PRODUCED FORMATION WATER PLAN FOR EPL230-01

PR-OP	00	17/12/24	Issued for Approval	pp. Signed by: Alexandra Rivera FF2E8AA9B46B4A0... G George	pp. Signed by: Alexandra Rivera FF2E8AA9B46B4A0... C Buenhombre	Signed by: Jamie Reilly 6760BE8F0290491... J Reilly	Signed by: Steve Johnston 535DA65AC4D6465... S Johnston	
Validity Status	Rev. Number	Date	Description	Prepared by	Checked by	Approved by	Contractor Approval	Company Approval
Revision index								

eni australia	Project name **BLACKTIP INLET COMPRESSION**	Company identification 710100PORVX0825 Job N.
kent		Contractor identification 2422-0000-4ERA-0003 Contract 5000020982
		Vendor identification Order N

Facility Name	Location	Scale	Sheet of Sheets
BLACKTIP – YELCHERR GAS PLANT	NORTHERN TERRITORY & WESTERN AUSTRALIA	1:1	1 / 389

Document Title **Produced Formation Water Plan for EPL230-01**	Supersedes N................. Superseded by N......... Plant Area / Plant Unit

REVISION HISTORY

Rev.	Date	Nr. of sheets	Description
00	17/12/24	389	Issued for approval

kent

Produced Water Outfall Mixing Zone Monitoring and Approvals Support

Produced Formation Water Plan for EPL230-01

Eni Australia

17 December 2024

kentplc.com

Engineering & Consulting

Projects

Completions, Commissioning & Start-up

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Document History

Document Title: Produced Formation Water Plan for EPL230-01

Eni Document Reference: 710100PORVX0825

Kent Document Reference: 2422-0000-4ERA-0003

Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
A	Issued for Review	pp. G George	pp. C Buenhombre	J Reilly	S Johnston	17/12/24
		Signed by: Alexandra Rivera FF2E8AA9B46B4A0...	Signed by: Alexandra Rivera FF2E8AA9B46B4A0...	Signed by: Jamie Reilly 6760BE6F0290491...	Signed by: Steve Johnston 535DA65AC4D6465...	

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1 EXECUTIVE SUMMARY

This document has been prepared to satisfy Environmental Protection License (EPL) 230-01, 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

– Confirm the offshore mixing zone for the discharge

– Identify marine water monitoring points around the diffuser where ANZG (2018) 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 PFW discharge achieves the trigger values specified in the EPL.

Due to the change in volume and composition of the PFW discharge into the marine receiving waters since 2021, it is appropriate to investigate the change in potential toxicity, update the mixing zone which is required to achieve adequate dilution and revise the field validation sampling.

Based on PFW sampling and analysis undertaken since commencement of production and the dispersion modelling, Eni proposes a circular mixing zone of radius 50 m centred on the diffuser mid-point **Error! Reference source not found.**. The dispersion models and PFW studies provide reasonable assurance that the ANZECC water quality guidelines will be met at this boundary.

The dominant drivers for the plume's behaviour within the mixing zone is the 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 field monitoring program is provided with the objective to validate the near field modelling predictions that meet the required dilution of 263-fold at the mixing zone boundary. Upon acceptance of the proposed field sampling program, Eni has issued detailed sampling and analysis plans for implementation which began during the 2024 dry season, subject to operational and logistical constraints. This program has been developed to ensure the water, sediment and biota quality objectives are being achieved at the mixing zone boundary and additional at sensitive environmental receptor, particularly the Walpinhthi Reef Exclusion Zone. The monitoring of receiving water depicted a substantial rise in PFW salinity, a major factor that drives dispersion. However, the updated near field modelling suggests that the required 263-fold dilution at lower current speeds is likely to be achieved following additional mixing that the plumes will undergo after striking the seabed.

Eni undertook several improvement activities intended to enhance the discharge of PFW. A plant trial of the lamella clarifier has been proposed to reduce BTEX and TSS levels in the PFW. An additional measure to reduce BTEX was performed by recirculating the water through baseline PW system to provide full exposure to N_2 sparging at the PW tank. The most recent results have indicated the achievement of 99% probability of marine species protection (highest level). A temporary trial using a high pH coagulant was conducted to facilitate the removal of metalloids and BTEX. The results indicate a sharp reduction of manganese and BTEX below detection levels. Eni has further proposed an investigation of the sparging system in base of PW Tank with off-the-shelf materials. This procedure is expected to assist in the removal of solids and heavy materials.

2 ABBREVIATIONS AND DEFINITIONS

2.1 Abbreviations

°C	Degrees Celsius
µ	Micro
AS	Australian Standard
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes
bwpd	Barrels of water per day
CH4	Methane
Cm	Centimetres
Cwlth	Commonwealth
EIF	Environmental Impact Factor
EIS	Environmental Impact Statement
EMP	Environmental Management Plan
Eni	Eni Australia B.V.
EPL	Environmental Protection Licence EPL230-01
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
M	Metres
m^3	Cubic metres
mg	Milligrams
mL	Millilitres
N_2O	Nitrous Oxide
NLC	Northern Land Council
NM	Not measured
NMHC	Non-methane hydrocarbons
NORM	Naturally occurring radioactive material
NO_x	Oxides of nitrogen
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
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
PPE	Personal Protective Equipment
psu	Practical Salinity Units
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)
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
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 EPL230-01 for contaminant levels which must not be exceeded in emissions.
Trigger value	Trigger values stated in EPL230-01 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 unstaffed 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. The processed gas is exported via an onshore export pipeline 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 (Lowest Astronomic Tide (LAT)).

Blacktip YGP commenced production on 26 August 2009. The operation of the YGP was 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. Since this initiation there have been two amendments and a new issue to the EPL as listed in Table 3.1.

Table 3.1 Environmental protection licences for Blacktip operations

Environmental Protection Licence	Date of issue	Purpose
EPL57	11/08/2009	Initial license
EPL57-01	16/12/2010	Amendment
EPL57-02	10/02/2015	Amendment
EPL230	21/05/2018	Amendment
EPL230-01	10/02/2020	Renewal

3.2 Purpose

The purpose of this report is to satisfy conditions of EPL230-01. Under these conditions, the EPL stipulates:

The licensee must ensure that annual marine sediment and biota monitoring is conducted by a suitably qualified professional, in accordance with the latest version of the Produced Formation Water Plan and The Australian Government National Assessment Guidelines for Dredging 2009, to determine the long-term impact of discharge of wastewater to the marine ecosystem including the Walpinhthi Reef Exclusion Zone.

65. The licensee must provide a report by 30 October 2022, that validates the hydrodynamic model predictions used in the latest version of the Produced Formation Water Plan. The report must:

65.1 define the mixing zone in accordance with the NT EPA Guidelines on Mixing Zones;

65.2 determine appropriate monitoring points in the receiving environment to detect any environmental impact from the authorised discharge; and

65.3 determine appropriate trigger values and/or limits to be applied in the receiving environment or at the authorised discharge point.

3.3 Scope of this report

Table 3.2 summarises the scope of this report, and how it meets the requirements that are specified under EPL230-01 conditions.

Table 3.2 Requirements of this report

EPL230-01 condition	Requirement	Section reference in this report
65.1	Define the mixing zone in accordance with the NT EPA *Guidelines on Mixing Zones*	Section 7.11
65.2	Determine appropriate monitoring points in the receiving environment to detect any environmental impact from the authorised discharge	Section 8.5
65.3	Determine appropriate trigger values and/or limits to be applied in the receiving environment or at the authorised discharge point	Section 8.1

Table 3.3 summarises the information relevant to the application for a mixing zone, and how the report meets the requirement specified under NT EPA Guidelines on Mixing Zones.

Table 3.3 Information provided for mixing zone application

S. No.	Requirement	Section reference in this report
1	Detailed information on site and facility	Section 4
2	Discharge and release conditions	Section 4.2
3	Receiving environment	Section 5
4	Exposure pathway between source and receptor	Section 7.9
5	Monitoring plan for the discharge, consistent with the NT EPA's Guidelines for Consultants Reporting on Environmental Issues	Section 8
6	Continuous improvement plan for managing wastewater discharge over time, so as to reduce the extent and impact of the mixing zone	Section 9
7	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: • representation of the source of the discharge • all flow scenarios, inclusive of: - wet and dry season flows - catchment flows	Section 7

S. No.	Requirement	Section reference in this report
	- variations of the discharge volume due to wastewater re-use, reduction • release and transport mechanisms for nutrients/toxicants away from the discharge and in and away from the mixing zone; and • a review of potential and actual receptors.	

3.4 Related documentation

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

- *Eni Blacktip Project Produced Water Management Plan* (document number 00036_DV_EX.HSE.0381.000_A03) (Ref. 0).
- *Eni Blacktip Project Produced Water Management Plan for EPL57-02 Condition 43* (document number 00036_DV_EX.HSE.1056.000 REV A04) (Ref. 0)
- *Blacktip Operations Onshore Gas Plant Environmental Management Plan* (EMP) (000036_DV_EX.HSE.0684.000) (Ref. 0);
- NRETAS Assessment Report No. 50 (Ref. 0);
- Environmental Impact Statement (Ref. 0, 0, 0);
- EPBC approval 1180/2003; and
- Environmental Protection Licence (EPL230-01).

4 FACILITY DESCRIPTION

4.1 Produced water treatment system

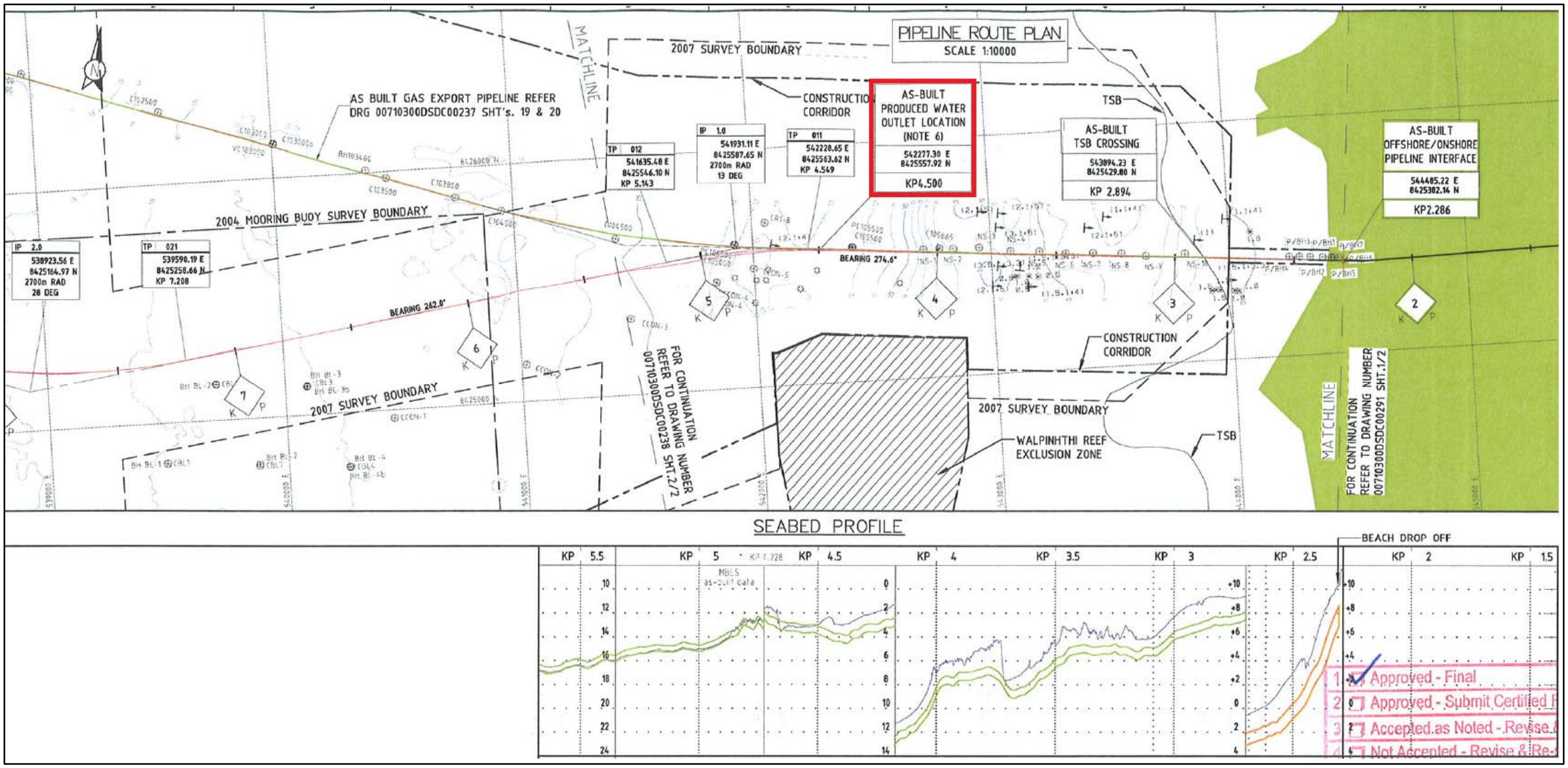
Produced Formation Water (PFW) or produced water (PW) separated from the liquids stream is further processed in the PFW system to remove free oil prior to disposal at sea. The key design functions of the PFW Treatment System are to:

- 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 25 ppm.
- maintain pH of discharged water between 6.5 and 8.5.

