | - |
| C17 hydrocarbons | 149 | 85 | 65 | 37 | - | - |
| C18 hydrocarbons | 126 | 77 | 52 | 44 | - | - |
| C19 hydrocarbons | 99 | 68 | 51 | 45 | - | - |
| C20 hydrocarbons | 79 | 73 | 50 | 53 | - | - |
| C21 hydrocarbons | 83 | 80 | 47 | 67 | - | - |
| C22 hydrocarbons | 36 | 78 | 51 | 78 | - | - |
| C23 hydrocarbons | 21 | 70 | 50 | 82 | - | - |
| C24 hydrocarbons | 13 | 66 | 51 | 88 | - | - |
| C25+ hydrocarbons | 22 | 220 | 75 | 417 | - | - |
| Relative n-alkane remaining (%) * | | | | | | |
| **PAHs** | | | | | | |
| Total PAH | <LoD | <LoD | <LoD | <LoD | - | - |

<LoD - Denotes concentration as being below the limit of detention listed in *Chemical Characterisation*

* Relative n-alkane calculations based on $C_{11}$ to $C_{29}$

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## Bioaccumulation Potential

Mussel tissue concentrations after 30 –days exposure

| Chemical Parameter | Concentration of Contaminant in Mussel Tissue (mg/kg, dry weight) [1] | | |
|---|---|---|---|
| | Control (seawater) | 0.1% Treatment [2] | 1% Treatment [3] |
| **Metals** | | | |
| Antimony | <LoD | <LoD | <LoD |
| Arsenic | 3.1 ± 0.06 | 2.9 ± 0.15 | 2.9 ± 0.15 |
| Barium | 0.08 ± 0.02 | 0.31 ± 0.04 | 9.8 ± 1.1 |
| Beryllium | <LoD | <LoD | <LoD |
| Boron | 5.17 ± 0.38 | 4.9 ± 0.1 | 4.7 ± 0 |
| Cadmium | 0.23 ± 0.12 | 0.20 ± 0.02 | 0.19 ± 0.02 |
| Chromium | 0.12 ± 0.02 | 0.12 ± 0.03 | 0.08 ± 0.02 |
| Cobalt | 0.07 ± 0.01 | 0.07 ± 0.01 | 0.05 ± 0.01 |
| Copper | 0.79 ± 0.01 | 0.76 ± 0.6 | 0.72 ± 0.13 |
| Lead | 0.15 ± 0.07 | 0.11 ± 0.04 | 0.07 ± 0.015 |
| Manganese | 0.83 ± 0.09 | 1.05 ± 0.18 | 1.97 ± 0.05 |
| Mercury | 0.01 ± 0.01 | 0.01 ± 0 | 0.01 ± 0 |
| Molybdenum | 0.16 ± 0.01 | 0.14 ± 0.01 | 0.11 ± 0.02 |
| Nickel | 0.21 ± 0.03 | 0.18 ± 0.02 | 0.18 ± 0.05 |
| Selenium | 1.13 ± 0.06 | 1.1 ± 0 | 1.00 ± 0.08 |
| Tin | 0.08 ± 0.04 | 0.05 ± 0.02 | 0.04 ± 0 |
| Zinc | 42.3 ± 8.5 | 39.7 ± 2.5 | 32.3 ± 8.5 |
| **BTEX** | | | |
| Benzene | <LoD | <LoD | <LoD |
| Toluene | <LoD | <LoD | <LoD |
| Ethylbenzene | <LoD | <LoD | <LoD |
| Xylenes | <LoD | <LoD | <LoD |
| **TPH - Speciated** | | | |
| $C_6 – C_9$ | <LoD | <LoD | <LoD |
| $C_{10} – C_{14}$ | <LoD | <LoD | <LoD |
| $C_{15} – C_{28}$ | <LoD | <LoD | <LoD |
| $C_{29} – C_{36}$ | <LoD | <LoD | <LoD |

[1] Mean concentration (n=3) ± 1 standard deviation, [2] Equivalent to a dilution factor of 1000, [3] Equivalent to a dilution factor of 100
<LoD - Denotes concentration as being below the limit of detention of 0.01 mg/kg, dry weight

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Mussel tissue concentrations after 60 days (30 day exposure, then 30 depuration)

| Chemical Parameter | Concentration of Contaminant in Mussel Tissue (mg/kg, dry weight) [1] | | |
|---|---|---|---|
| | Control (seawater) | 0.1% Treatment [2] | 1% Treatment [3] |
| **Metals** | | | |
| Antimony | <LoD | <LoD | <LoD |
| Arsenic | 2.9 ± 0.1 | 2.67 ± 0.21 | 2.9 ± 0.17 |
| Barium | 0.06 ± 0.02 | 0.09 ± 0.03 | 6.47 ± 0.95 |
| Beryllium | <LoD | <LoD | <LoD |
| Boron | 4.73 ± 0.21 | 4.7 ± 0.1 | 4.83 ± 0.06 |
| Cadmium | 0.24 ± 0.03 | 0.24 ± 0.02 | 0.24 ± 0.04 |
| Chromium | 0.11 ± 0.01 | 0.13 ± 0.02 | 0.13 ± 0.01 |
| Cobalt | 0.08 ± 0.01 | 0.08 ± 0.01 | 0.09 ± 0.02 |
| Copper | 0.75 ± 0.11 | 0.67 ± 0.05 | 0.70 ± 0.05 |
| Lead | 0.10 ± 0.04 | 0.10 ± 0.02 | 0.07 ± 0 |
| Manganese | 0.68 ± 0.12 | 0.65 ± 0.04 | 1.43 ± 0.21 |
| Mercury | 0.01 ± 0.01 | 0.02 ± 0.01 | 0.01 ± 0 |
| Molybdenum | 0.13 ± 0.01 | 0.13 ± 0.02 | 0.13 ± 0.01 |
| Nickel | 0.23 ± 0.02 | 0.23 ± 0.04 | 0.28 ± 0.05 |
| Selenium | 0.98 ± 0.02 | 0.96 ± 0.05 | 0.96 ± 0.13 |
| Tin | 0.07 ± 0.01 | 0.05 ± 0.02 | 0.05 ± 0.01 |
| Zinc | 39.7 ± 5.1 | 37.3 ± 5.1 | 50.0 ± 3.6 |
| **BTEX** | | | |
| Benzene | <LoD | <LoD | <LoD |
| Toluene | <LoD | <LoD | <LoD |
| Ethylbenzene | <LoD | <LoD | <LoD |
| Xylenes | <LoD | <LoD | <LoD |
| **TPH - Speciated** | | | |
| $C_6 - C_9$ | <LoD | <LoD | <LoD |
| $C_{10} - C_{14}$ | <LoD | <LoD | <LoD |
| $C_{15} - C_{28}$ | <LoD | <LoD | <LoD |
| $C_{29} - C_{36}$ | <LoD | <LoD | <LoD |

[1] Mean concentration (n=3) ± 1 standard deviation, [2] Equivalent to a dilution factor of 1000, [3] Equivalent to a dilution factor of 100
- Denotes concentration as being below the Practical Quantitation Limit (PQL) of 0.1 mg/kg, dry weight

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**General Comments**

***Chemical Characterisation***

Chemical characterisation of the produced water sample identified zinc at concentrations exceeding ANZECC/ARMCANZ (2000) marine water quality guideline trigger values for 99% species protection. Although water quality guideline trigger values were not available for barium, boron, manganese, and TPH, elevated concentrations were noted.

Quality assurance and quality control criteria were within acceptable limits for all chemical analyses.

***Ecotoxicity Testing***

The dilution of the produced water in the concentration series resulted in precipitation of manganese and iron oxides (due to the increase in pH with dilution). This observation was consistent with the formation of oxyhydroxide phases (e.g. Fe-OOH), often occurring when soluble iron and manganese (e.g. $Fe^{2+}$) present in lower pH waters oxidises and precipitates following an increase in pH to 8.0 (naturally buffered seawater). Thus the sample had to be filtered through a 0.45µm filter to remove the precipitate. Unfiltered controls were conducted to ensure that the sample modifications did not alter toxicity. This implied that any contaminants present in the produced water were not complexed with the precipitate and the predicted bioavailability would be representative of discharge in the mixing zone.

Based on the EC10 data from five chronic and two acute marine bioassays, the dilution factors required to achieve 99, 95, 90 or 80% species protection in seawater were determined to be 52, 45, 42, and 37(respectively). The Northern Territory Environmental Protection Licence (Licence No. EPL57) stipulates a 99% level of species protection be achieved in the mixing zone. Therefore, a dilution factor of 52 (based on chronic effect EC10 values) will be sufficient to achieve compliance, i.e. diluting the produced water by a factor of 52 will result in only 1% of the exposed species showing a 10% reduction in growth or reproduction in the mixing zone.

Based on the chemical characterisation the observed toxicity is potentially due a complex mixture of chemicals in the PFW with contributions potentially from zinc, barium, and TPH. Zinc requires a 5.7 fold dilution to be at concentrations below ANZECC/ARMCANZ (2000) trigger value. Based on the EC10 values it is likely that zinc may be contributing to the toxicity at the high concentrations of the PFW. Barium has been linked as a cause of the toxicity of produced waters in other studies to mussels and sea urchins (Payne et al 2011, Spangenberg and Cherr 1996, Schatten et al. 1985) and therefore could be contributing to the observed toxicity. TPH is also likely to contribute to toxicity; however, as barium and TPH do not have any ANZECC/ARMCANZ (2000) trigger values and there is limited toxicity data to compare to, it is unknown what proportion of the toxicity they are responsible for. Additionally there could be other chemicals not analysed that could be contributing to the toxicity.

Quality assurance and quality control criteria were within acceptable limits for all ecotoxicity bioassays preformed.

***Biodegradation Potential***

Toxicity of the produced water to the marine bacterium *Vibrio fischeri* (15-min Microtox bioassay) only slightly decreased over 14 days, with the 15-min EC50 (i.e. the concentration at which bioluminescence is inhibited by 50% compared to the control after a 15-minute exposure) increasing from 33.7% on Day 0 to 58.1% on Day 14, a 42% decrease in toxicity.

Significant reductions in BTEX were observed at 24 hrs (56% reduction) and was almost below detection limits (>99% reduction) at the 48-hour time interval. Total TPH however did not significantly change with only a 7% reduction at day 5 (some variability was observed at day 2 likely due to analytical variability of the low concentrations of TPH). The losses of TPH were predominantly the C13- C18 hydrocarbon range. Despite the reductions in BTEX and TPH the Microtox bioassay showed only a slight reduction in toxicity with EC50 from 33.7% at day 0 to 58% at day 14. Suggesting the toxicity is likely caused by metals and/or higher molecular weight hydrocarbons which did not biodegrade.

Results from the biodegradation study indicate that the toxicity from the produced water (based on Microtox results) will potentially under environmental conditions exist for more than 14-days undiluted. As the toxicity observed did not match the reduction in BTEX the toxicity is most likely due to the metals or TPH which remained after 5 days. Despite the low degradation potential of the sample, if the sample is diluted to the recommended 99% species protection dilution factor (see above) environmental risk should be low.

Quality assurance and quality control criteria were within acceptable limits for all chemical analyses and ecotoxicity bioassays.

***Bioaccumulation potential***

The bioaccumulation study was performed to assess the uptake and retention of contaminants by the bivalve *Mytilis edulis*. The bivalves were exposed in semi-static chambers to a control treatment (seawater only) and two sublethal concentrations of the produced water, including 0.1% and 1% concentrations (equivalent to dilution factors of 1000 and 100, respectively). In accordance with OECD Test Guideline 305, a continuous exposure period of 30-days (uptake phase) was followed by an additional 30-day period of depuration in clean seawater.

Barium and manganese were observed at elevated levels in the mussel tissues during the bioaccumulation test. Barium was found to be at elevated concentrations at both the 0.1 and 1% concentrations after the 30 day exposure; after the depuration period only the 1% treatment showed elevated levels of barium (100x greater than controls). Manganese had elevated tissue concentrations at the 1% treatment after the 30 day exposure and also after the depuration period, however to a lesser extent then barium. All measurements for BTEX and speciated TPHs were below the limit of practical quantitation (i.e. concentrations of BTEX and TPH were negligible). Quality assurance and quality control criteria were within acceptable limits for all chemical analyses and bioassays.

There is little environmental risk from the observed bioaccumulation of manganese and barium in the mussel. Manganese is an essential trace element actively regulated by several marine organisms, including bivalves. Accurately determining the extent of biological effects from internally sequestered manganese is complex and often variable. Barium is most likely bioaccumulated as barite which is considered to have little toxicity and low bioaccumulation potential (Neff 2002). However, as the level of barium was 100x greater in the 1% concentration after the depuration period than the control treatment barium is bioaccumulating, nevertheless as there was no significant differences in bivalve mortality over the 60-day exposure, it suggesting that the tissue concentrations are not likely to cause acute toxicity (mortality).

***Summary and Recommendations***

The produced water contained zinc at concentrations exceeding ANZECC/ARMCANZ (2000) marine water quality guideline trigger values for 99% species protection. Elevated concentrations of barium, manganese, and TPHs, were also noted.

Based on results from the produced water chemical characterisation, ecotoxicity and biodegradation studies, a minimum safe dilution factor of 52 in the mixing zone will be sufficient to achieve a 99% level of species protection. The dilution factor of 52 will lower all contaminants identified in the produced water to concentrations below the ANZECC/ARMCANZ (2000) marine water quality guideline trigger values recommended for a 99% level of species protection.

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**Report Approval**

| | |
|---|---|
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# APPENDIX B:

## BLACKTIP OPERATIONS MARINE SURVEY 2016

# BLACKTIP OPERATIONS MARINE SURVEY 2016

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| Validity Status | Rev. Number | Date | Description | Prepared by | Checked by | Approved by | Contractor Approval | Company Approval |
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| PR-OP | 01 | 13/02/17 | Final Issue | TLU | AHA | KCO | | |
| PR-OP | 00 | 06/02/17 | Issued for Comments | TLU | | | | |
| Revision index | | | | | | | | |

| | | |
|---|---|---|
| eni australia | Project name<br>**BLACKTIP OPERATIONS** | Company identification<br>000036_DV_PR.HSE.1104.000<br>Job N. ___ |
| | | Contractor identification<br>Contract ___ |
| (Vendor logo and business name) | | Vendor identification<br>......................................<br>Order N............................ |
| Facility Name<br>BLACKTIP | Location | Scale: 1:1 / Sheet of Sheets: 1 / 85 |
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| | | | |

# TABLE OF CONTENTS

# TABLES



# FIGURES



## APPENDICES

# 1. ABBREVIATIONS

| ACRONYM | DEFINITION |
|---|---|
| Eni | Eni Australia B.V. |
| ANZECC | Australian and New Zealand Environment and Conservation Council |
| ARMCANZ | Agriculture and Resource Management Council of Australia and New Zealand |
| BTP | Blacktip |
| BTEX | Benzene Toluene Ethylbenzene and Xylene |
| C | Control |
| EIS | Environmental Impact Statement |
| EPL | Environment Protection Licence |
| FID | Flame Ionisation Detection |
| GC | Gas Chromatography |
| GC-MS | Gas Chromatography Mass Spectrometry |
| GPS | Global Positioning System |
| ID | Insufficient Data |
| ICP-OES | Inductively Coupled Plasma Optical Emission Spectroscopy |
| ISQG | Interim Sediment Quality Guidelines |
| kg | Kilograms |
| mg | Milligrams |
| NA | Not applicable |
| NATA | National Association of Testing Authorities |
| ND | Not detected |
| NT | Not tested |
| NRETAS | Department of Natural Resources, Environment, the Arts and Sport |
| NTEL | Northern Territory Environmental Laboratories |
| PAH | Polycyclic Aromatic Hydrocarbons |
| PQL | Practical Quantitation Limit |
| PW | Produced Water |
| RH | Rocky Headland |
| Sed | Sediment |
| SF | Shellfish |
| SPM | Single Point Mooring |
| TBD | To Be Determined |
| TOC | Total Organic Carbon |
| TPH | Total Petroleum Hydrocarbons |
| TRH | Total Residual Hydrocarbons |
| USEPA | United States Environmental Protection Authority |

## 2. EXECUTIVE SUMMARY

Eni has an annual commitment, set out in *Produced Water Management Plan* 000036_DV_EX.HSE.0381.000_A02, to undertake sediment and shellfish sampling in the vicinity of the produced water pipeline to monitor any impacts on sediment and biota. The survey conducted in May 2016 found all metal and hydrocarbon readings in sediment were below the Interim Sediment Quality Guideline (ISQG) trigger values (ANZECC 2000) or consistent with, and in many cases lower than, readings from the control site and previous surveys. The only exception was arsenic, which was measured slightly above the lower ISQG trigger value at Location 2, consistent with the naturally high arsenic levels reported during baseline surveys. All hydrocarbon readings in sediment were below the detection limit.

The majority of metal readings were slightly higher than the 2015 readings across all sites, but much lower than the historical maximums and within the range measured previously. The exceptions are barium, chromium and nickel, which were measured higher across all sites, particularly Location 1 – south end (mangroves only), Location 2 – north end (mangroves and rocky headlands), and the Control site (mangroves only). Hydrocarbons, $C_{10}$-$C_{28}$, were also detected in shellfish across all sites, suggesting a natural or regional source. Further advice will be sought with respect to the hydrocarbon, nickel and chromium results. No other hydrocarbons were detected in shellfish.

Overall, the results were consistent across the sampling sites, with little variation between the control and monitoring sites, providing confidence that there are no adverse impacts from produced water discharge.

# 3. INTRODUCTION

## 3.1 Background

Eni Australia B.V. (Eni) operates the Blacktip Gas Field, approximately 300 km south-west of Darwin, and 110 km from Wadeye, in the Joseph Bonaparte Gulf (Figure 3.1 and Figure 3.2).

The field consists of a small unmanned offshore wellhead platform (WHP), a subsea pipeline bringing whole well stream fluid (i.e. gas, condensate and produced water) past Yelcherr Beach and onto the Yelcherr Gas Plant (YGP). Processed gas is exported via an onshore export pipeline to customers in the Northern Territory. The condensate is exported via a subsea pipeline to a single-point mooring (SPM) for shipping via tanker vessel.

Produced Water (PW) generated at the YGP is treated and discharged through a long-sea outfall offshore (Figure 3.2). Details on the Blacktip PW system and its predicted environmental impact are described in the *Produced Water Management Plan* 000036_DV_EX.HSE.0381.000_A02 (Ref.[3]).

The *Produced Water Management Plan* also sets out a commitment to undertake annual marine monitoring to assess whether there are chronic effects from the discharge of produced water.

## 3.2 Purpose of this report

This document presents results for the 2016 annual marine monitoring. The samples were collected on 23 May 2016 from Yelcherr Beach and a control site north of the beach.

Sediment and shellfish were analysed for hydrocarbons and heavy metals, the contaminants of concern for PW. Sampling and analysis was undertaken in accordance with the National Assessment Guidelines for Dredging (NAGD) (Ref.[2]).

## 3.3 Monitoring objectives

The objective of the marine monitoring program is to characterise the sediment and biota from locations within the vicinity of the PW pipeline. Annual sampling and laboratory analysis allows a comparison of data with the original 2010 baseline survey data, to provide an indication of any build-up of contamination in the marine environment as a result of the PW discharge. The comparison between each annual dataset is included in the results and discussion section of this report.

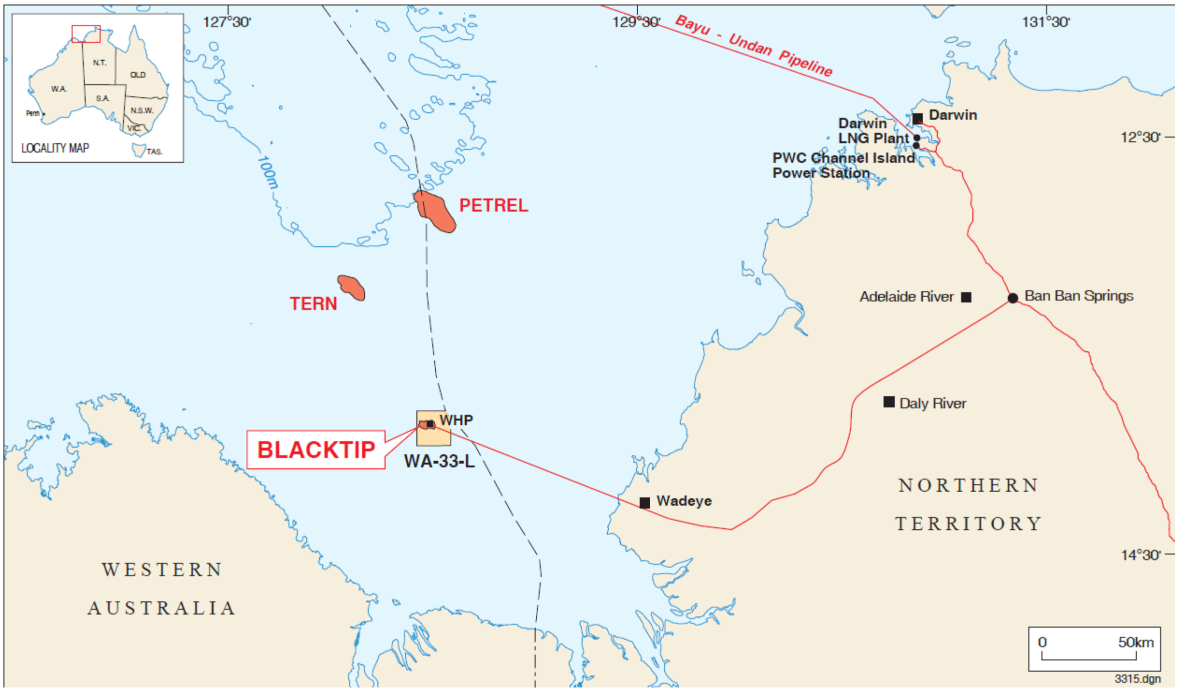


**Figure 3.1: Blacktip Field location**

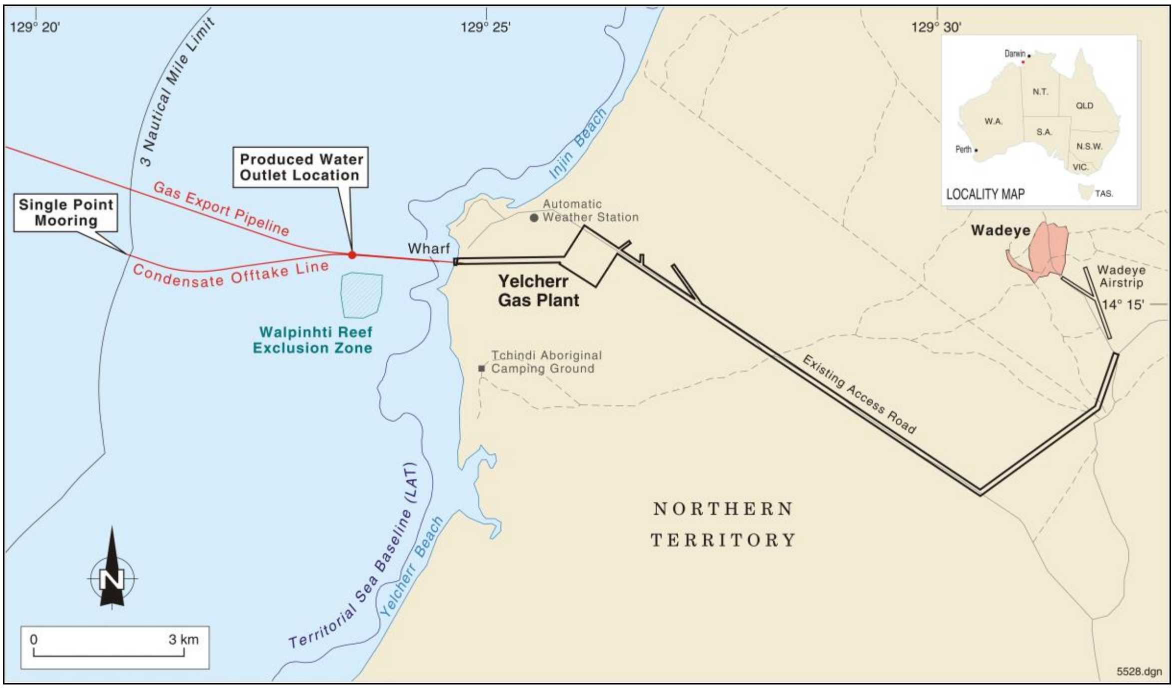


**Figure 3.2: Nearshore pipelines and produced water outlet location**

# 4. METHODS

## 4.1 Sampling locations

Onshore sampling locations include the southern and northern mangrove and rocky headland areas at each end of Yelcherr beach, as well as accompanying control sample location approximately 7 km north of the beach.

As indicated in the 2010, 2011 and 2012 reports, the seabed at the proposed offshore sampling locations consists mainly of shells and rocks and therefore it is not possible to obtain sediment samples for laboratory testing at these offshore locations. Therefore only onshore samples can be collected and analysed.

The control station was chosen using the following criteria:

- sufficiently far from the produced water outfall such that it would be unaffected by produced water discharge as indicated by the dispersion modelling (Ref. [3]);
- similar hydrodynamic and environmental conditions;
- undisturbed and not impacted by polluting activities;
- representative of regional background levels.

The sample locations are named as per Table 4.1.

**Table 4.1: Marine monitoring sample location nomenclature**

| Project | Location Type | Location | Sample Type | Sample Number |
|---|---|---|---|---|
| BT: Blacktip | M: Mangrove<br>RH: Rocky Headland | 01: Southern end<br>02: Northern end<br>C: Control | Sed: Sediment<br>SF: Shellfish | 01: Sample 1<br>02: Sample 2 |

Sample locations surveyed in 2016 are outlined in Table 4.2. Figure 4.1 shows the onshore sampling locations, including the southern and northern mangrove and rocky headland areas at each end of Yelcherr beach and control locations approximately 6 km north of the beach.

**Table 4.2: Marine survey sample locations**

| Location name | Recorded sample code | Site Description | Coordinates |
|---|---|---|---|
| Control 1 | BT-M-C-SED-01<br>BT-M-C-SF-01<br>BT-RH-C-SF-01 | Control site (same as previous years) | -14.191592<br>129.454255 |
| Location 1 | BT-M-01-SED-01<br>BT-M-01-SF-01<br>BT-RH-01-SF-01 | Southern end of Yelcherr Beach | -14.248081<br>129.407773 |
| Location 2 | BT-M-02-SED-01<br>BT-M-02-SF-01<br>BT-RH-02-SF-01 | Northern end of Yelcherr Beach | -14.238457<br>129.411085 |

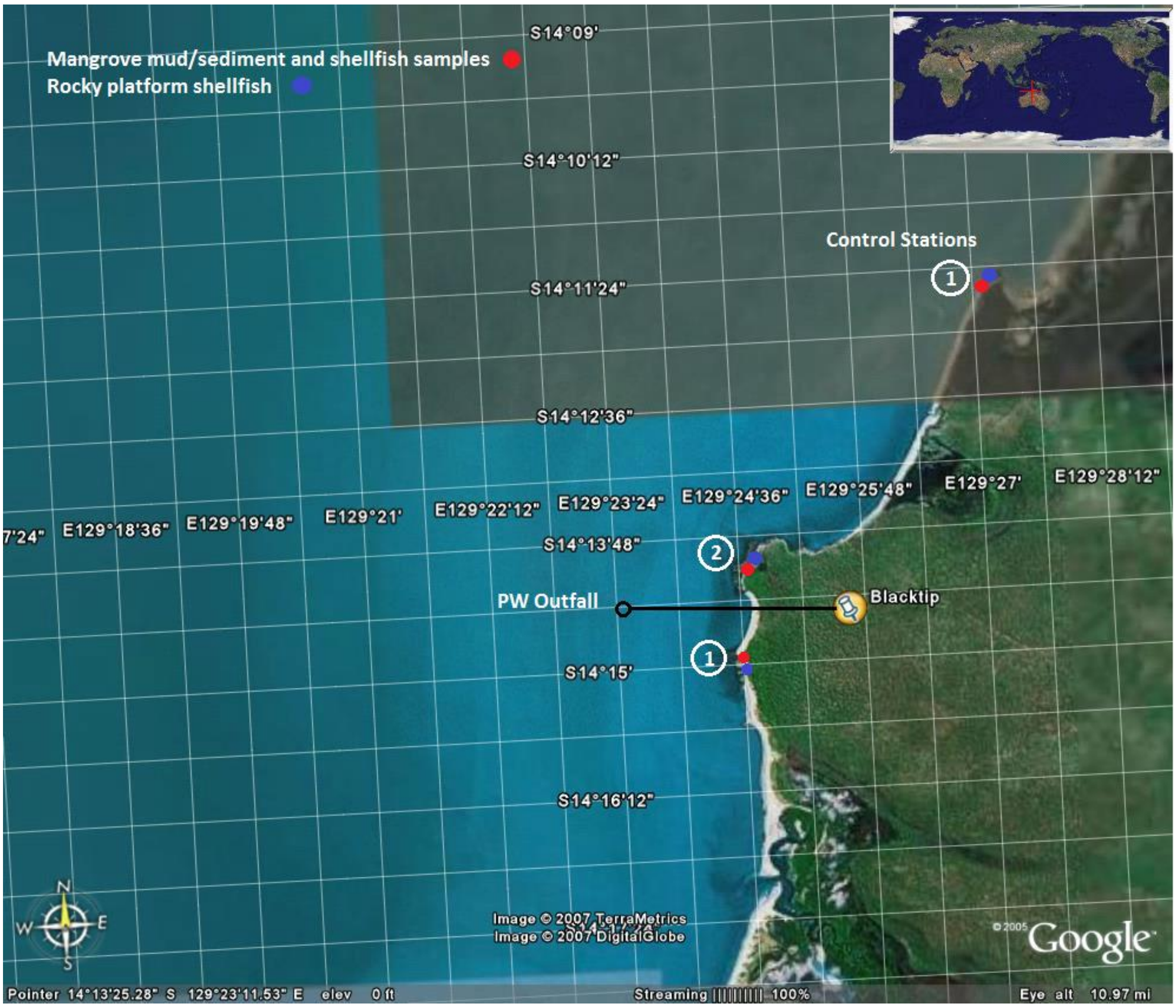


**Figure 4.1: Marine monitoring sampling locations**

## 4.2 Sediment sampling

Sediment were taken using latex gloves and a steel trowel, and transferred into glass jars.

## 4.3 Shellfish sampling

*Telescopium telescopium* and *Terebralia* sp. (mud whelks) were collected from mangrove forests (*Rhizophore stylosa*) either side of Yelcherr Beach and two control sites north of the Beach (Figure 4.2). These species were targeted as they are the most abundant and are also food sources for the local community (Figure 4.3). Samples were stored in plastic sealable bags.

**Figure 4.2: Terebralia sp. in the mangrove forests (commonly Rhizophore stylosa)**

**Figure 4.3: Shells left on the beach**

## 4.4 Sample analysis

### 4.4.1 Overview

All samples were delivered to Intertek, a National Association of Testing Authorities (NATA) accredited laboratory. On receipt of the shellfish samples, the tissue was extracted from the shells and combined to form one composite shellfish sample for each of the sample locations. Shellfish samples comprised of a variety of different species with varying sizes and tissue contents. Tissue samples were analysed for metals, BTEX, PAHs, TPHs and phenols. Sediment samples were analysed based on whole sediment concentrations for the same analytes. Metals were analysed by Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). TPH content was determined by extraction in organic solvent and compared to a sample spiked with diesel. Phenols, BTEX, and PAHs were determined by GC-MS. The laboratory report for the analysis is provided in Appendix C.

### 4.4.2 Trace metals

Table 4.3 summarises the suite of metals and metalloids assayed. Resulting concentrations were benchmarked against the ANZECC and ARMCANZ (2000) guidelines where possible (Ref. [1]).

**Table 4.3: Sediment and shellfish metals analyses – metals and metalloids**

| Metals and metalloids | Practical Quantitation Limit (PQL) | Method | ANZECC and ARMCANZ (2000) guidelines (mg/kg dry weight) |
|---|---|---|---|
| Copper (Cu) | 0.1 – 1.5 mg/kg (dry weight) | APHA 3120B | 65 |
| Lead (Pb) | | | 50 |
| Zinc (Zn) | | | 200 |
| Chromium (Cr) | | | 80 |
| Nickel (Ni) | | | 21 |
| Cadmium (Cd) | | | 1.5 |
| Arsenic (As) | | | 20 |
| Silver (Ag) | | | 1.0 |
| Mercury (Hg) | | | 0.15 |
| Manganese (Mn) | | | ID |
| Aluminium (Al) | | | ID |
| Cobalt (Co) | | | ID |
| Iron (Fe) | | | ID |
| Vanadium (V) | | | ID |
| Selenium | | | ID |
| Sulfur (S) | | | ID |
| Antimony (Sb) | | | ID |
| Notes: ID – Insufficient Data; TBD – to be determined | | | |

### 4.4.3 Hydrocarbons

Table 4.4 summarises the hydrocarbon analysis undertaken. TPH was assayed using Gas Chromatography Flame Ionisation Detection (GC FID) after a solvent extraction with dichloromethane. Samples for PAH analysis were analysed by gas chromatography with a mass selective detector (GCMS), by USEPA method 8270.