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. The offshore section is piggybacked to the Condensate Export Pipeline using a block and strap clamping arrangement.

The end of the outfall pipe is located 2 km offshore in approximately 12 m of water (LAT) (**Error! Reference source not found.**). 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 4-2. 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.



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

Figure 4-1 Produced water discharge location

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 (2 km offshore)
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	Average of 175 m^3/day over the past 3 calendar years from 2021 to 2023
Number of days discharging	158 during the 2023 calendar year
Discharge flowrate	9.88 m^3/hr
Ambient conditions	
Depth	12 m below LAT
Ambient velocity	0.05-1 m/s
Stratified condition	Unstratified. Refer to Section 5.7.
Ambient temperature	28°C
Ambient salinity	34 psu

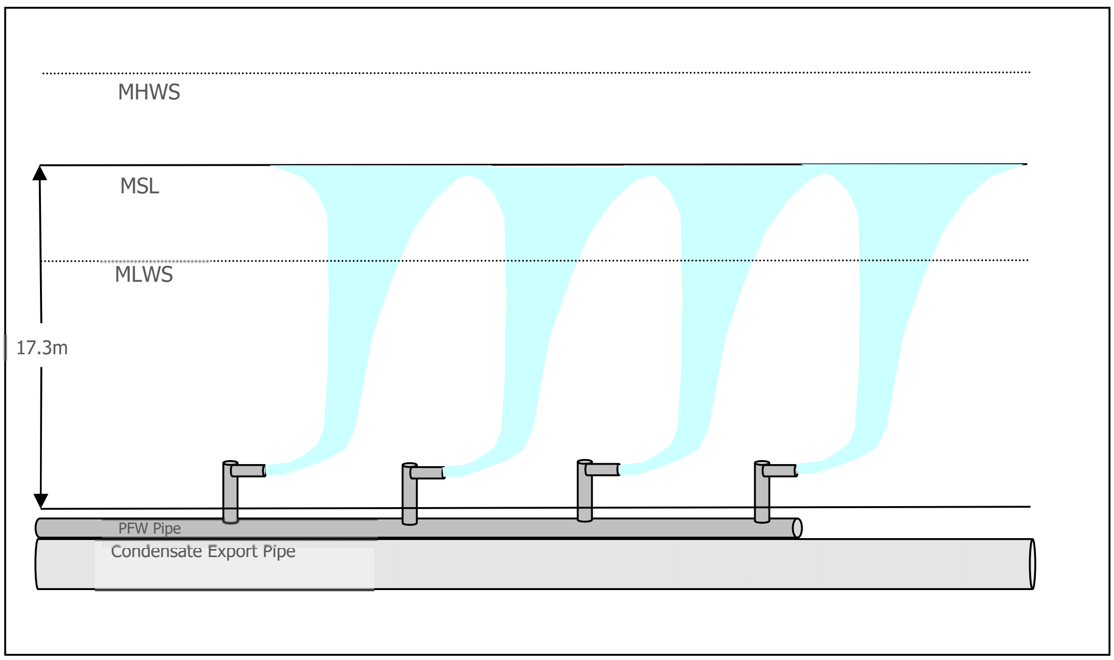


Figure 4-2 Illustration of four port discharge diffuser

4.3 Water production

4.4 Historical production

Table 4.2 summarises the historical PFW 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
2017	1,700	2,199
2018	1,900	1,899
2019	6,000	6,039
2020	6,000	5,787
2021[4]	10,500	10,503
2022	31,000	31,440
2023	40,900	37,458

[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.
[4] Due to staff transition the data gathering method for 2021 data may be different to the approach used in 2019 and 2020. However, it has been shown that produced water volumes increased in 2021, hence a significant increase in the number of discharge days is expected.

4.5 Current production

Currently, produced water predominantly consists of condensate water from gas dehydration. Over the past calendar year (10 February 2023 – 09 February 2024), the total PFW production volume and average daily rate were 40,900 m^3 and 112.05 m^3/day, respectively.

The total volume discharged over the 2023 calendar year is shown in Table 4.3 and was approximately 37,458 m^3 over 158 separate days. The average discharge volume was approximately 237 m^3 per discharge event at an average frequency of about once every two days.

Table 4.3 PFW discharges during 2023-2024

Date	Quantity	Average OIW
13/Feb/2023	222	21.3

Date	Quantity	Average OIW
14/Feb/2023	98.2	22.4
15/Feb/2023	216.5	15
16/Feb/2023	255.1	15
17/Feb/2023	103	17.8
18/Feb/2023	108.6	14.7
19/Feb/2023	78.8	18.2
20/Feb/2023	116.2	17.2
21/Feb/2023	165	19.3
24/Feb/2023	146	21
26/Feb/2023	269	20
27/Feb/2023	150	24
28/Feb/2023	407.1	19.5
1/Mar/2023	207	11.2
2/Mar/2023	203	10.3
3/Mar/2023	185	8.2
5/Mar/2023	180	6.5
6/Mar/2023	151.4	10.1
7/Mar/2023	78.5	15
8/Mar/2023	102.23	16.9
9/Mar/2023	147.1	24
10/Mar/2023	144.5	11.2
11/Mar/2023	85.9	16.8
12/Mar/2023	142.2	11.8
13/Mar/2023	128	15.9
14/Mar/2023	133	23.4
15/Mar/2023	127.6	19.2
18/Mar/2023	80	16.1
19/Mar/2023	95.8	13.7
20/Mar/2023	67.1	21.8
23/Mar/2023	447	7.9
24/Mar/2023	73.1	16.4
31/Mar/2023	85.1	10.1
2/Apr/2023	218.8	8.7
3/Apr/2023	11.3	18.2
4/Apr/2023	100.1	18.2
7/Apr/2023	434.9	10.3
8/Apr/2023	148.1	10.5
11/Apr/2023	99.2	1.1

Date	Quantity	Average OIW
13/Apr/2023	75	8.7
16/Apr/2023	101.1	13.7
18/Apr/2023	474.6	12.67
23/Apr/2023	284.4	21.8
24/Apr/2023	115.9	9.4
28/Apr/2023	332.2	23.9
1/May/2023	579.6	14.6
5/May/2023	10	12.4
6/May/2023	118.9	12.4
7/May/2023	378.4	16.9
9/May/2023	216.5	2.2
10/May/2023	199.8	15.9
11/May/2023	87.7	18.1
14/May/2023	388.74	5.6
16/May/2023	81.8	5.8
17/May/2023	46.9	8.8
18/May/2023	303.5	12.9
19/May/2023	121.2	5.4
20/May/2023	203.1	5.6
21/May/2023	147.7	6.3
22/May/2023	133.3	11.5
23/May/2023	175.7	11.8
24/May/2023	206.2	16
26/May/2023	53	10.8
29/May/2023	257.6	10.4
31/May/2023	108	21.6
1/Jun/2023	108	21.6
2/Jun/2023	277.8	12.1
3/Jun/2023	221.6	7.6
4/Jun/2023	510	4.9
5/Jun/2023	108.9	15.4
6/Jun/2023	588.6	6
9/Jun/2023	640.2	22.8
14/Jun/2023	426	6
19/Jun/2023	557	2
22/Jun/2023	551.8	16.7
27/Jun/2023	579.1	1.4
30/Jun/2023	632	5.7

Date	Quantity	Average OIW
6/Jul/2023	530.2	0
6/Jul/2023	125.7	0.1
9/Jul/2023	386	9.3
14/Jul/2023	536.2	16.3
16/Jul/2023	405.4	9.6
17/Jul/2023	380.4	13
19/Jul/2023	203.3	12.6
24/Jul/2023	236.4	13.1
24/Jul/2023	552.27	5.4
26/Jul/2023		7.8
29/Jul/2023	381.3	13.3
2/Aug/2023	483.6	18
5/Aug/2023	429.86	4.8
8/Aug/2023	301.11	2.2
10/Aug/2023	45.4	4.3
18/Aug/2023	150.7	11.9
20/Aug/2023	391.4	13.3
22/Aug/2023	402.5	21.1
24/Aug/2023	414.9	3.35
26/Aug/2023	550	5.6
29/Aug/2023	207.2	12.9
30/Aug/2023	428	10.5
2/Sep/2023	412.53	7.5
3/Sep/2023	202.39	9.85
5/Sep/2023	502.3	20.9
7/Sep/2023	288	5.1
8/Sep/2023	164.37	8.3
9/Sep/2023	136.9	7.2
10/Sep/2023	306.22	8.8
12/Sep/2023	277.16	9.375
14/Sep/2023	281.6	5.1
18/Sep/2023	341.6	8.3
19/Sep/2023	310.3	9.9
22/Sep/2023	54.03	17.9
24/Sep/2023	312.63	15.9
25/Sep/2023	272.43	11.1
27/Sep/2023	246.2	17.8
28/Sep/2023	194.25	5

Date	Quantity	Average OIW
29/Sep/2023	73.47	21.9
30/Sep/2023		6.7
2/Oct/2023	348.6	9.5
4/Oct/2023	193.7	11
5/Oct/2023	112.18	11
10/Oct/2023	407.94	4.7
11/Oct/2023	36	7.55
12/Oct/2023	287	16.8
13/Oct/2023	57.55	16.8
14/Oct/2023	377.13	4.1
16/Oct/2023	297.2	5.4
17/Oct/2023	64.67	6.05
18/Oct/2023	438.11	8.4
21/Oct/2023	400.02	7.7
24/Oct/2023	578.8	2
26/Oct/2023	201.55	8
28/Oct/2023	364.96	3.7
29/Oct/2023	230.3	20
30/Oct/2023	164.37	16
1/Nov/2023	214.22	17.9
2/Nov/2023	185.1	17.9
3/Nov/2023	121.3	23
4/Nov/2023	147.2	18
7/Nov/2023	201.84	7
8/Nov/2023	269.61	15.4
9/Nov/2023	128.1	5.1
11/Nov/2023	241.29	5.4
13/Nov/2023	226.9	9.4
18/Nov/2023	311.5	10
19/Nov/2023	158.94	11.3
20/Nov/2023	269.2	13.1
22/Nov/2023	74	8.2
23/Nov/2023	74	8.2
27/Nov/2023	57.9	21.9
28/Nov/2023	171.8	23.5
7/Dec/2023	118.3	6.1
8/Dec/2023	118.3	6.1
18/Dec/2023	149.7	10

Date	Quantity	Average OIW
30/Dec/2023	12.7	17.3
3/Jan/2024	300.18	16.8
5/Jan/2024	180.1	15.6
9/Jan/2024	253.99	7.6
10/Jan/2024	120.8	6.3
22/Jan/2024	128	0.3
	37,326.54[1]	**11.96**[2]

[1]Total
[2]Weighted average

4.6 Future production

The annual PFW production over the remaining life of the field is projected to be approximately 26,467 m^3 over 150 events (days). The average discharge volume would be approximately 175 m^3 per discharge event.

The future production forecast was estimated based on the average of annual PFW discharge volumes from 2021 to 2023. It is to be noted that produced formation water production is variable and projections vary with well performance, as evidenced by the historical discharge volumes summarised in Table 4.3.

5 RECEIVING ENVIRONMENT

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.

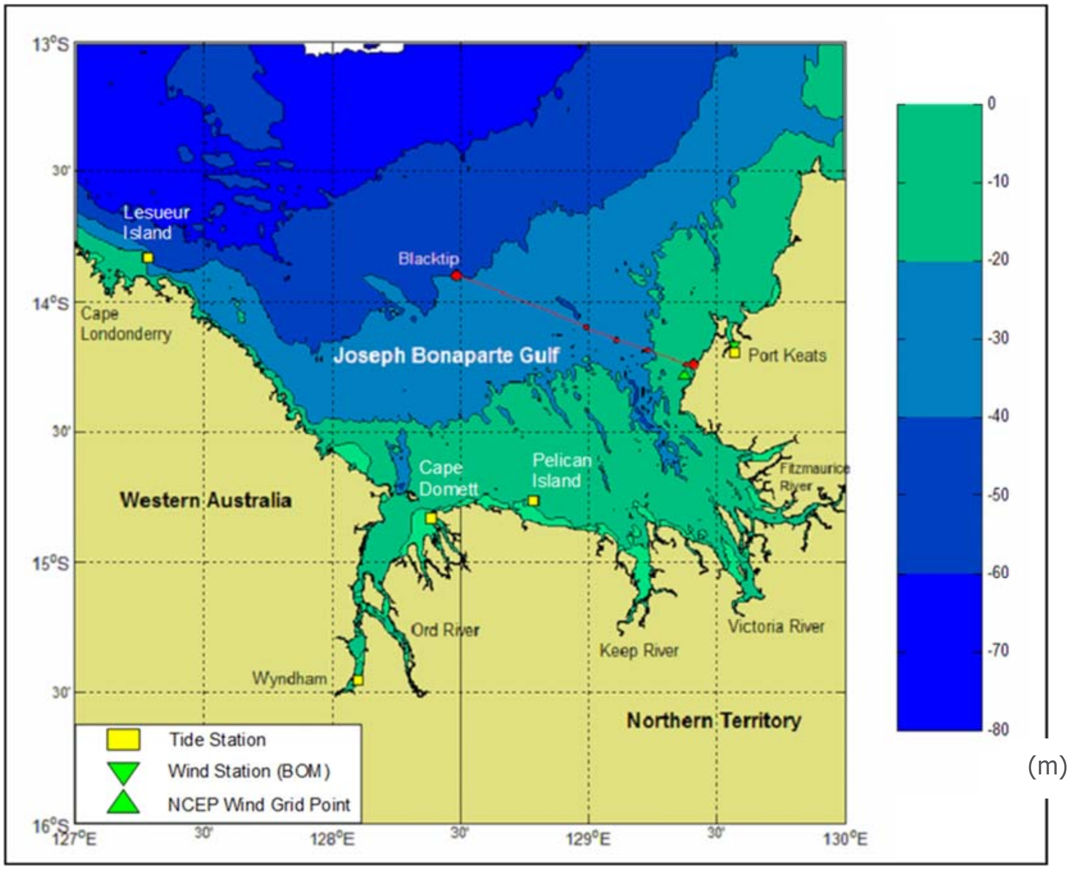


Figure 5-1 The Joseph Bonaparte Gulf (Ref. 0)

5.1 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.

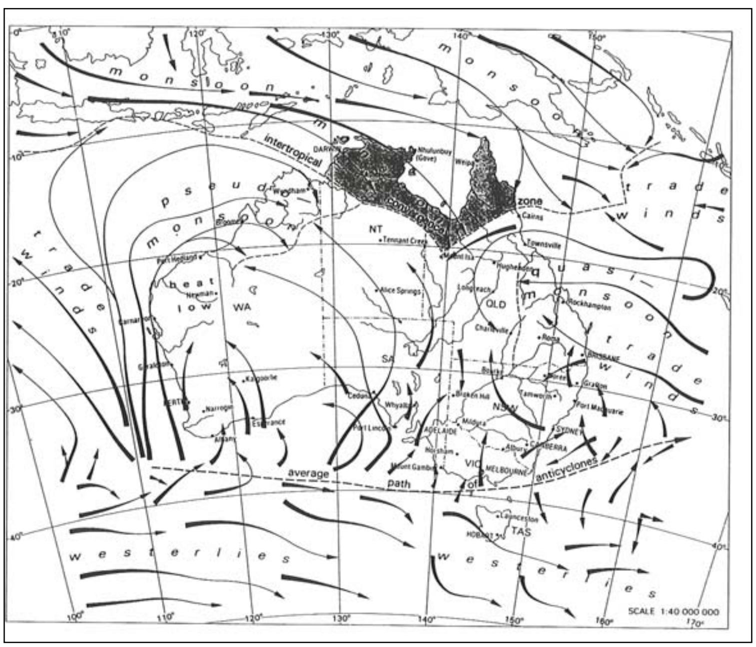
The early part of the season is marked by frequent thunderstorms. As the season progresses moist ocean air from the north and northwest streams into the lows and several days of heavy rain may occur. Occasionally one of the lows may strengthen and move southeast over the interior. When this happens, widespread rains follows and under exceptional circumstances the clouds may be affected 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.

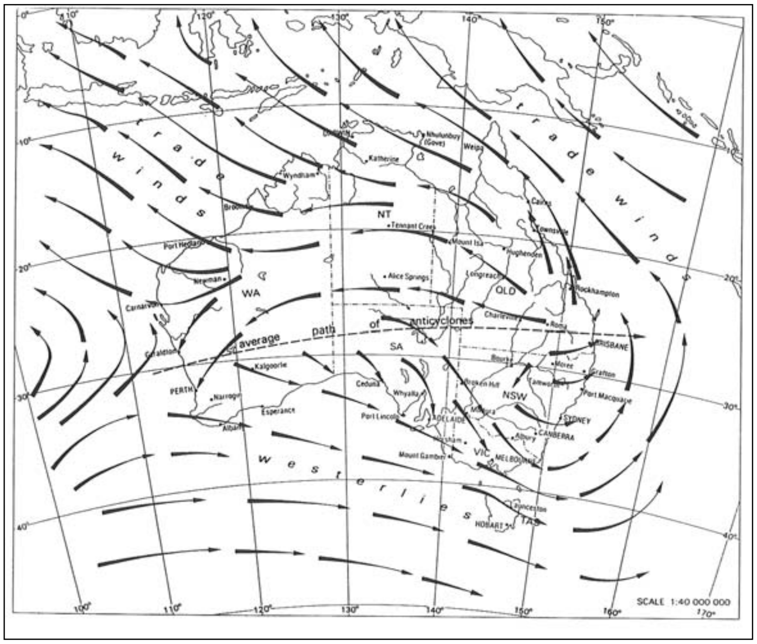
Mean daily maximum temperatures for Port Keats range from about 30 to 34°C, and minima from 14.5°C to 25°C. Annual rainfall is 750 to 900 mm. Almost all rainfall occurs between November and April, the greatest falls being in January and February. The frequency and severity of the thunderstorms produce a large variation in the monthly rainfall. Rainfall during the dry months is sporadic and light (Ref. 0).

5.2 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

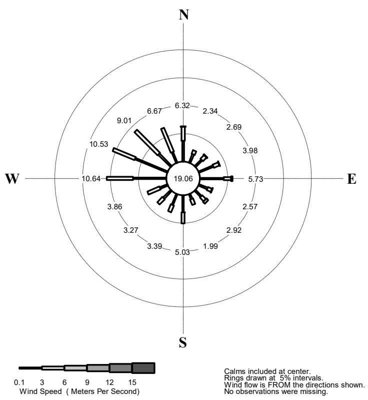


(b) Winter

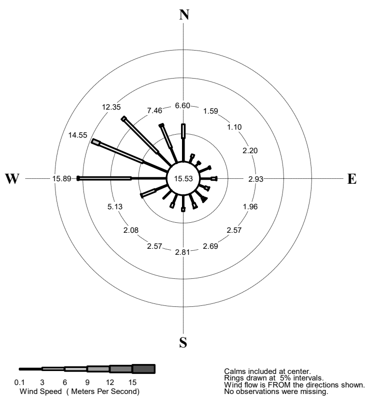
Source: Ref. [6]

Figure 5-2 Generalised atmospheric circulation over Australia in winter (July) and summer (January) (Ref. 0)

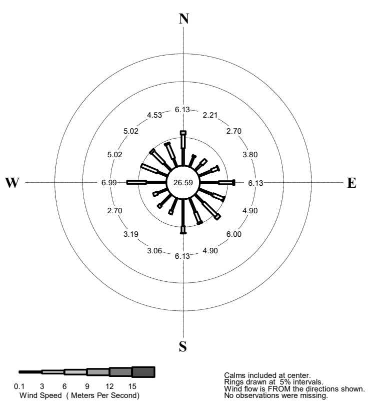
January



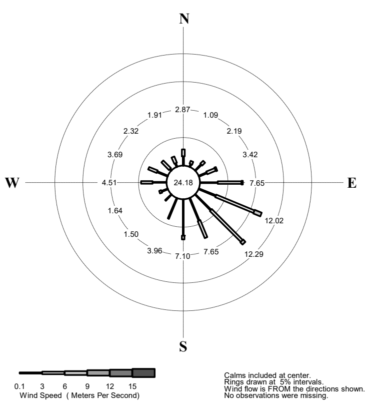
February



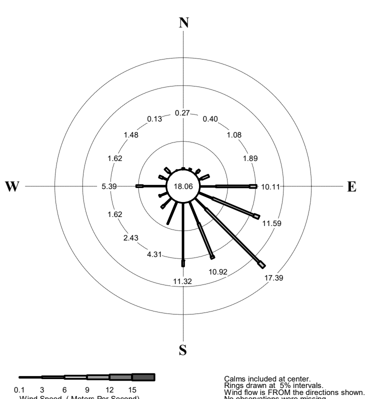
March



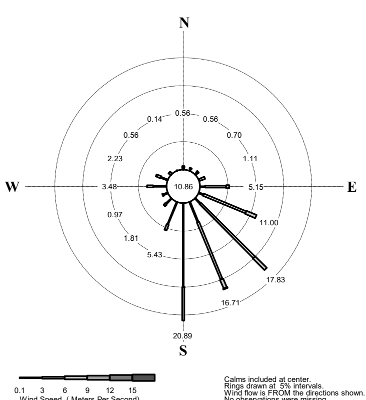
April



May



June



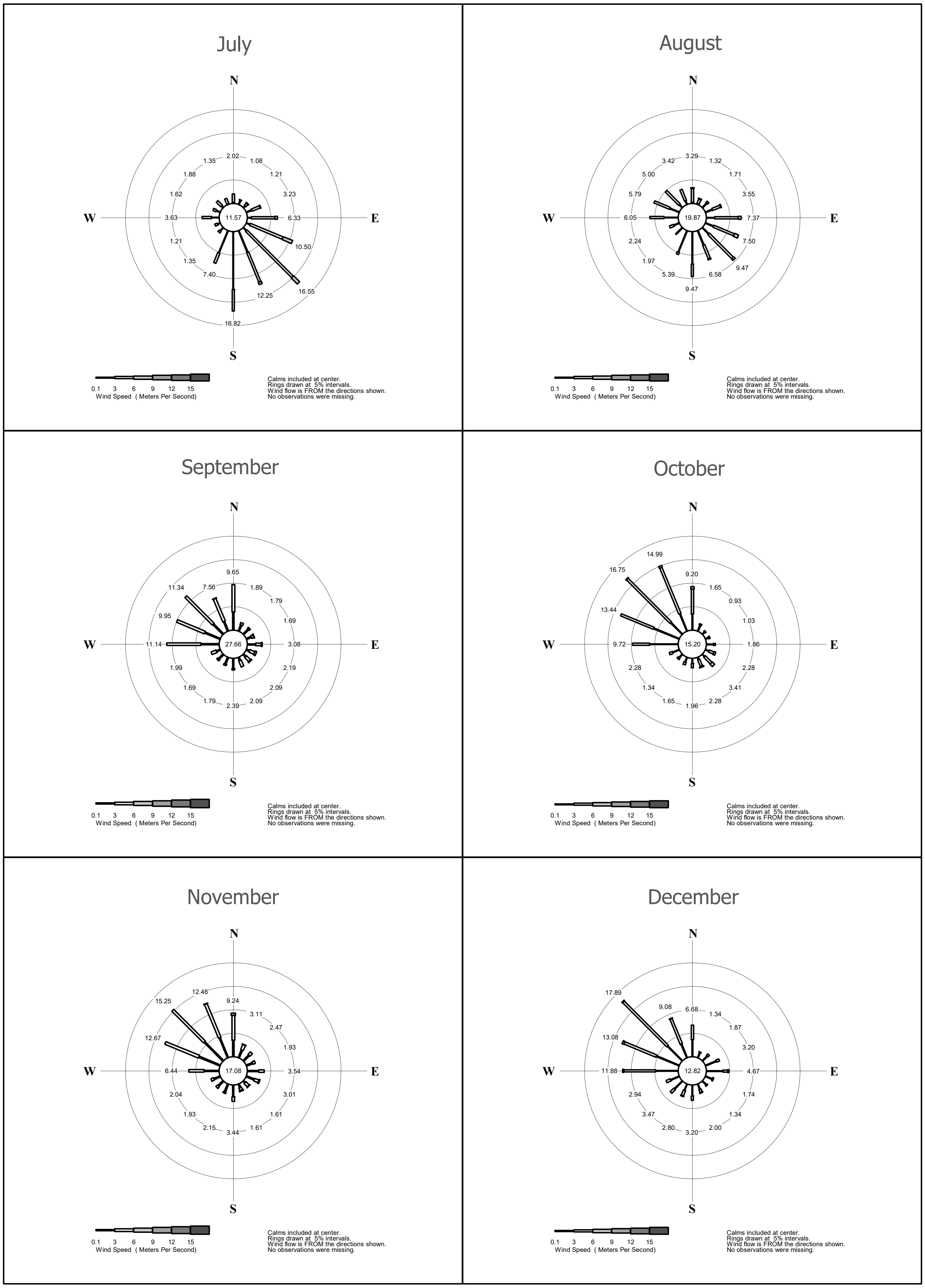

July
N
W
E
S
2.02
1.08
1.21
3.23
6.33
10.50
16.55
12.25
16.82
7.40
1.35
1.21
3.63
1.62
1.88
1.35
11.57
0.1 3 6 9 12 15
Wind Speed (Meters Per Second)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.
August
N
W
E
S
3.29
1.32
1.71
3.55
7.37
7.50
9.47
6.58
9.47
5.39
1.97
2.24
6.05
5.79
5.00
3.42
19.87
0.1 3 6 9 12 15
Wind Speed (Meters Per Second)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.
September
N
W
E
S
9.65
1.89
1.79
1.69
3.08
2.19
2.09
2.09
2.39
1.79
1.69
1.99
11.14
9.95
11.34
7.56
27.66
0.1 3 6 9 12 15
Wind Speed (Meters Per Second)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.
October
N
W
E
S
9.20
1.65
0.93
1.03
1.86
2.28
3.41
2.28
1.96
1.65
1.34
2.28
9.72
13.44
16.75
14.99
15.20
0.1 3 6 9 12 15
Wind Speed (Meters Per Second)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.
November
N
W
E
S
9.24
3.11
2.47
1.93
3.54
3.01
1.61
1.61
3.44
2.15
1.93
2.04
6.44
12.67
15.25
12.46
17.08
0.1 3 6 9 12 15
Wind Speed (Meters Per Second)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.
December
N
W
E
S
6.68
1.34
1.87
3.20
4.67
1.74
1.34
2.00
3.20
2.80
3.47
2.94
11.88
13.08
17.89
9.08
12.82
0.1 3 6 9 12 15
Wind Speed (Meters Per Second)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Figure 5-3 Monthly wind roses for Port Keats (2000-2003) (Ref. 0)

5.3 Oceanography

5.4 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 (Ref. 0).