**Table 4.4: Sediment and shellfish organic analyses – hydrocarbons**

| Parameter | Practical Quantitation Limit (PQL) | Method | Screening Level (ISQG Trigger Value) |
|---|---|---|---|
| TRH (Total Residual hydrocarbons): | | | |
| (C6-C9, C10 – C14, C15 – C18, C19 – C28 and C29-C36) | 25 - 100 mg/kg (dry weight) | USEPA 8015C | 550 mg/kg (dry weight) |
| Polycyclic Aromatic Hydrocarbons (PAHs), including: | | | |
| Phenanthene, Anthracene, Benz[b]fluoranthene, Fluoranthene, Indeno[1,2,3-cd]pyrene, Benzo[k]fluoranthene, Chrysene, coronene, Dibenz[ah] anthracene, Benzo[e]pyrene, benzo[a]pyrene, perylene, pyrene | 10 - 100 µg/kg (dry weight) | USEPA 3550B | See Table 3.5.1 in ANZECC/ARMCANZ (2000) (Ref. [1]). |
| Sum of PAHs | 10 - 100 µg/kg (dry weight) | | 4,000 µg/kg (dry weight) |
| Benzene, toluene, ethylbenzene, zylene (BTEX) | 1 mg/kg (dry weight) | | ID |
| Phenol/Phenolics | 10 - 100 mg/kg (dry weight) | | ID |
| Notes: ID – Insufficient Data; TBD – to be determined; ISQG - Interim Sediment Quality Guidelines | | | |

# 5. RESULTS AND DISCUSSION

## 5.1 Sediment samples

Sediment samples were taken from the mangrove muds at either end of Yelcherr beach, with control samples taken from a location 7 km to the north (see Figure 4.1).

Overall, the majority of readings were well within the levels measured in previous years and fairly consistent across the sites, with no major difference between the Yelcherr beach samples and control samples.

### 5.1.1 Metals in sediment samples

Table 4.1 and Appendix A present the measured metal concentrations in the mangrove sediment between 2010 and 2016. The key findings are summarised below:

- Overall, the readings were well within the levels measured in previous years and fairly consistent across the sites with no major difference between the Yelcherr beach samples and control samples.
- Only arsenic was measured slightly above the lower Interim Sediment Quality Guideline (ISQG) trigger value (Ref. [1]) at Location 2, consistent with the naturally high arsenic levels reported previously.

**Comparison with ANZECC Interim Sediment Quality Guideline trigger values**

Only arsenic levels in the mangrove sediment sample from location 2 (northern end of Yelcherr Beach) exceeded the lower ISQG trigger values (ANZECC 2000).

Naturally high arsenic levels in the area have been described in the 2004 Draft Environmental Impact Statement (EIS) (Ref. [10]), which showed arsenic readings on the beach and mangrove areas typically ranging between 10 and 20 mg/kg. Therefore, this result is not of concern. Furthermore, arsenic levels measured at both monitoring sites were still less than the arsenic levels measured at the control site in 2014 (43 mg/kg) and 2015 (42 mg/kg).

All other readings were below the trigger values.

**Comparison with the 2010 baseline survey and last survey conducted in 2015**

- The Location 1 (south end) sample contained slightly higher levels of the following metals compared with the 2010 baseline survey:
  - Aluminium;
  - Arsenic;
  - Iron;
  - Lead; and

- Manganese.

All readings were lower than the previous 2015 survey results.

- The Location 2 (north end) sample was found to contain slightly higher levels of the following metals compared with the 2010 baseline survey:

  - Aluminium (also higher than 2015);
  - Arsenic (also higher than 2015 and lower ISQG trigger value);
  - Cobalt (also higher than 2015);
  - Iron (also higher than 2015); and
  - Manganese (also higher than 2015).

  A number of other metal readings (chromium, copper, lead, nickel and zinc) were also slightly higher than measured in the previous 2015 survey.

- The Control site 1 sample was found to contain higher levels of the following metals compared with the 2010 baseline survey:

  - Aluminium;
  - Arsenic;
  - Cobalt;
  - Iron;
  - Lead; and
  - Manganese (also higher than 2015).

  Manganese readings in 2016 were also higher than 2015 readings. It is noted that the 2014 results indicated significant increase in metals levels at Control site 1. Many of the metals have returned to the previous levels, and it is noted that the 2016 arsenic reading is below the lower ISQG trigger value. Overall, these changes are not considered to be of concern.

**Table 5.1: Measured metal concentrations in mangrove sediment between 2010-2016**

| Metals (PQL mg/kg) | Year | BT-M-C-SED-01 | BT-M-C2-SED | BT-M-01-SED | BT-M-02-SED | ISQG-Low (Ref. [1]) | ISQG-High (Ref. [1]) |
|---|---|---|---|---|---|---|---|
| | | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg |
| Aluminium (<5 mg/kg) | 2010 | 1100 | NA | 950 | 2050 | ID | ID |
| | 2011 | 1800 | NA | 2000 | 8800 | | |
| | 2012 | 1500 | NA | 4700 | 3100 | | |
| | 2014 | 45000 | NA | 2200 | 3800 | | |
| | 2015 | 7800 | 13000 | 3100 | 4100 | | |
| | 2016 | 5700 | | 1600 | 11000 | | |
| Antimony (<0.5 mg/kg) | 2010 | <0.05 | NA | <0.05 | <0.05 | 2 | 25 |
| | 2011 | 0 | NA | 0 | 0 | | |
| | 2012 | <2 | NA | <2 | 9 | | |
| | 2014 | 8 | NA | 6 | 6 | | |
| | 2015 | <0.5 | <0.5 | <0.5 | <0.5 | | |
| | 2016 | NA | NA | NA | NA | | |
| Arsenic (<0.4 mg/kg) | 2010 | 9 | NA | 11 | 14.5 | 20 | 70 |
| | 2011 | 17 | NA | 8.5 | 22 | | |
| | 2012 | 13 | NA | 13 | 36 | | |
| | 2014 | 43 | NA | 10 | 23 | | |
| | 2015 | 9.7 | 42 | 23 | 10 | | |
| | 2016 | 12 | NA | 15 | 23 | | |
| Barium (NA) | 2010 | NA | NA | NA | NA | ID | ID |
| | 2011 | NA | NA | NA | NA | | |
| | 2012 | NA | NA | NA | NA | | |
| | 2014 | 3 | NA | 5 | 4 | | |
| | 2015 | NA | NA | NA | NA | | |
| | 2016 | 7 | NA | 2 | 9 | | |
| Cadmium (<0.1 mg/kg) | 2010 | 0.5 | NA | 0.9 | 0.9 | 1.5 | 10 |
| | 2011 | 0.1 | NA | nd | 0.15 | | |
| | 2012 | 0.1 | NA | 0.1 | 0.4 | | |
| | 2014 | 1.9 | NA | 0.2 | 0.7 | | |
| | 2015 | <0.4 | <0.4 | <0.4 | <0.4 | | |
| | 2016 | <0.4 | NA | <0.1 | <0.4 | | |
| Chromium (<0.1 mg/kg) | 2010 | 120 | NA | 90 | 70 | 80 | 370 |
| | 2011 | 27 | NA | 8.9 | 31 | | |
| | 2012 | 15 | NA | 17 | 33 | | |
| | 2014 | 120 | NA | 10 | 16 | | |
| | 2015 | 9.4 | 66 | 50 | 13 | | |
| | 2016 | 16 | NA | 19 | 33 | | |
| Cobalt (<0.5 mg/kg) | 2010 | 2.55 | NA | 2 | 3.85 | ID | ID |
| | 2011 | 2.2 | NA | 1.9 | 5.7 | | |
| | 2012 | 2 | NA | 5 | 4 | | |
| | 2014 | 4 | NA | 2 | 3 | | |
| | 2015 | 2.9 | 11 | 6.5 | 3 | | |
| | 2016 | 4 | NA | 2 | 7 | | |

| Metals (PQL mg/kg) | Year | BT-M-C-SED-01 | BT-M-C2-SED | BT-M-01-SED | BT-M-02-SED | ISQG-Low (Ref. [1]) | ISQG-High (Ref. [1]) |
|---|---|---|---|---|---|---|---|
| | | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg |
| Copper (<0.1 mg/kg) | 2010 | 49.2 | NA | 29 | 152 | 65 | 270 |
| | 2011 | 1.2 | NA | 1.4 | 7 | | |
| | 2012 | 3 | NA | 8 | 6 | | |
| | 2014 | 3 | NA | 6 | 10 | | |
| | 2015 | 2 | 16 | 1.7 | 2 | | |
| | 2016 | 4 | NA | <1 | 9 | | |
| Iron (<10 mg/kg) | 2010 | 3760 | NA | 1980 | 2720 | ID | ID |
| | 2011 | 18000 | NA | 8300 | 40000 | | |
| | 2012 | 8600 | NA | 9800 | 24000 | | |
| | 2014 | 55000 | NA | 6800 | 21000 | | |
| | 2015 | 22000 | 240000 | 47000 | 12000 | | |
| | 2016 | 14000 | NA | 14000 | 36000 | | |
| Lead (<0.5 mg/kg) | 2010 | 1.6 | NA | 1.6 | 7.8 | 50 | 220 |
| | 2011 | 2.3 | NA | 1.7 | 5 | | |
| | 2012 | 2 | NA | 3 | 2 | | |
| | 2014 | 12 | NA | 3 | 6 | | |
| | 2015 | 2.4 | 14 | 6.2 | 2.3 | | |
| | 2016 | 4 | NA | 4 | 6 | | |
| Manganese (<5 mg/kg) | 2010 | 106 | NA | 86.6 | 80.2 | ID | ID |
| | 2011 | 140 | NA | 140 | 210 | | |
| | 2012 | 130 | NA | 220 | 96 | | |
| | 2014 | 420 | NA | 150 | 93 | | |
| | 2015 | 160 | 190 | 230 | 120 | | |
| | 2016 | 210 | NA | 180 | 210 | | |
| Mercury (<0.01 mg/kg) | 2010 | <0.2 | NA | 0.4 | <0.2 | 0.15 | 1 |
| | 2011 | 0 | NA | nd | nd | | |
| | 2012 | <0.02 | NA | <0.02 | <0.02 | | |
| | 2014 | 0.03 | NA | <0.02 | <0.02 | | |
| | 2015 | <0.1 | <0.1 | <0.1 | <0.1 | | |
| | 2016 | <0.1 | NA | <0.1 | <0.1 | | |
| Nickel (<0.1 mg/kg) | 2010 | 35 | NA | 22.2 | 24.2 | 21 | 52 |
| | 2011 | 3.7 | NA | 2.3 | 9.2 | | |
| | 2012 | 3 | NA | 5 | 6 | | |
| | 2014 | 7 | NA | 2 | 5 | | |
| | 2015 | 3.1 | 14 | 7.1 | 3.2 | | |
| | 2016 | 5 | NA | 3 | 11 | | |
| Selenium (<0.1 mg/kg) | 2010 | 2010 | NA | na | na | ID | ID |
| | 2011 | 2011 | NA | nd | 0.13 | | |
| | 2012 | 2012 | NA | <2 | <2 | | |
| | 2014 | 2014 | NA | <2 | <2 | | |
| | 2015 | <1.0 | <1.0 | <1.0 | <1.0 | | |
| | 2016 | <2 | NA | <2 | <2 | | |
| Sulfur (<0.1 mg/kg) | 2010 | 7060 | NA | 9440 | 8260 | ID | ID |
| | 2011 | na | NA | na | na | | |

| Metals (PQL mg/kg) | Year | BT-M-C-SED-01 mg/kg | BT-M-C2-SED mg/kg | BT-M-01-SED mg/kg | BT-M-02-SED mg/kg | ISQG-Low (Ref. [1]) mg/kg | ISQG-High (Ref. [1]) mg/kg |
|---|---|---|---|---|---|---|---|
| | 2012 | na | NA | na | na | | |
| | 2014 | na | NA | na | na | | |
| | 2015 | NA | NA | NA | NA | | |
| | 2016 | NA | NA | NA | NA | | |
| Silver (<0.1 mg/kg) | 2010 | 0.25 | NA | 2.2 | 0.45 | 1 | 3.7 |
| | 2011 | 0 | NA | nd | nd | | |
| | 2012 | <1 | NA | <1 | <1 | | |
| | 2014 | <1 | NA | <1 | <1 | | |
| | 2015 | <0.5 | <0.5 | <0.5 | <0.5 | | |
| | 2016 | NA | NA | NA | NA | | |
| Vanadium (<0.1 mg/kg) | 2010 | 10 | NA | <10 | <10 | ID | ID |
| | 2011 | 45 | NA | 18 | 72 | | |
| | 2012 | 26 | NA | 27 | 76 | | |
| | 2014 | 140 | NA | 20 | 56 | | |
| | 2015 | 19 | 120 | 95 | 23 | | |
| | 2016 | NA | NA | NA | NA | | |
| Zinc (<0.5 mg/kg) | 2010 | 73.5 | NA | 55 | 154 | 200 | 410 |
| | 2011 | 6.5 | NA | 4.3 | 16 | | |
| | 2012 | 6 | NA | 9 | 11 | | |
| | 2014 | 9 | NA | 3 | 7 | | |
| | 2015 | 7.3 | 63 | 18 | 8.7 | | |
| | 2016 | 9 | NA | 5 | 23 | | |
| Notes: ND = Not Detected; NT = Not Tested; ID = Insufficient Data; NA = Not Applicable | | | | | | | |

### 5.1.2 Hydrocarbons in sediment samples

Table 5.2 presents the measured hydrocarbon concentrations in the mangrove sediment samples. All concentrations were found to be below detection limits.

**Table 5.2: Measured TRH, BTEX and PAH concentrations in mangrove sediment 2016**

| Chemical parameter | Control 1 BT-M-C-SED-01 mg/kg | Location 1 BT-M-01-SED-01 mg/kg | Location 2 BT-M-02-SED-01 mg/kg | ISQG trigger values (Ref. [1]) mg/kg |
|---|---|---|---|---|
| **BTEX** | | | | |
| Benzene | <0.2 | <0.2 | <0.2 | ID |
| Toluene | <0.5 | <0.5 | <0.5 | ID |
| Ethylbenzene | <1 | <1 | <1 | ID |
| m+p-xylenes | <2 | <2 | <2 | ID |
| o-xylene | <1 | <1 | <1 | ID |
| Naphthalene | <1 | <1 | <1 | ID |
| **TRH -Speciated** | | | | |
| C6 – C9 | <25 | <25 | <25 | ID |
| C10 – C14 | <50 | <50 | <50 | ID |

| **Chemical parameter** | **Control 1 BT-M-C-SED-01** | **Location 1 BT-M-01-SED-01** | **Location 2 BT-M-02-SED-01** | **ISQG trigger values (Ref. [1])** |
|---|---|---|---|---|
| | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** |
| C15 – C28 | <100 | <100 | <100 | ID |
| C29 – C36 | <100 | <100 | <100 | ID |
| **PAH -Speciated** | | | | |
| Naphthalene | <0.01 | <0.01 | <0.01 | 160 |
| Acenaphthylene | <0.01 | <0.01 | <0.01 | 16 |
| Acenaphthene | <0.01 | <0.01 | <0.01 | 44 |
| Fluorene | <0.01 | <0.01 | <0.01 | 19 |
| Phenanthrene | <0.01 | <0.01 | <0.01 | 240 |
| Anthracene | <0.01 | <0.01 | <0.01 | 85 |
| Fluoranthene | <0.01 | <0.01 | <0.01 | 600 |
| Pyrene | <0.01 | <0.01 | <0.01 | 665 |
| Benz(a)anthracene | <0.01 | <0.01 | <0.01 | 261 |
| Chrysene | <0.01 | <0.01 | <0.01 | 384 |
| Benzo(b)fluoranthene | <0.02 | <0.02 | <0.02 | ID |
| Benzo(k)fluoranthene | <0.01 | <0.01 | <0.01 | ID |
| Benzo(a)pyrene | <0.05 | <0.05 | <0.05 | 430 |
| Indeno(1,2,3-c,d)pyrene | <0.01 | <0.01 | <0.01 | ID |
| Dibenz(a,h)anthracene | <0.01 | <0.01 | <0.01 | 63 |
| Benzo(ghi)perylene | <0.16 | <0.16 | <0.16 | ID |
| Total PAH | NIL (+)IVE | NIL (+)IVE | NIL (+)IVE | ID |

**Table 5.3: Speciated TPH measured in sediment between 2010-2016**

| **TPH** | **Year** | **Control site 1 BT-M-C-SED-01** | **Control site 2 BT-M-C2-SED-01** | **Location 1 BT-M-01-SED-01** | **Location 2 BT-M-02-SED-01** |
|---|---|---|---|---|---|
| | | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** |
| $C_6$-$C_9$ | 2010 | ND | NT | ND | ND |
| | 2011 | <10 | NT | <10 | NT |
| | 2012 | <0.2 | NT | <0.2 | <0.2 |
| | 2014 | <0.1 | NT | <0.1 | <0.1 |
| | 2015 | <25 | <25 | <25 | <25 |
| | 2016 | <25 | NT | <25 | <25 |
| $C_{10}$-$C_{14}$ | 2010 | ND | NT | ND | ND |
| | 2011 | <10 | NT | <10 | NT |
| | 2012 | <0.2 | NT | <0.2 | <0.2 |
| | 2014 | <0.1 | NT | <0.1 | <0.1 |
| | 2015 | <50 | <50 | <50 | <50 |
| | 2016 | <50 | NT | <50 | <50 |
| $C_{15}$-$C_{28}$ | 2010 | ND | NT | ND | ND |
| | 2011 | <50 | NT | <50 | NT |
| | 2012 | <0.4 | NT | <0.4 | <0.4 |
| | 2014 | 8 | NT | 6 | 7 |
| | 2015 | <100 | <100 | <100 | <100 |

| TPH | Year | Control site 1<br>BT-M-C-SED-01 | Control site 2<br>BT-M-C2-SED-01 | Location 1<br>BT-M-01-SED-01 | Location 2<br>BT-M-02-SED-01 |
|---|---|---|---|---|---|
| | | mg/kg | mg/kg | mg/kg | mg/kg |
| | 2016 | <100 | NT | <100 | <100 |
| $C_{29}$-$C_{36}$ | 2010 | ND | NT | ND | ND |
| | 2011 | <50 | NT | <50 | NT |
| | 2012 | <0.4 | NT | <0.4 | <0.4 |
| | 2014 | <0.1 | NT | <0.1 | <0.1 |
| | 2015 | <100 | <100 | <100 | <100 |
| | 2016 | <100 | NT | <100 | <100 |
| >$C_{36}$ | 2010 | ND | NT | ND | ND |
| | 2011 | NT | NT | NT | NT |
| | 2012 | <0.4 | NT | <0.4 | <0.4 |
| | 2014 | NT | NT | NT | NT |
| | 2015 | NT | NT | NT | NT |
| | 2016 | NT | NT | NT | NT |
| Notes: ND = Not Detected; NT = Not Tested; ID = Insufficient Data; NA = Not Applicable | | | | | |

## 5.2 Shellfish samples

### 5.2.1 Overview

Shellfish were collected from the mangroves at each end of Yelcherr beach, with control samples taken from two locations 7 km to the north (see Figure 3.1).

### 5.2.2 Metals in shellfish samples

Table 4.3 and Appendix B present the measured metal concentrations in shellfish samples between 2010 and 2016.

The majority of metal readings were slightly higher than the 2015 readings across all sites, but much lower than the historical maximums and within the range measured previously. The exceptions are barium, chromium and nickel.

Barium was only measured in 2012 and 2016. The 2016 readings ranged from 4 – 8 mg/kg and were higher than the 2012 values. However, the readings are inherently low and not of concern.

Both chromium and nickel were detected at higher levels than measured previously at the following sites: Location 1 – south end (mangroves only), Location 2 – north end (mangroves and rocky headlands), and the Control site (mangroves only). Chromium readings at those sites ranged between 26 – 82 mg/kg, in comparison with the previous maximum reading of 30 mg/kg in 2010 measured in shellfish collected from the rocky headlands at the Control site and Location 2.

Nickel readings in 2016 ranged between 10 – 30 mg/kg, in comparison with the previous maximum reading of 9.2 mg/kg in 2010 measured in shellfish collected from the rocky headlands at Location 2. There are no published guidelines for acceptable concentrations of chromium or nickel in shellfish tissue. Therefore, while the readings are an anomaly, they are not of immediate concern. Further advice will be sought with respect to the results.

With the exception of chromium and nickel, the results also fall within a consistent range across the various locations, providing confidence that there are no chronic effects from produced water discharge.

**Table 5.4: Measured metal concentrations (mg/kg dry weight) in shellfish samples between 2010-2016**

| Concentration of contaminant in shellfish tissue (mg/kg, dry weight)[1] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Metals (PQL mg/kg) | Year | Rocky headlands | | | | Mangroves | | |
| | | Control 1 | Control 2 | Location 1 | Location 2 | Control 2 | Location 1 | Location 2 |
| Aluminium (<5 mg/kg) | 2010 | 360 | NT | 640 | 240 | 1660 | 1740 | 2030 |
| | 2011 | 615 | NT | 350 | 450 | 220 | 350 | 1050 |
| | 2012 | 234.5 | NT | 330 | 160 | 370 | NT | 400 |
| | 2014 | NT | NT | NT | NT | 13000 | NT | 2000 |
| | 2015 | 260 | 520 | 490 | 370 | 120 | 220 | 120 |
| | 2016 | 62 | NT | 34 | 350 | 61 | 170 | 530 |
| Antimony (<0.5 mg/kg) | 2010 | <0.05 | NT | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| | 2011 | 0 | NT | 0 | 0 | 0 | 0 | 0 |
| | 2012 | 0 | NT | 0 | 0 | 0 | NT | 0 |
| | 2014 | NT | NT | NT | NT | <2 | NT | <2 |
| | 2015 | <0.01 | <0.01 | 0.01 | <0.01 | 0.02 | <0.01 | <0.01 |
| | 2016 | NT | NT | NT | NT | NT | NT | NT |
| Arsenic (<0.4 mg/kg) | 2010 | 7.5 | NT | 17.5 | 6 | 8.5 | 6.5 | 10 |
| | 2011 | 4.1 | NT | 14 | 6.4 | 1.7 | 2.4 | 2.6 |
| | 2012 | 6.2 | NT | 8.1 | 3.2 | 2.2 | NT | 2.4 |
| | 2014 | NT | NT | NT | NT | 6.9 | NT | 8.9 |
| | 2015 | 1.8 | 2.3 | 3 | 2.7 | 2.3 | 2.8 | 2.8 |
| | 2016 | 4 | NT | 4 | 5 | 5 | 7 | 8 |
| Barium (NA) | 2010 | NT | NT | NT | NT | NT | NT | NT |
| | 2011 | NT | NT | NT | NT | NT | NT | NT |
| | 2012 | 0.15 | NT | 0.36 | 0.59 | 0.14 | NT | 0.14 |
| | 2014 | NT | NT | NT | NT | 2 | NT | 2 |
| | 2015 | NT | NT | NT | NT | NT | NT | NT |
| | 2016 | 6 | NT | 4 | 2 | 5 | 2 | 1 |
| Cadmium (<0.1 mg/kg) | 2010 | 0.85 | NT | 1.55 | 0.9 | <0.05 | <0.05 | <0.05 |
| | 2011 | 1 | NT | 0.7 | 0.49 | 0.23 | 0.17 | 0.13 |
| | 2012 | 0.675 | NT | 0.65 | 0.35 | 1.3 | NT | 1.4 |
| | 2014 | NT | NT | NT | NT | 6.9 | NT | 8.9 |
| | 2015 | 0.27 | 0.03 | 0.45 | 0.4 | 0.94 | 0.17 | 0.12 |
| | 2016 | 0.4 | NT | 0.5 | 0.6 | 0.4 | 0.5 | 0.5 |
| Chromium (<0.1 | 2010 | 30 | NT | 20 | 30 | 15 | 10 | 20 |
| | 2011 | 1.74 | NT | 1.8 | 2.6 | 0.97 | 0.93 | 3.2 |

| Concentration of contaminant in shellfish tissue (mg/kg, dry weight)[1] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Metals (PQL mg/kg)** | **Year** | **Rocky headlands** | | | | **Mangroves** | | |
| | | **Control 1** | **Control 2** | **Location 1** | **Location 2** | **Control 2** | **Location 1** | **Location 2** |
| mg/kg) | 2012 | 0.32 | NT | 0.38 | 0.24 | 0.28 | NT | 0.28 |
| | 2014 | NT | NT | NT | NT | 4 | NT | 4 |
| | 2015 | 0.74 | 1.2 | 1 | 0.71 | 0.31 | 0.68 | 0.36 |
| | 2016 | 1 | NT | 1 | 82 | 26 | 60 | 66 |
| Cobalt (<0.5 mg/kg) | 2010 | 1.8 | NT | 1.5 | 1.25 | 2.2 | 2.4 | 2.45 |
| | 2011 | 0.62 | NT | 0.4 | 0.47 | 0.18 | 0.44 | 0.49 |
| | 2012 | 14.5 | NT | 20 | 8.3 | 12 | NT | 10 |
| | 2014 | NT | NT | NT | NT | <1 | NT | <1 |
| | 2015 | 0.26 | 0.39 | 1.5 | 1.1 | 1.8 | 0.23 | 0.19 |
| | 2016 | <1 | NT | <1 | 2 | 3 | 1 | 2 |
| Copper (<0.1 mg/kg) | 2010 | 72.4 | NT | 100 | 35.2 | 1.6 | 1.6 | 2.8 |
| | 2011 | 13.5 | NT | 30 | 23 | 13 | 16 | 11 |
| | 2012 | 395 | NT | 520 | 220 | 640 | NT | 720 |
| | 2014 | NT | NT | NT | NT | 35 | NT | 60 |
| | 2015 | 17 | 41 | 30 | 24 | 47 | 13 | 5.9 |
| | 2016 | 49 | NT | 89 | 91 | 100 | 62 | 49 |
| Iron (<10 mg/kg) | 2010 | 1280 | NT | 1710 | 800 | 9710 | 6450 | 15100 |
| | 2011 | 995 | NT | 550 | 670 | 410 | 440 | 1230 |
| | 2012 | 0.145 | NT | 0.18 | 0.09 | 0.26 | NT | 0.16 |
| | 2014 | NT | NT | NT | NT | 2700 | NT | 4000 |
| | 2015 | 500 | 740 | 740 | 660 | 290 | 370 | 290 |
| | 2016 | 900 | NT | 120 | 1600 | 510 | 1000 | 220 |
| Lead (<0.5 mg/kg) | 2010 | 0.4 | NT | 0.8 | 0.2 | 3.4 | 2.2 | 2.8 |
| | 2011 | 0.275 | NT | 0.2 | 0.22 | 0.11 | 0.18 | 0.27 |
| | 2012 | 27.55 | NT | 14 | 8.4 | 26 | NT | 19 |
| | 2014 | NT | NT | NT | NT | 0.8 | NT | 0.7 |
| | 2015 | 0.16 | 0.23 | 0.23 | 0.19 | 0.09 | 0.15 | 0.08 |
| | 2016 | 9 | NT | <1 | <1 | <1 | <1 | <1 |
| Manganese (<5 mg/kg) | 2010 | 57.7 | NT | 41.8 | 15.9 | 124 | 149 | 73.6 |
| | 2011 | 88.5 | NT | 7.9 | 13 | 21 | 19 | 33 |
| | 2012 | 0.015 | NT | 0.02 | 0.01 | 0.01 | NT | 0.01 |
| | 2014 | NT | NT | NT | NT | 160 | NT | 85 |
| | 2015 | 21 | 15 | 14 | 11 | 8.9 | 18 | 9.6 |
| | 2016 | 35 | NT | 11 | 70 | 42 | 40 | 50 |
| Mercury (<0.01 mg/kg) | 2010 | <0.2 | NT | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| | 2011 | 0.01 | NT | 0 | 0.01 | 0.01 | 0.03 | 0 |
| | 2012 | 1.3 | NT | 0.89 | 1.2 | 0.48 | NT | 0.44 |
| | 2014 | NT | NT | NT | NT | <0.02 | NT | <0.02 |
| | 2015 | 0.02 | 0.02 | 0.02 | 0.01 | <0.01 | 0.04 | 0.01 |
| | 2016 | <0.1 | NT | <.01 | <0.1 | <0.1 | <0.1 | <0.1 |
| Nickel (<0.1 mg/kg) | 2010 | 5.6 | NT | 6.8 | 9.2 | 3 | 2.4 | 4.2 |
| | 2011 | 1.95 | NT | 0.9 | 1.1 | 0.54 | 0.79 | 0.8 |
| | 2012 | 0.415 | NT | 0.53 | 0.68 | 0.27 | NT | 0.27 |
| | 2014 | NT | NT | NT | NT | 2 | NT | 2 |

| Concentration of contaminant in shellfish tissue (mg/kg, dry weight)[1] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Metals (PQL mg/kg) | Year | Rocky headlands | | | | Mangroves | | |
| | | Control 1 | Control 2 | Location 1 | Location 2 | Control 2 | Location 1 | Location 2 |
| | 2015 | 0.41 | 0.48 | 0.64 | 0.86 | 0.73 | 0.34 | 0.39 |
| | 2016 | 1 | NT | 1 | 30 | 10 | 24 | 27 |
| Selenium (<0.1 mg/kg) | 2010 | n/a | NT | n/a | n/a | n/a | n/a | n/a |
| | 2011 | 0 | NT | 0 | 0 | 0 | 0 | 0 |
| | 2012 | 0 | NT | 0 | 0 | 0 | 0 | 0 |
| | 2014 | NT | NT | NT | NT | 0.9 | NT | 1 |
| | 2015 | 0.23 | 0.28 | 0.44 | 0.45 | 0.45 | 0.28 | 0.33 |
| | 2016 | <2 | NT | <2 | <2 | <2 | <2 | <2 |
| Sulfur (<0.1 mg/kg) | 2010 | 6180 | NT | 16000 | 6560 | 1780 | 2700 | 5480 |
| | 2011 | NT | NT | NT | NT | NT | NT | NT |
| | 2012 | NT | NT | NT | NT | NT | NT | NT |
| | 2014 | NT | NT | NT | NT | NT | NT | NT |
| | 2015 | NT | NT | NT | NT | NT | NT | NT |
| | 2016 | NT | NT | NT | NT | NT | NT | NT |
| Silver (<0.1 mg/kg) | 2010 | 0.1 | NT | 0.1 | 0.1 | <0.05 | <0.05 | <0.05 |
| | 2011 | 0.205 | NT | 0.08 | 0.04 | 0.21 | 0.41 | 0.07 |
| | 2012 | 0.885 | NT | 1.3 | 0.42 | 1.6 | NT | 1.5 |
| | 2014 | NT | NT | NT | NT | NT | NT | NT |
| | 2015 | 0.22 | 0.08 | 0.16 | 0.07 | 0.13 | 0.24 | <0.02 |
| | 2016 | NT | NT | NT | NT | NT | NT | NT |
| Vanadium (<0.1 mg/kg) | 2010 | NT | NT | NT | NT | NT | NT | NT |
| | 2011 | 2.485 | NT | 1.3 | 1.4 | 1 | 0.95 | 2.4 |
| | 2012 | 12.5 | NT | 5.9 | 7.7 | 14 | NT | 10 |
| | 2014 | NT | NT | NT | NT | 6 | NT | 7 |
| | 2015 | 1.4 | 1.5 | 1.7 | 1.1 | 0.55 | 0.91 | 0.6 |
| | 2016 | NT | NT | NT | NT | NT | NT | NT |
| Zinc (<0.5 mg/kg) | 2010 | 69 | NT | 34 | 24 | 5 | 5.5 | 9 |
| | 2011 | 19.5 | NT | 21 | 7.9 | 12 | 21 | 15 |
| | 2012 | 234.5 | NT | 330 | 160 | 370 | NT | 400 |
| | 2014 | NT | NT | NT | NT | 69 | NT | 70 |
| | 2015 | 9.6 | 15 | 19 | 22 | 39 | 12 | 12 |
| | 2016 | 76 | NT | 73 | 40 | 140 | 31 | 29 |

Notes:
[1] Composite shellfish samples
ND = Not Detected; NT = Not Tested; ID = Insufficient Data; NA – Not Available

### 5.2.3 Hydrocarbons in shellfish samples

Table 5.5 presents the TRH, BTEX and PAH concentrations measured in the shellfish samples. Table 5.6 shows the speciated TPH in shellfish collected from the mangroves between 2010 and 2016.

All readings were below detection limits, except $C_{10}$-$C_{36}$, which was detected in shellfish across all sites. The highest readings were measured in shellfish from the Control site, which suggests a naturally occurring or regional source of hydrocarbons.

In 2015, the $C_{15}$-$C_{28}$ fraction was also detected in shellfish from Control site, and a similar result in 2014 was attributed to plant sources due to the predominance of odd over even n-alkanes. Further advice will be sought with respect to the 2016 hydrocarbon results.