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. 0)

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 can appreciably raise sea levels above the predicted astronomical tidal height and inundate low-lying areas (Ref. 0).

5.5 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.0). 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
- 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
- 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 (Ref. 0).

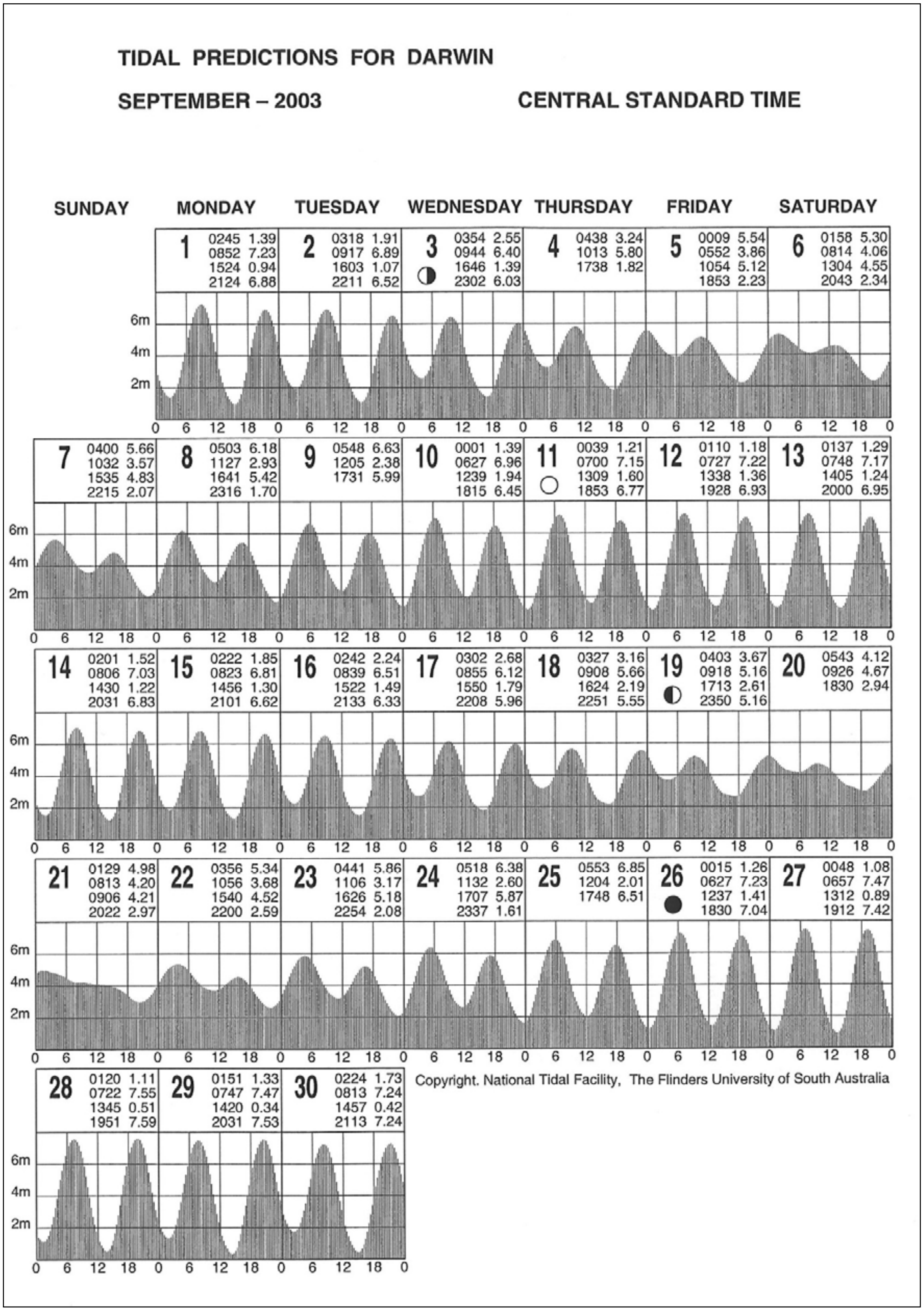
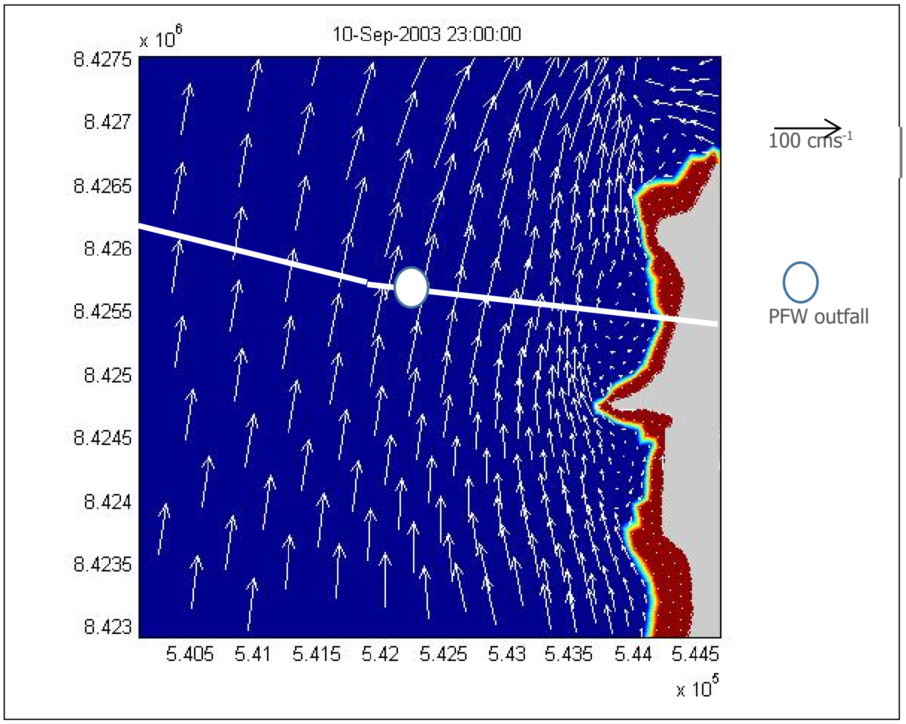

TIDAL PREDICTIONS FOR DARWIN
SEPTEMBER – 2003
CENTRAL STANDARD TIME
SUNDAY
MONDAY
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
SATURDAY
1 0245 1.39 0852 7.23 1524 0.94 2124 6.88
2 0318 1.91 0917 6.89 1603 1.07 2211 6.52
3 0354 2.55 0944 6.40 1646 1.39 2302 6.03
4 0438 3.24 1013 5.80 1738 1.82
5 0009 5.54 0552 3.86 1054 5.12 1853 2.23
6 0158 5.30 0814 4.06 1304 4.55 2043 2.34
7 0400 5.66 1032 3.57 1535 4.83 2215 2.07
8 0503 6.18 1127 2.93 1641 5.42 2316 1.70
9 0548 6.63 1205 2.38 1731 5.99
10 0001 1.39 0627 6.96 1239 1.94 1815 6.45
11 0039 1.21 0700 7.15 1309 1.60 1853 6.77
12 0110 1.18 0727 7.22 1338 1.36 1928 6.93
13 0137 1.29 0748 7.17 1405 1.24 2000 6.95
14 0201 1.52 0806 7.03 1430 1.22 2031 6.83
15 0222 1.85 0823 6.81 1456 1.30 2101 6.62
16 0242 2.24 0839 6.51 1522 1.49 2133 6.33
17 0302 2.68 0855 6.12 1550 1.79 2208 5.96
18 0327 3.16 0908 5.66 1624 2.19 2251 5.55
19 0403 3.67 0918 5.16 1713 2.61 2350 5.16
20 0543 4.12 0926 4.67 1830 2.94
21 0129 4.98 0813 4.20 0906 4.21 2022 2.97
22 0356 5.34 1056 3.68 1540 4.52 2200 2.59
23 0441 5.86 1106 3.17 1626 5.18 2254 2.08
24 0518 6.38 1132 2.60 1707 5.87 2337 1.61
25 0553 6.85 1204 2.01 1748 6.51
26 0015 1.26 0627 7.23 1237 1.41 1830 7.04
27 0048 1.08 0657 7.47 1312 0.89 1912 7.42
28 0120 1.11 0722 7.55 1345 0.51 1951 7.59
29 0151 1.33 0747 7.47 1420 0.34 2031 7.53
30 0224 1.73 0813 7.24 1457 0.42 2113 7.24
6m
4m
2m
0 6 12 18 0

Figure 5-4 Darwin tide curve for September 2003 (Ref. 0)

(a) Ebb Tide



(b) Flood Tide

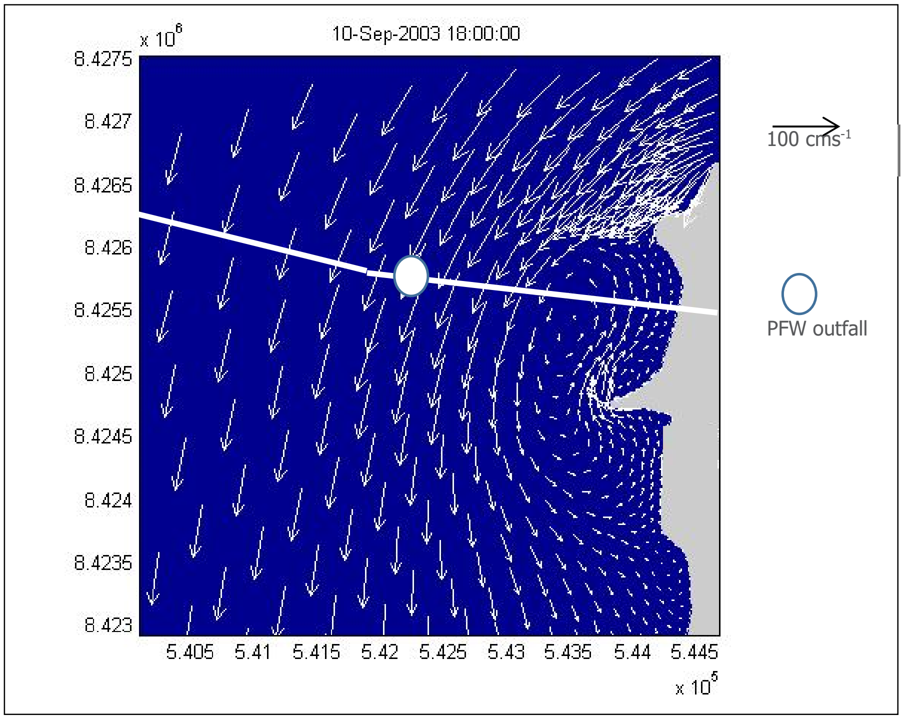


Figure 5-5 Predicted spring tide vector fields in the vicinity of the landfall for the Blacktip pipeline (Ref. 0)

5.6 Waves

Wave data were derived from a two-degree global database constructed from a combination of remotely sensed satellite and modelled data (Ref. 0). 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.

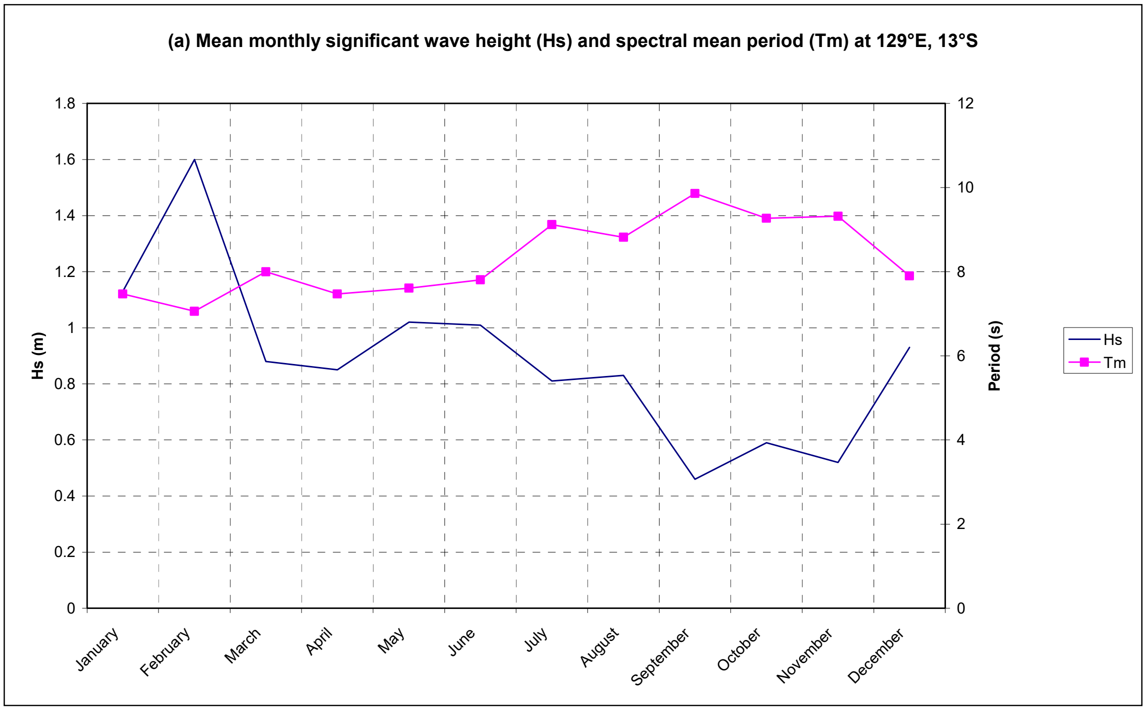
During the winter season, the ambient wave climate at Blacktip will be composed of waves generated from the prevailing south and south-easterly trade winds. Wave generation will be fetched limited and mean monthly significant wave heights are predicted to be fairly constant, ranging between 0.8 m and 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 (Ref. 0).

5.7 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. 0). 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.



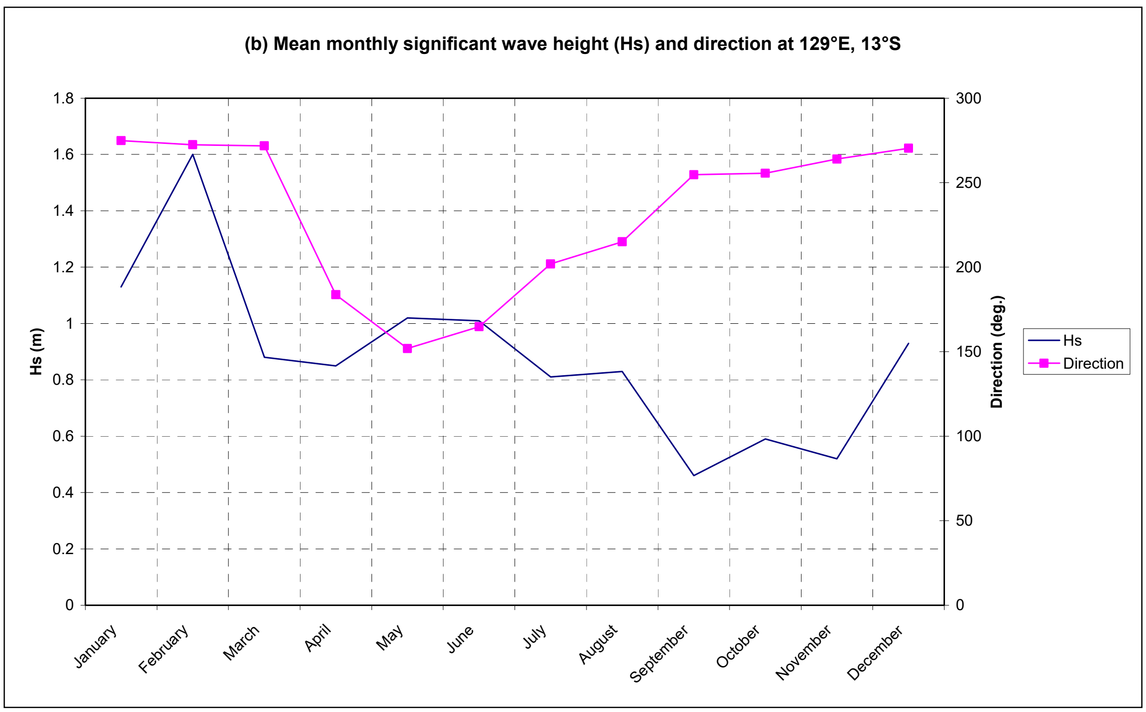


Figure 5-6 Monthly mean wave parameters for grid location129°E, 13°S (approximately 100 km NNE of Blacktip) (Ref. 0)

5.8 Marine habitats

Coastal habitats in the vicinity of the discharge include:

- pelagic
- benthic
- intertidal zones.

Section 7 and Appendix B of the EIS (Ref. 0, 0, 0) 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 dugongs, 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

Near 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, bryozoans, hydroids, polychaetes, molluscs, echinoderms, 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

– mangroves.

Northern Yelcherr 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 Yelcherr 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 Yelcherr 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 Yelcherr 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 denser. 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. 0, 0, 0).

5.9 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.

Name	Description
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.

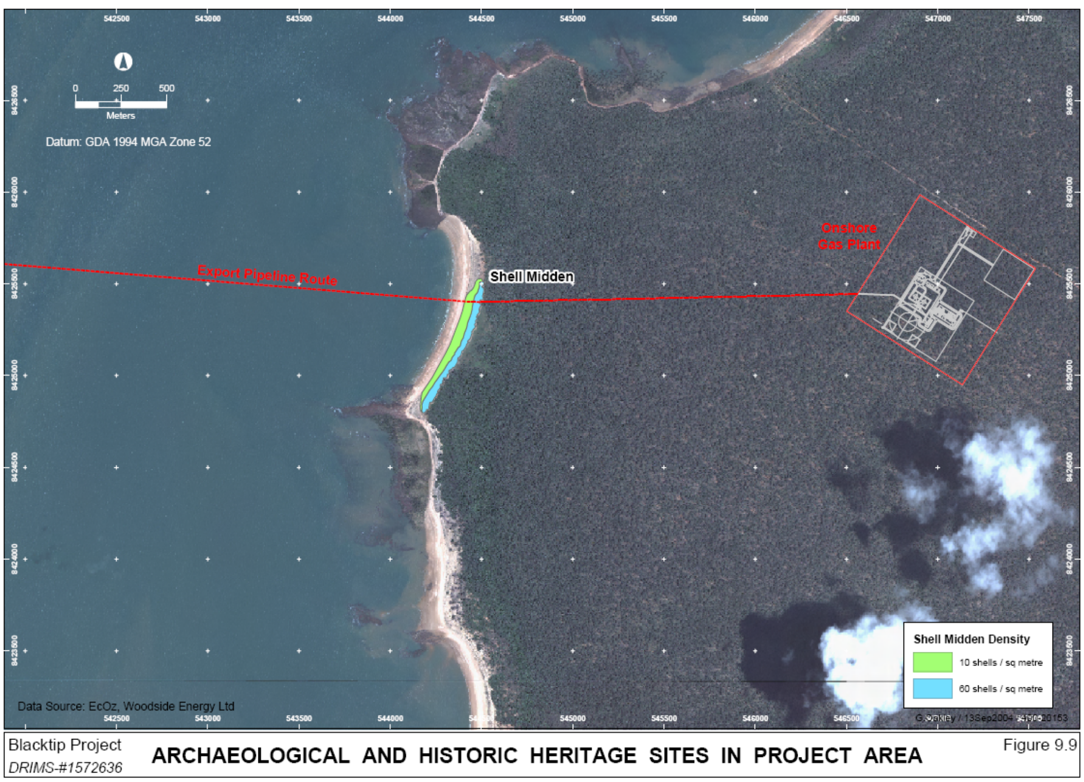
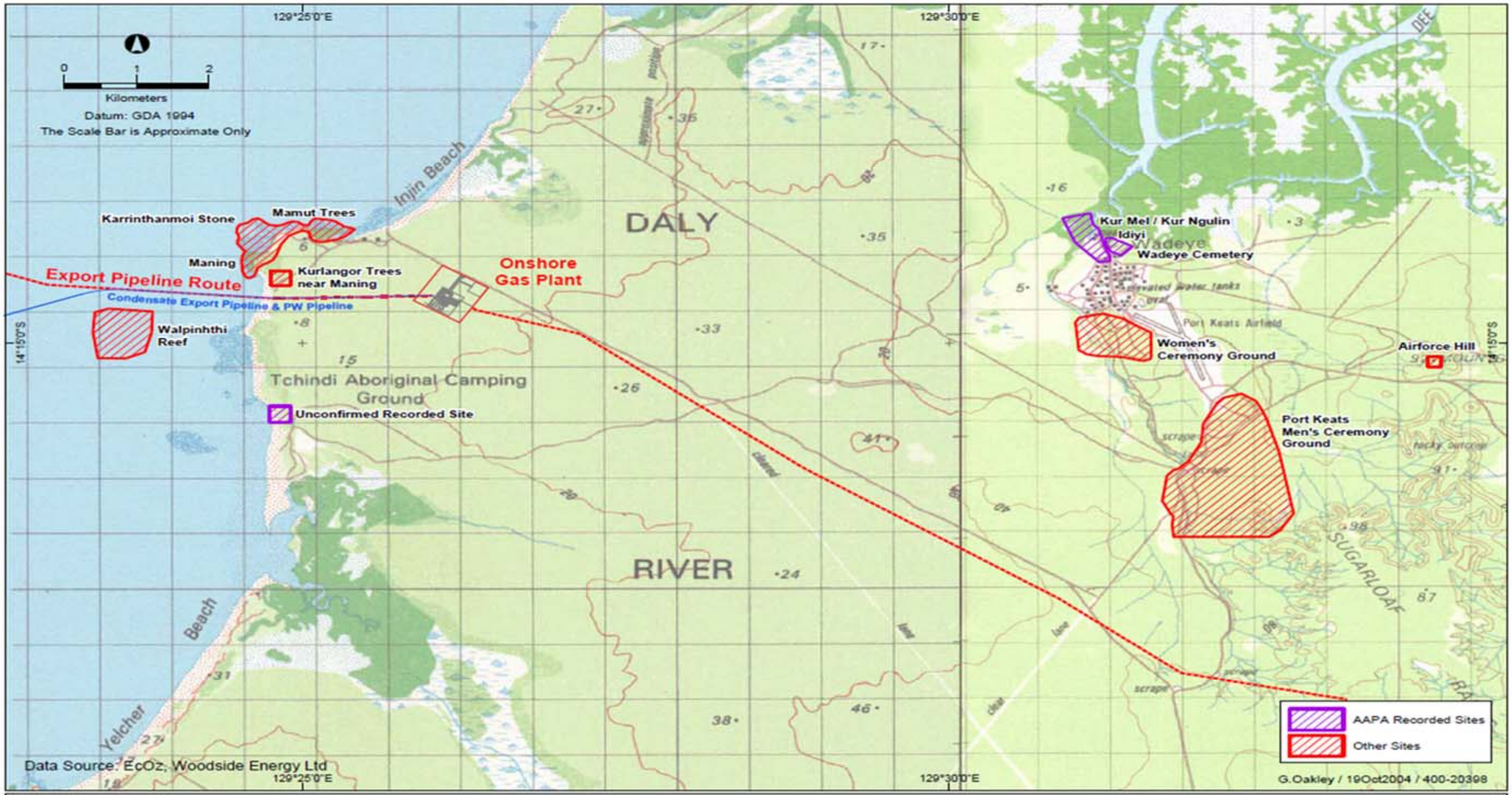


Figure 5-7 Archaeological sites



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APPROXIMATE LOCATIONS OF ABORIGINAL SACRED AND SIGNIFICANT SITES

Figure 9.10

Figure 5-8 Approximate locations of aboriginal sacred and significant sites

6 HISTORICAL PFW MONITORING

6.1 Produced water studies

Produced water studies were conducted under EPL57-01 which included:

- Chemical characterisation
- Ecotoxicology
- Biodegradatio
- Bioaccumulation potential.

Produced water studies were conducted in October 2010 (Ref.0), February 2012 (Ref. 0) and September 2013 (Ref. 0). The latter three analyses were 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 2010* (Ref. 0) 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 (Ref. **Error! Reference source not found.**).

6.2 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
- Residual process chemicals.

The results of the chemical analyses from the PFW studies 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, 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 testing of produced water had been often <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.