**Table 5.5: Measured BTEX, TRH and PAH concentrations in shellfish 2016**

| Concentration of contaminant in shellfish tissue (mg/kg, dry weight)[1] | | | | | | |
|---|---|---|---|---|---|---|
| **Parameter** | **Rocky headlands** | | | **Mangroves** | | |
| | **Control 1** | **Location 1** | **Location 2** | **Control 1** | **Location 1** | **Location 2** |
| **BTEX** | | | | | | |
| Benzene | <0.8 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Toluene | <2 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Ethylbenzene | <4 | <1 | <1 | <1 | <1 | <1 |
| m+p-xylenes | <8 | <2 | <2 | <2 | <2 | <2 |
| o-xylene | <4 | <1 | <1 | <1 | <1 | <1 |
| Naphthalene | <4 | <1 | <1 | <1 | <1 | <1 |
| **TRH –Speciated** | | | | | | |
| C6 – C9 | <100 | <25 | <25 | <25 | <25 | <25 |
| C10 – C14 | 3100 | 1400 | 610 | 1900 | 350 | 160 |
| C15 – C28 | 7900 | 8800 | 3200 | 9600 | 2900 | 940 |
| C29 – C36 | 2900 | 2500 | 1100 | 4100 | 2300 | 2100 |
| **PAH -Speciated** | | | | | | |
| Naphthalene | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Acenaphthylene | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Acenaphthene | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Fluorene | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Phenanthrene | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Anthracene | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Fluoranthene | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Pyrene | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Benz(a)anthracene | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Chrysene | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Benzo(b)&(k)fluoranthene | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 |
| Benzo(a)pyrene | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Indeno(1,2,3-cd)pyrene | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Dibenzo(a,h)anthracene | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Benzo(g,h,i)perylene | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Benzo(a)pyrene TEQ | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Total PAH | NIL (+)IVE | NIL (+)IVE | NIL (+)IVE | NIL (+)IVE | NIL (+)IVE | NIL (+)IVE |
| Notes:<br>[1] Composite shellfish samples | | | | | | |

**Table 5.6: Speciated TRH measured in shellfish between 2010-2016**

| Concentration of contaminant in shellfish Tissue (mg/kg, dry weight)[1] |
|---|

| TRH | Year | BT-M-C-SF-01 | BT-M-01-SF-01 | BT-M-02-SF-01 |
|---|---|---|---|---|
| $C_6$-$C_9$ | 2010 | NT | NT | NT |
| | 2011 | ND | ND | ND |
| | 2012 | <25 | NT | <25 |
| | 2014 | <100 | NT | <100 |
| | 2015 | NT | <25 | <25 |
| | 2016 | <25 | <25 | <25 |
| $C_{10}$-$C_{14}$ | 2010 | NT | NT | NT |
| | 2011 | ND | ND | ND |
| | 2012 | <50 | NT | <50 |
| | 2014 | <100 | NT | <100 |
| | 2015 | <50 | <50 | <50 |
| | 2016 | 1900 | 350 | 160 |
| $C_{15}$-$C_{28}$ | 2010 | NT | NT | NT |
| | 2011 | ND | ND | ND |
| | 2012 | <100 | NT | <100 |
| | 2014 | 96[2] | NT | 46[2] |
| | 2015 | 200 | <100 | <100 |
| | 2016 | 9600 | 2900 | 940 |
| $C_{29}$-$C_{36}$ | 2010 | NT | NT | NT |
| | 2011 | NT | NT | NT |
| | 2012 | ND | ND | ND |
| | 2014 | <100 | NT | <100 |
| | 2015 | <100 | NT | <100 |
| | 2016 | 4100 | 2300 | 2100 |

Notes:
[1] Composite shellfish samples

# 6. CONCLUSION

Overall, the majority of readings were well within the levels measured in previous years, with no major difference between the Yelcherr beach samples and control samples. This year's results were also generally lower than previous years' results

With the exception of arsenic, all metal concentrations in mangrove sediments were below the Interim Sediment Quality Guideline (ISQG) trigger value (Ref. [1]). Arsenic concentrations in sediment were measured slightly above the lower ISQG trigger value at Location 2. This is consistent with the naturally high arsenic levels reported previously. All hydrocarbon concentrations were found to be below detection limits.

Metal concentrations in shellfish samples were much lower than historical maximums and typically much lower than baseline and 2014 results.

Therefore all results are considered satisfactory.

# 7. REFERENCES

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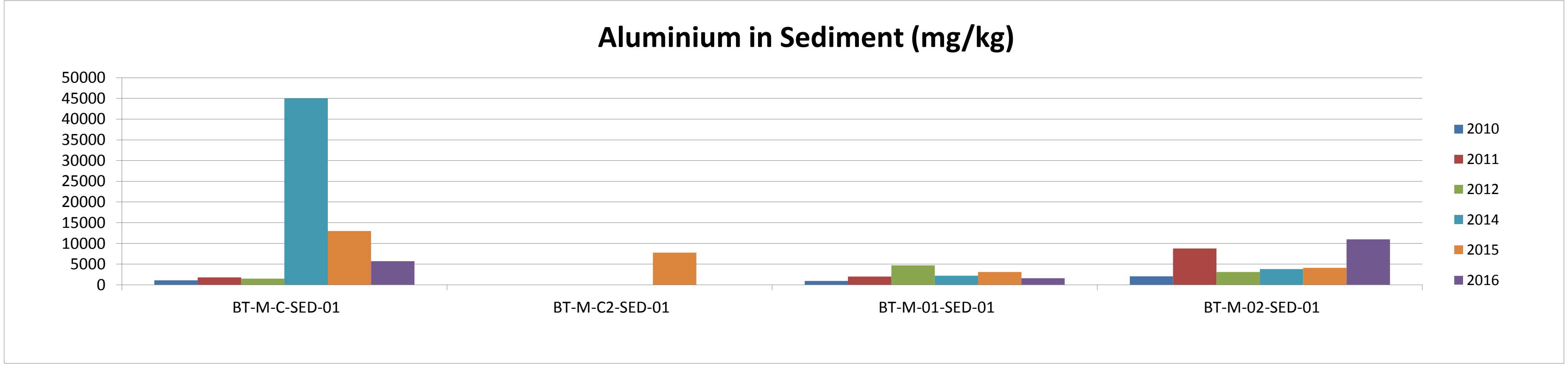
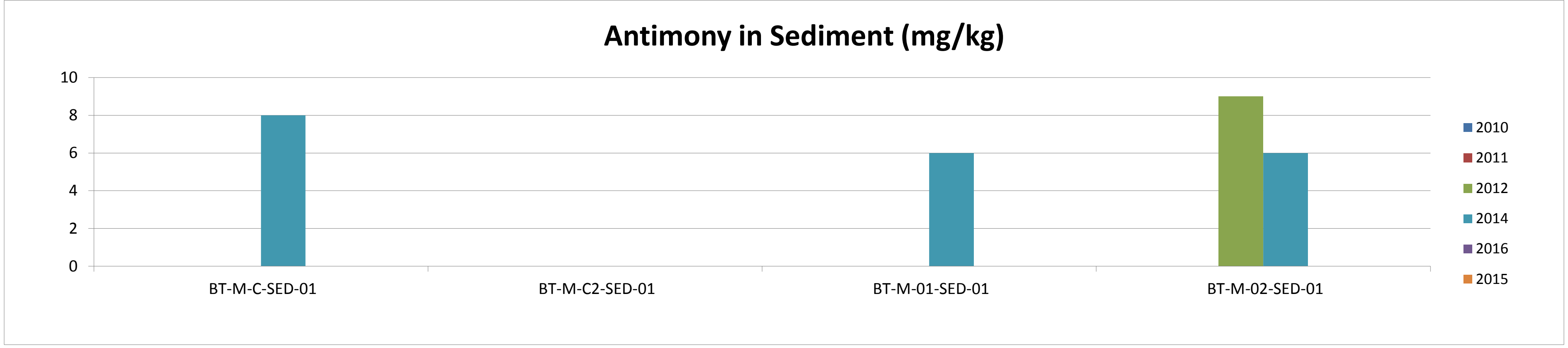
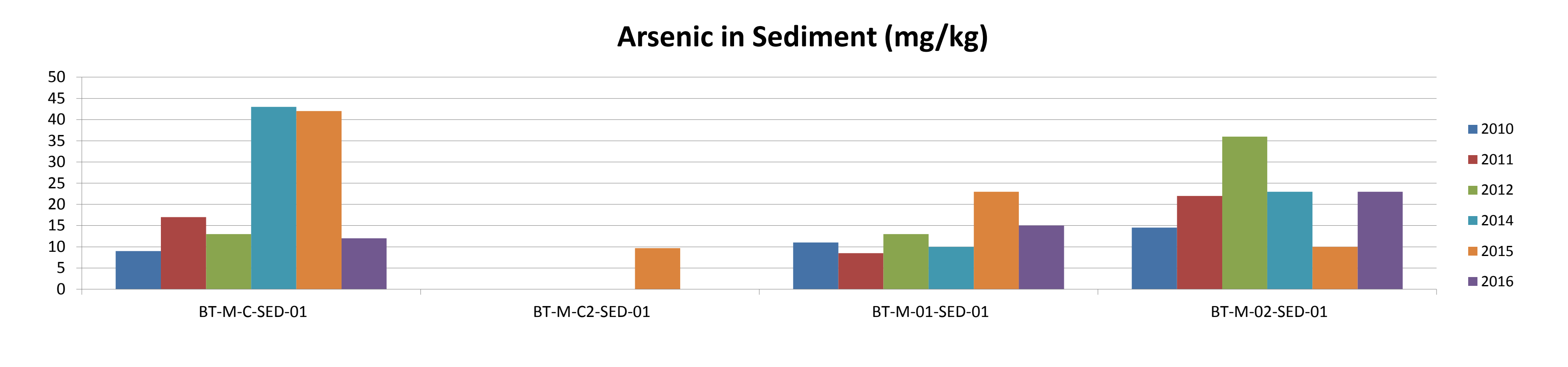
# APPENDICES

# APPENDIX A:

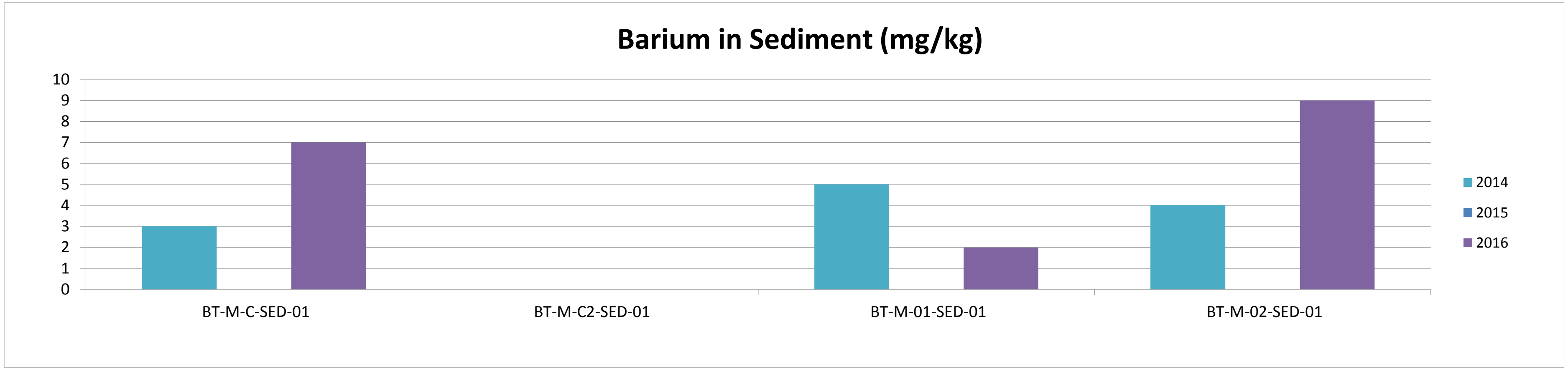
# MEASURED METAL CONCENTRATIONS IN MANGROVE MUD SEDIMENT 2010–2015


Aluminium in Sediment (mg/kg)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
BT-M-C-SED-01
BT-M-C2-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016

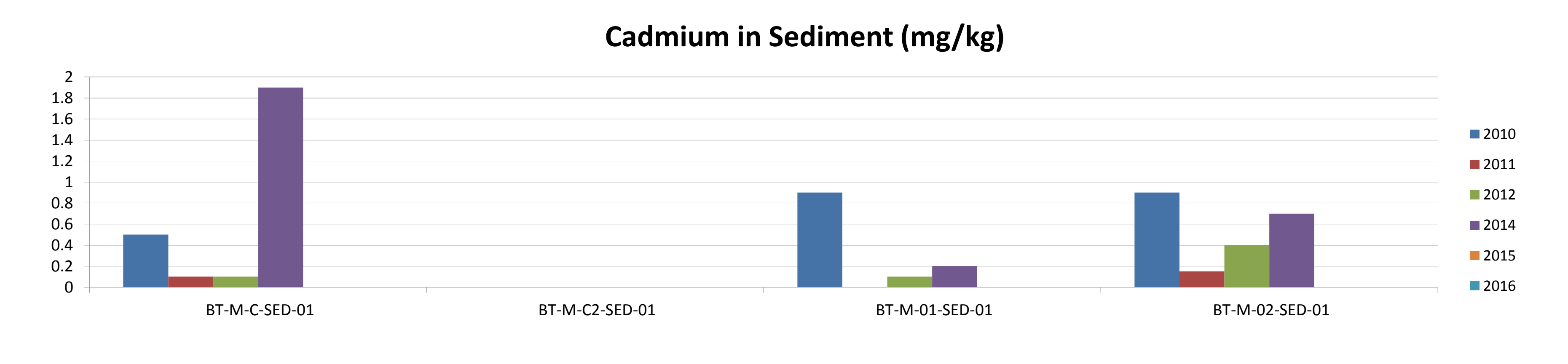

Antimony in Sediment (mg/kg)
10
8
6
4
2
0
BT-M-C-SED-01
BT-M-C2-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2016
2015



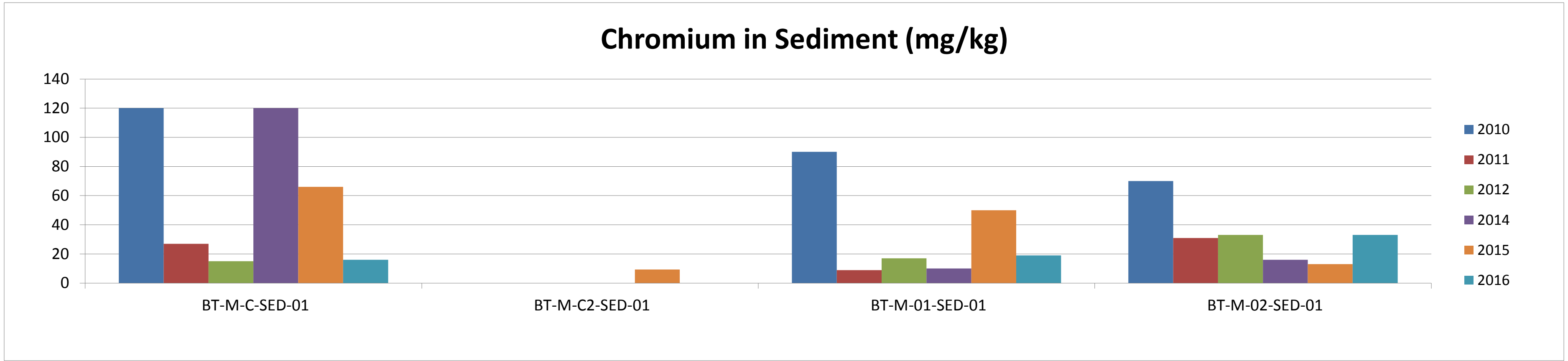
Arsenic in Sediment (mg/kg)
50
45
40
35
30
25
20
15
10
5
0
BT-M-C-SED-01
BT-M-C2-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016

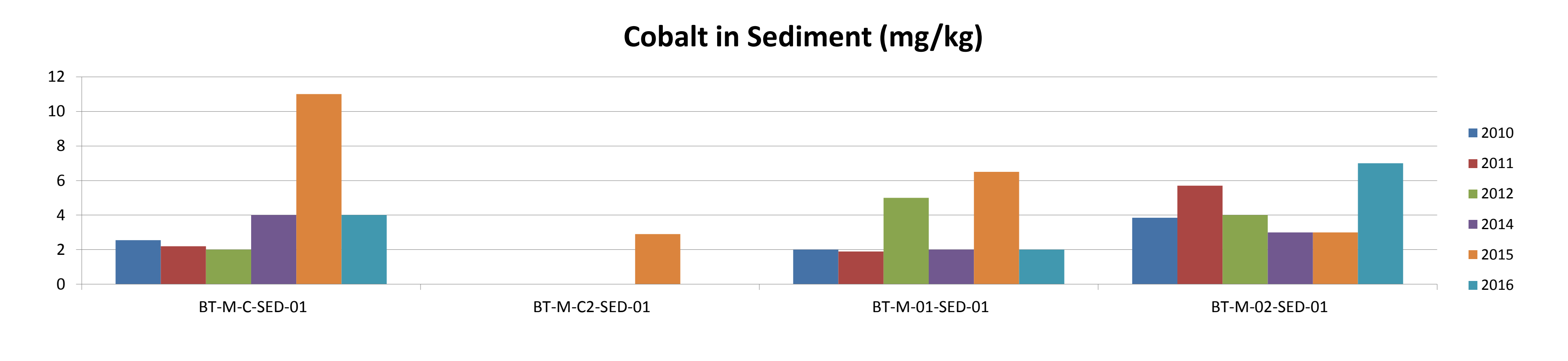
Barium in Sediment (mg/kg)
10
9
8
7
6
5
4
3
2
1
0
BT-M-C-SED-01
BT-M-C2-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2014
2015
2016



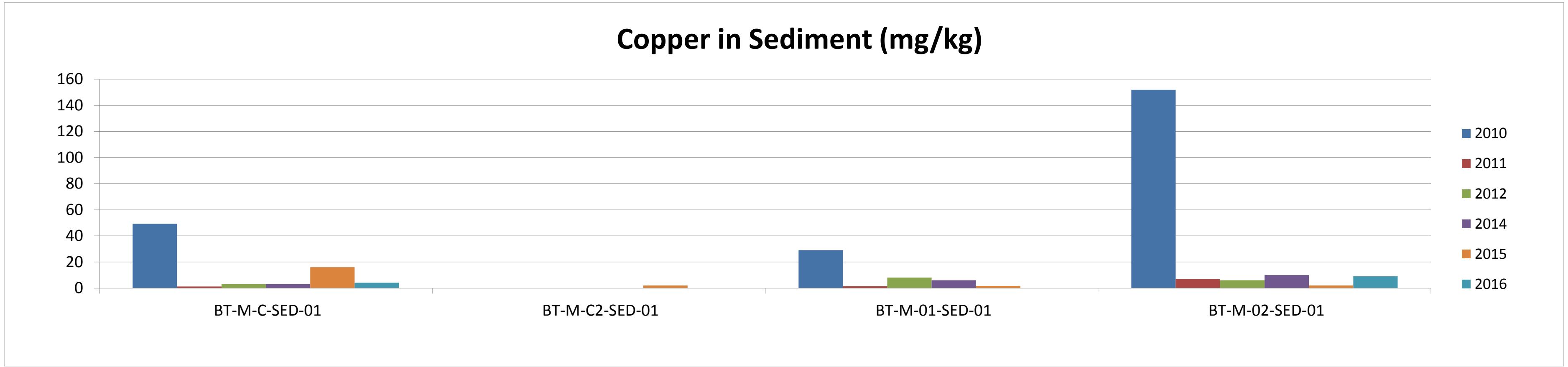
Cadmium in Sediment (mg/kg)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
BT-M-C-SED-01
BT-M-C2-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016

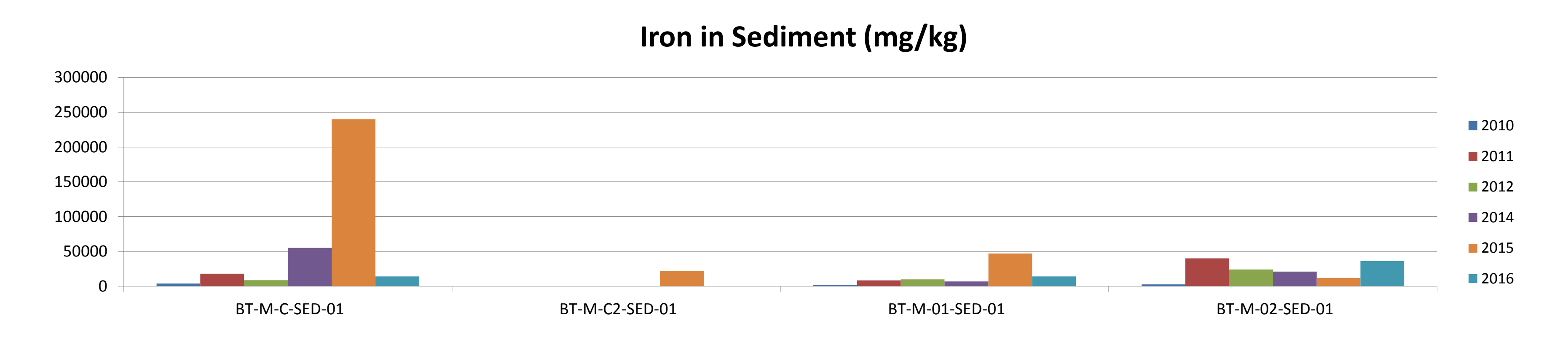
Chromium in Sediment (mg/kg)
140
120
100
80
60
40
20
0
BT-M-C-SED-01
BT-M-C2-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016



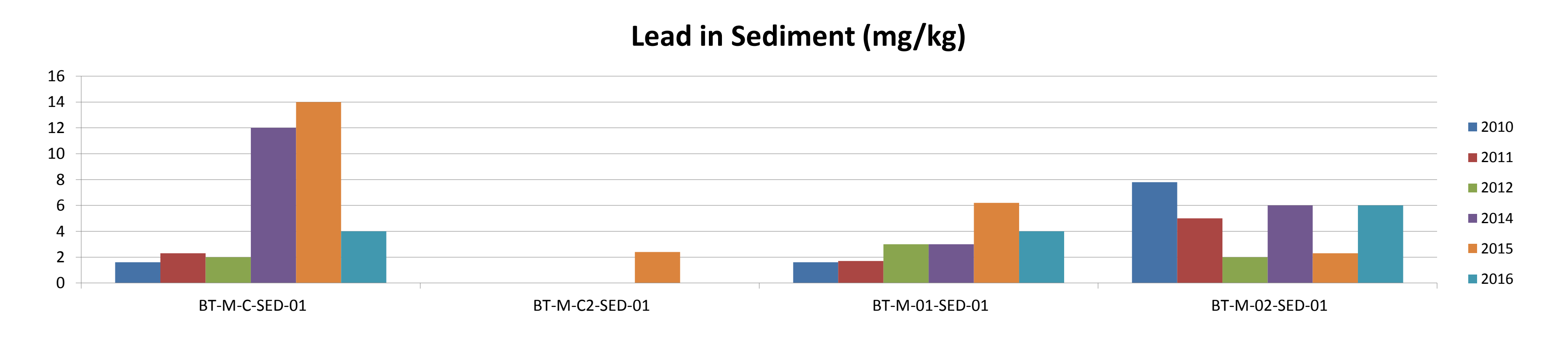
Cobalt in Sediment (mg/kg)
12
10
8
6
4
2
0
BT-M-C-SED-01
BT-M-C2-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016

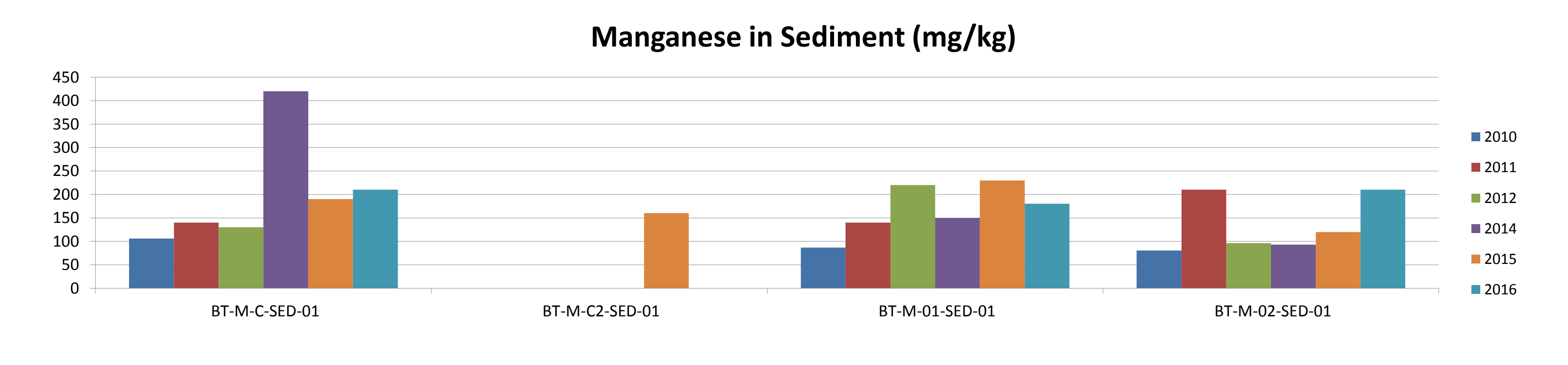
Copper in Sediment (mg/kg)
160
140
120
100
80
60
40
20
0
BT-M-C-SED-01
BT-M-C2-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016

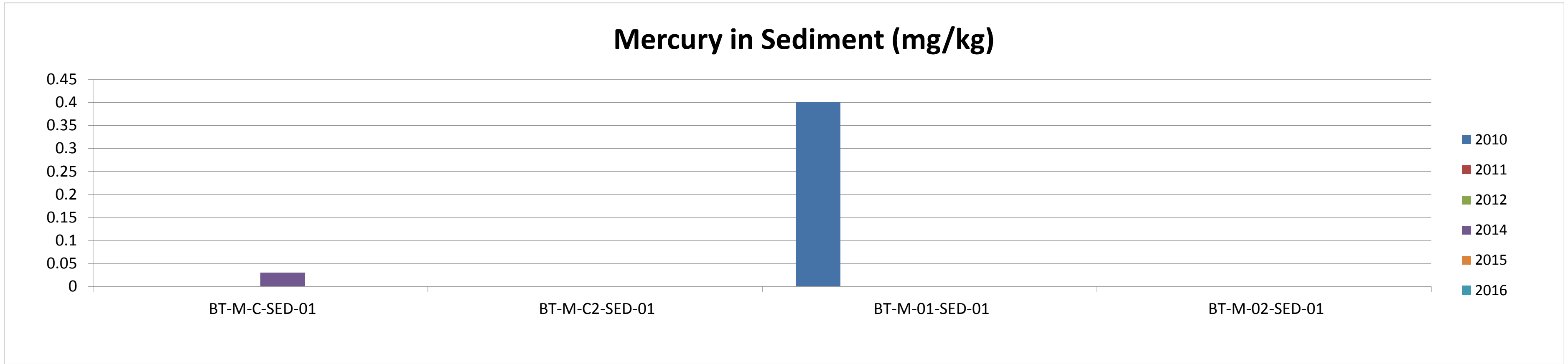


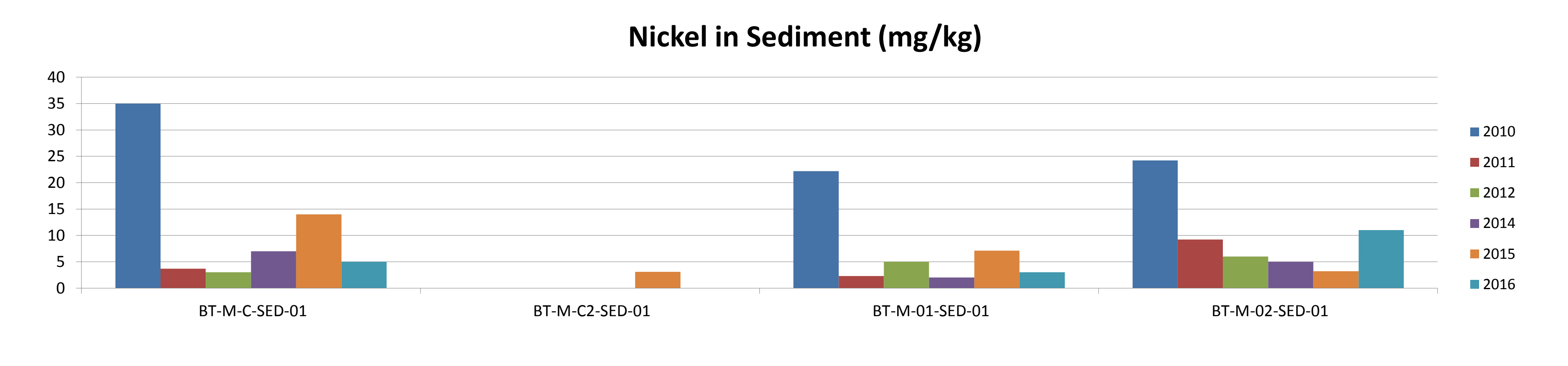
Iron in Sediment (mg/kg)
300000
250000
200000
150000
100000
50000
0
BT-M-C-SED-01
BT-M-C2-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016

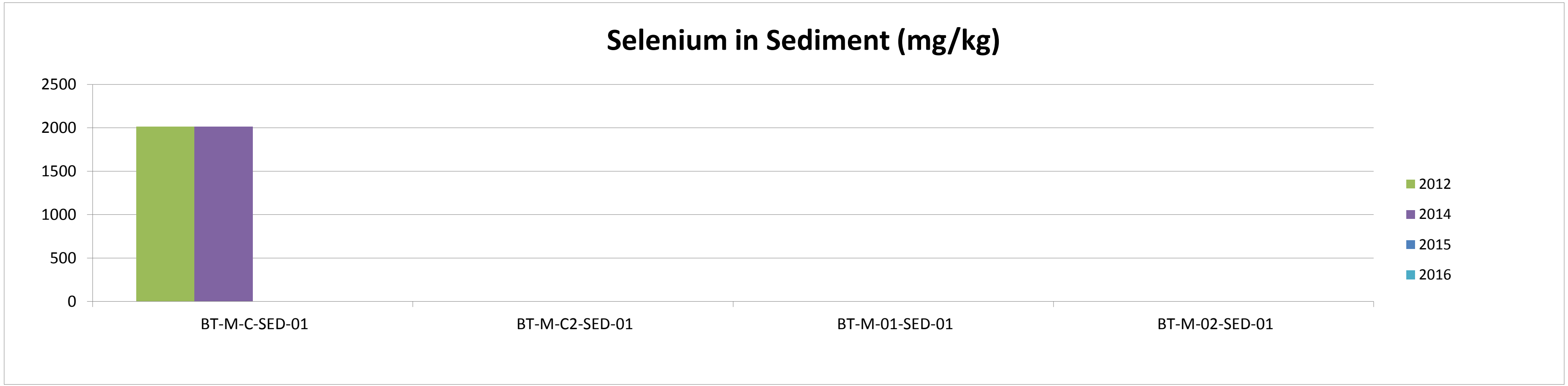
Lead in Sediment (mg/kg)
16
14
12
10
8
6
4
2
0
BT-M-C-SED-01
BT-M-C2-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016


Manganese in Sediment (mg/kg)
450
400
350
300
250
200
150
100
50
0
BT-M-C-SED-01
BT-M-C2-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016

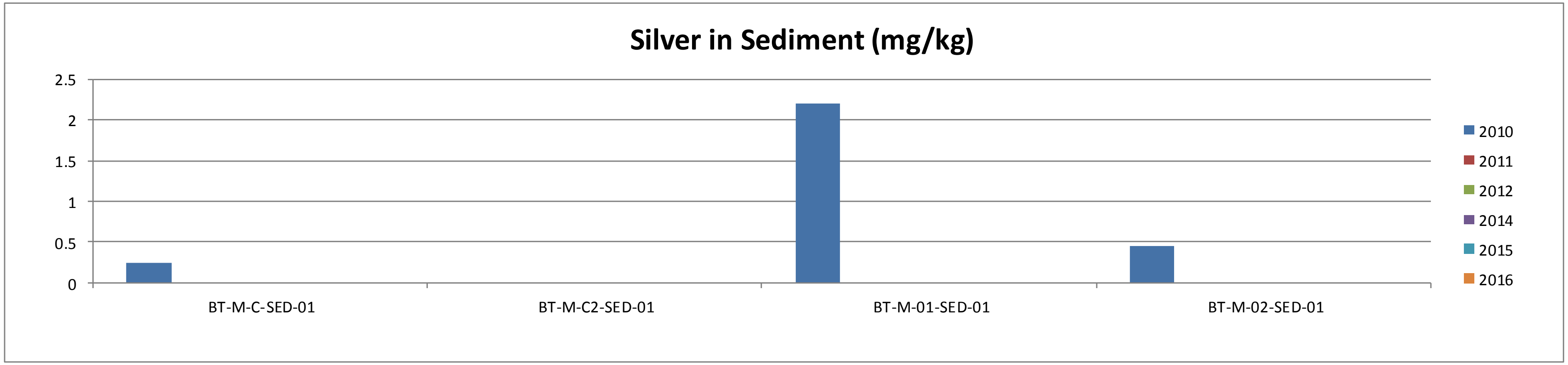

Mercury in Sediment (mg/kg)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
BT-M-C-SED-01
BT-M-C2-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016



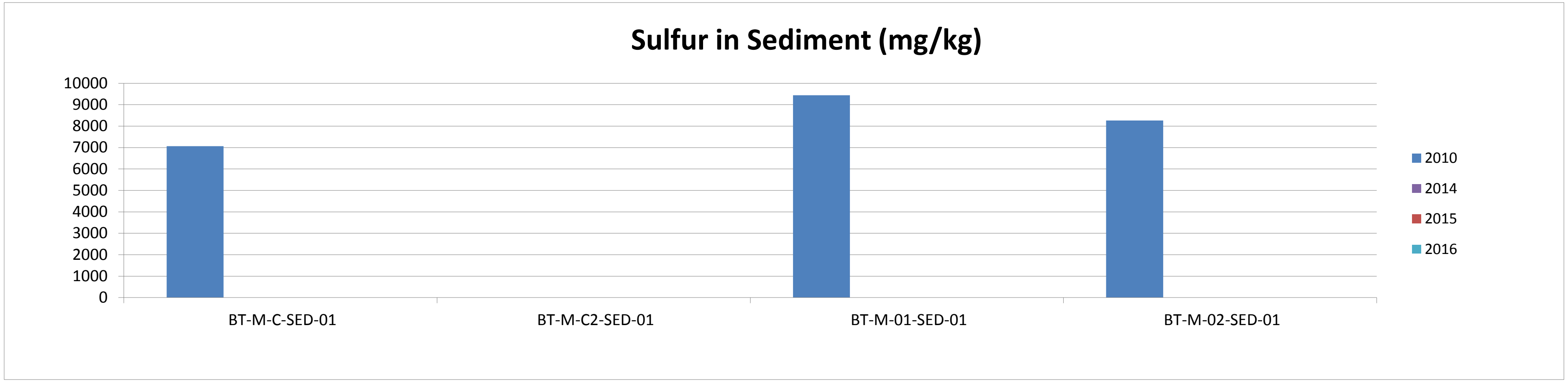
Nickel in Sediment (mg/kg)
40
35
30
25
20
15
10
5
0
BT-M-C-SED-01
BT-M-C2-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016