6.3 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:

- Microtox
- Microalgae cell division
- Sea urchin fertilisation
- Mussel larvae development
- Copepod development
- Fish larvae development
- 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. 0, 0, 0).

In the absence of toxicity data for Blacktip PFW at the time, the *Blacktip Produced Water Management Plan 2010* (Ref. 0) 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.

6.4 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.

6.5 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.

6.6 Baseline marine monitoring

The Environment Protection Licence specifies annual marine monitoring of the area in the vicinity of the PFW discharge outfall. Eni monitoring program 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.

The annual marine monitoring remains a commitment under the *Produced Water Management Plan* (Ref. 0).

6.7 2010 Baseline marine monitoring

The baseline monitoring (Ref. 0) 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 6-1 and Figure 6-2. 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 more than ANZECC/ARMCANZ trigger values. Concentrations of silver, chromium, copper and mercury were also measured in mangrove sediments more than ANZECC/ARMCANZ trigger values.

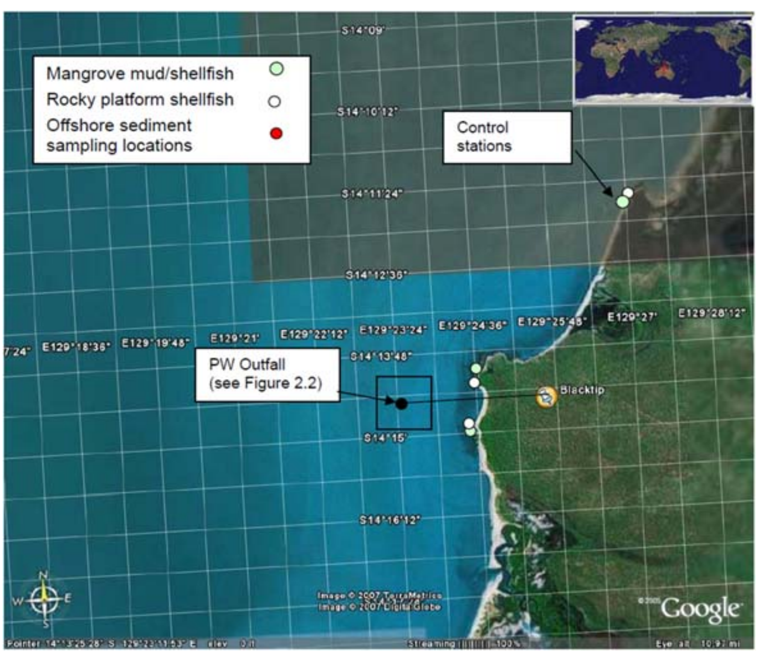


Figure 6-1 2010 baseline marine monitoring sampling locations

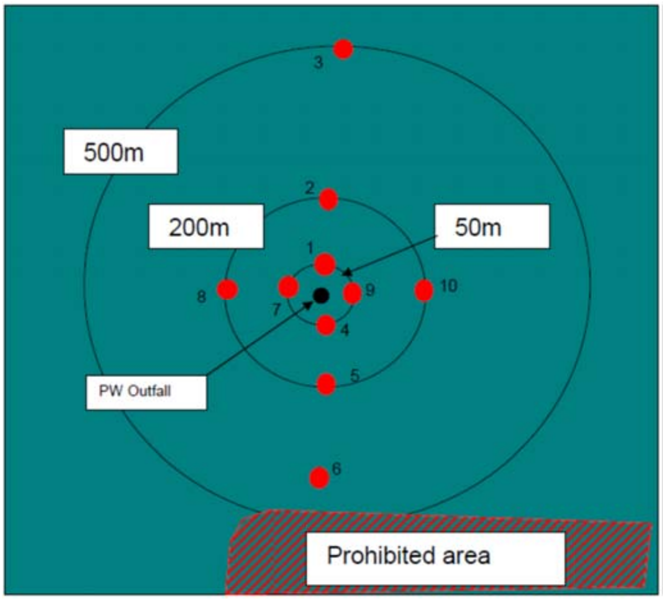


Figure 6-2 2010 offshore marine monitoring sampling locations

6.8 2011-2016 Marine monitoring

Annual marine monitoring (Ref. 0, 0, 0, 0) was conducted during the dry season of 2011-2012 and 2014-2016 and consisted of the following:

- Three onshore samples of sediment (mangrove mud), including one control sample taken from an area north of the beach (Ref. 0, 0, 0, 0)
- Onshore samples of *Echinolittorina trochoides* and *Rhizophore stylosa* shellfish were collected from rocky headlands and mangrove forests either side of Yelcherr beach.

Exceedances of arsenic at sediments sites also occurred at the control site in 2011. This is most likely attributed to the naturally high arsenic levels in the area as indicated in the EIS (Ref. 0, 0).

Table 6.2 Exceedances recorded during annual marine monitoring for PFW

Year	Month	Impact	
		Sediment	Shellfish
2011	June	As 22 mg/kg	None
2012	June	As	-
2013	Not conducted	-	-
2014	April	-	-
2015	June	As	-
2016	May	As	-

6.9 2017-2024 Annual marine monitoring

Annual marine monitoring (Ref. **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**) was conducted during the dry season during 2017-2024 and consisted of the following:

– Three onshore samples of sediment (mangrove mud), including one control sample taken from an area north of the beach

– Onshore samples of Rhizophore stylosa shellfish were collected from rocky headlands and mangrove forests either side of Yelcherr beach.

Table 6.3 Exceedances recorded during annual marine monitoring for PFW

Year	Month	Impact	
		Sediment	Shellfish
2017	May	As	None
2018	May	As and Cr	None
2019	May	As	None
2020	November	Mn	Acenaphthene and Phenanthrene
2021	May	None	C6-C10, Acenaphthene and Phenanthrene
2022	July	None	None
2023	November	None	None
2024	August and October	None	None

6.10 2017 Marine monitoring

The survey conducted in May 2017 found most readings were well within the levels measured in previous years, with no major difference between the Yelcherr beach samples and control samples. The results are detailed in Blacktip Operations Marine Survey 2017 (000036_DV_PR.HSE.1097.000) (Ref. **Error! Reference source not found.**).

With the exception of arsenic, all metal concentrations in mangrove sediments were below the Interim Sediment Quality Guideline (ISQG) trigger value. Arsenic concentrations in sediment were measured slightly above the lower ISQG trigger value at both locations; however, concentrations were 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 all within the historical range and mostly lower than baseline and 2016 results. All values were consistent with those measured previously.

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.

6.11 2018 Marine monitoring

The survey conducted in May 2018 found most readings were well within the levels measured in previous years, with no major difference between the Yelcherr beach samples and control samples. The results are detailed in Blacktip Operations Marine Survey 2018 (000036_DV_PR.HSE.1130.000) (Ref. **Error! Reference source not found.**).

With the exception of arsenic and chromium, all metal concentrations in mangrove sediments were below the Interim Sediment Quality Guideline (ISQG) trigger value. Arsenic concentrations in sediment were measured slightly above the lower ISQG trigger value at both locations; however, concentrations were consistent with the naturally high arsenic levels reported previously. Chromium was measured at Location 2 only slightly above the lower ISQG trigger value. All hydrocarbon concentrations were found to be below detection limits. Metal concentrations in shellfish samples were all within the historical range and mostly lower than baseline and 2017 results. All values were consistent with those measured previously.

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.

6.12 2019 Marine monitoring

The survey conducted in May 2019 found most readings were well within the levels measured in previous years, with no major difference between the Yelcherr beach samples and control samples. The results are detailed in Blacktip Operations Marine Survey 2019 (000036_DV_PR.HSE.0859.000) (Ref. **Error! Reference source not found.**).

With the exception of arsenic, all metal concentrations in mangrove sediments were below the Interim Sediment Quality Guideline (ISQG) trigger value. The arsenic concentration was measured slightly above the lower ISQG trigger value in sediment at the northern end of Yelcherr Beach; however, concentrations were 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 all within the historical range and mostly lower than baseline and 2018 results. All values were consistent with those measured previously.

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.

6.13 2020 Marine monitoring

The sampling was conducted on 24 November 2020 and the laboratory report was received on 10 February 2021. The results are detailed in Blacktip Operations Marine Survey 2020 (000036_DV_PR.HSE.1141.000) (Ref. **Error! Reference source not found.**). The survey found all metal concentrations in mangrove sediments were below the Interim Sediment Quality Guideline (ISQG) trigger values. Hydrocarbon was not detected in mangrove sediment samples.

Metal concentrations in shellfish samples were all within the historical range except for manganese, an essential trace metal, which was measured at increased levels in samples from the Control Site and Location 1. Following further analysis and considering the historical variability in manganese levels, these changes were attributed to natural sources. All other values were consistent with those measured previously.

No petroleum compounds were detected in shellfish samples except for acenaphthene and phenanthrene, which were detected for the first time in the monitoring programme. Acenaphthene has not been detected in Blacktip produced water since February 2016 and is therefore attributed to other external sources. Phenanthrene was detected in shellfish at both monitoring sites, but not the control site, at levels slightly above the detection limit. It is probable that the phenanthrene detected also originated from the same external source as acenaphthene. Nevertheless, the ANZECC 99% species protection level will be adopted as a trigger value for monitoring phenanthrene in Produced Water until site specific trigger values are determined.

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

6.14 2021 Marine monitoring

The sampling was conducted on 11 May 2021 and the results are detailed in Blacktip Operations Marine Survey 2021 (000036_DV_PR.HSE.0882.000) (Ref. **Error! Reference source not found.**). All metal concentrations in mangrove sediments were below the Australian and New Zealand default guideline values. All hydrocarbon concentrations were below detection limits in mangrove sediment samples. Metal concentrations in shellfish samples were all within the historical ranges across the various locations.

Petroleum compounds were below detection in shellfish samples except for C6-C10, acenaphthene and phenanthrene. A review of the main C6-C10 compounds identified determined that they are all associated with metabolism in plants or organisms and therefore originate from natural sources. Acenaphthene has not been detected in Blacktip produced water since February 2016 and is therefore attributed to other external sources. Phenanthrene was detected in shellfish at the rocky headlands at the northern end of Yelcherr Beach at levels slightly above the detection limit. Given phenanthrene was last detected in produced water at the practical quantitation limit of 1 µg/L in September 2020, it is probable that the phenanthrene detected in the May 2021 samples also originated from an external source.

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.

6.15 2022 Marine monitoring

The sampling was conducted on 12 July 2022 and the results are detailed in Blacktip Operations Marine Survey 2022 (000036_DV_PR.HSE.0900.000) (Ref. **Error! Reference source not found.**). All metal concentrations in mangrove sediments were below the Australian and New Zealand default guideline values. All hydrocarbon concentrations were below detection limits in mangrove sediment samples. Metal concentrations in shellfish samples were all within the historical ranges across the various locations. Petroleum compounds were below detection in shellfish samples.

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.

6.16 2023 Marine monitoring

The sampling was conducted on 28th November 2023 and the results are detailed in Blacktip Operations Marine Survey 2023 (000036_DV_PR.HSE.1206.000) (Ref. **Error! Reference source not found.**). All metal concentrations in mangrove sediments were below the Australian and New Zealand default guideline values. All hydrocarbon concentrations were below detection limits in mangrove sediment samples. Metal concentrations in shellfish samples were all within the historical ranges across the various locations.

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.

6.17 2024 Marine monitoring

The sampling was conducted on 6th August and 2nd October 2024 and the results are detailed in Blacktip Operations Marine Survey 2024 (710000PGRV00071_00) (Ref. **Error! Reference source not found.**). On 6

August 2024 one site could not be reached due to tides and the beach being closed for "Sorry Business", the final sampling was taken on 2nd October 2024. All metal concentrations in mangrove sediments were below the Australian and New Zealand default guideline values. All hydrocarbon concentrations were below detection limits in mangrove sediment samples. Metal concentrations in shellfish samples were all within the historical ranges across the various locations and the trend is declining. All metals at locations 1 & 2 were below last year's results.

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, due to the reduction in the produced water discharge.

6.18 2024 Receiving waters monitoring

Monitoring of receiving waters was conducted on 3 July 2024. It consisted of offshore monitoring near the outfall diffuser and onshore monitoring of Produced Formation Water (PFW) at the licence discharge point (PW-02) into the outfall pipe. Forty-two offshore samples were collected across several locations, depths and tidal conditions including reference site. The offshore water samples were analysed for a broad list of licence analytes and the PW-02 licence limit was used for comparative purposes. Also, eight onshore sampling rounds were taken at the PW-02 sample point on the same day (Ref. **Error! Reference source not found.**).

Key observations from the program are presented below:

6.19 Onshore water quality

Onshore monitoring the PFW indicated that it may have had a greater density than that of the receiving environment. This would result in the poor performance by the outfall, which was designed to accommodate a PFW that is less dense than the receiving body. As a result composition of the PFW will be reassessed, in particular its density relative to that of seawater.

6.20 Offshore water quality

- The offshore monitoring demonstrated almost all licence parameters were diluted below the onshore (PW-02) licence limit including during the worst-case slack tide conditions.
- The water column appeared to be well mixed during slack, flood and ebb tides.
- The only offshore parameter above the PW-02 limit attributed to the outfall discharge was copper - noting that most (32 of 36 and 34 of 36 Intermediate Mixing Zone (IMZ)/Mixing Zone (MZ) samples) were still below the trigger value and licence limits respectively.
- The one slack tide MZ result for zinc above the PW-02 licence limit was not attributed to the outfall discharge. This is because many of the mixing zone results were below the reference site values, and a reference site sample was also recorded above the licence limit. Most (35 of 36 IMZ/MZ samples) were still below the licence limit and trigger value.
- Toluene, ethyl benzene, naphthalene, phenol, and manganese were found to be within the licence limits for the MZ/IMZ samples. This again demonstrated the positive effect of the outfall in diluting the discharged effluent as the onshore (PW-02) samples exceeded the licence limits for -m & p-xylenes, copper (total and dissolved), manganese (total), zinc (total and dissolved), and total suspended solids. All MZ/IMZ samples for TSS above were above its trigger thresholds.

6.21 Statistical analysis

A one-way analysis of variance (ANOVA) was performed to determine if there were any statistically significant differences in the means of physical parameters across slack, ebb and flood tidal situations.

- No parameters were elevated relative to reference site at the MZ sites during ebb tides.
- During slack and flood tides, several parameters were elevated relative to reference site at the MZ sites. Only concentrations of ammoniacal N (surface depth), salinity (mid depth) and TSS (bottom depth) were determined to be statistically significant and attributable to the offshore discharge.
- The observed minor variations in physiochemical parameters were considered statistically insignificant between flood and ebb tidal situations.
- However, some parameters varied significantly between slack and flood tides and between slack and ebb tides.
- No statistical differences in water quality were observed between MZ and IMZ sites.
- Therefore as the IMZ sites are inside the mixing zone boundary, IMZ sites will be removed from future monitoring.

6.22 Mixing zone (dilution) assessment

- The use of low concentrations of naturally occurring 'tracers' have made it difficult to assess dilution and validate hydrodynamic model predictions. Therefore, future monitoring programs will include a specific dye dispersion study to assess dilution.
- Consistent with other studies undertaken in the Northern Territory, this would enable an unambiguous interpretation of the effectiveness of the mixing zone.
- Subject to NT EPA approval and the outcome of consultation with key stakeholders including indigenous custodians, Eni proposed the use of Rhodamine WT for this study.

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 and is used in the Environmental Impact Factor (EIF) tool (Ref. 0). 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 the whole effluent of individual compounds.

A risk assessment was completed in 2015 (Ref.0) which examined 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
- Appropriate mixing zone.

An ALARP and acceptability assessment was 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
- 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.

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

– 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 (Ref. 0). As a general rule, linear hydrocarbons are more easily biodegraded than aromatic hydrocarbons (Ref. 0) .

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 (Ref. 0). The bioavailability of hydrocarbons decreases sharply with increasing carbon chain length and molecular weight.

Aquatic biota do not only degrade pollutant chemicals, but they may also accumulate them. Bioaccumulation is the uptake and retention of bioavailable chemicals from any one-off, 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.

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. Biomagnification 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.

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. 0) and the produced water management plan. 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).

7.7 Updated near field modelling 2015

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 7.1 UM3 near field model inputs 0

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[1])	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 50 psu @ 5 m 65 psu, model cannot predict, intersect seabed	35 psu @ -1 m 50 psu @ -1 m 65 psu, model cannot predict, intersect seabed	Model cannot predict	Model cannot predict	Model cannot predict

It is to be noted that the salinity of the PFW samples collected during the monitoring of receiving waters in 2024 was significantly higher than those reported in 2020. The estimated salinity (51 psu) in 2024 samples was much higher than the values recorded earlier, but within the range of PFW salinities used in the model (5-65 psu) (Ref. **Error! Reference source not found.**). In this case, the UM3 model fails to predict if required 263-fold dilution is achieved at the edge of the mixing zone at lower current speeds. As mentioned above, the required 263-fold dilution at lower current speeds is likely to be achieved following additional mixing that the plumes will undergo after striking the seabed.

7.8 Far field modelling

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

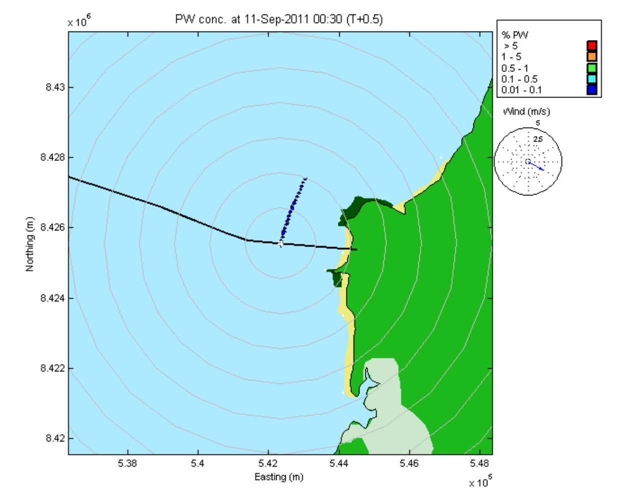
- To derive an effective disposal strategy by predicting the fate of PFW discharged from different locations
- To predict the environmental risk associated with the discharge.

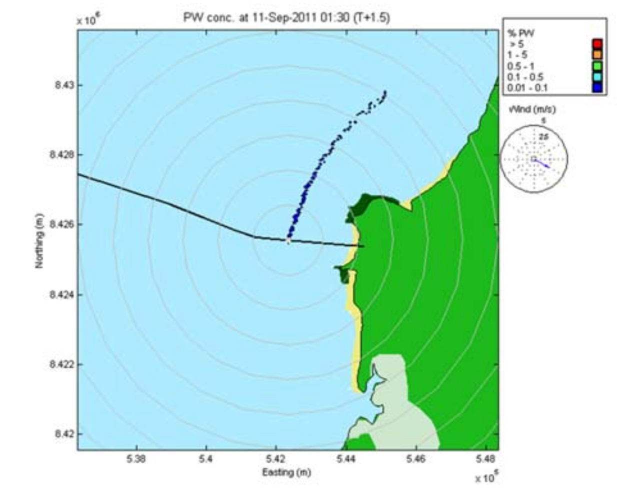
Standard particle tracking dispersion algorithms and diffusion coefficients were applied in the model. These are detailed in the produced formation water assessment conducted as part of the EIS (Ref. 0, 0). The model was also validated against tidal stations around the coastline. Comparisons with measured data compare favourably with modelled hydrodynamics, giving confidence that the hydrodynamic model is fit for purpose.

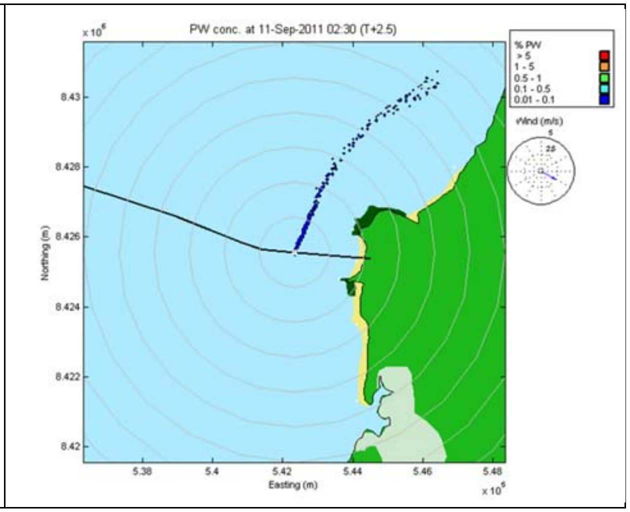
Again, the modelled discharge volumes are much higher than the current average discharge volumes and nearly two-fold greater than the projected maximum PFW volume of 450 m^3/day. Therefore, the modelling is considered representative of worst-case conditions in terms of PFW discharge.

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 7-1 and Figure 7-2 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.

eni australia	Company document identification	Owner document identification	Rev. index.		Sheet of sheets
			Validity Status	Rev. No.	
	710100PORVX0825	2422-0000-4ERA-0003	PR-OP	00	55 / 389







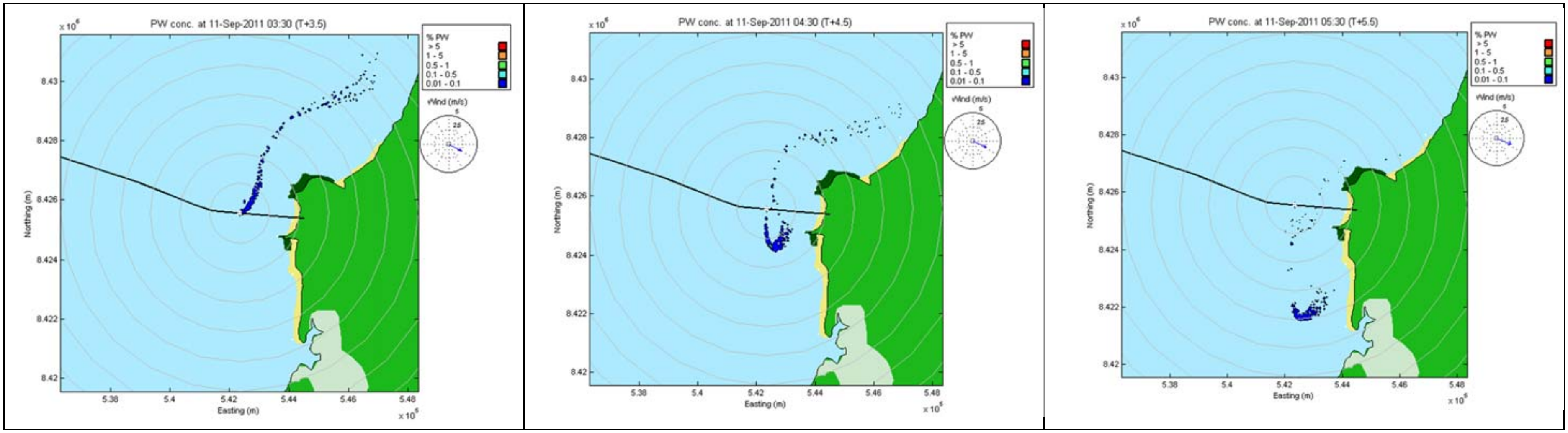
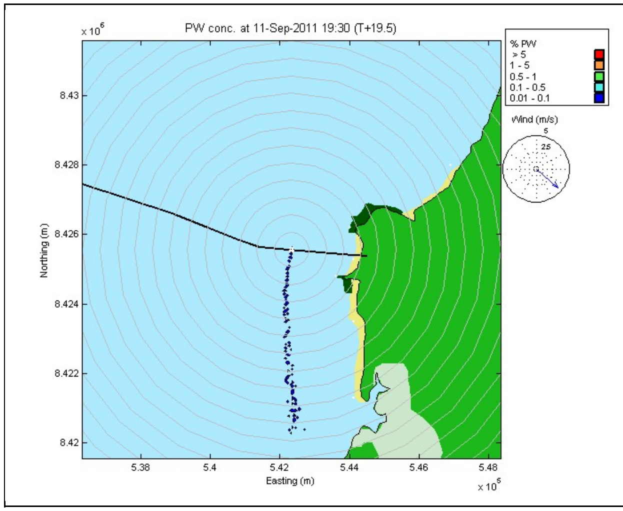
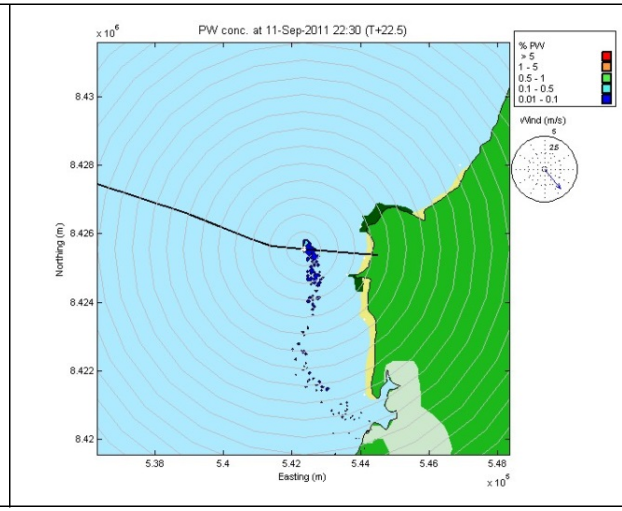
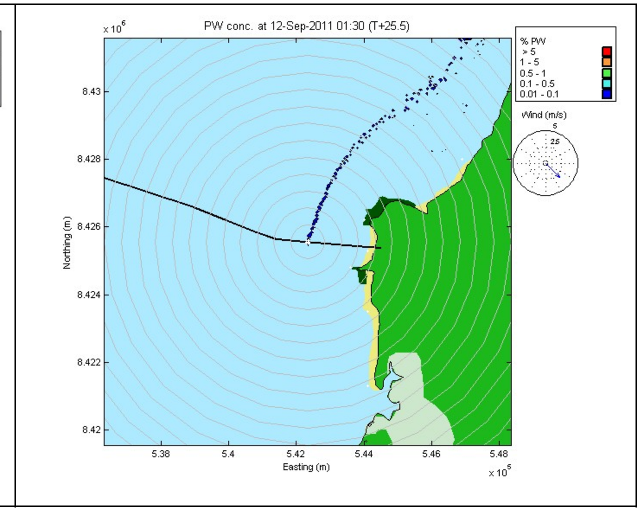