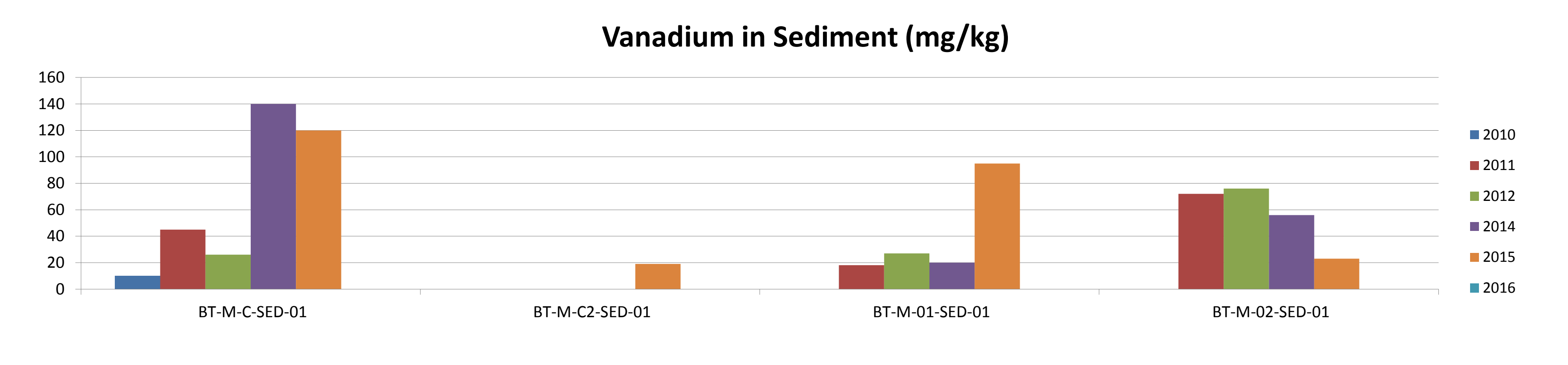
Selenium in Sediment (mg/kg)
2500
2000
1500
1000
500
0
BT-M-C-SED-01
BT-M-C2-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2012
2014
2015
2016

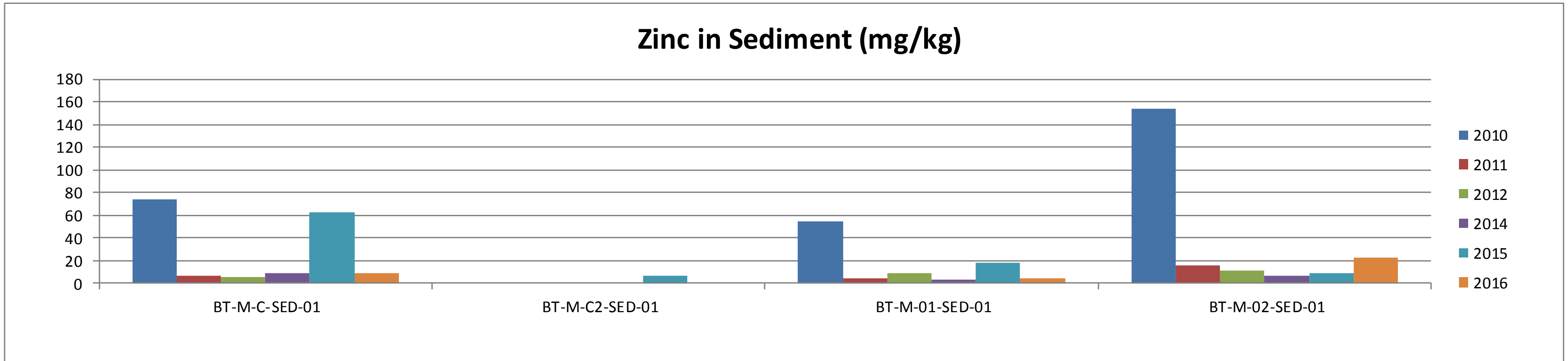


Silver in Sediment (mg/kg)
2.5
2
1.5
1
0.5
0
BT-M-C-SED-01
BT-M-C2-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016

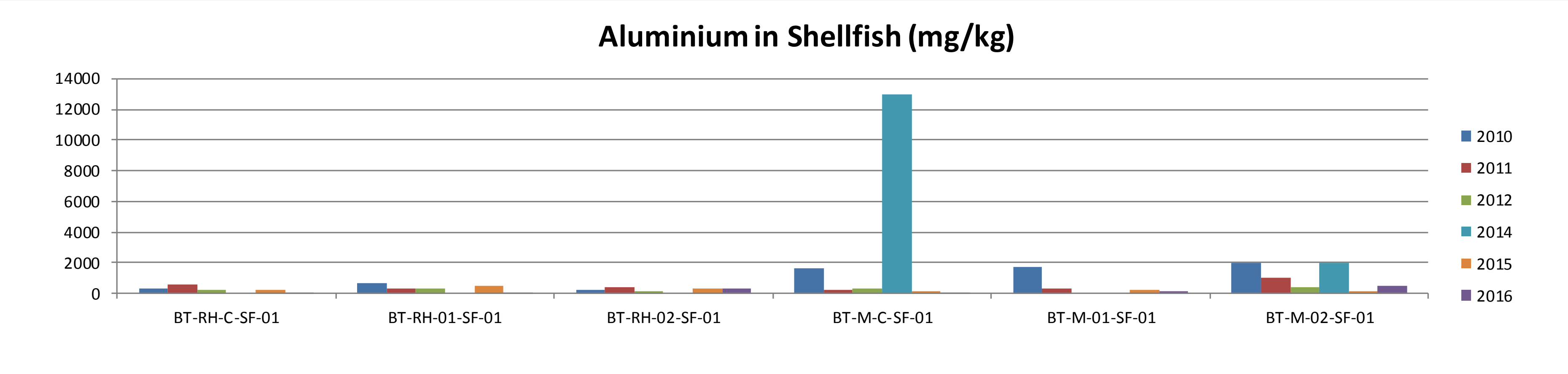
Sulfur in Sediment (mg/kg)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
BT-M-C-SED-01
BT-M-C2-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2014
2015
2016


Vanadium in Sediment (mg/kg)
160
140
120
100
80
60
40
20
0
BT-M-C-SED-01
BT-M-C2-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016

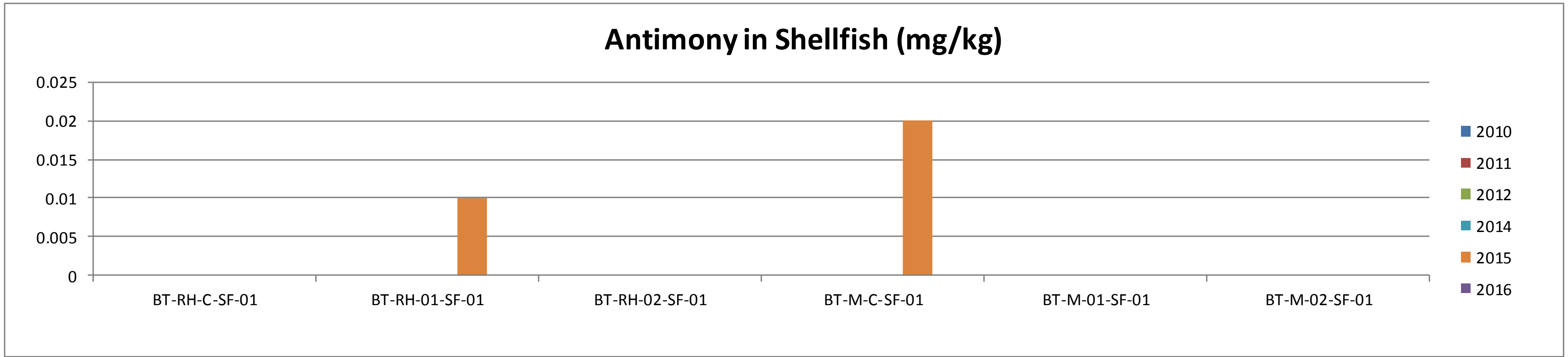

Zinc in Sediment (mg/kg)
180
160
140
120
100
80
60
40
20
0
BT-M-C-SED-01
BT-M-C2-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016

# APPENDIX B:

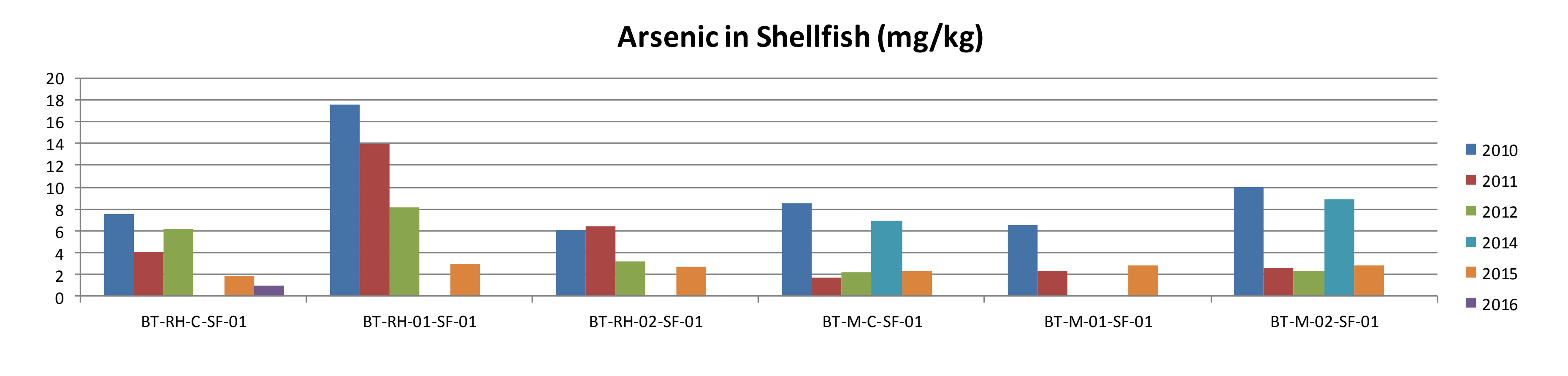
# MEASURED METAL CONCENTRATIONS IN SHELLFISH 2010-2016

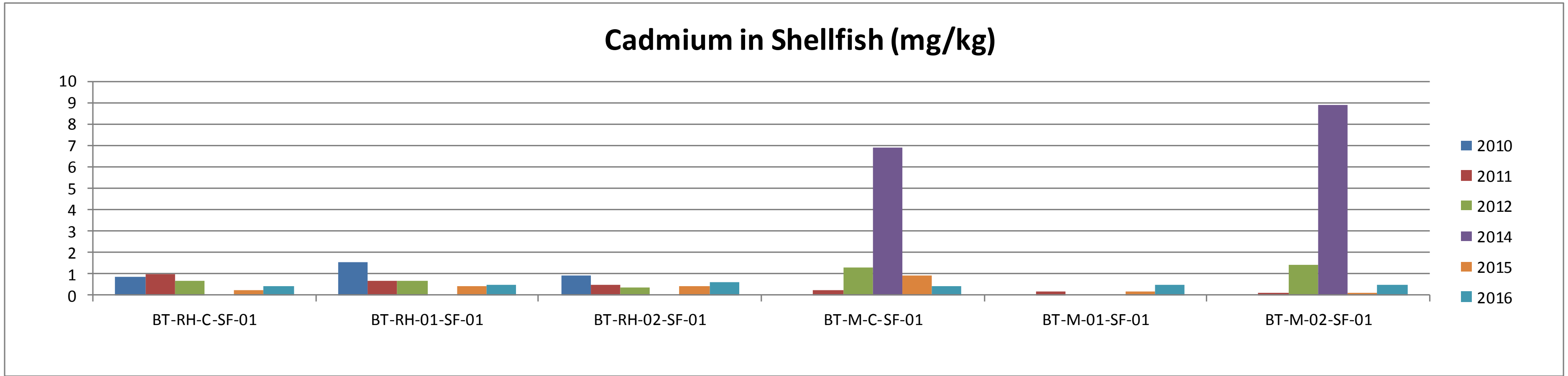


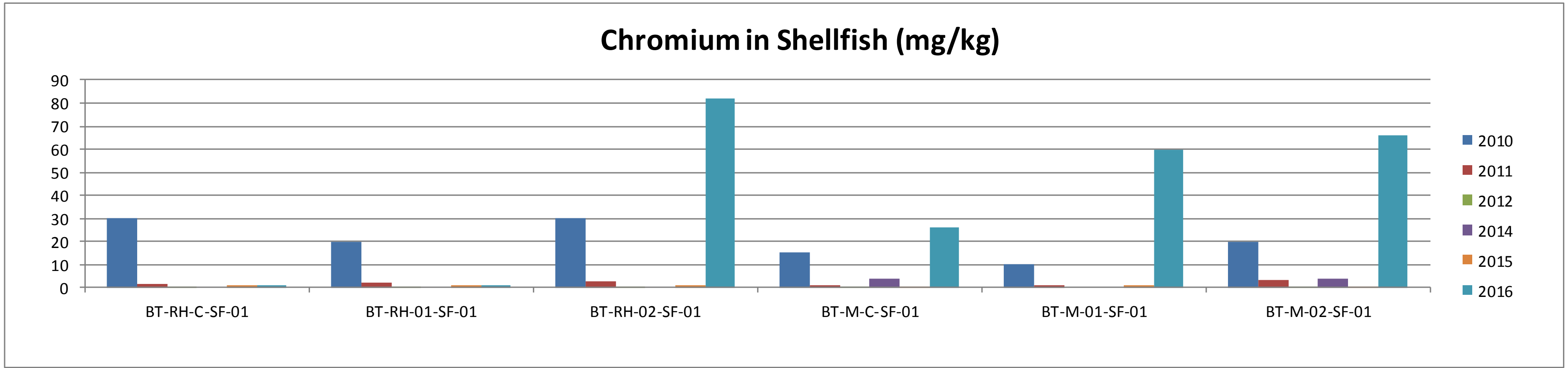
Aluminium in Shellfish (mg/kg)
14000
12000
10000
8000
6000
4000
2000
0
BT-RH-C-SF-01
BT-RH-01-SF-01
BT-RH-02-SF-01
BT-M-C-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
2014
2015
2016

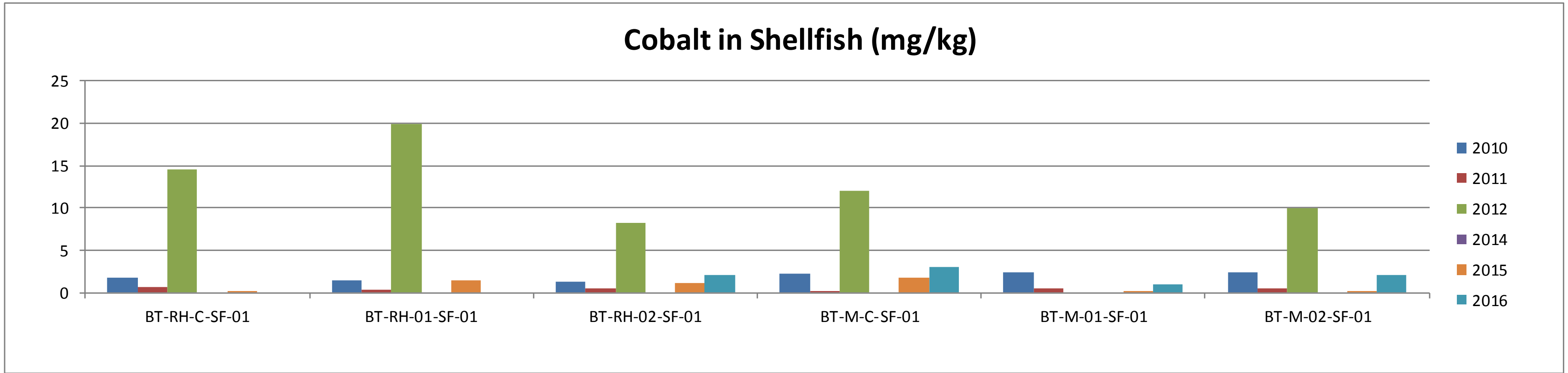
Antimony in Shellfish (mg/kg)
0.025
0.02
0.015
0.01
0.005
0
BT-RH-C-SF-01
BT-RH-01-SF-01
BT-RH-02-SF-01
BT-M-C-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
2014
2015
2016


Arsenic in Shellfish (mg/kg)
20
18
16
14
12
10
8
6
4
2
0
BT-RH-C-SF-01
BT-RH-01-SF-01
BT-RH-02-SF-01
BT-M-C-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
2014
2015
2016

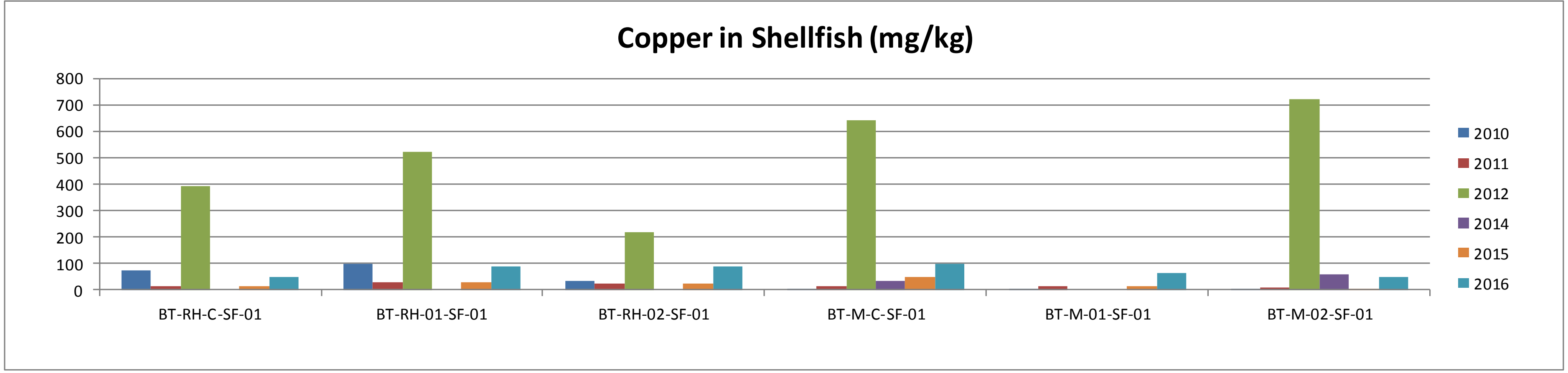

Cadmium in Shellfish (mg/kg)
10
9
8
7
6
5
4
3
2
1
0
BT-RH-C-SF-01
BT-RH-01-SF-01
BT-RH-02-SF-01
BT-M-C-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
2014
2015
2016



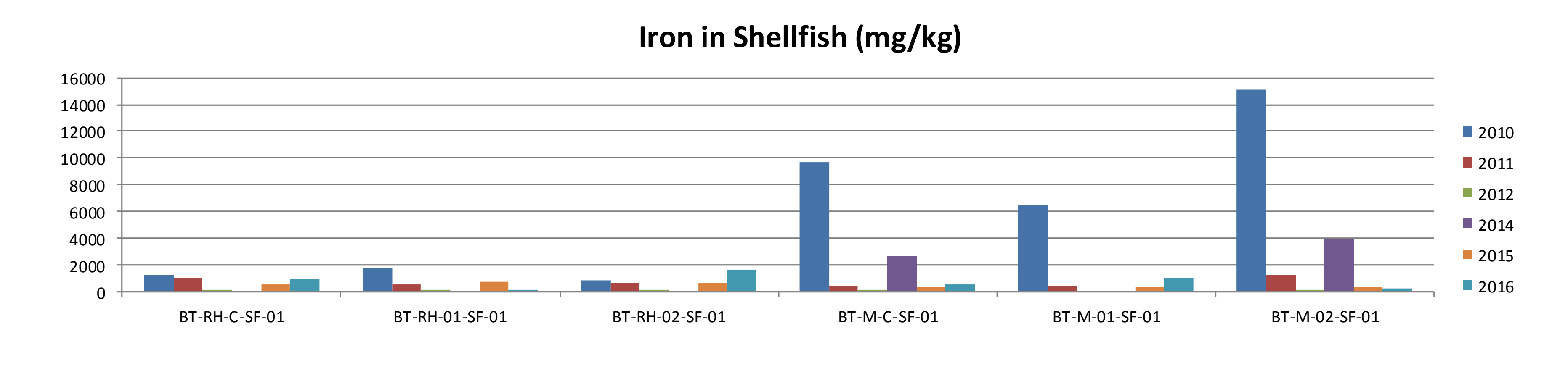
Chromium in Shellfish (mg/kg)
90
80
70
60
50
40
30
20
10
0
BT-RH-C-SF-01
BT-RH-01-SF-01
BT-RH-02-SF-01
BT-M-C-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
2014
2015
2016

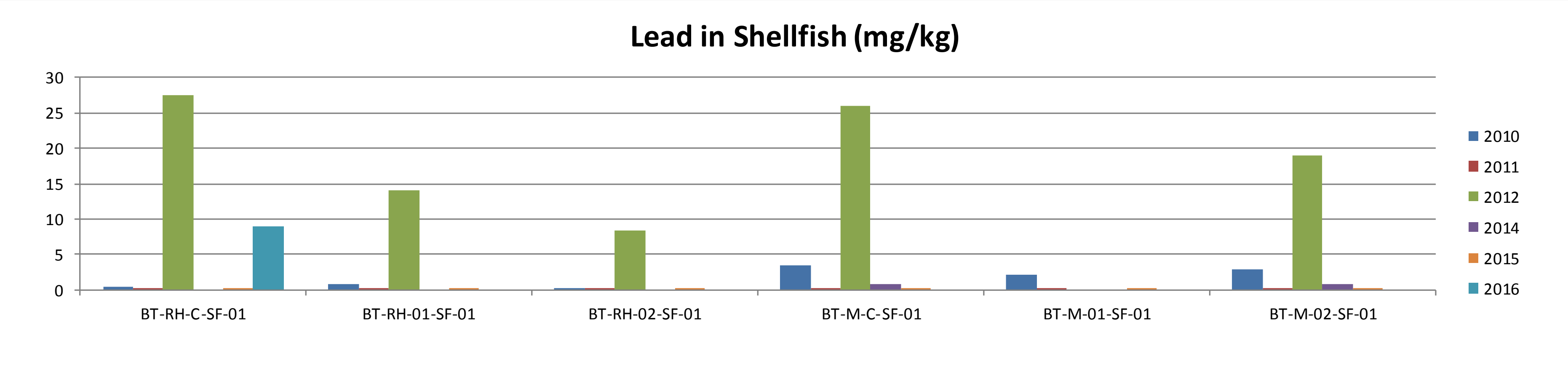
Cobalt in Shellfish (mg/kg)
25
20
15
10
5
0
BT-RH-C-SF-01
BT-RH-01-SF-01
BT-RH-02-SF-01
BT-M-C-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
2014
2015
2016

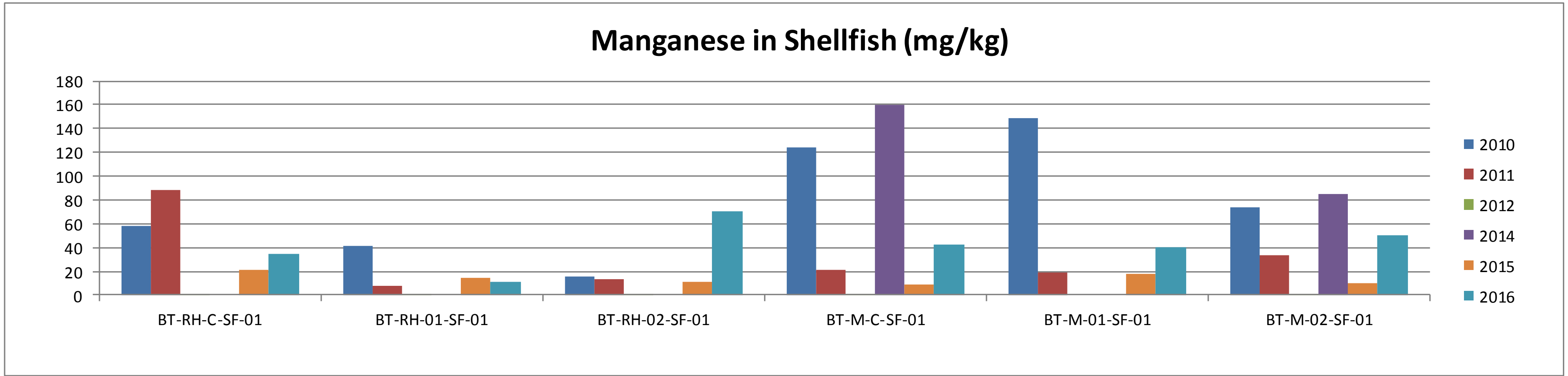


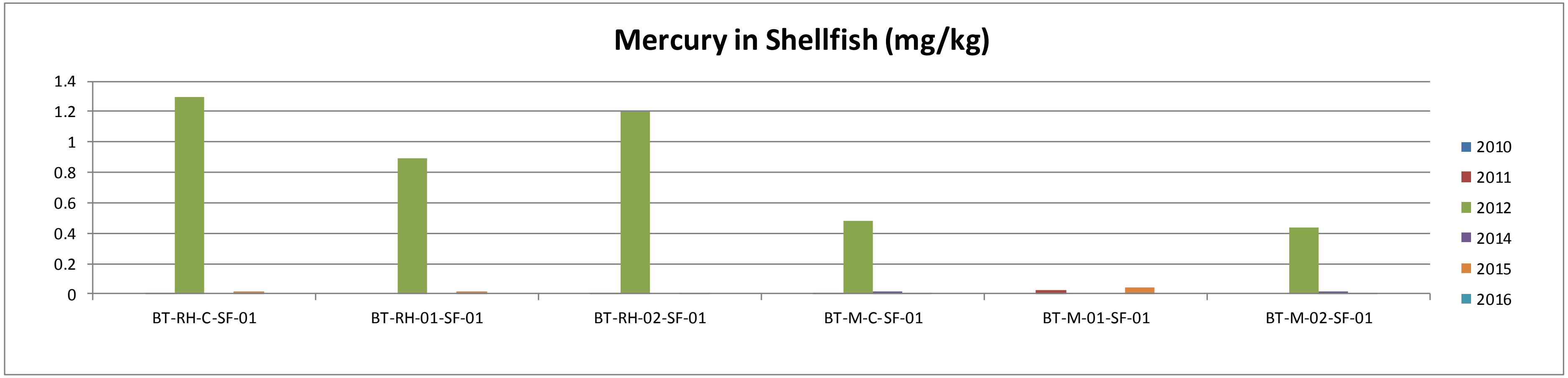
Copper in Shellfish (mg/kg)
800
700
600
500
400
300
200
100
0
BT-RH-C-SF-01
BT-RH-01-SF-01
BT-RH-02-SF-01
BT-M-C-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
2014
2015
2016

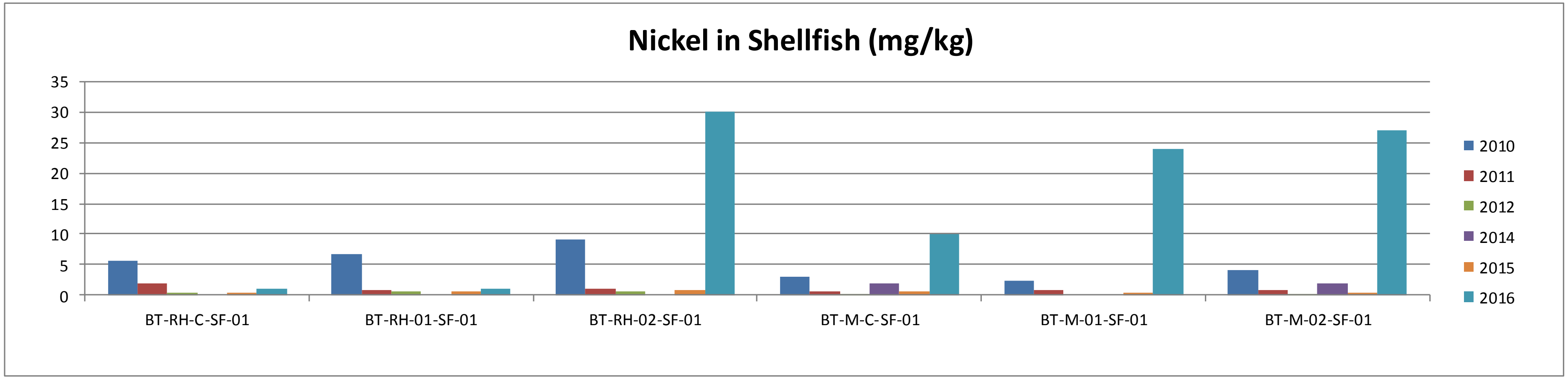
Iron in Shellfish (mg/kg)
16000
14000
12000
10000
8000
6000
4000
2000
0
BT-RH-C-SF-01
BT-RH-01-SF-01
BT-RH-02-SF-01
BT-M-C-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
2014
2015
2016


Lead in Shellfish (mg/kg)
30
25
20
15
10
5
0
BT-RH-C-SF-01
BT-RH-01-SF-01
BT-RH-02-SF-01
BT-M-C-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
2014
2015
2016

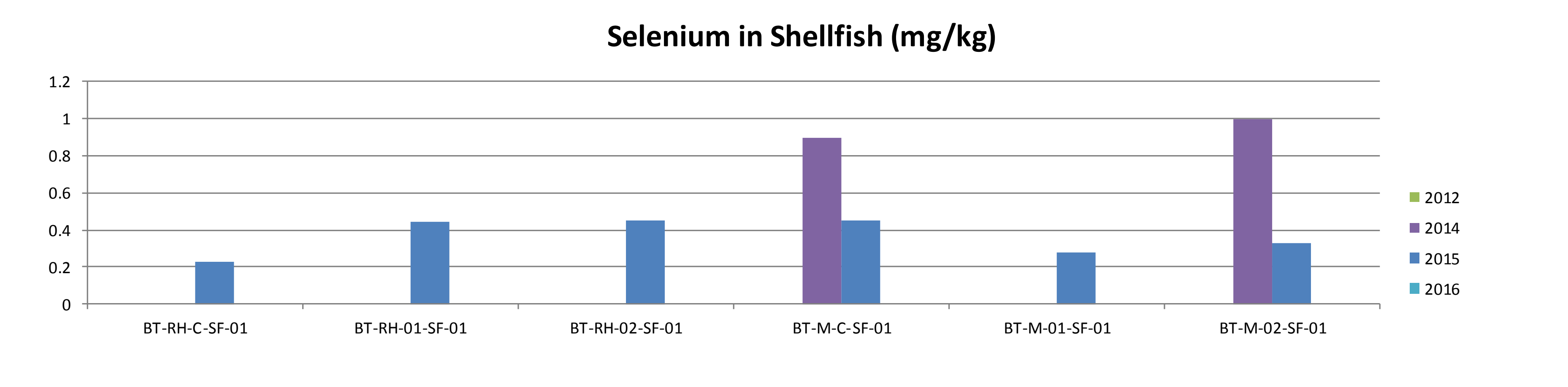

Manganese in Shellfish (mg/kg)
180
160
140
120
100
80
60
40
20
0
BT-RH-C-SF-01
BT-RH-01-SF-01
BT-RH-02-SF-01
BT-M-C-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
2014
2015
2016

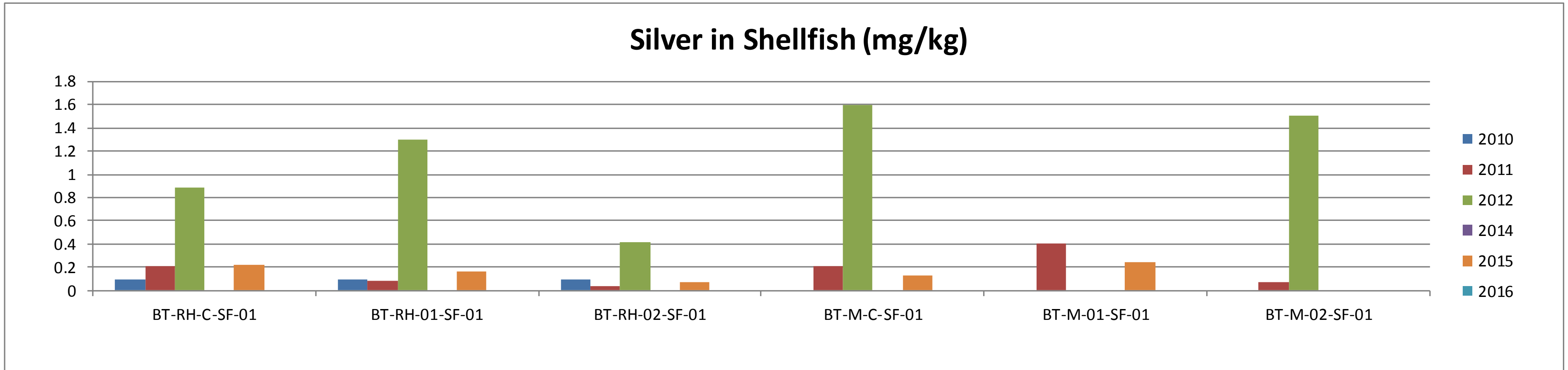


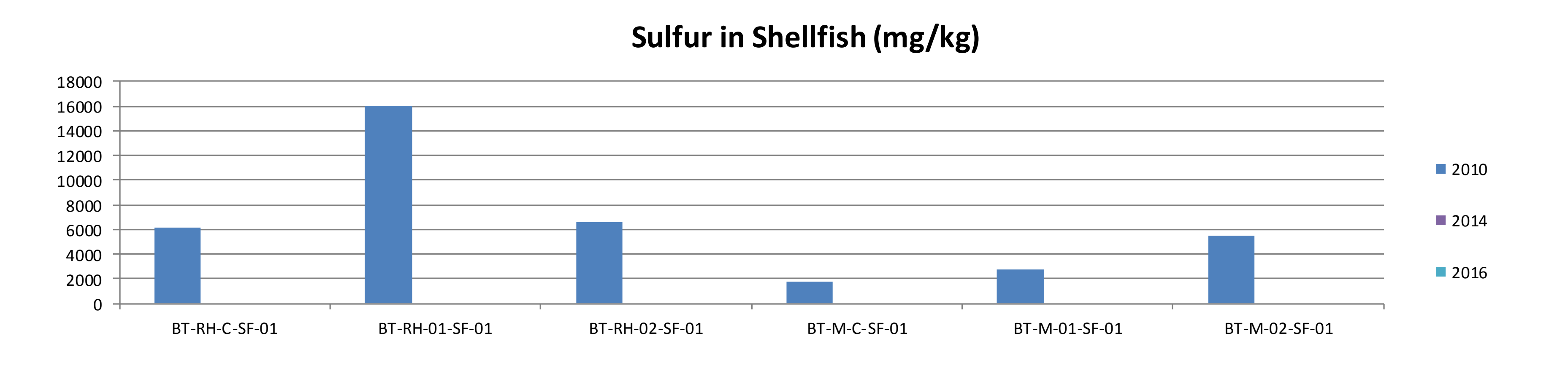
Mercury in Shellfish (mg/kg)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
BT-RH-C-SF-01
BT-RH-01-SF-01
BT-RH-02-SF-01
BT-M-C-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
2014
2015
2016

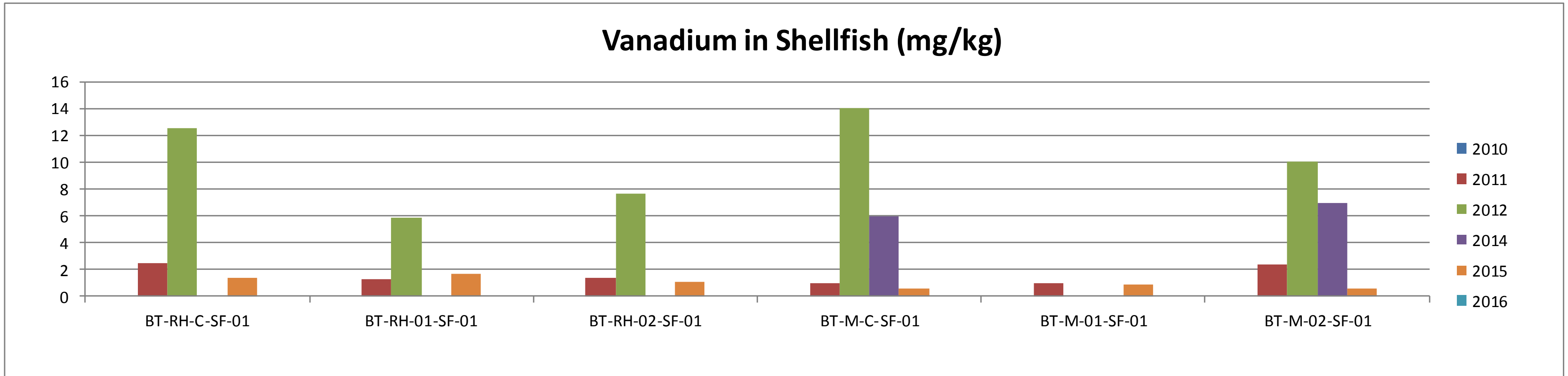
Nickel in Shellfish (mg/kg)
35
30
25
20
15
10
5
0
BT-RH-C-SF-01
BT-RH-01-SF-01
BT-RH-02-SF-01
BT-M-C-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
2014
2015
2016


Selenium in Shellfish (mg/kg)
1.2
1
0.8
0.6
0.4
0.2
0
BT-RH-C-SF-01
BT-RH-01-SF-01
BT-RH-02-SF-01
BT-M-C-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2012
2014
2015
2016

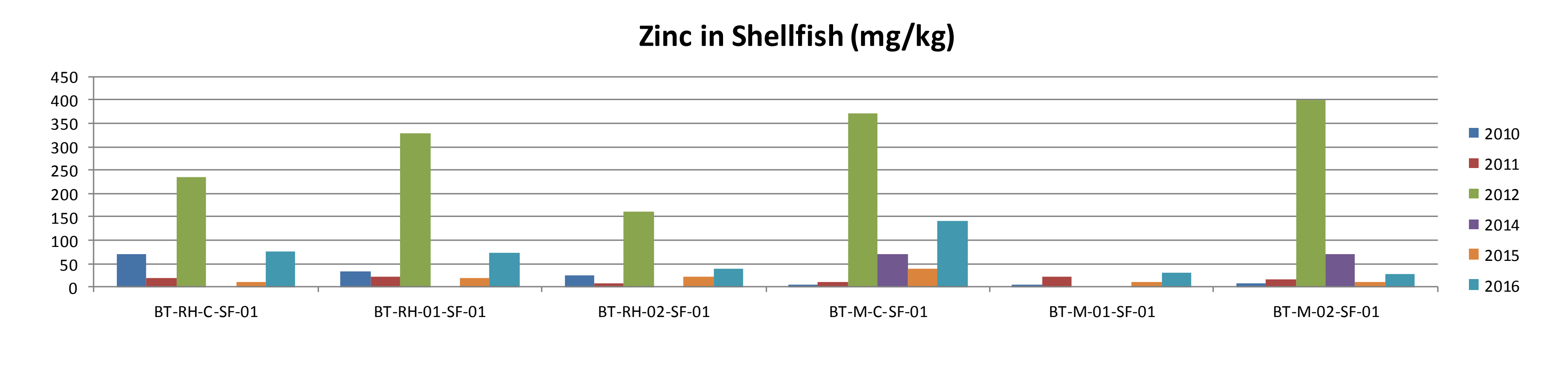

Silver in Shellfish (mg/kg)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
BT-RH-C-SF-01
BT-RH-01-SF-01
BT-RH-02-SF-01
BT-M-C-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
2014
2015
2016



Sulfur in Shellfish (mg/kg)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
BT-RH-C-SF-01
BT-RH-01-SF-01
BT-RH-02-SF-01
BT-M-C-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2014
2016

Vanadium in Shellfish (mg/kg)
16
14
12
10
8
6
4
2
0
BT-RH-C-SF-01
BT-RH-01-SF-01
BT-RH-02-SF-01
BT-M-C-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
2014
2015
2016


Zinc in Shellfish (mg/kg)
450
400
350
300
250
200
150
100
50
0
BT-RH-C-SF-01
BT-RH-01-SF-01
BT-RH-02-SF-01
BT-M-C-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
2014
2015
2016

# APPENDIX C:

# LABORATORY REPORTS

800 Berrimah Rd East Arm, Northern Territory 0828, Australia
PO Box 37920 Winnellie, Northern Territory 0821, Australia
Tel +61 8 8947 3346, Fax: +61 8 8947 3348
Website: www.intertek.com

# Test Report

ENI Australia
Blacktip OGP
Port Keats, Northern Territory
Attention: Plant Operations Superintendent

**Report Number:** AU115-3400 **Test Certificate Number:** **AU115-1208**

---

Product Name: Sediment
Sample Location: Yellcherr South (BT-M-01-SED-1)
Intertek Sample Number: 16/0115
Analysis Suite: 10.0 Metals and Metalloids
Date Sampled: 25.05.2016
Date Received: 25.05.2016
Sample Drawn By: ENI

| Analysis | Test Method | Unit | Source | Limits | Result |
|---|---|---|---|---|---|
| Aluminum | ICP-MS | mg/kg | Intertek (1) | - | 5700 |
| Arsenic | ICP-MS | mg/kg | Intertek (1) | - | 12 |
| Barium | ICP-MS | mg/kg | Intertek (1) | - | 7 |
| Beryllium | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Boron | ICP-MS | mg/kg | Intertek (1) | - | 30 |
| Cadmium | ICP-MS | mg/kg | Intertek (1) | - | <0.4 |
| Cobalt | ICP-MS | mg/kg | Intertek (1) | - | 4 |
| Copper | ICP-MS | mg/kg | Intertek (1) | - | 4 |
| Chromium | ICP-MS | mg/kg | Intertek (1) | - | 16 |
| Iron | ICP-MS | mg/kg | Intertek (1) | - | 14000 |
| Mercury | ICP-MS | mg/kg | Intertek (1) | - | <0.1 |
| Manganese | ICP-MS | mg/kg | Intertek (1) | - | 210 |
| Molybdenum | ICP-MS | mg/kg | Intertek (1) | - | <1 |

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| **Analysis** | **Test Method** | mg/kg | **Source** | **Limits** | **Result** |
|---|---|---|---|---|---|
| Lead | ICP-MS | mg/kg | Intertek (1) | - | 4 |
| Nickel | ICP-MS | mg/kg | Intertek (1) | - | 5 |
| Selenium | ICP-MS | mg/kg | Intertek (1) | - | <2 |
| Tin | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Zinc | ICP-MS | mg/kg | Intertek (1) | - | 9 |

Note (1): Analysis subcontracted to EnviroLab, report number 147397.

For and on Behalf of Intertek:

Date Issued: 14.06.2016

Prepared By: Chamikara Wijesinghe
Title: Chemist

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# Test Report

ENI Australia
Blacktip OGP
Port Keats, Northern Territory
Attention: Plant Operations Superintendent

**Report Number:** AU115-3400 **Test Certificate Number:** **AU115-1209**

| | |
|---|---|
| Product Name: | Sediment |
| Sample Location: | Yellcherr North (BT-M-02-SED-2) |
| Intertek Sample Number: | 16/0116 |
| Analysis Suite: | 10.0 Metals and Metalloids |
| Date Sampled: | 25.05.2016 |
| Date Received: | 25.05.2016 |
| Sample Drawn By: | ENI |

| **Analysis** | **Test Method** | **Unit** | **Source** | **Limits** | **Result** |
|---|---|---|---|---|---|
| Aluminum | ICP-MS | mg/kg | Intertek (1) | - | 11000 |
| Arsenic | ICP-MS | mg/kg | Intertek (1) | - | 23 |
| Barium | ICP-MS | mg/kg | Intertek (1) | - | 9 |
| Beryllium | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Boron | ICP-MS | mg/kg | Intertek (1) | - | 40 |
| Cadmium | ICP-MS | mg/kg | Intertek (1) | - | <0.4 |
| Cobalt | ICP-MS | mg/kg | Intertek (1) | - | 7 |
| Copper | ICP-MS | mg/kg | Intertek (1) | - | 9 |
| Chromium | ICP-MS | mg/kg | Intertek (1) | - | 33 |
| Iron | ICP-MS | mg/kg | Intertek (1) | - | 36000 |
| Mercury | ICP-MS | mg/kg | Intertek (1) | - | <0.1 |
| Manganese | ICP-MS | mg/kg | Intertek (1) | - | 210 |
| Molybdenum | ICP-MS | mg/kg | Intertek (1) | - | <1 |

| Analysis | Test Method | mg/kg | Source | Limits | Result |
|---|---|---|---|---|---|
| Lead | ICP-MS | mg/kg | Intertek (1) | - | 6 |
| Nickel | ICP-MS | mg/kg | Intertek (1) | - | 11 |
| Selenium | ICP-MS | mg/kg | Intertek (1) | - | <2 |
| Tin | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Zinc | ICP-MS | mg/kg | Intertek (1) | - | 23 |

Note (1): Analysis subcontracted to EnviroLab, report number 147397.

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Title: Chemist

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# Test Report

ENI Australia
Blacktip OGP
Port Keats, Northern Territory
Attention: Plant Operations Superintendent

**Report Number:** AU115-3400 **Test Certificate Number:** **AU115-1210**

| | |
|---|---|
| Product Name: | Sediment |
| Sample Location: | Control Site (BT-M-C-SED-1) |
| Intertek Sample Number: | 16/0117 |
| Analysis Suite: | 10.0 Metals and Metalloids |
| Date Sampled: | 25.05.2016 |
| Date Received: | 25.05.2016 |
| Sample Drawn By: | ENI |

| **Analysis** | **Test Method** | **Unit** | **Source** | **Limits** | **Result** |
|---|---|---|---|---|---|
| Aluminum | ICP-MS | mg/kg | Intertek [(1)] | - | 1600 |
| Arsenic | ICP-MS | mg/kg | Intertek [(1)] | - | 15 |
| Barium | ICP-MS | mg/kg | Intertek [(1)] | - | 2 |
| Beryllium | ICP-MS | mg/kg | Intertek [(1)] | - | <1 |
| Boron | ICP-MS | mg/kg | Intertek [(1)] | - | 10 |
| Cadmium | ICP-MS | mg/kg | Intertek [(1)] | - | <0.4 |
| Cobalt | ICP-MS | mg/kg | Intertek [(1)] | - | 2 |
| Copper | ICP-MS | mg/kg | Intertek [(1)] | - | <1 |
| Chromium | ICP-MS | mg/kg | Intertek [(1)] | - | 19 |
| Iron | ICP-MS | mg/kg | Intertek [(1)] | - | 14000 |
| Mercury | ICP-MS | mg/kg | Intertek [(1)] | - | <0.1 |
| Manganese | ICP-MS | mg/kg | Intertek [(1)] | - | 180 |
| Molybdenum | ICP-MS | mg/kg | Intertek [(1)] | - | <1 |

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| **Analysis** | **Test Method** | mg/kg | **Source** | **Limits** | **Result** |
|---|---|---|---|---|---|
| Lead | ICP-MS | mg/kg | Intertek (1) | - | 4 |
| Nickel | ICP-MS | mg/kg | Intertek (1) | - | 3 |
| Selenium | ICP-MS | mg/kg | Intertek (1) | - | <2 |
| Tin | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Zinc | ICP-MS | mg/kg | Intertek (1) | - | 5 |

Note (1): Analysis subcontracted to EnviroLab, report number 147397.

For and on Behalf of Intertek: Date Issued: 14.06.2016

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Title: Chemist

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# Test Report

ENI Australia
Blacktip OGP
Port Keats, Northern Territory
Attention: Plant Operations Superintendent

**Report Number:** AU115-3400 **Test Certificate Number:** **AU115-1211**

| | |
|---|---|
| Product Name: | Shell Fish |
| Sample Location: | Yellcherr South (BT-M-01-SF-1) |
| Intertek Sample Number: | 16/0118 |
| Analysis Suite: | 10.0 Metals and Metalloids |
| Date Sampled: | 25.05.2016 |
| Date Received: | 25.05.2016 |
| Sample Drawn By: | ENI |

| **Analysis** | **Test Method** | **Unit** | **Source** | **Limits** | **Result** |
|---|---|---|---|---|---|
| Aluminum | ICP-MS | mg/kg | Intertek (1) | - | 170 |
| Arsenic | ICP-MS | mg/kg | Intertek (1) | - | 7 |
| Barium | ICP-MS | mg/kg | Intertek (1) | - | 2 |
| Beryllium | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Boron | ICP-MS | mg/kg | Intertek (1) | - | 20 |
| Cadmium | ICP-MS | mg/kg | Intertek (1) | - | 0.5 |
| Cobalt | ICP-MS | mg/kg | Intertek (1) | - | 1 |
| Copper | ICP-MS | mg/kg | Intertek (1) | - | 62 |
| Chromium | ICP-MS | mg/kg | Intertek (1) | - | 60 |
| Iron | ICP-MS | mg/kg | Intertek (1) | - | 1000 |
| Mercury | ICP-MS | mg/kg | Intertek (1) | - | <0.1 |
| Manganese | ICP-MS | mg/kg | Intertek (1) | - | 40 |
| Molybdenum | ICP-MS | mg/kg | Intertek (1) | - | <1 |

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| **Analysis** | **Test Method** | mg/kg | **Source** | **Limits** | **Result** |
|---|---|---|---|---|---|
| Lead | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Nickel | ICP-MS | mg/kg | Intertek (1) | - | 24 |
| Selenium | ICP-MS | mg/kg | Intertek (1) | - | <2 |
| Tin | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Zinc | ICP-MS | mg/kg | Intertek (1) | - | 31 |

Note (1): Analysis subcontracted to EnviroLab, report number 147397-A.

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# Test Report

ENI Australia
Blacktip OGP
Port Keats, Northern Territory
Attention: Plant Operations Superintendent

**Report Number:** AU115-3400 **Test Certificate Number:** **AU115-1212**

| | |
|---|---|
| Product Name: | Shell Fish |
| Sample Location: | Yellcherr South (BT-RH-01-SF-1) |
| Intertek Sample Number: | 16/0119 |
| Analysis Suite: | 10.0 Metals and Metalloids |
| Date Sampled: | 25.05.2016 |
| Date Received: | 25.05.2016 |
| Sample Drawn By: | ENI |

| Analysis | Test Method | Unit | Source | Limits | Result |
|---|---|---|---|---|---|
| Aluminum | ICP-MS | mg/kg | Intertek (1) | - | 34 |
| Arsenic | ICP-MS | mg/kg | Intertek (1) | - | <4 |
| Barium | ICP-MS | mg/kg | Intertek (1) | - | 4 |
| Beryllium | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Boron | ICP-MS | mg/kg | Intertek (1) | - | 20 |
| Cadmium | ICP-MS | mg/kg | Intertek (1) | - | 0.5 |
| Cobalt | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Copper | ICP-MS | mg/kg | Intertek (1) | - | 89 |
| Chromium | ICP-MS | mg/kg | Intertek (1) | - | 1 |
| Iron | ICP-MS | mg/kg | Intertek (1) | - | 120 |
| Mercury | ICP-MS | mg/kg | Intertek (1) | - | <0.1 |
| Manganese | ICP-MS | mg/kg | Intertek (1) | - | 11 |
| Molybdenum | ICP-MS | mg/kg | Intertek (1) | - | <1 |

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| **Analysis** | **Test Method** | mg/kg | **Source** | **Limits** | **Result** |
|---|---|---|---|---|---|
| Lead | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Nickel | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Selenium | ICP-MS | mg/kg | Intertek (1) | - | <2 |
| Tin | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Zinc | ICP-MS | mg/kg | Intertek (1) | - | 73 |

Note (1): Analysis subcontracted to EnviroLab, report number 147397-A.

For and on Behalf of Intertek: Date Issued: 14.06.2016

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Title: Chemist

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# Test Report

ENI Australia
Blacktip OGP
Port Keats, Northern Territory
Attention: Plant Operations Superintendent

**Report Number:** AU115-3400 **Test Certificate Number:** **AU115-1213**

---

Product Name: Shell Fish
Sample Location: Yellcherr North (BT-M-02-SF-1)
Intertek Sample Number: 16/0120
Analysis Suite: 10.0 Metals and Metalloids
Date Sampled: 25.05.2016
Date Received: 25.05.2016
Sample Drawn By: ENI

| **Analysis** | **Test Method** | **Unit** | **Source** | **Limits** | **Result** |
|---|---|---|---|---|---|
| Aluminum | ICP-MS | mg/kg | Intertek (1) | - | 530 |
| Arsenic | ICP-MS | mg/kg | Intertek (1) | - | 8 |
| Barium | ICP-MS | mg/kg | Intertek (1) | - | 1 |
| Beryllium | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Boron | ICP-MS | mg/kg | Intertek (1) | - | 34 |
| Cadmium | ICP-MS | mg/kg | Intertek (1) | - | 0.5 |
| Cobalt | ICP-MS | mg/kg | Intertek (1) | - | 2 |
| Copper | ICP-MS | mg/kg | Intertek (1) | - | 49 |
| Chromium | ICP-MS | mg/kg | Intertek (1) | - | 66 |
| Iron | ICP-MS | mg/kg | Intertek (1) | - | 2200 |
| Mercury | ICP-MS | mg/kg | Intertek (1) | - | <0.1 |
| Manganese | ICP-MS | mg/kg | Intertek (1) | - | 50 |
| Molybdenum | ICP-MS | mg/kg | Intertek (1) | - | <1 |

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| Analysis | Test Method | mg/kg | Source | Limits | Result |
|---|---|---|---|---|---|
| Lead | ICP-MS | mg/kg | Intertek [(1)] | - | <1 |
| Nickel | ICP-MS | mg/kg | Intertek [(1)] | - | 27 |
| Selenium | ICP-MS | mg/kg | Intertek [(1)] | - | <2 |
| Tin | ICP-MS | mg/kg | Intertek [(1)] | - | <1 |
| Zinc | ICP-MS | mg/kg | Intertek [(1)] | - | 29 |

Note (1): Analysis subcontracted to EnviroLab, report number 147397-A.

For and on Behalf of Intertek:

Date Issued: 14.06.2016

Prepared By: Chamikara Wijesinghe

Title: Chemist

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# Test Report

ENI Australia
Blacktip OGP
Port Keats, Northern Territory
Attention: Plant Operations Superintendent

**Report Number:** AU115-3400 **Test Certificate Number:** **AU115-1214**

| | |
|---|---|
| Product Name: | Shell Fish |
| Sample Location: | Yellcherr North (BT-RH-02-SF-1) |
| Intertek Sample Number: | 16/0121 |
| Analysis Suite: | 10.0 Metals and Metalloids |
| Date Sampled: | 25.05.2016 |
| Date Received: | 25.05.2016 |
| Sample Drawn By: | ENI |

| **Analysis** | **Test Method** | **Unit** | **Source** | **Limits** | **Result** |
|---|---|---|---|---|---|
| Aluminum | ICP-MS | mg/kg | Intertek (1) | - | 350 |
| Arsenic | ICP-MS | mg/kg | Intertek (1) | - | 5 |
| Barium | ICP-MS | mg/kg | Intertek (1) | - | 2 |
| Beryllium | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Boron | ICP-MS | mg/kg | Intertek (1) | - | 10 |
| Cadmium | ICP-MS | mg/kg | Intertek (1) | - | 0.6 |
| Cobalt | ICP-MS | mg/kg | Intertek (1) | - | 2 |
| Copper | ICP-MS | mg/kg | Intertek (1) | - | 91 |
| Chromium | ICP-MS | mg/kg | Intertek (1) | - | 82 |
| Iron | ICP-MS | mg/kg | Intertek (1) | - | 1600 |
| Mercury | ICP-MS | mg/kg | Intertek (1) | - | <0.1 |
| Manganese | ICP-MS | mg/kg | Intertek (1) | - | 70 |
| Molybdenum | ICP-MS | mg/kg | Intertek (1) | - | <1 |

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| **Analysis** | **Test Method** | mg/kg | **Source** | **Limits** | **Result** |
|---|---|---|---|---|---|
| Lead | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Nickel | ICP-MS | mg/kg | Intertek (1) | - | 30 |
| Selenium | ICP-MS | mg/kg | Intertek (1) | - | <2 |
| Tin | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Zinc | ICP-MS | mg/kg | Intertek (1) | - | 40 |

Note (1): Analysis subcontracted to EnviroLab, report number 147397-A.

For and on Behalf of Intertek: Date Issued: 14.06.2016

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Title: Chemist

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# Test Report

ENI Australia
Blacktip OGP
Port Keats, Northern Territory
Attention: Plant Operations Superintendent

**Report Number:** AU115-3400 **Test Certificate Number:** **AU115-1215**

Product Name: Shell Fish
Sample Location: Control (BT-M-C-SF-1)
Intertek Sample Number: 16/0122
Analysis Suite: 10.0 Metals and Metalloids
Date Sampled: 25.05.2016
Date Received: 25.05.2016
Sample Drawn By: ENI

| **Analysis** | **Test Method** | **Unit** | **Source** | **Limits** | **Result** |
|---|---|---|---|---|---|
| Aluminum | ICP-MS | mg/kg | Intertek (1) | - | 61 |
| Arsenic | ICP-MS | mg/kg | Intertek (1) | - | 5 |
| Barium | ICP-MS | mg/kg | Intertek (1) | - | 5 |
| Beryllium | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Boron | ICP-MS | mg/kg | Intertek (1) | - | 10 |
| Cadmium | ICP-MS | mg/kg | Intertek (1) | - | 0.4 |
| Cobalt | ICP-MS | mg/kg | Intertek (1) | - | 3 |
| Copper | ICP-MS | mg/kg | Intertek (1) | - | 100 |
| Chromium | ICP-MS | mg/kg | Intertek (1) | - | 26 |
| Iron | ICP-MS | mg/kg | Intertek (1) | - | 510 |
| Mercury | ICP-MS | mg/kg | Intertek (1) | - | <0.1 |
| Manganese | ICP-MS | mg/kg | Intertek (1) | - | 42 |
| Molybdenum | ICP-MS | mg/kg | Intertek (1) | - | <1 |

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| **Analysis** | **Test Method** | mg/kg | **Source** | **Limits** | **Result** |
|---|---|---|---|---|---|
| Lead | ICP-MS | mg/kg | Intertek [(1)] | - | <1 |
| Nickel | ICP-MS | mg/kg | Intertek [(1)] | - | 10 |
| Selenium | ICP-MS | mg/kg | Intertek [(1)] | - | <2 |
| Tin | ICP-MS | mg/kg | Intertek [(1)] | - | <1 |
| Zinc | ICP-MS | mg/kg | Intertek [(1)] | - | 140 |

Note (1): Analysis subcontracted to EnviroLab, report number 147397-A.

For and on Behalf of Intertek: Date Issued: 14.06.2016

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Title: Chemist

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# Test Report

ENI Australia
Blacktip OGP
Port Keats, Northern Territory
Attention: Plant Operations Superintendent

**Report Number:** AU115-3400 **Test Certificate Number:** **AU115-1216**

Product Name: Shell Fish
Sample Location: Control (BT-RH-C-SF-1)
Intertek Sample Number: 16/0123
Analysis Suite: 10.0 Metals and Metalloids
Date Sampled: 25.05.2016
Date Received: 25.05.2016
Sample Drawn By: ENI

| **Analysis** | **Test Method** | **Unit** | **Source** | **Limits** | **Result** |
|---|---|---|---|---|---|
| Aluminum | ICP-MS | mg/kg | Intertek (1) | - | 62 |
| Arsenic | ICP-MS | mg/kg | Intertek (1) | - | 4 |
| Barium | ICP-MS | mg/kg | Intertek (1) | - | 6 |
| Beryllium | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Boron | ICP-MS | mg/kg | Intertek (1) | - | 10 |
| Cadmium | ICP-MS | mg/kg | Intertek (1) | - | <0.4 |
| Cobalt | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Copper | ICP-MS | mg/kg | Intertek (1) | - | 49 |
| Chromium | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Iron | ICP-MS | mg/kg | Intertek (1) | - | 900 |
| Mercury | ICP-MS | mg/kg | Intertek (1) | - | <0.1 |
| Manganese | ICP-MS | mg/kg | Intertek (1) | - | 35 |
| Molybdenum | ICP-MS | mg/kg | Intertek (1) | - | <1 |

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| **Analysis** | **Test Method** | mg/kg | **Source** | **Limits** | **Result** |
|---|---|---|---|---|---|
| Lead | ICP-MS | mg/kg | Intertek (1) | - | 9 |
| Nickel | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Selenium | ICP-MS | mg/kg | Intertek (1) | - | <2 |
| Tin | ICP-MS | mg/kg | Intertek (1) | - | <1 |
| Zinc | ICP-MS | mg/kg | Intertek (1) | - | 76 |

Note (1): Analysis subcontracted to EnviroLab, report number 147397-A.

For and on Behalf of Intertek:

Date Issued: 14.06.2016

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# Test Report

ENI Australia
Blacktip OGP
Port Keats, Northern Territory
Attention: Plant Operations Superintendent

**Report Number:** AU115-3400 **Test Certificate Number:** **AU115-L1217**

| | |
|---|---|
| Product Name: | Sediment |
| Sample Location: | Yellcherr South (BT-M-01-SED-1) |
| Intertek Sample Number: | 16/0115 |
| Analysis Suite: | 10.1 Hydrocarbons |
| Date Sampled: | 25.05.2016 |
| Date Received: | 25.05.2016 |
| Sample Drawn By: | ENI |

| **Analysis** | **Test Method** | **Unit** | **Source** | **Limits** | **Result** |
|---|---|---|---|---|---|
| **vTRH(C6-10)/BTEX** | | | | | |
| $TRHC_6-C_9$ | GC-MS | mg/kg | Intertek(1) | - | <25 |
| $TRHC_6-C_{10}$ | GC-MS | mg/kg | Intertek(1) | - | <25 |
| $TRHC_6-C_{10}$ less BTEX (F1) | GC-MS | mg/kg | Intertek(1) | - | <25 |
| Benzene | GC-MS | mg/kg | Intertek(1) | - | <0.2 |
| Toluene | GC-MS | mg/kg | Intertek(1) | - | <0.5 |
| Ethylbenzene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| m+p-xylene | GC-MS | mg/kg | Intertek(1) | - | <2 |
| o-xylene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| Naphthalene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| | | | | | |
| **svTRH (C10-C40)** | | | | | |
| $TRHC_{10}-C_{14}$ | GC-FID | mg/kg | Intertek(1) | - | <50 |
| $TRHC_{15}-C_{28}$ | GC-FID | mg/kg | Intertek(1) | - | <100 |
| $TRHC_{29}-C_{36}$ | GC-FID | mg/kg | Intertek(1) | - | <100 |
| $TRH>C_{10}-C_{16}$ | GC-FID | mg/kg | Intertek(1) | - | <50 |
| $TRH>C_{10}-C_{16}$ less Napthalene (F2) | GC-FID | mg/kg | Intertek(1) | - | <50 |
| $TRH>C_{16}-C_{34}$ | GC-FID | mg/kg | Intertek(1) | - | <100 |
| $TRH>C_{34}-C_{40}$ | GC-FID | mg/kg | Intertek(1) | - | <100 |

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| **Polycyclic Aromatic Hydrocarbons (PAH)** | | | | | |
|---|---|---|---|---|---|
| Naphthalene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Acenaphthylene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Acenaphthene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Fluorene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Phenanthrene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Anthracene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Fluoranthene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Pyrene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(a)anthracene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Chrysene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(b,j+k)fluoranthene | GC-MS | mg/kg | Intertek(1) | - | <0.2 |
| Benzo(a)pyrene | GC-MS | mg/kg | Intertek(1) | - | <0.05 |
| Indeno(1,2,3-c,d)pyrene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Dibenzo(a,h)anthracene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(g,h,i)perylene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(a)pyrene TEQ | GC-MS | mg/kg | Intertek(1) | - | <0.5 |
| Total +ve PAH's | GC-MS | mg/kg | Intertek(1) | - | NIL (+) IVE |

Note (1): Analysis subcontracted to EnviroLab, report number 147397.

For and on Behalf of Intertek:

Date Issued: 14.06.2016

Prepared By: Chamikara Wijesinghe
Title: Chemist


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# Test Report

ENI Australia
Blacktip OGP
Port Keats, Northern Territory
Attention: Plant Operations Superintendent

**Report Number:** AU115-3400 **Test Certificate Number:** **AU115-L1218**

| | |
|---|---|
| Product Name: | Sediment |
| Sample Location: | Yellcherr North (BT-M-02-SED-2) |
| Intertek Sample Number: | 16/0116 |
| Analysis Suite: | 10.1 Hydrocarbons |
| Date Sampled: | 25.05.2016 |
| Date Received: | 25.05.2016 |
| Sample Drawn By: | ENI |

| Analysis | Test Method | Unit | Source | Limits | Result |
|---|---|---|---|---|---|
| **vTRH(C6-10)/BTEX** | | | | | |
| $TRHC_6$-$C_9$ | GC-MS | mg/kg | Intertek(1) | - | <25 |
| $TRHC_6$-$C_{10}$ | GC-MS | mg/kg | Intertek(1) | - | <25 |
| $TRHC_6$-$C_{10}$ less BTEX (F1) | GC-MS | mg/kg | Intertek(1) | - | <25 |
| Benzene | GC-MS | mg/kg | Intertek(1) | - | <0.2 |
| Toluene | GC-MS | mg/kg | Intertek(1) | - | <0.5 |
| Ethylbenzene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| m+p-xylene | GC-MS | mg/kg | Intertek(1) | - | <2 |
| o-xylene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| Naphthalene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| | | | | | |
| **svTRH (C10-C40)** | | | | | |
| $TRHC_{10}$-$C_{14}$ | GC-FID | mg/kg | Intertek(1) | - | <50 |
| $TRHC_{15}$-$C_{28}$ | GC-FID | mg/kg | Intertek(1) | - | <100 |
| $TRHC_{29}$-$C_{36}$ | GC-FID | mg/kg | Intertek(1) | - | <100 |
| TRH>$C_{10}$-$C_{16}$ | GC-FID | mg/kg | Intertek(1) | - | <50 |
| TRH>$C_{10}$-$C_{16}$ less Napthalene (F2) | GC-FID | mg/kg | Intertek(1) | - | <50 |
| TRH>$C_{16}$-$C_{34}$ | GC-FID | mg/kg | Intertek(1) | - | <100 |
| TRH>$C_{34}$-$C_{40}$ | GC-FID | mg/kg | Intertek(1) | - | <100 |

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| **Polycyclic Aromatic Hydrocarbons (PAH)** | | | | | |
|---|---|---|---|---|---|
| Naphthalene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Acenaphthylene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Acenaphthene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Fluorene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Phenanthrene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Anthracene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Fluoranthene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Pyrene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(a)anthracene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Chrysene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(b,j+k)fluoranthene | GC-MS | mg/kg | Intertek(1) | - | <0.2 |
| Benzo(a)pyrene | GC-MS | mg/kg | Intertek(1) | - | <0.05 |
| Indeno(1,2,3-c,d)pyrene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Dibenzo(a,h)anthracene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(g,h,i)perylene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(a)pyrene TEQ | GC-MS | mg/kg | Intertek(1) | - | <0.5 |
| Total +ve PAH's | GC-MS | mg/kg | Intertek(1) | - | NIL (+) IVE |

Note (1): Analysis subcontracted to EnviroLab, report number 147397.

For and on Behalf of Intertek:

Date Issued: 14.06.2016

Prepared By: Chamikara Wijesinghe
Title: Chemist

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# Test Report

ENI Australia
Blacktip OGP
Port Keats, Northern Territory
Attention: Plant Operations Superintendent

**Report Number:** AU115-3400 **Test Certificate Number:** **AU115-L1219**

| | |
|---|---|
| Product Name: | Sediment |
| Sample Location: | Control Site (BT-M-C-SED-1) |
| Intertek Sample Number: | 16/0117 |
| Analysis Suite: | 10.1 Hydrocarbons |
| Date Sampled: | 25.05.2016 |
| Date Received: | 25.05.2016 |
| Sample Drawn By: | ENI |

| Analysis | Test Method | Unit | Source | Limits | Result |
|---|---|---|---|---|---|
| **vTRH(C6-10)/BTEX** | | | | | |
| $TRHC_6$-$C_9$ | GC-MS | mg/kg | Intertek(1) | - | <25 |
| $TRHC_6$-$C_{10}$ | GC-MS | mg/kg | Intertek(1) | - | <25 |
| $TRHC_6$-$C_{10}$ less BTEX (F1) | GC-MS | mg/kg | Intertek(1) | - | <25 |
| Benzene | GC-MS | mg/kg | Intertek(1) | - | <0.2 |
| Toluene | GC-MS | mg/kg | Intertek(1) | - | <0.5 |
| Ethylbenzene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| m+p-xylene | GC-MS | mg/kg | Intertek(1) | - | <2 |
| o-xylene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| Naphthalene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| | | | | | |
| **svTRH (C10-C40)** | | | | | |
| $TRHC_{10}$-$C_{14}$ | GC-FID | mg/kg | Intertek(1) | - | <50 |
| $TRHC_{15}$-$C_{28}$ | GC-FID | mg/kg | Intertek(1) | - | <100 |
| $TRHC_{29}$-$C_{36}$ | GC-FID | mg/kg | Intertek(1) | - | <100 |
| TRH>$C_{10}$-$C_{16}$ | GC-FID | mg/kg | Intertek(1) | - | <50 |
| TRH>$C_{10}$-$C_{16}$ less Napthalene (F2) | GC-FID | mg/kg | Intertek(1) | - | <50 |
| TRH>$C_{16}$-$C_{34}$ | GC-FID | mg/kg | Intertek(1) | - | <100 |
| TRH>$C_{34}$-$C_{40}$ | GC-FID | mg/kg | Intertek(1) | - | <100 |

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| **Polycyclic Aromatic Hydrocarbons (PAH)** | | | | | |
|---|---|---|---|---|---|
| Naphthalene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Acenaphthylene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Acenaphthene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Fluorene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Phenanthrene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Anthracene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Fluoranthene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Pyrene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(a)anthracene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Chrysene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(b,j+k)fluoranthene | GC-MS | mg/kg | Intertek(1) | - | <0.2 |
| Benzo(a)pyrene | GC-MS | mg/kg | Intertek(1) | - | <0.05 |
| Indeno(1,2,3-c,d)pyrene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Dibenzo(a,h)anthracene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(g,h,i)perylene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(a)pyrene TEQ | GC-MS | mg/kg | Intertek(1) | - | <0.5 |
| Total +ve PAH’s | GC-MS | mg/kg | Intertek(1) | - | NIL (+) IVE |

Note (1): Analysis subcontracted to EnviroLab, report number 147397.

For and on Behalf of Intertek: Date Issued: 14.06.2016

Prepared By: Chamikara Wijesinghe
Title: Chemist


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# Test Report

ENI Australia
Blacktip OGP
Port Keats, Northern Territory
Attention: Plant Operations Superintendent

**Report Number:** AU115-3400 **Test Certificate Number:** **AU115-L1220**

| | |
|---|---|
| Product Name: | Shell Fish |
| Sample Location: | Yellcherr South (BT-M-01-SF-1) |
| Intertek Sample Number: | 16/0118 |
| Analysis Suite: | 10.1 Hydrocarbons |
| Date Sampled: | 25.05.2016 |
| Date Received: | 25.05.2016 |
| Sample Drawn By: | ENI |

| **Analysis** | **Test Method** | **Unit** | **Source** | **Limits** | **Result** |
|---|---|---|---|---|---|
| **vTRH(C6-10)/BTEX** | | | | | |
| $TRHC_6$-$C_9$ | GC-MS | mg/kg | Intertek(1) | - | <25 |
| $TRHC_6$-$C_{10}$ | GC-MS | mg/kg | Intertek(1) | - | <25 |
| $TRHC_6$-$C_{10}$ less BTEX (F1) | GC-MS | mg/kg | Intertek(1) | - | <25 |
| Benzene | GC-MS | mg/kg | Intertek(1) | - | <0.2 |
| Toluene | GC-MS | mg/kg | Intertek(1) | - | <0.5 |
| Ethylbenzene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| m+p-xylene | GC-MS | mg/kg | Intertek(1) | - | <2 |
| o-xylene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| Naphthalene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| | | | | | |
| **svTRH (C10-C40)** | | | | | |
| $TRHC_{10}$-$C_{14}$ | GC-FID | mg/kg | Intertek(1) | - | 350 |
| $TRHC_{15}$-$C_{28}$ | GC-FID | mg/kg | Intertek(1) | - | 2900 |
| $TRHC_{29}$-$C_{36}$ | GC-FID | mg/kg | Intertek(1) | - | 2300 |
| TRH>$C_{10}$-$C_{16}$ | GC-FID | mg/kg | Intertek(1) | - | 380 |
| TRH>$C_{10}$-$C_{16}$ less Napthalene (F2) | GC-FID | mg/kg | Intertek(1) | - | 380 |
| TRH>$C_{16}$-$C_{34}$ | GC-FID | mg/kg | Intertek(1) | - | 5000 |
| TRH>$C_{34}$-$C_{40}$ | GC-FID | mg/kg | Intertek(1) | - | 530 |

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| **Polycyclic Aromatic Hydrocarbons (PAH)** | | | | | |
|---|---|---|---|---|---|
| Naphthalene | GC-MS | mg/kg | Intertek[(1)] | - | <0.1 |
| Acenaphthylene | GC-MS | mg/kg | Intertek[(1)] | - | <0.1 |
| Acenaphthene | GC-MS | mg/kg | Intertek[(1)] | - | <0.1 |
| Fluorene | GC-MS | mg/kg | Intertek[(1)] | - | <0.1 |
| Phenanthrene | GC-MS | mg/kg | Intertek[(1)] | - | <0.1 |
| Anthracene | GC-MS | mg/kg | Intertek[(1)] | - | <0.1 |
| Fluoranthene | GC-MS | mg/kg | Intertek[(1)] | - | <0.1 |
| Pyrene | GC-MS | mg/kg | Intertek[(1)] | - | <0.1 |
| Benzo(a)anthracene | GC-MS | mg/kg | Intertek[(1)] | - | <0.1 |
| Chrysene | GC-MS | mg/kg | Intertek[(1)] | - | <0.1 |
| Benzo(b,j+k)fluoranthene | GC-MS | mg/kg | Intertek[(1)] | - | <0.2 |
| Benzo(a)pyrene | GC-MS | mg/kg | Intertek[(1)] | - | <0.05 |
| Indeno(1,2,3-c,d)pyrene | GC-MS | mg/kg | Intertek[(1)] | - | <0.1 |
| Dibenzo(a,h)anthracene | GC-MS | mg/kg | Intertek[(1)] | - | <0.1 |
| Benzo(g,h,i)perylene | GC-MS | mg/kg | Intertek[(1)] | - | <0.1 |
| Benzo(a)pyrene TEQ | GC-MS | mg/kg | Intertek[(1)] | - | <0.5 |
| Total +ve PAH's | GC-MS | mg/kg | Intertek[(1)] | - | NIL (+) IVE |

Note (1): Analysis subcontracted to EnviroLab, report number 147397-A.

For and on Behalf of Intertek: Date Issued: 14.06.2016

Prepared By: Chamikara Wijesinghe
Title: Chemist


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# Test Report

ENI Australia
Blacktip OGP
Port Keats, Northern Territory
Attention: Plant Operations Superintendent

**Report Number:** AU115-3400 **Test Certificate Number:** **AU115-L1221**

| | |
|---|---|
| Product Name: | Shell Fish |
| Sample Location: | Yellcherr South (BT-RH-01-SF-1) |
| Intertek Sample Number: | 16/0119 |
| Analysis Suite: | 10.1 Hydrocarbons |
| Date Sampled: | 25.05.2016 |
| Date Received: | 25.05.2016 |
| Sample Drawn By: | ENI |

| **Analysis** | **Test Method** | **Unit** | **Source** | **Limits** | **Result** |
|---|---|---|---|---|---|
| **vTRH(C6-10)/BTEX** | | | | | |
| $TRHC_6$-$C_9$ | GC-MS | mg/kg | Intertek(1) | - | <25 |
| $TRHC_6$-$C_{10}$ | GC-MS | mg/kg | Intertek(1) | - | <25 |
| $TRHC_6$-$C_{10}$ less BTEX (F1) | GC-MS | mg/kg | Intertek(1) | - | <25 |
| Benzene | GC-MS | mg/kg | Intertek(1) | - | <0.2 |
| Toluene | GC-MS | mg/kg | Intertek(1) | - | <0.5 |
| Ethylbenzene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| m+p-xylene | GC-MS | mg/kg | Intertek(1) | - | <2 |
| o-xylene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| Naphthalene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| | | | | | |
| **svTRH (C10-C40)** | | | | | |
| $TRHC_{10}$-$C_{14}$ | GC-FID | mg/kg | Intertek(1) | - | 1400 |
| $TRHC_{15}$-$C_{28}$ | GC-FID | mg/kg | Intertek(1) | - | 8800 |
| $TRHC_{29}$-$C_{36}$ | GC-FID | mg/kg | Intertek(1) | - | 2500 |
| TRH>$C_{10}$-$C_{16}$ | GC-FID | mg/kg | Intertek(1) | - | 1700 |
| TRH>$C_{10}$-$C_{16}$ less Napthalene (F2) | GC-FID | mg/kg | Intertek(1) | - | 1700 |
| TRH>$C_{16}$-$C_{34}$ | GC-FID | mg/kg | Intertek(1) | - | 10000 |
| TRH>$C_{34}$-$C_{40}$ | GC-FID | mg/kg | Intertek(1) | - | 2100 |

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| **Polycyclic Aromatic Hydrocarbons (PAH)** | | | | | |
|---|---|---|---|---|---|
| Naphthalene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Acenaphthylene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Acenaphthene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Fluorene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Phenanthrene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Anthracene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Fluoranthene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Pyrene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(a)anthracene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Chrysene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(b,j+k)fluoranthene | GC-MS | mg/kg | Intertek(1) | - | <0.2 |
| Benzo(a)pyrene | GC-MS | mg/kg | Intertek(1) | - | <0.05 |
| Indeno(1,2,3-c,d)pyrene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Dibenzo(a,h)anthracene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(g,h,i)perylene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(a)pyrene TEQ | GC-MS | mg/kg | Intertek(1) | - | <0.5 |
| Total +ve PAH's | GC-MS | mg/kg | Intertek(1) | - | NIL (+) IVE |

Note (1): Analysis subcontracted to EnviroLab, report number 147397-A.

For and on Behalf of Intertek:

Date Issued: 14.06.2016

Prepared By: Chamikara Wijesinghe
Title: Chemist

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# Test Report

ENI Australia
Blacktip OGP
Port Keats, Northern Territory
Attention: Plant Operations Superintendent

**Report Number:** AU115-3400 **Test Certificate Number:** **AU115-L1222**

| | |
|---|---|
| Product Name: | Shell Fish |
| Sample Location: | Yellcherr North (BT-M-02-SF-1) |
| Intertek Sample Number: | 16/0120 |
| Analysis Suite: | 10.1 Hydrocarbons |
| Date Sampled: | 25.05.2016 |
| Date Received: | 25.05.2016 |
| Sample Drawn By: | ENI |

| **Analysis** | **Test Method** | **Unit** | **Source** | **Limits** | **Result** |
|---|---|---|---|---|---|
| **vTRH(C6-10)/BTEX** | | | | | |
| $TRHC_6$-$C_9$ | GC-MS | mg/kg | Intertek(1) | - | <25 |
| $TRHC_6$-$C_{10}$ | GC-MS | mg/kg | Intertek(1) | - | <25 |
| $TRHC_6$-$C_{10}$ less BTEX (F1) | GC-MS | mg/kg | Intertek(1) | - | <25 |
| Benzene | GC-MS | mg/kg | Intertek(1) | - | <0.2 |
| Toluene | GC-MS | mg/kg | Intertek(1) | - | <0.5 |
| Ethylbenzene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| m+p-xylene | GC-MS | mg/kg | Intertek(1) | - | <2 |
| o-xylene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| Naphthalene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| | | | | | |
| **svTRH (C10-C40)** | | | | | |
| $TRHC_{10}$-$C_{14}$ | GC-FID | mg/kg | Intertek(1) | - | 160 |
| $TRHC_{15}$-$C_{28}$ | GC-FID | mg/kg | Intertek(1) | - | 940 |
| $TRHC_{29}$-$C_{36}$ | GC-FID | mg/kg | Intertek(1) | - | 2100 |
| TRH>$C_{10}$-$C_{16}$ | GC-FID | mg/kg | Intertek(1) | - | 130 |
| TRH>$C_{10}$-$C_{16}$ less Napthalene (F2) | GC-FID | mg/kg | Intertek(1) | - | 130 |
| TRH>$C_{16}$-$C_{34}$ | GC-FID | mg/kg | Intertek(1) | - | 2900 |
| TRH>$C_{34}$-$C_{40}$ | GC-FID | mg/kg | Intertek(1) | - | 850 |

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| Polycyclic Aromatic Hydrocarbons (PAH) | | | | | |
|---|---|---|---|---|---|
| Naphthalene | GC-MS | mg/kg | Intertek[1] | - | <0.1 |
| Acenaphthylene | GC-MS | mg/kg | Intertek[1] | - | <0.1 |
| Acenaphthene | GC-MS | mg/kg | Intertek[1] | - | <0.1 |
| Fluorene | GC-MS | mg/kg | Intertek[1] | - | <0.1 |
| Phenanthrene | GC-MS | mg/kg | Intertek[1] | - | <0.1 |
| Anthracene | GC-MS | mg/kg | Intertek[1] | - | <0.1 |
| Fluoranthene | GC-MS | mg/kg | Intertek[1] | - | <0.1 |
| Pyrene | GC-MS | mg/kg | Intertek[1] | - | <0.1 |
| Benzo(a)anthracene | GC-MS | mg/kg | Intertek[1] | - | <0.1 |
| Chrysene | GC-MS | mg/kg | Intertek[1] | - | <0.1 |
| Benzo(b,j+k)fluoranthene | GC-MS | mg/kg | Intertek[1] | - | <0.2 |
| Benzo(a)pyrene | GC-MS | mg/kg | Intertek[1] | - | <0.05 |
| Indeno(1,2,3-c,d)pyrene | GC-MS | mg/kg | Intertek[1] | - | <0.1 |
| Dibenzo(a,h)anthracene | GC-MS | mg/kg | Intertek[1] | - | <0.1 |
| Benzo(g,h,i)perylene | GC-MS | mg/kg | Intertek[1] | - | <0.1 |
| Benzo(a)pyrene TEQ | GC-MS | mg/kg | Intertek[1] | - | <0.5 |
| Total +ve PAH's | GC-MS | mg/kg | Intertek[1] | - | NIL (+) IVE |

Note (1): Analysis subcontracted to EnviroLab, report number 147397-A.

For and on Behalf of Intertek: Date Issued: 14.06.2016

Prepared By: Chamikara Wijesinghe
Title: Chemist

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# Test Report

ENI Australia
Blacktip OGP
Port Keats, Northern Territory
Attention: Plant Operations Superintendent

**Report Number:** AU115-3400 **Test Certificate Number:** **AU115-L1223**

Product Name: Shell Fish
Sample Location: Yellcherr North (BT-RH-02-SF-1)
Intertek Sample Number: 16/0121
Analysis Suite: 10.1 Hydrocarbons
Date Sampled: 25.05.2016
Date Received: 25.05.2016
Sample Drawn By: ENI

| **Analysis** | **Test Method** | **Unit** | **Source** | **Limits** | **Result** |
|---|---|---|---|---|---|
| **vTRH(C6-10)/BTEX** | | | | | |
| TRH$C_6$-$C_9$ | GC-MS | mg/kg | Intertek(1) | - | <25 |
| TRH$C_6$-$C_{10}$ | GC-MS | mg/kg | Intertek(1) | - | <25 |
| TRH$C_6$-$C_{10}$ less BTEX (F1) | GC-MS | mg/kg | Intertek(1) | - | <25 |
| Benzene | GC-MS | mg/kg | Intertek(1) | - | <0.2 |
| Toluene | GC-MS | mg/kg | Intertek(1) | - | <0.5 |
| Ethylbenzene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| m+p-xylene | GC-MS | mg/kg | Intertek(1) | - | <2 |
| o-xylene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| Naphthalene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| | | | | | |
| **svTRH (C10-C40)** | | | | | |
| TRH$C_{10}$-$C_{14}$ | GC-FID | mg/kg | Intertek(1) | - | 610 |
| TRH$C_{15}$-$C_{28}$ | GC-FID | mg/kg | Intertek(1) | - | 3200 |
| TRH$C_{29}$-$C_{36}$ | GC-FID | mg/kg | Intertek(1) | - | 1100 |
| TRH>$C_{10}$-$C_{16}$ | GC-FID | mg/kg | Intertek(1) | - | 640 |
| TRH>$C_{10}$-$C_{16}$ less Napthalene (F2) | GC-FID | mg/kg | Intertek(1) | - | 640 |
| TRH>$C_{16}$-$C_{34}$ | GC-FID | mg/kg | Intertek(1) | - | 4100 |
| TRH>$C_{34}$-$C_{40}$ | GC-FID | mg/kg | Intertek(1) | - | 450 |



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| **Polycyclic Aromatic Hydrocarbons (PAH)** | | | | | |
|---|---|---|---|---|---|
| Naphthalene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Acenaphthylene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Acenaphthene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Fluorene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Phenanthrene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Anthracene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Fluoranthene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Pyrene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(a)anthracene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Chrysene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(b,j+k)fluoranthene | GC-MS | mg/kg | Intertek(1) | - | <0.2 |
| Benzo(a)pyrene | GC-MS | mg/kg | Intertek(1) | - | <0.05 |
| Indeno(1,2,3-c,d)pyrene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Dibenzo(a,h)anthracene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(g,h,i)perylene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(a)pyrene TEQ | GC-MS | mg/kg | Intertek(1) | - | <0.5 |
| Total +ve PAH's | GC-MS | mg/kg | Intertek(1) | - | NIL (+) IVE |

Note (1): Analysis subcontracted to EnviroLab, report number 147397-A.

For and on Behalf of Intertek:

Date Issued: 14.06.2016

Prepared By: Chamikara Wijesinghe
Title: Chemist

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# Test Report

ENI Australia
Blacktip OGP
Port Keats, Northern Territory
Attention: Plant Operations Superintendent

**Report Number:** AU115-3400 **Test Certificate Number:** **AU115-L1224**

Product Name: Shell Fish
Sample Location: Control (BT-M-C-SF-1)
Intertek Sample Number: 16/0122
Analysis Suite: 10.1 Hydrocarbons
Date Sampled: 25.05.2016
Date Received: 25.05.2016
Sample Drawn By: ENI

| Analysis | Test Method | Unit | Source | Limits | Result |
|---|---|---|---|---|---|
| **vTRH(C6-10)/BTEX** | | | | | |
| TRH$C_6$-$C_9$ | GC-MS | mg/kg | Intertek(1) | - | <25 |
| TRH$C_6$-$C_{10}$ | GC-MS | mg/kg | Intertek(1) | - | <25 |
| TRH$C_6$-$C_{10}$ less BTEX (F1) | GC-MS | mg/kg | Intertek(1) | - | <25 |
| Benzene | GC-MS | mg/kg | Intertek(1) | - | <0.2 |
| Toluene | GC-MS | mg/kg | Intertek(1) | - | <0.5 |
| Ethylbenzene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| m+p-xylene | GC-MS | mg/kg | Intertek(1) | - | <2 |
| o-xylene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| Naphthalene | GC-MS | mg/kg | Intertek(1) | - | <1 |
| | | | | | |
| **svTRH (C10-C40)** | | | | | |
| TRH$C_{10}$-$C_{14}$ | GC-FID | mg/kg | Intertek(1) | - | 1900 |
| TRH$C_{15}$-$C_{28}$ | GC-FID | mg/kg | Intertek(1) | - | 9600 |
| TRH$C_{29}$-$C_{36}$ | GC-FID | mg/kg | Intertek(1) | - | 4100 |
| TRH>$C_{10}$-$C_{16}$ | GC-FID | mg/kg | Intertek(1) | - | 2600 |
| TRH>$C_{10}$-$C_{16}$ less Napthalene (F2) | GC-FID | mg/kg | Intertek(1) | - | 2600 |
| TRH>$C_{16}$-$C_{34}$ | GC-FID | mg/kg | Intertek(1) | - | 12000 |
| TRH>$C_{34}$-$C_{40}$ | GC-FID | mg/kg | Intertek(1) | - | 1300 |

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| **Polycyclic Aromatic Hydrocarbons (PAH)** | | | | | |
|---|---|---|---|---|---|
| Naphthalene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Acenaphthylene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Acenaphthene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Fluorene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Phenanthrene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Anthracene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Fluoranthene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Pyrene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(a)anthracene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Chrysene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(b,j+k)fluoranthene | GC-MS | mg/kg | Intertek(1) | - | <0.2 |
| Benzo(a)pyrene | GC-MS | mg/kg | Intertek(1) | - | <0.05 |
| Indeno(1,2,3-c,d)pyrene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Dibenzo(a,h)anthracene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(g,h,i)perylene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(a)pyrene TEQ | GC-MS | mg/kg | Intertek(1) | - | <0.5 |
| Total +ve PAH’s | GC-MS | mg/kg | Intertek(1) | - | NIL (+) IVE |

Note (1): Analysis subcontracted to EnviroLab, report number 147397-A.

For and on Behalf of Intertek:

Date Issued: 14.06.2016

Prepared By: Chamikara Wijesinghe
Title: Chemist

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# Test Report

ENI Australia
Blacktip OGP
Port Keats, Northern Territory
Attention: Plant Operations Superintendent

**Report Number:** AU115-3400 **Test Certificate Number:** **AU115-L1225**

---

Product Name: Shell Fish
Sample Location: Control (BT-RH-C-SF-1)
Intertek Sample Number: 16/0123
Analysis Suite: 10.1 Hydrocarbons
Date Sampled: 25.05.2016
Date Received: 25.05.2016
Sample Drawn By: ENI

| Analysis | Test Method | Unit | Source | Limits | Result |
|---|---|---|---|---|---|
| **vTRH(C6-10)/BTEX** | | | | | |
| $TRHC_6$-$C_9$ | GC-MS | mg/kg | Intertek(1) | - | <100 |
| $TRHC_6$-$C_{10}$ | GC-MS | mg/kg | Intertek(1) | - | <100 |
| $TRHC_6$-$C_{10}$ less BTEX (F1) | GC-MS | mg/kg | Intertek(1) | - | <25 |
| Benzene | GC-MS | mg/kg | Intertek(1) | - | <0.8 |
| Toluene | GC-MS | mg/kg | Intertek(1) | - | <2 |
| Ethylbenzene | GC-MS | mg/kg | Intertek(1) | - | <4 |
| m+p-xylene | GC-MS | mg/kg | Intertek(1) | - | <8 |
| o-xylene | GC-MS | mg/kg | Intertek(1) | - | <4 |
| Naphthalene | GC-MS | mg/kg | Intertek(1) | - | <4 |
| | | | | | |
| **svTRH (C10-C40)** | | | | | |
| $TRHC_{10}$-$C_{14}$ | GC-FID | mg/kg | Intertek(1) | - | 3100 |
| $TRHC_{15}$-$C_{28}$ | GC-FID | mg/kg | Intertek(1) | - | 7900 |
| $TRHC_{29}$-$C_{36}$ | GC-FID | mg/kg | Intertek(1) | - | 2900 |
| TRH>$C_{10}$-$C_{16}$ | GC-FID | mg/kg | Intertek(1) | - | 3500 |
| TRH>$C_{10}$-$C_{16}$ less Napthalene (F2) | GC-FID | mg/kg | Intertek(1) | - | 3500 |
| TRH>$C_{16}$-$C_{34}$ | GC-FID | mg/kg | Intertek(1) | - | 9300 |
| TRH>$C_{34}$-$C_{40}$ | GC-FID | mg/kg | Intertek(1) | - | 1400 |



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| **Polycyclic Aromatic Hydrocarbons (PAH)** | | | | | |
|---|---|---|---|---|---|
| Naphthalene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Acenaphthylene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Acenaphthene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Fluorene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Phenanthrene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Anthracene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Fluoranthene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Pyrene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(a)anthracene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Chrysene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(b,j+k)fluoranthene | GC-MS | mg/kg | Intertek(1) | - | <0.2 |
| Benzo(a)pyrene | GC-MS | mg/kg | Intertek(1) | - | <0.05 |
| Indeno(1,2,3-c,d)pyrene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Dibenzo(a,h)anthracene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(g,h,i)perylene | GC-MS | mg/kg | Intertek(1) | - | <0.1 |
| Benzo(a)pyrene TEQ | GC-MS | mg/kg | Intertek(1) | - | <0.5 |
| Total +ve PAH's | GC-MS | mg/kg | Intertek(1) | - | NIL (+) IVE |

Note (1): Analysis subcontracted to EnviroLab, report number 147397-A.

For and on Behalf of Intertek: Date Issued: 14.06.2016

Prepared By: Chamikara Wijesinghe
Title: Chemist

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# APPENDIX C:

# DISPERSION MODEL VERIFICATION RESULTS

| |
|---|
| **Verification of model outputs** |
| **NTG 26a:** It is noted on pp 14 of (Teikoku Oil (Bonaparte Gulf) Co Ltd 1994) that the high turbidity of waters within Joseph Bonaparte Gulf (the Gulf) ' improves markedly' north of Point Pearce. This would suggest that the discharge location is not under the influence of currents experienced in the lower sections of the Gulf (Teikoku Oil (Bonaparte Gulf) Co Ltd 1994). On page 50 of Appendix J Volume Two Technical Appendices Blacktip Environmental Impact Statement it is stated that " there are no specific current measurements in the region of the Blacktip development….". Considering the importance of the nearshore environment to traditional subsistence, will verification of modelled current movements be undertaken prior to discharge of hydrotest waters from the condensate or produced formation water discharge pipelines? |
| **NTG 26b** The wind data used as input to the model parameters utilises records for the years 2000 to 2003. For the purposes of running a robust model is the wind data sufficient to represent the typical of the wind regime for the nearshore area? |

***NTG 26a: Will verification of modelled current movements be undertaken prior to discharge of hydrotest waters?***

Since undertaking the modelling and publishing the Draft EIS, measured current data have become available along the pipeline route. **Figure 2** to **Figure 13** presents the model verification plots. It can be seen that both modelled current directions and speeds compare favourably with measured data. The model is therefore deemed fit for the purpose of simulating the fate of discharges to the marine environment.

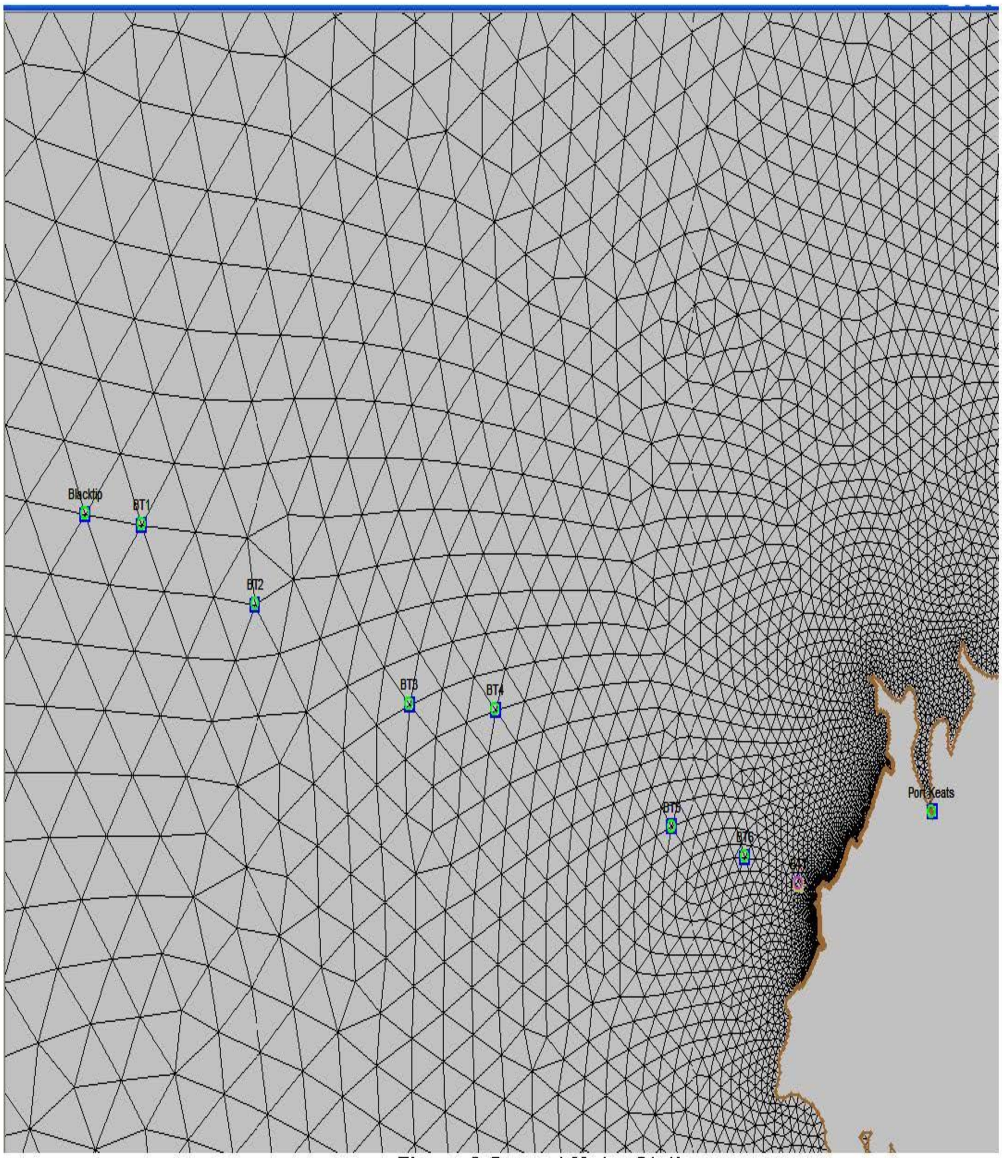
***NTG 26b: Is the wind data used as input to the model parameters sufficient to represent the typical wind regime for the nearshore area?***

Wind information for the study was sourced from the Bureau of Meteorology station at Port Keats. This is the best available information for the region of interest. Analysis showed that the record was consistent with average temporal weather patterns in the area and was therefore deemed fit for the purpose of the modelling.

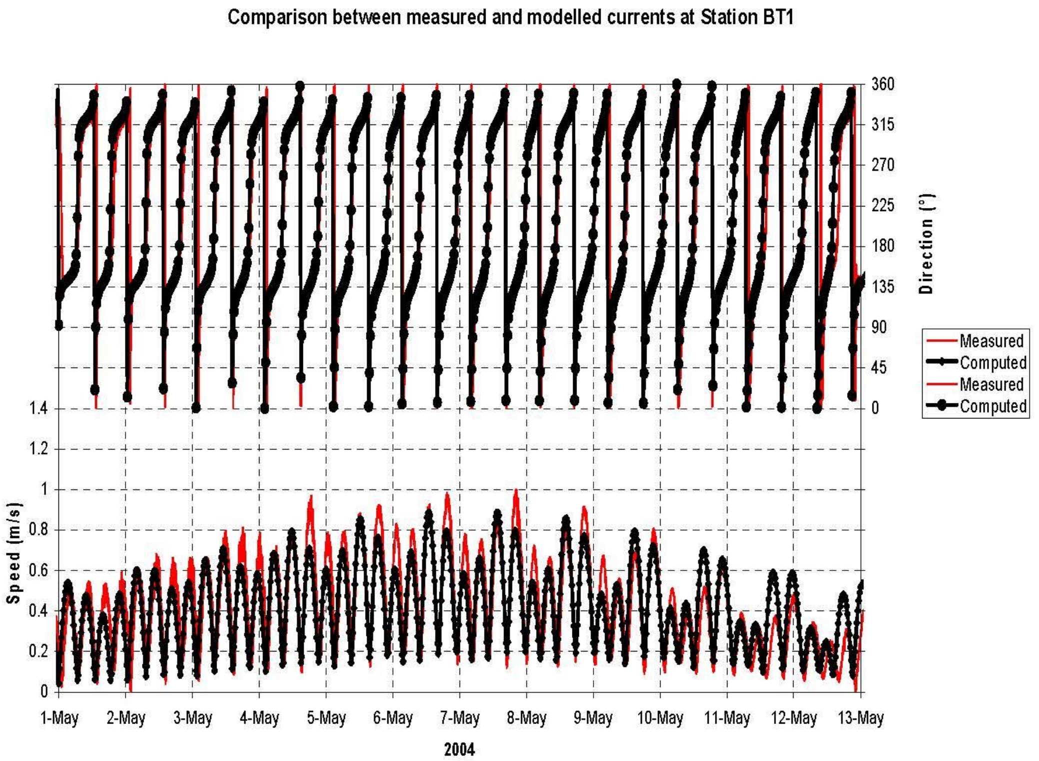
Inter-annual, variability of winds in the region can be linked to La Niña and El Nino events. La Niña and El Nino events are correlated with the Southern Oscillation Index (SOI). A moderate to strongly negative SOI (persistently below -10) is usually characteristic of El Niño, which is often associated with below average rainfall over eastern Australia, and a weaker than normal monsoon in the north. A moderate to strongly positive SOI (persistently above +10) is usually characteristic of La Niña, which is often associated with above average rainfall over parts of tropical and eastern Australia, and an earlier than normal start to the northern monsoon season.

A general review of wind speeds suggests that they are likely to be slightly stronger than average during strong La Niña events and slightly weaker during El Nino events. Over the last five years there has been a weak La Niña in 1999 – 2000 and a weak El Nino in 2003 – 2003. Port Keats therefore covers an El Nino event but misses a La Niña event.

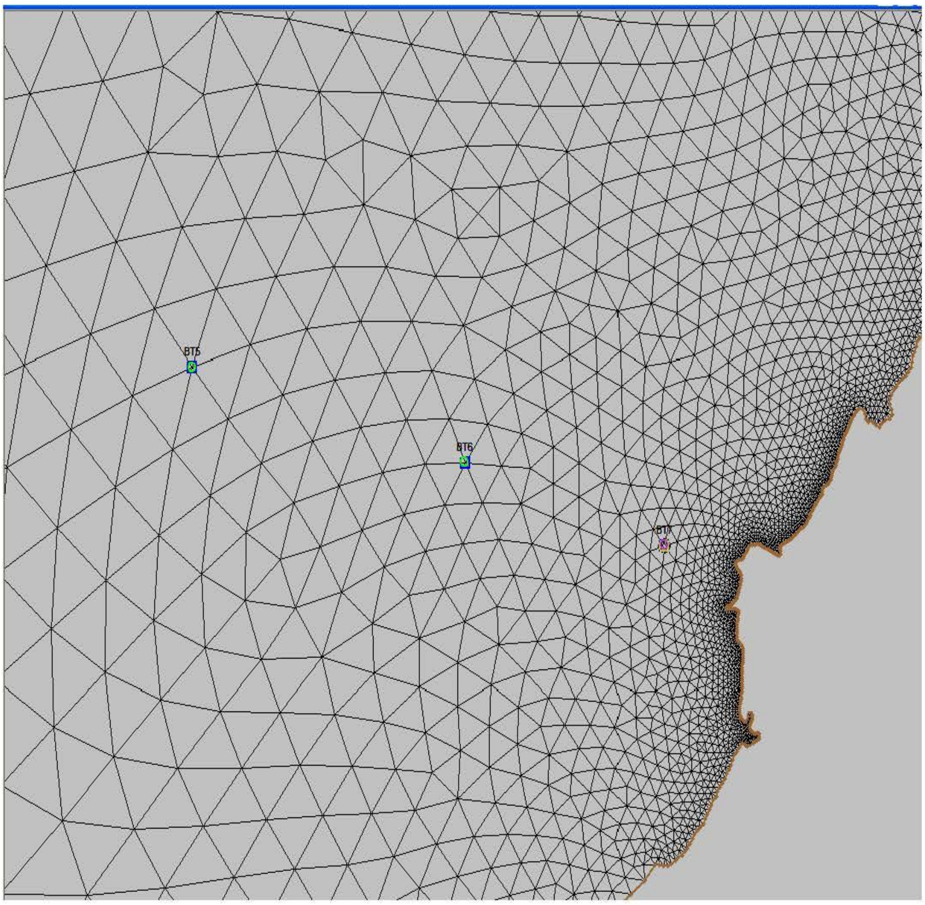
Inter-annual variability should not be an issue for the PW modelling, as onshore winds of low wind speeds were applied. These were deemed worst case for PW dispersion. It may be more of an issue for the stochastic oil spill modelling, however, due to the nature of the scenarios modelled it is not believed that a longer wind record would change the results or the conclusions from the modelling significantly.



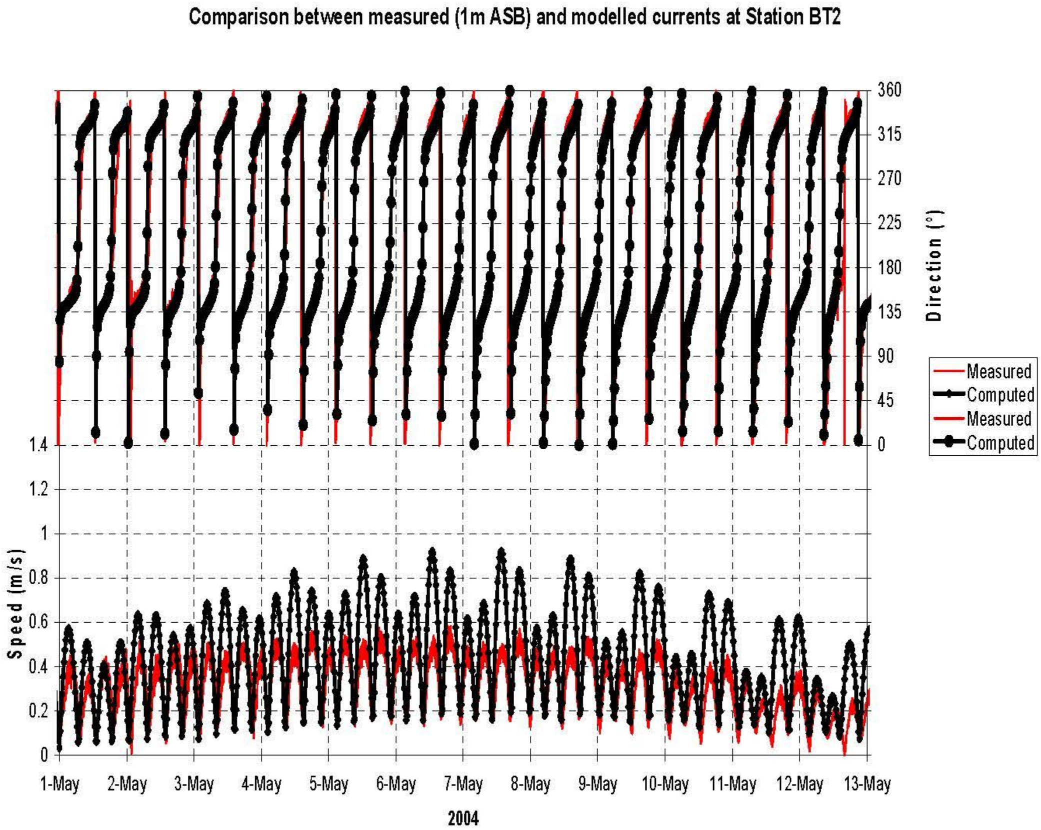

- **Figure 2 Current Meter Stations**



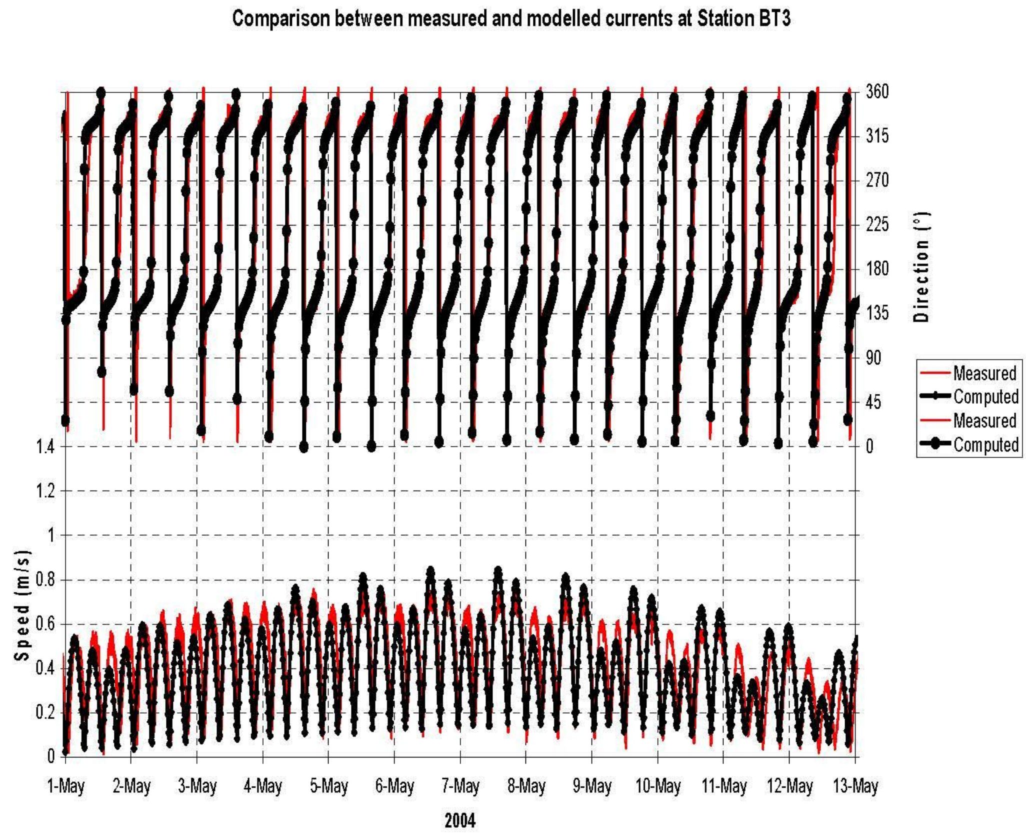

- **Figure 3 Location of Station BT7**



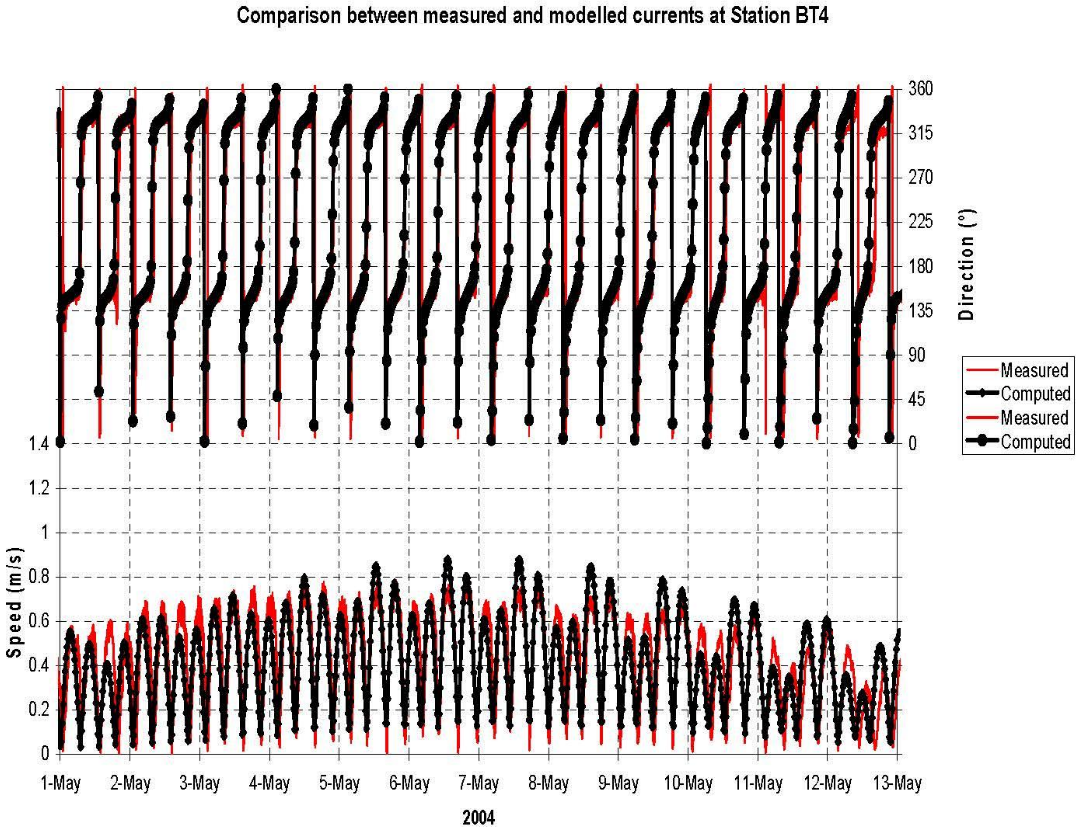

- **Figure 4 Comparison between Measured and Modelled Currents at Station BT1**



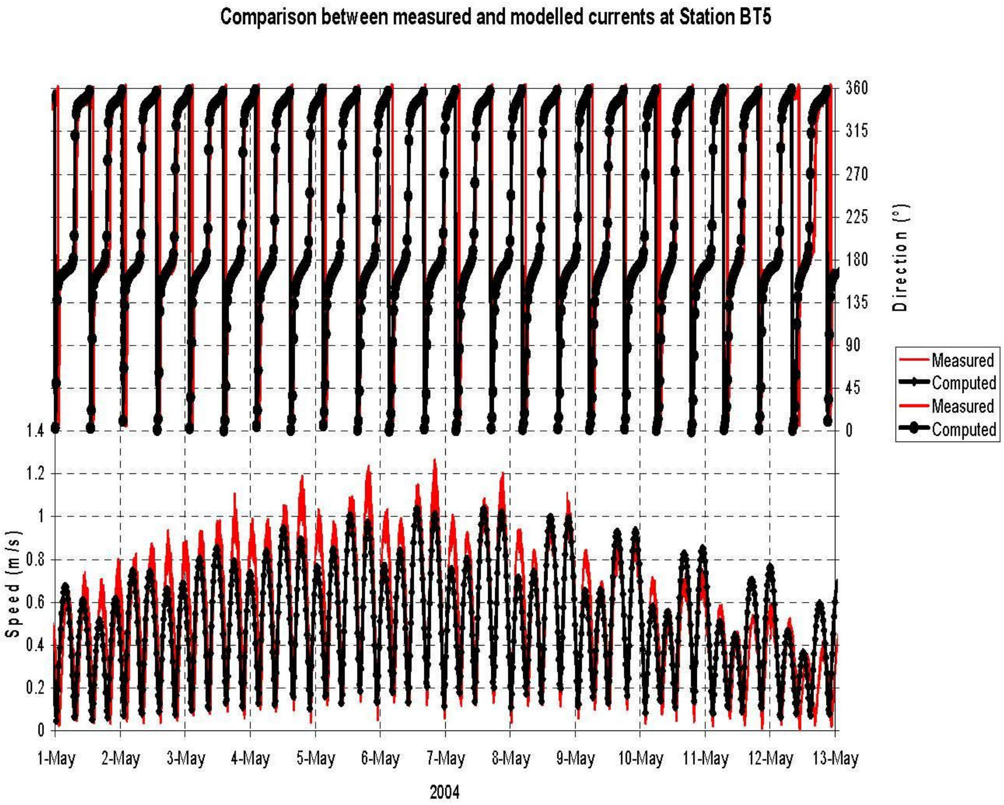

- **Figure 5 Comparison between Measured and Modelled Currents at Station BT2**



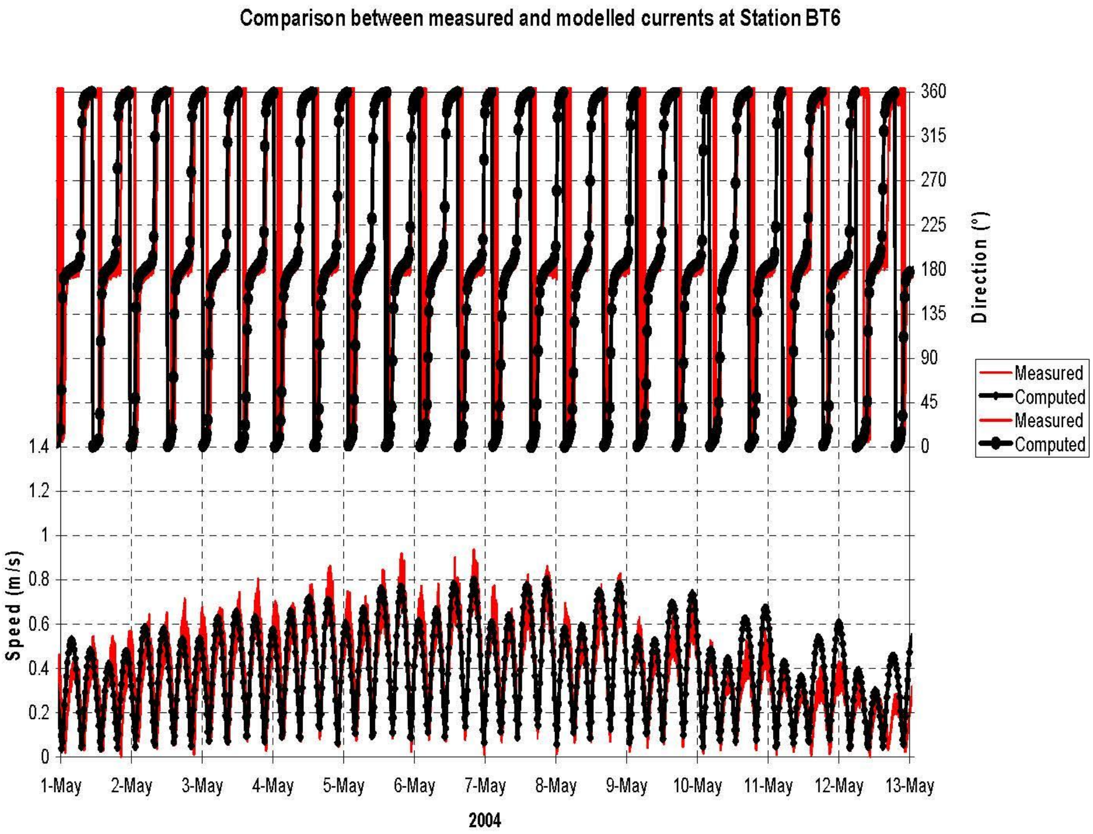

- **Figure 6 Comparison between Measured and Modelled Currents at Station BT3**



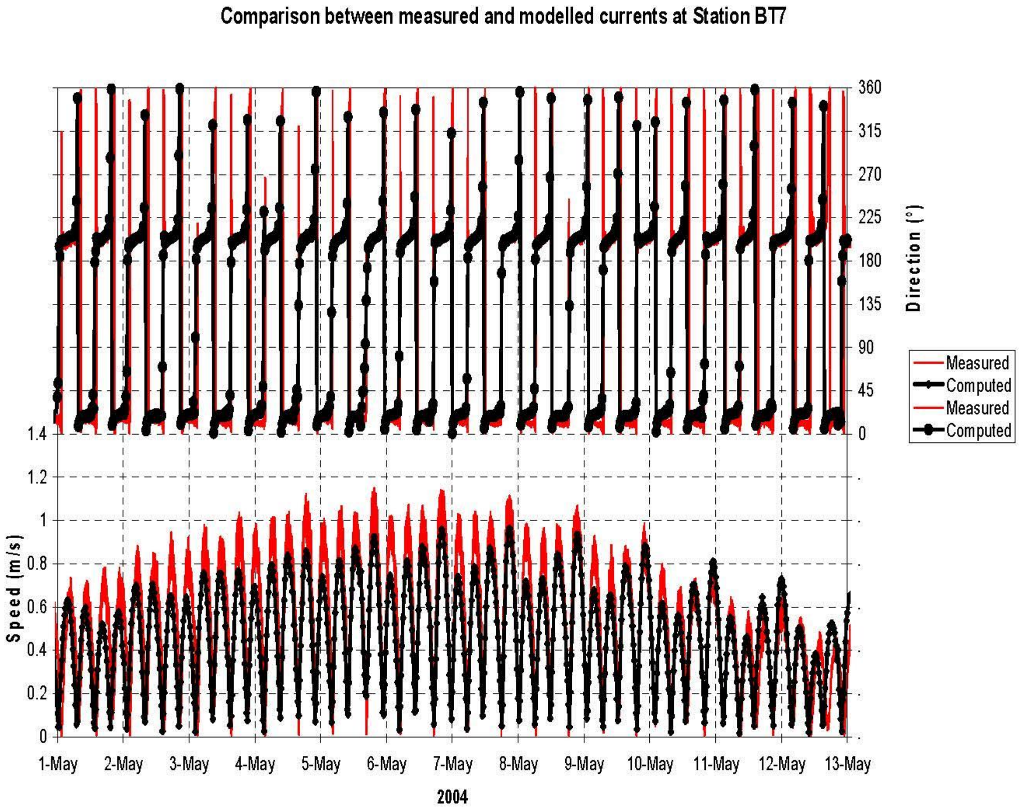

- **Figure 7 Comparison between Measured and Modelled Currents at Station BT4**




- **Figure 8 Comparison between Measured and Modelled Currents at Station BT5**



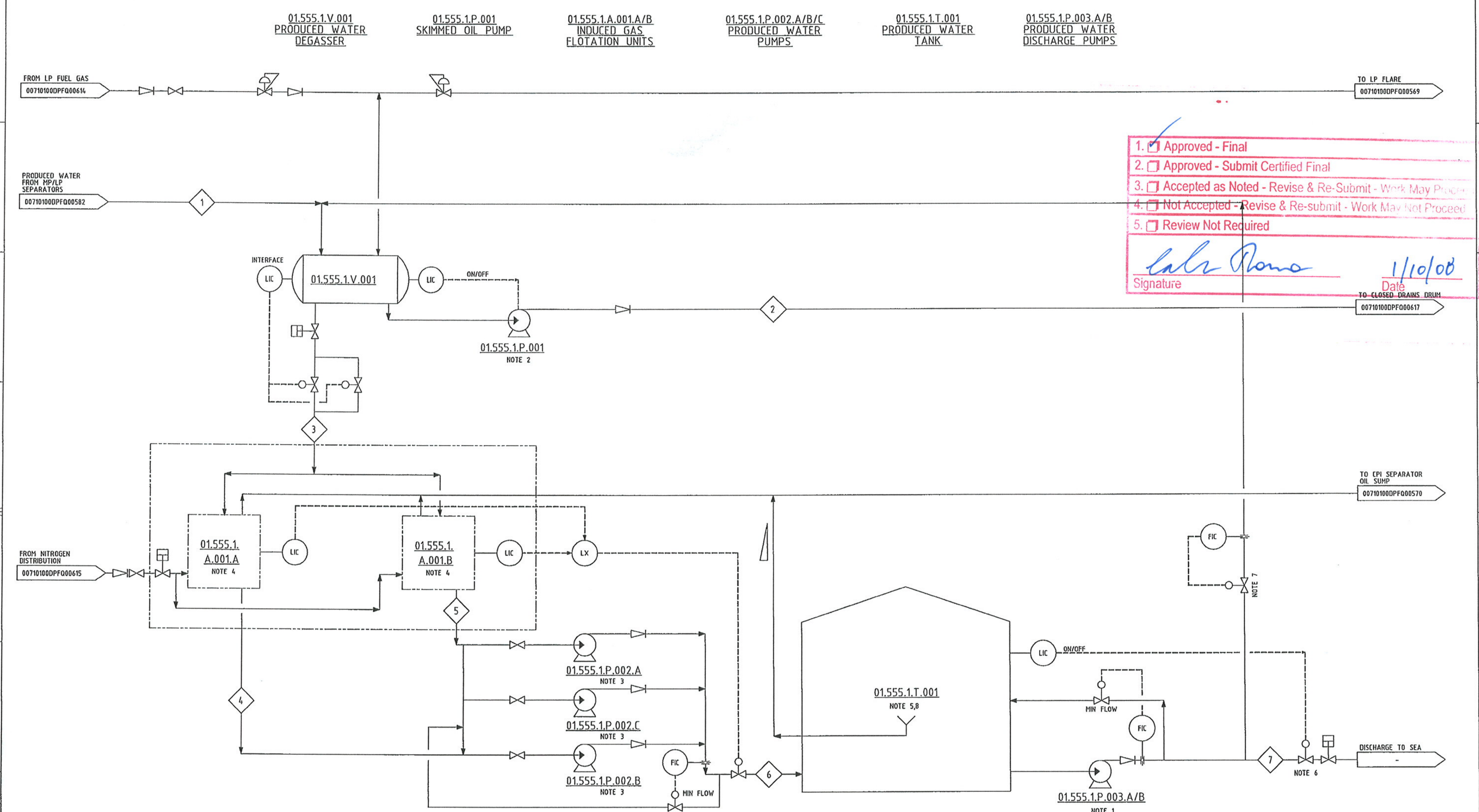

- **Figure 9 Comparison between Measured and Modelled Currents at Station BT6**




- **Figure 10 Comparison Between Measured And Modelled Current Stations at Station BT7**

# APPENDIX D:

# PROCESS UTILITY FLOW DIAGRAMS




| STREAM No | UNITS | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| MAXIMUM FLOW | kg/h | 62267 | 3958 | 62267 | 31134 | 31134 | 62267 | 62267 |
| NORMAL FLOW | kg/h | 13248 | 0 | 13248 | 6624 | 6624 | 13248 | 13248 |
| PRESSURE | kPag | 50 | 35 | 35 | 20 | 20 | 135 | 900 |
| TEMPERATURE | °C | AMB | AMB | AMB | AMB | AMB | AMB | AMB |
| MOL WT | kg/kmol | - | - | - | - | - | - | - |
| DENSITY | $kg/m^3$ | 999 | 765 | 999 | 999 | 999 | 999 | 999 |
| INTERMITTENT | | N | Y | N | N | N | N | Y |

NOTES

1. PUMP OPERATION IS 2 X 100%.
2. PUMP OPERATION 1 x 100%.
3. PUMP OPERATION 3 x 50%. 01.555.1.P.002.C IS A COMMON SPARE FOR 01.555.1.A.001.A/B.
4. 2 x 50% INDUCED GAS FLOTATION UNITS.
5. BREAK TANK FITTED WITH FLOATING SKIMMER.
6. LIC ON PRODUCED WATER TANK OPENS EXPORT VALVE.
7. FIC ALLOWS OFF SPEC WATER TO BE RECYCLED BACK FOR FURTHER TREATMENT.
8. TANK CONTAINS EXPORT VOLUME AND ALSO OFF SPEC HANDLING VOLUME WHICH ALLOWS CONTINUED PRODUCTION WHEN IGFU ARE OFF SPEC.

| REV | DATE | DESCRIPTION | DRAFTED | ENG. | CHECK | LEAD | APP'D |
|---|---|---|---|---|---|---|---|
| 1 | 19.09.08 | RE-ISSUED AFD | JT | SSI | DCH | BJL | BJL |
| 0 | 23.08.07 | APPROVED FOR DESIGN | ACA | DOB | TRE | TRE | MPE |
| A | 13.07.07 | ISSUED FOR REVIEW | ACA | DOB | TRE | TRE | MPE |

REVISIONS

1 ☑ Approved - Final
2 ☐ Approved - Submit Certified Final
3 ☐ Accepted as Noted - Revise & Re-Submit - Work May Proceed
4 ☐ Not Accepted - Revise & Re-Submit - Work May Not Proceed
5 ☐ Review Not Required

Signature ........ Date 1/10/08

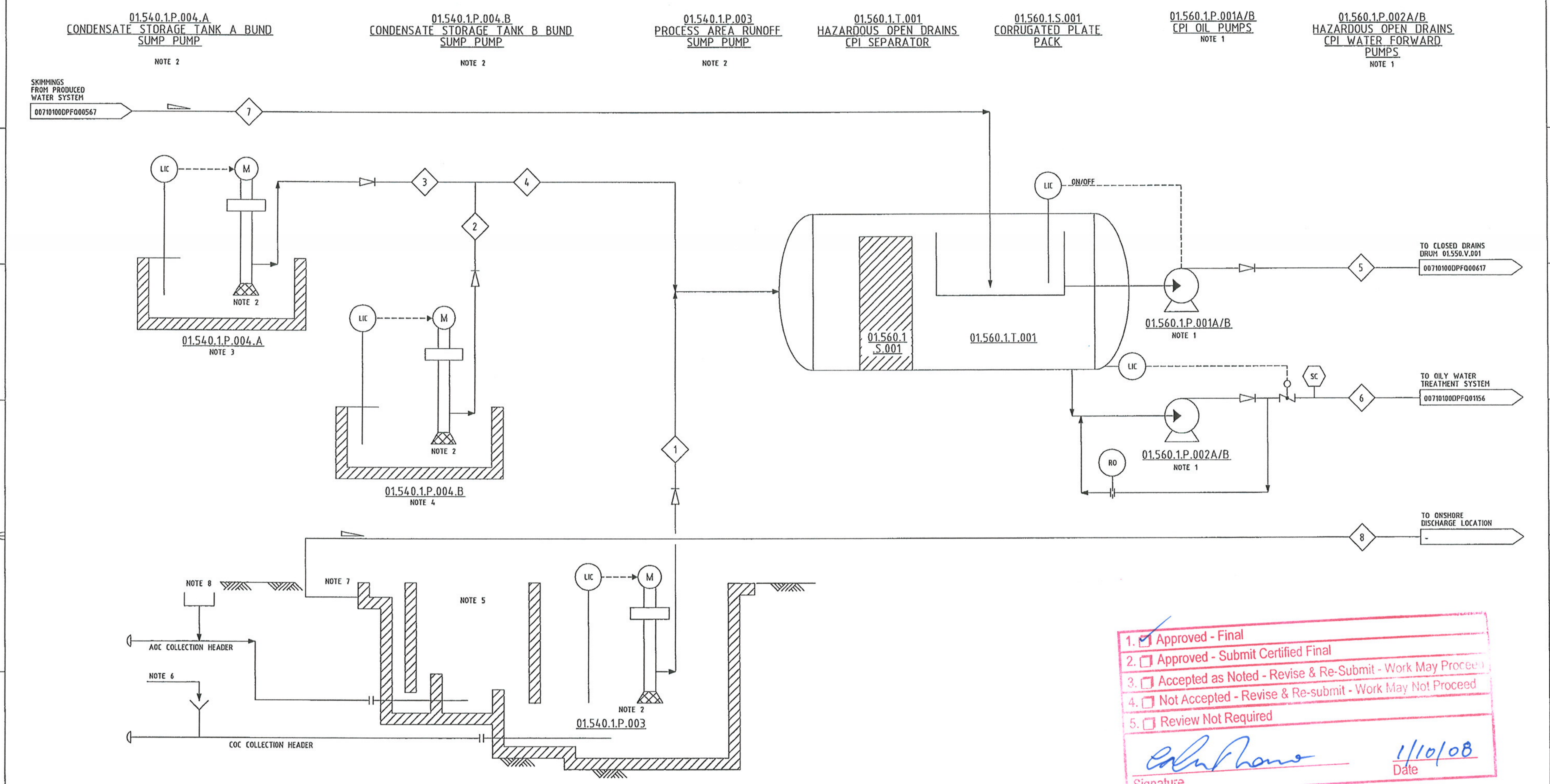
Acceptance of this document by Eni does not relieve the Contractor of its obligations under the contract.

GENESIS

Eni

BLACKTIP DEVELOPMENT
ONSHORE GAS PLANT
UFD PRODUCED WATER

| SCALE | | | |
|---|---|---|---|
| | ENI DRAWING No: | 00710100DPFQ00567 | REV. A02 |
| | GENESIS DRAWING No: | J9508-P-DW-12030 | REV. 1 |




1. ☑ Approved - Final
2. ☐ Approved - Submit Certified Final
3. ☐ Accepted as Noted - Revise & Re-Submit - Work May Proceed
4. ☐ Not Accepted - Revise & Re-submit - Work May Not Proceed
5. ☐ Review Not Required

Signature [signature] Date 1/10/08

| STREAM No | UNITS | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| MAXIMUM FLOW | kg/h | 40640/30420 NOTE 9 | 89550/68427 NOTE 9 | 89550/68427 NOTE 9 | 89550/68427 NOTE 9 | 11684/8746 NOTE 9 | 89,550 | 4,606 | 1,201,928 |
| NORMAL FLOW | kg/h | NNF | NNF | NNF | NNF | NNF | NNF | NNF | NNF |
| PRESSURE | kPag | 142 | 273 | 273 | 273 | 56 | 473 | ATM | ATM |
| TEMPERATURE | °C | AMB | AMB | AMB | AMB | AMB | AMB | AMB | AMB |
| MOL WT/ DENSITY | kg/kmol $kg/m^3$ | 995/1016 760.5 NOTE 9 | 995/760.3 NOTE 9 | 995/760.3 NOTE 9 | 995/760.3 NOTE 9 | 1016/760.5 NOTE 9 | 995 | 995 | 995-1016 |
| INTERMITTENT | | Y | Y | Y | Y | Y | Y | Y | Y |

NOTES

1. PUMP OPERATION 2 x 100%.
2. PUMP OPERATION 1 x 100%.
3. PUMP SUMP ASSOCIATED WITH CONDENSATE. STORAGE TANK A 01.220.1.T.001.A BUNDED AREA.
4. PUMP SUMP ASSOCIATED WITH CONDENSATE. STORAGE TANK B 01.220.1.T.001.B BUNDED AREA.
5. PROCESS AREA RUNOFF SUMP.
6. FROM TYPICAL PROCESS COC COLLECTION POINT.
7. GRAVITY OVERFLOW TO STORM WATER.
8. FROM TYPICAL PROCESS AOC COLLECTION POINT.
9. DEPENDANT ON FLUID IN SUMP (WATER/CONDENSATE).

1 ☐ Approved - Final
2 ☐ Approved - Submit Certified Final
3 ☐ Accepted as Noted - Revise & Re-Submit - Work May Proceed
4 ☐ Not Accepted - Revise & Re-Submit - Work May Not Proceed
5 ☐ Review Not Required

Signature ............................ Date ..................

Acceptance of this document by Eni does not relieve the Contractor of its obligations under the contract.

| REV | DATE | DESCRIPTION | DRAFTED | ENG. | CHECK | LEAD | APP'D |
|---|---|---|---|---|---|---|---|
| 2 | 19.09.08 | RE-ISSUED AFD | JT | SSI | DCH | BJL | BJL |
| 1 | 03.04.08 | RE-ISSUED AFD | ACA | DCH | RJE | RJE | MPE |
| 0 | 23.08.07 | APPROVED FOR DESIGN | ACA | DOB | TRE | TRE | MPE |
| A | 13.07.07 | ISSUED FOR REVIEW | ACA | DOB | SSM | TRE | MPE |

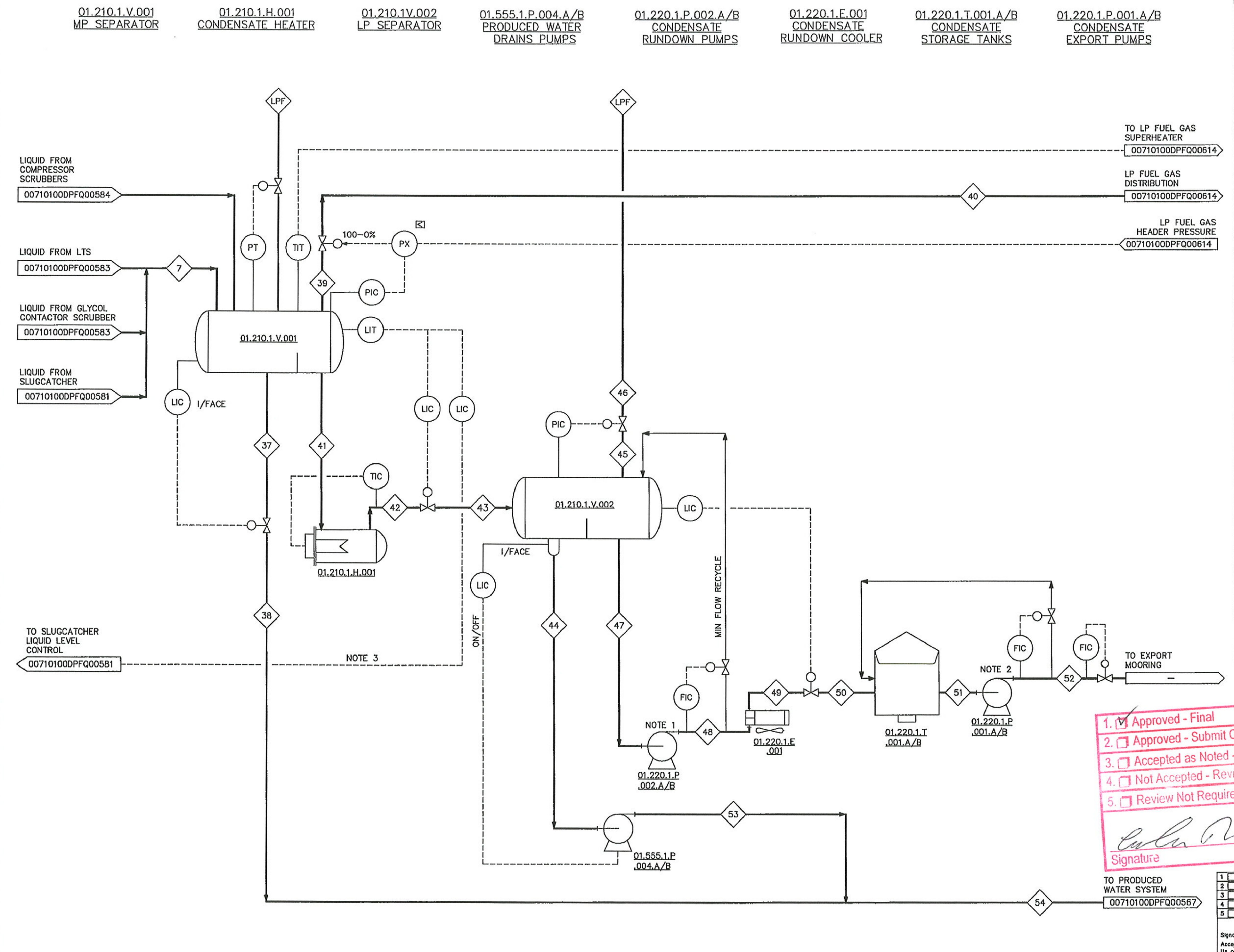
REVISIONS

GENESIS

Eni

BLACKTIP DEVELOPMENT
ONSHORE GAS PLANT
UFD HAZARDOUS OPEN DRAINS

SCALE | ENI DRAWING No: 00710100DPFQ00570 | REV. A03
GENESIS DRAWING No: J9508-P-DW-12033 | REV. 2




NOTES:

1. 2 x 50%-01.220.1.P002A/B.
2. 2 x 50%-01.220.1.P.001A/B.
3. ON INCREASING MP SEPARATOR LIQUID LEVEL, SLUGCATCHER LIQUID OUTLET IS CLOSED.

1. ☑ Approved - Final
2. ☐ Approved - Submit Certified Final
3. ☐ Accepted as Noted - Revise & Re-Submit - Work May Proceed
4. ☐ Not Accepted - Revise & Re-submit - Work May Not Proceed
5. ☐ Review Not Required

Signature [signature] Date 5/5/08

| | |
|---|---|
| 1 ☐ | Approved – Final |
| 2 ☐ | Approved – Submit Certified Final |
| 3 ☐ | Accepted as Noted – Revise & Re-Submit – Work May Proceed |
| 4 ☐ | Not Accepted – Revise & Re-Submit – Work May Not Proceed |
| 5 ☐ | Review Not Required |

Signature ............ Date ............

Acceptance of this document by Eni does not relieve the Contractor of its obligations under the contract.

| REV | DATE | DESCRIPTION | DRAFTED | ENG. | CHECK | LEAD | APP'D |
|---|---|---|---|---|---|---|---|
| 1 | 23.04.08 | RE-ISSUED AFD | ACA | RJE | JBE | JBE | MPE |
| 0 | 27.07.07 | APPROVED FOR DESIGN | ACA | RJE | JBE | JBE | MPE |
| B | 23.04.07 | ISSUED FOR REVIEW | ACA | RJE | JBE | JBE | MPE |
| P00 | 29.01.07 | ISSUED FOR REVIEW | HP | RJ | JPB | JPB | MJP |

REVISIONS

GENESIS Eni

BLACKTIP DEVELOPMENT ONSHORE GAS PLANT
PROCESS FLOW DIAGRAM
CONDENSATE PROCESSING AND EXPORT

SCALE | ENI DRAWING No: 00710100DPFQ00582 | REV. A02
GENESIS DRAWING No: J9508-P-DW-12011 | REV. 1

# APPENDIX E:

# CORMIX1 MODEL OUTPUT FILE

```
CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111
111111111111
                      CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:
Subsystem version:
 Submerged Single Port Discharges           CORMIX_v.3.20
_____September_1996
----------------------------------------------------------------
------------
----------------------------------------------------------------
------------
CASE DESCRIPTION
 Site name/label:         BT
 Design case:             BT02
 FILE NAME:               cormix\sim\BT02    .cx1
 Time of Fortran run:     08/21/07--11:06:26

ENVIRONMENT PARAMETERS (metric units)
 Unbounded section
 HA    =     12.00  HD    =     12.00
 UA    =      .050 F     =      .021 USTAR = .2588E-02
 UW    =     3.000 UWSTAR= .3377E-02
 Uniform density environment
 STRCND=  U         RHOAM = 1025.0000

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =   2500.00
 D0    =      .020 A0    =      .000 H0    =      1.00
 THETA =      .00  SIGMA =     90.00
 U0    =    12.739 Q0    =      .004       = .4000E-02
 RHO0  = 1015.0000  DRHO0 = .1000E+02  GP0   = .9567E-01
 C0    = .1000E+03  CUNITS=  %
 IPOLL =  1         KS    = .0000E+00  KD    = .0000E+00

FLUX VARIABLES (metric units)
 Q0    = .4000E-02  M0    = .5098E-01  J0    = .3829E-03  SIGNJ0=
1.0
 Associated length scales (meters)
 LQ    =       .02  LM    =      5.48  Lm    =      4.51  Lb    =
3.06
                                       Lmp   =  99999.00  Lbp   =
99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =    291.21  R     =    254.77

FLOW CLASSIFICATION
 111111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    H2     1
 1  Applicable layer depth HS =    12.00  1
 111111111111111111111111111111111111111111
```

```
MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = .1000E+03  CUNITS=  %
 NTOX  =  0
 NSTD  =  0
 REGMZ =  0
 XINT  =   1200.00  XMAX  =   1200.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the
port:
      2500.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis
points upward.
NSTEP = 50 display intervals per module
-----------------------------------------------------------------
------------
-----------------------------------------------------------------
------------
BEGIN MOD101: DISCHARGE MODULE

       X        Y       Z        S       C       B
       .00      .00    1.00     1.0  .100E+03    .01

END OF MOD101: DISCHARGE MODULE
-----------------------------------------------------------------
------------
-----------------------------------------------------------------
------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet-like motion in weak crossflow.

 Zone of flow establishment:            THETAE=       .00
SIGMAE=     89.57
  LE    =       .10  XE    =       .00  YE    =       .10  ZE
=      1.00

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if
any)

       X        Y       Z        S       C       B
       .00      .00    1.00     1.0  .100E+03    .01
       .00      .10    1.00     1.0  .100E+03    .01
       .01      .63    1.00     5.9  .170E+02    .07
       .05     1.16    1.00    10.9  .921E+01    .13
       .10     1.69    1.01    15.9  .628E+01    .19
       .18     2.23    1.02    21.4  .468E+01    .25
       .28     2.75    1.04    26.9  .371E+01    .32
```

| | | | | | |
|---|---|---|---|---|---|
| .40 | 3.27 | 1.07 | 32.8 | .305E+01 | .38 |
| .55 | 3.78 | 1.10 | 39.2 | .255E+01 | .45 |
| .74 | 4.29 | 1.15 | 46.3 | .216E+01 | .53 |
| .95 | 4.78 | 1.21 | 53.9 | .185E+01 | .60 |
| 1.19 | 5.24 | 1.29 | 62.2 | .161E+01 | .68 |
| 1.46 | 5.70 | 1.37 | 71.4 | .140E+01 | .76 |
| 1.77 | 6.14 | 1.47 | 81.8 | .122E+01 | .85 |
| 2.09 | 6.55 | 1.59 | 92.6 | .108E+01 | .94 |
| 2.44 | 6.93 | 1.71 | 104.3 | .959E+00 | 1.03 |
| 2.82 | 7.30 | 1.85 | 117.0 | .855E+00 | 1.11 |
| 3.21 | 7.64 | 1.99 | 129.7 | .771E+00 | 1.20 |
| 3.61 | 7.95 | 2.14 | 142.7 | .701E+00 | 1.28 |
| 4.02 | 8.24 | 2.30 | 156.1 | .640E+00 | 1.36 |
| 4.46 | 8.53 | 2.47 | 170.3 | .587E+00 | 1.43 |
| 4.89 | 8.78 | 2.65 | 184.2 | .543E+00 | 1.51 |
| 5.33 | 9.02 | 2.82 | 198.3 | .504E+00 | 1.58 |
| 5.78 | 9.24 | 3.01 | 212.7 | .470E+00 | 1.65 |
| 6.25 | 9.46 | 3.20 | 227.7 | .439E+00 | 1.72 |
| 6.70 | 9.65 | 3.39 | 242.4 | .413E+00 | 1.78 |
| 7.16 | 9.84 | 3.58 | 257.3 | .389E+00 | 1.84 |
| 7.64 | 10.01 | 3.79 | 272.9 | .366E+00 | 1.91 |
| 8.11 | 10.17 | 3.99 | 288.2 | .347E+00 | 1.97 |
| 8.58 | 10.33 | 4.19 | 303.8 | .329E+00 | 2.03 |
| 9.05 | 10.47 | 4.39 | 319.5 | .313E+00 | 2.09 |
| 9.53 | 10.61 | 4.60 | 336.0 | .298E+00 | 2.15 |
| 10.01 | 10.74 | 4.80 | 352.2 | .284E+00 | 2.21 |
| 10.48 | 10.86 | 5.01 | 368.6 | .271E+00 | 2.26 |
| 10.96 | 10.98 | 5.21 | 385.3 | .260E+00 | 2.32 |
| 11.45 | 11.09 | 5.43 | 402.7 | .248E+00 | 2.38 |
| 11.93 | 11.20 | 5.64 | 419.8 | .238E+00 | 2.43 |
| 12.41 | 11.30 | 5.84 | 437.2 | .229E+00 | 2.49 |
| 12.89 | 11.39 | 6.05 | 454.8 | .220E+00 | 2.54 |
| 13.38 | 11.48 | 6.27 | 473.2 | .211E+00 | 2.60 |
| 13.87 | 11.57 | 6.47 | 491.3 | .204E+00 | 2.65 |
| 14.35 | 11.65 | 6.68 | 509.6 | .196E+00 | 2.71 |
| 14.85 | 11.73 | 6.90 | 528.8 | .189E+00 | 2.76 |
| 15.33 | 11.81 | 7.10 | 547.6 | .183E+00 | 2.82 |
| 15.82 | 11.88 | 7.31 | 566.6 | .177E+00 | 2.87 |
| 16.30 | 11.95 | 7.52 | 585.8 | .171E+00 | 2.92 |
| 16.80 | 12.02 | 7.73 | 605.9 | .165E+00 | 2.97 |
| 17.29 | 12.08 | 7.94 | 625.6 | .160E+00 | 3.03 |
| 17.77 | 12.15 | 8.14 | 645.6 | .155E+00 | 3.08 |
| 18.26 | 12.20 | 8.35 | 665.7 | .150E+00 | 3.13 |
| 18.76 | 12.26 | 8.56 | 686.8 | .146E+00 | 3.18 |
| 19.25 | 12.32 | 8.76 | 707.0 | .141E+00 | 3.23 |

Cumulative travel time = 224. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

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```
BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X        Y        Z        S        C       B
     19.25    12.32    8.76   707.0  .141E+00   3.23

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects,
if any)

       X        Y        Z        S        C       BV        BH
ZU      ZL
     16.02    12.67   12.00   707.0  .141E+00    .00       .00
12.00   12.00
     16.99    12.67   12.00   707.0  .141E+00   4.36      2.19
12.00    7.64
     17.96    12.67   12.00   707.0  .141E+00   5.17      3.10
12.00    6.83
     18.93    12.67   12.00   707.0  .141E+00   5.69      3.80
12.00    6.31
     19.90    12.67   12.00   726.4  .138E+00   6.07      4.39
12.00    5.93
     20.87    12.67   12.00   816.5  .122E+00   6.36      4.90
12.00    5.64
     21.84    12.67   12.00   941.0  .106E+00   6.58      5.37
12.00    5.42
     22.81    12.67   12.00  1054.4  .948E-01   6.74      5.80
12.00    5.26
     23.78    12.67   12.00  1132.2  .883E-01   6.85      6.20
12.00    5.15
     24.75    12.67   12.00  1174.5  .851E-01   6.91      6.58
12.00    5.09
     25.72    12.67   12.00  1202.0  .832E-01   6.93      6.93
12.00    5.07
 Cumulative travel time =         353. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH
-----------------------------------------------------------------
------------
** End of NEAR-FIELD REGION (NFR) **
-----------------------------------------------------------------
------------
BEGIN MOD141: BUOYANT AMBIENT SPREADING

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
```

ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

| X | Y | Z | S | C | BV | BH | ZU | ZL |
|---|---|---|---|---|---|---|---|---|
| 25.72 | 12.67 | 12.00 | 1202.0 | .832E-01 | 6.93 | 6.93 | 12.00 | 5.07 |
| 49.20 | 12.67 | 12.00 | 1421.9 | .703E-01 | 4.24 | 13.40 | 12.00 | 7.76 |
| 72.69 | 12.67 | 12.00 | 1552.8 | .644E-01 | 3.35 | 18.54 | 12.00 | 8.65 |
| 96.18 | 12.67 | 12.00 | 1657.3 | .603E-01 | 2.88 | 23.04 | 12.00 | 9.12 |
| 119.66 | 12.67 | 12.00 | 1752.0 | .571E-01 | 2.58 | 27.13 | 12.00 | 9.42 |
| 143.15 | 12.67 | 12.00 | 1844.4 | .542E-01 | 2.39 | 30.93 | 12.00 | 9.61 |
| 166.63 | 12.67 | 12.00 | 1938.6 | .516E-01 | 2.25 | 34.51 | 12.00 | 9.75 |
| 190.12 | 12.67 | 12.00 | 2037.2 | .491E-01 | 2.15 | 37.90 | 12.00 | 9.85 |
| 213.60 | 12.67 | 12.00 | 2142.1 | .467E-01 | 2.08 | 41.15 | 12.00 | 9.92 |
| 237.09 | 12.67 | 12.00 | 2254.5 | .444E-01 | 2.04 | 44.27 | 12.00 | 9.96 |
| 260.58 | 12.67 | 12.00 | 2375.6 | .421E-01 | 2.01 | 47.29 | 12.00 | 9.99 |
| 284.06 | 12.67 | 12.00 | 2506.2 | .399E-01 | 2.00 | 50.21 | 12.00 | 10.00 |
| 307.55 | 12.67 | 12.00 | 2647.1 | .378E-01 | 2.00 | 53.04 | 12.00 | 10.00 |
| 331.03 | 12.67 | 12.00 | 2798.8 | .357E-01 | 2.01 | 55.80 | 12.00 | 9.99 |
| 354.52 | 12.67 | 12.00 | 2961.9 | .338E-01 | 2.03 | 58.49 | 12.00 | 9.97 |
| 378.00 | 12.67 | 12.00 | 3136.9 | .319E-01 | 2.05 | 61.13 | 12.00 | 9.95 |
| 401.49 | 12.67 | 12.00 | 3324.3 | .301E-01 | 2.09 | 63.70 | 12.00 | 9.91 |
| 424.97 | 12.67 | 12.00 | 3524.5 | .284E-01 | 2.13 | 66.22 | 12.00 | 9.87 |
| 448.46 | 12.67 | 12.00 | 3737.7 | .268E-01 | 2.18 | 68.70 | 12.00 | 9.82 |
| 471.95 | 12.67 | 12.00 | 3964.5 | .252E-01 | 2.23 | 71.13 | 12.00 | 9.77 |
| 495.43 | 12.67 | 12.00 | 4205.0 | .238E-01 | 2.29 | 73.52 | 12.00 | 9.71 |
| 518.92 | 12.67 | 12.00 | 4459.7 | .224E-01 | 2.35 | 75.87 | | |

```
12.00    9.65
    542.40    12.67    12.00   4728.8  .211E-01    2.42     78.19
12.00    9.58
    565.89    12.67    12.00   5012.6  .199E-01    2.49     80.47
12.00    9.51
    589.37    12.67    12.00   5311.3  .188E-01    2.57     82.72
12.00    9.43
    612.86    12.67    12.00   5625.3  .178E-01    2.65     84.94
12.00    9.35
    636.34    12.67    12.00   5954.7  .168E-01    2.73     87.14
12.00    9.27
    659.83    12.67    12.00   6299.9  .159E-01    2.82     89.30
12.00    9.18
    683.32    12.67    12.00   6660.9  .150E-01    2.91     91.44
12.00    9.09
    706.80    12.67    12.00   7038.1  .142E-01    3.01     93.55
12.00    8.99
    730.29    12.67    12.00   7431.7  .135E-01    3.11     95.65
12.00    8.89
    753.77    12.67    12.00   7841.9  .128E-01    3.21     97.71
12.00    8.79
    777.26    12.67    12.00   8268.9  .121E-01    3.32     99.76
12.00    8.68
    800.74    12.67    12.00   8712.8  .115E-01    3.42    101.79
12.00    8.58
    824.23    12.67    12.00   9173.9  .109E-01    3.54    103.80
12.00    8.46
    847.72    12.67    12.00   9652.4  .104E-01    3.65    105.78
12.00    8.35
    871.20    12.67    12.00  10148.4  .985E-02    3.77    107.75
12.00    8.23
    894.69    12.67    12.00  10662.2  .938E-02    3.89    109.70
12.00    8.11
    918.17    12.67    12.00  11193.8  .893E-02    4.01    111.64
12.00    7.99
    941.66    12.67    12.00  11743.5  .852E-02    4.14    113.56
12.00    7.86
    965.14    12.67    12.00  12311.5  .812E-02    4.27    115.46
12.00    7.73
    988.63    12.67    12.00  12897.9  .775E-02    4.40    117.35
12.00    7.60
   1012.11    12.67    12.00  13502.9  .741E-02    4.53    119.22
12.00    7.47
   1035.60    12.67    12.00  14126.5  .708E-02    4.67    121.08
12.00    7.33
   1059.09    12.67    12.00  14769.1  .677E-02    4.81    122.92
12.00    7.19
   1082.57    12.67    12.00  15430.7  .648E-02    4.95    124.76
12.00    7.05
   1106.06    12.67    12.00  16111.6  .621E-02    5.09    126.57
12.00    6.91
   1129.54    12.67    12.00  16811.7  .595E-02    5.24    128.38
```

```
12.00    6.76
   1153.03    12.67   12.00 17531.4  .570E-02   5.39   130.17
12.00    6.61
   1176.51    12.67   12.00 18270.7  .547E-02   5.54   131.95
12.00    6.46
   1200.00    12.67   12.00 19029.7  .525E-02   5.69   133.72
12.00    6.31
 Cumulative travel time =       23839. sec

 Simulation limit based on maximum specified distance =   1200.00
m.
   This is the REGION OF INTEREST limitation.

END OF MOD141: BUOYANT AMBIENT SPREADING
-----------------------------------------------------------------
------------
-----------------------------------------------------------------
------------
CORMIX1: Submerged Single Port Discharges              End of
Prediction File
11111111111111111111111111111111111111111111111111111111111111111
111111111111
```

# APPENDIX F:

# TDRQ #00193 - PRODUCED WATER TREATMENT

# TECHNICAL DEVIATION REQUEST OR QUERY

## SECTION A: INITIATION (To be completed by the REQUEST originator and entered in the TDRQ Register)

| | | | | |
|---|---|---|---|---|
| **Title of request or query:** | **Produced Water Circulation Rate** | | | **TDRQ #: 00193**<br>Assigned by Facility Engineering |
| **Location:** | **Blacktip** | **Date: 27/04/2017** | **Originator:** | **A. Mastey** |

| Priority Classification | Type of Query | Timing | Nature of request |
|---|---|---|---|
| ☒ HSE | ☒ Improvement | ☐Emergency (immediate action) | ☒ Case to Operate |
| ☐ Production | ☐ Deviation | ☒ Urgent (response within 5 days) | ☒ Equipment |
| ☐ Maintenance | ☐ Issue | ☒ Routine (next available resource) | ☐ Process/Activity |
| ☒ Engineering | | | ☐ Procedure |
| ☐ Materials and Logistics | | | ☐ Drawings |
| | | | ☐ Other |

**Description of Request**
(attach as much info as you can to help us understand the request or query. The more info the better the answer – and quicker!.

e.g marked up P&ID's, datasheets, photos, extra sheets of description, emails etc..

Produced Formation water is currently treated by the produced water treatment package and the permanently installed CETCO filter skid alongside the produced water package.
Although these skids successfully bring produced water into specification for discharge, this often requires multiple cycles through the skids, leading to potential process interruptions.
Can we modify the plant or install additional plant to reduce the cycle rate required to bring produced water on specification?

**Known Implications**: (why this request needs to be resolved – what impact is it having?)

Reduce cycle rate of water treatment, reduce consumables (filters), reduce produced water inventory mitigating process interruptions.

## SECTION B: EVALUATION – to be completed by Facilities Engineering

| Identification of Stakeholders | **Stakeholder List** | **Impact** | **Notification of Change Required** |
|---|---|---|---|
| | Eng. Supt. | Engineering | Y |
| | POS | Operations | Y |
| | HSE Manager | Process Safety | Y |
| | | | |
| | | | |

| | | | |
|---|---|---|---|
| Identification of Affected Systems: | ☐Safety Case | ☐ Environment Plan | ☐ Management System |
| Identification of applicable Codes and Standards | | N/A | |
| Contingency planning in place? | | N/A | |
| Additional technical support or expertise sourced? | | None | |
| Documentation required to properly answer query (list): | | ☐ Attached | ☒ Not Required |

Drawing / Documents Delivery / Acceptance Details:

Further to the existing infrastructure, the Blacktip plant will be trialling Hi-Flow Filters with upstream Spiral Wound Filters and Hydro cyclone technology to further improve the performance of the produced water treatment package.

The Hi-Flow package will utilise coalescence to merge smaller oil droplets to form larger oil droplets which are more readily separated from the water phase. The media is packaged in radial flow, nonferrous elements comprising of a retaining mesh, specific density media and ABS plastic sealing caps at either end of the elements. As the oily water passes through the Hi-Flow media, the oil droplets are captured and held by the fibres on the media. As further oil droplets pass through the media structure, the droplets collide, merge and migrate through the fibre/polymer blend. The structure of the media is such that it forms flow paths which, over the path length of the material, massively increases the contact potential of even very small oil droplets. At the surface of the Hi-Flow element mesh, the coalesced oil is generated as a film of oil. Droplets liberating from this surface have such a diameter and volume that they quickly rise to the uppermost oil recover bleed point.

The Hi-Flow media will be protected from any solids which may be present in the fluid high efficiency spiral wound solids filters will be utilised upstream of the Hi-Flow unit.

In addition, a test Hydro cyclone package will be placed online to further remove oil and grease content. A hydrocyclone is a mechanical device designed to separate hydrocarbon and water due to different densities, by means of centripetal force within a vortexVarious configurations will be tested and a final result will lead to permanent installation of any or all of the above technology.


Figure 1 – Hydrocyclone Unit

Figure 2 – Spiral Wound Filter

## SECTION C: RISK ASSESSMENT – to be completed by Facilities Engineering with HSE input

*Assess risk associated with the current state – this assigns priority to the TDRQ. A formal risk assessment may be required – consult the Hazard Identification and Risk Assessment Procedure. See Eni Australia Risk Matrix.*

| | |
|---|---|
| Consequence 2 (Minor Impact) | Probability A (Rare) |
| Risk Ranking | Low (100) |
| Conditions & mitigation measures (what must be done) | A Minor Impact based on safety has been selected for this query. Minor health effect / injury based on the possibility of affecting work performance, such as restriction to activities or a need to take a few days to fully recover (up to 10 days off). Offsite medical treatment or LTI (Lost Time In jury).<br>This is based on the additional maintenance and operations requirements that the additional equipment will have.<br><br>This query and subsequent testing and plant modification will have no impact on the Environment as off-specification is never released nor will the possibility of an accidental release change as part of this query. |

## Risk Matrix

| Consequence | | | | | | | | | | Likelihood or Annual Frequency | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 0 | A | B | C | D | E | |
| Severity | Stakeholder Relations | Company Image | Labour | Community | Health | Safety | Environment | Assets / Operations | Financial | 0-Non credible / Possible E&P industry. | A-Rare / Occured E&P industry. | B-Unlikely / Once in Company. | C-Possible / >1 in Company. | D-Likely / >1/year in Company. | E-Almost certain / >1/year @ 1 location. | Severity Factor |
| 1 | 1-Slight impact. | 1-Slight impact. | 1-Slight impact. | 1-Slight impact. | 1-Slight impact. | 1-Slight impact. | 1-Slight impact. | 1-Slight impact. | 1-Slight impact. | Low 10 | Low 50 | Low 100 | Medium 150 | Medium 200 | High 250 | 10 |
| 2 | 2-Minor impact. | 2-Minor impact. | 2-Minor impact. | 2-Minor impact. | 2-Minor impact. | 2-Minor impact. | 2-Minor impact. | 2-Minor impact. | 2-Minor impact. | Low 20 | Low 100 | Medium 200 | Medium 300 | High 400 | Critical 500 | 20 |
| 3 | 3-Significant impact. | 3-Local impact. | 3-Significant impact. | 3-Significant impact. | 3-Significant impact. | 3-Significant impact. | 3-Significant impact. | 3-Significant impact. | 3-Significant impact. | Low 40 | Medium 200 | High 400 | High 600 | Critical 800 | Critical 1000 | 40 |
| 4 | 4-Major impact. | 4-National impact. | 4-Major impact. | 4-Major impact. | 4-Major impact. | 4-Major impact. | 4-Major impact. | 4-Major impact. | 4-Major impact. | Medium 70 | High 350 | High 700 | Critical 1050 | Critical 1400 | Critical 1750 | 70 |
| 5 | 5-Extensive impact. | 5-International impact. | 5-Extensive impact. | 5-Extensive impact. | 5-Extensive impact. | 5-Extensive impact. | 5-Extensive impact. | 5-Extensive impact. | 5-Extensive impact. | Medium 100 | High 500 | Critical 1000 | Critical 1500 | Critical 2000 | Critical 2500 | 100 |
| NB: Refer to the "Eni Consequence / Severity Table" for consequence descriptions. | | | | | | | | | | 1 | 5 | 10 | 15 | 20 | 25 | |
| | | | | | | | | | | Frequency Factor | | | | | | |

## Control Hierarchy Table

| Control Category | Description |
|---|---|
| **Elimination** | Can the risk be eliminated all together i.e. does the job need to be done? This removes the causes of the hazardous event such that it is not longer credible that it will occur. |

| | |
|---|---|
| **Substitution (Alternatives)** | Can something else be used to reduce the risk (e.g. the use of less hazardous substances). |
| **Engineering (plant and Equipment)** | Can equipment (physical controls) be used to reduce the risk (e.g. exhaust ventilation, mechanical aids etc.). |
| **Procedural** | Human controls (e.g. supervision, work methods, housekeeping, personal hygiene, information, instruction and training). |
| **Personal Protective Equipment (PPE)** | In all cases the use of PPE should be considered as the only barrier, only when control measures within the above categories are not practicable. |

## SECTION D: APPROVAL

*If formal risk assessment was carried out, the HSE Rep. signature indicates they have been consulted about the change.*

**Technical Approval**: Brett Gillespie (Print name) (Signature) Digitally signed by brett.gillespie@eni.com DN: cn=brett.gillespie@eni.com Date: 2017.05.09 10:52:12 +08'00' (Date)
(Eng. Design Coordinator)

**Operations Approval**: Mick Perkusich (Print name) (Signature) Digitally signed by michael.perkusich@eni.com DN: cn=michael.perkusich@eni.com Date: 2017.04.28 16:45:08 +09'30' (Date)
(OIM/PIC or Operations Manager)

**HSE Rep. Consulted:** David Warby (Print name) (Signature) david.warby@eniaustralia.com.au 2017.05.09 10:59:01 +08'00' (Date)

Change communicated to:

☒ Facility Staff ☐ Heli Operator ☐ Supply Board Ops.
☐ Eni ☐ Regulators ☐ Third Parties

Training packages complete?

## SECTION E: TDRQ COMPLETION & CLOSE-OUT – to be completed by Facilities Engineering and agreed by the TDRQ originator

Request or Query answered as described: Yes ☒ No ☐
Deviations: No deviation to plant or operating procedure

MoC initiated?: Yes ☐ No ☐ Not Required ☒

Comments: No Further Action Required

**Originator Close-out:** Mick Perkusich (Print name) (Signature) Digitally signed by michael.perkusich@eni.com DN: cn=michael.perkusich@eni.com Date: 2017.04.28 16:45:55 +09'30' (Date)
(OIM/PIC or Operations Manager)

**Facilities Engineering Close-out:** Brett Gillespie (Print name) (Signature) Digitally signed by brett.gillespie@eni.com DN: cn=brett.gillespie@eni.com Date: 2017.05.17 10:02:30 +08'00' (Date)
As required

**Date closed out on Register:** 28/04/2017 **Name:** Adam Mastey