Figure 7-1 Predicted PFW concentrations during neap tide and light onshore winds for water production of 200 bbl/d (30 m3/d) (Ref. 0)


PW conc. at 11-Sep-2011 19:30 (T+19.5)
% PW
> 5
1 - 5
0.5 - 1
0.1 - 0.5
0.01 - 0.1
Wind (m/s)
Northing (m)
Easting (m)


PW conc. at 11-Sep-2011 22:30 (T+22.5)
% PW
> 5
1 - 5
0.5 - 1
0.1 - 0.5
0.01 - 0.1
Wind (m/s)
Northing (m)
Easting (m)


PW conc. at 12-Sep-2011 01:30 (T+25.5)
% PW
> 5
1 - 5
0.5 - 1
0.1 - 0.5
0.01 - 0.1
Wind (m/s)
Northing (m)
Easting (m)

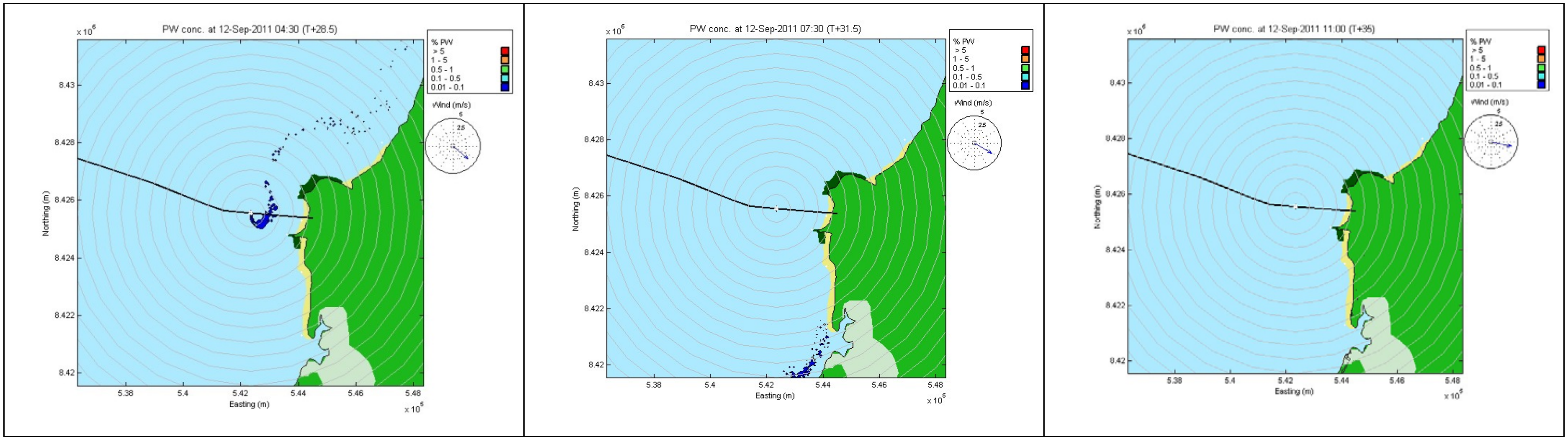


Figure 7-2 Predicted PFW concentrations during neap tide and light onshore winds for water production of 6000 bbl/d (900 m^3/d) (Ref. 0)

7.9 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
- 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). 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 (Ref. 0) around the outfall, exposure times for PFW concentrations above the PNEC would likely be in the order of minutes. There is 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.

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. The typical exposure periods for fish are conceptually similar to that for motile organisms. 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. The coarse sediments in the vicinity of the outfall limit the development of a deposit feeding community (Ref. 0, 0, 0). 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. But they are 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. 0). 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.

7.10 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.

From 2010 to 2016, chemical characterisation of the treated PFW 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 2000 ANZEC ANZECC/ARMCANZ (2000) marine water quality guideline trigger values for 99% protection of slightly to moderately disturbed ecosystems.

Barium is known to precipitate upon contact with seawater to form barium sulfate, which has low solubility and is commonly indicated to have low toxicity potential (Ref. 0). 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. 0, 0, 0, 0).

Chemical characterisation from 2017 onwards also identified dissolved metals (including cobalt, cadmium, copper, chromium, lead, manganese, mercury, nickel and zinc), BTEX and phenol exceeding ANZG (2018) values for marine water quality at 99% level of species protection. Additional parameters exceeding ANZG (2018) values include pentachlorophenol, 2,4,6-trichlorophenol, naphthalene, anthracene, fluoranthene, benzo(a)pyrene and phenanthrene.

Based on the ANZG (2018) values for a 99% level of species protection and the chemical characterisation studies, the required dilution factors were determined for all relevant parameters recorded from 2017 onwards. The key parameters requiring a higher level of dilution are summarised in Table 7.2. All other parameters were always within 100 dilutions of the ANZG (2018) values for 99% level of species protection.

Table 7.2 Required dilution factors to achieve 2018 ANZG toxicant trigger values for a 99% level of species protection

Parameter	Oct 2010[1]	Feb 2012[1]	Sep 2013[1]	2015[1]	May 2016[1]	Dec 2016[1]	2017[2]	2018[2]	2019[2]	2020[2]	2021[2]	2022-2023[2]	2023-2024[2]
pH[2]	1,451	633	178	8.4	14.2	4.1	38	8	8	4	3	4	3
Ammoniacal nitrogen	10	22	141	5	1	0	0	0	0	0	0	0	0
Filterable Cobalt	ND[3]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	117	260
Total Cobalt	1,000	ND	0	400	0	200	200	200	200	200	200	80	260
Chromium (VI)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	238	223
Filterable Zinc	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	137	14
Total Zinc	407	ND	6	4	287	6	20	2	46	6	20	24	17
Anthracene	ND	ND	ND	ND	ND	ND	100	550	400	100	93	100	186
Direct Toxicity Assessment	91	263	52	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

[1] Dilution factors were evaluated against 2000 ANZEC ANZECC/ARMCANZ (2000) marine water quality guideline trigger values for 99% protection of slightly to moderately disturbed ecosystems.

[2] Dilution Factors were evaluated against ANZG (2018) values for marine water quality at 99% level of species protection.

[3] ND: No Data

[2] Note that upon release of PFW discharge into the marine environment, the buffering capacity via chemical process will 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.

Also presented in Table 7.2 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[3] (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 based on the same rationale.

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

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 (Ref. 0).

7.11 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 wastewater 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 7-1 and Figure 7-2 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 m3/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. Therefore, 50 m radius mixing zone centred on the outfall diffuser is considered a practical and reasonable to achieve 99% species protection.

The basic mixing zone assessment is summarised in Table 7.3.

[3] 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).

Table 7.3 Summary of basic assessment 0

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) have demonstrated inconclusive evidence to demonstrate 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). However, annual marine monitoring from 2017 to 2024 (Ref. **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**) 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 bio-accumulative substances or chemicals in the discharge	As described in Section 6.1, Blacktip PFW contains low level hydrocarbons and heavy metals at or slightly above ANZG (2018) 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 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. From 2010 to 2016, the PFW contained total nitrogen and ammoniacal nitrogen at levels above the ANZECC/ARMCANZ (2000) marine water quality guideline trigger

Aspect	Criteria	Assessment
		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 7.10.
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 5.9). 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).
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.

7.12 ALARP and acceptability assessment

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

7.13 ALARP

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

– there are no reasonably 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

– Administration (development of procedures or training).

ALARP may also be determined by referring to existing 'good practice'. Table 7.4 provides the ALARP demonstrates in relation to the management of PFW.

Table 7.4 Demonstration of ALARP

Demonstration of ALARP	
Eliminate	

Demonstration of ALARP	
Substitute	Alternatives for PFW disposal, to eliminate or substitute the risk, were considered during the design phase of the project. Alternatives to ocean discharge include: 1. trucking back to Darwin for treatment; and 2. installation of evaporation ponds within the boundary of the gas plant. 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 hydrocarbon emissions and increase 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. Evaporation ponds were considered a viable alternative; however, there were concerns about: • land and/or aquifer contamination • animals drinking from the ponds • low evaporation rate, particularly if there is an oily film • emission of VOCs • residue disposal. 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: • CPI separators • GFU • CETCO filters • Long sea outfall • Diffusers at the end of the outfall. 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 Management of Change Form #00658 (Appendix F). Further to the existing infrastructure, the Blacktip plant will be trialling lamella clarifier to reduce BTEX and TSS levels in the PFW. An additional measure to reduce BTEX was performed by recirculating the water through baseline PW system to provide full exposure to N_2 sparging at the PW tank. The most recent results have indicated the achievement of 99% probability of marine species protection (highest level). A temporary trial using a high pH coagulant was conducted to facilitate the removal of metalloids and BTEX. The results indicate a sharp reduction of manganese and BTEX below detection levels. Eni has further proposed an investigation of the sparging system in base of PW Tank with off-the-shelf materials. This procedure is expected to assist in the removal of solids and heavy materials.
Isolate the risk	This is not relevant for PFW discharge and is not considered further.

Demonstration of ALARP	
Administration (development of procedures or training)	Administrative arrangements for PFW discharge include: • *Blacktip Operations Environmental Monitoring Requirements* (Doc No. 000036_DV_PR.HSE.1020.000) • Competent onsite operators aware of EPL230-01 requirements as they apply to PFW • *Blacktip Operations Yelcherr Gas Plant Oil in Water Sampling and Testing Procedure* (Doc No. 000036_DV_PR.DPM.1053.000) • *Blacktip Operations Water Sampling Procedure* (Doc No. 000036_DV_PR.HSE.1013.000).

7.14 Acceptability

Table 7.5 summarises the criteria against which acceptability is assessed.

Table 7.5 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.* Eni has strict legal requirements and conditions associated with PFW discharge, specified in the: • EPL230-01; and • EPBC Approval 1180/2003 conditions.
Policy Compliance	*The risk or impact must be compliant with the objectives of Eni policies.* 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.* An Environmental Impact Assessment was prepared for the project and involved extensive stakeholder consultation (Ref. 0, 0, 0). 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. [HOLD1]
Area Sensitivity/Biodiversity	*The proposed risk or impact controls, environmental performance objectives and standards must be consistent with the nature of the receiving environment.* • Receiving waters are well flushed with strong tidal currents. • Water production is variable resulting in an intermittent discharge of low volume. • 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 7.13).

8 MONITORING

8.1 Ongoing PFW chemical characterisation prior to discharge

The chemical characteristics of the PFW shall continue to be monitored in accordance with EPL230-01 (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	EPL230-01 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)
Quarterly	PW-02	*Environment parameters 1*[1]	External laboratory analysis	As above
		Environment parameters 2[1]		50 mg/L TSS
		Metals and metalloids[1]		-
		Hydrocarbons[1]		25 mg/L OIW
		Speciated phenols[1]		-
		Nutrient indicators[1]		-
		Copper		8 µg/L
		Manganese		80 µg/L
		Zinc		43 µg/L
		Benzene		2000 µg/L
		Toluene		330 µg/L
		Ethyl benzene		160 µg/L
		m+p-xylene		150 µg/L
		Naphthalene		120 µg/L
		Anthracene		7 µg/L
		Fluoranthene		2 µg/L
		Benzo(a)pyrene		0.7 µg/L
		Phenol		1200 µg/L
		Pentachlorophenol		55 µg/L
Annually	PW-02	*NORMS*[1]	External laboratory analysis	-

[1]Test suites as defined in Table 8.2.
Source: EPL230-01

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
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

Parameter	Abbrev	Unit	Analysis type	Test method[1]
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
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				

Parameter	Abbrev	Unit	Analysis type	Test method[1]
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

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 PFW discharge events 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.

8.3 Receiving waters assessment outline

The purpose of the field surveys is to:

- Validate the near field and far field dispersion models, discussed in Section 7.6
- Demonstrate a 50 m mixing zone radius around the diffuser will reasonably assure a 99% species protection level outside of this nominated area
- Conduct an annual marine sediment assessment, in conjunction with the existing shoreline sediment and biota program, to determine the long-term impact of discharge of wastewater to the marine ecosystem including the Walpinhthi Reef Exclusion Zone.

The key objectives are to demonstrate that a minimum dilution of 263-fold is achieved within a 50 m radius (Ref. **Error! Reference source not found.**) of the diffuser and to demonstrate that no accumulation of contaminants is occurring outside of the modelled mixing zone. This will be completed through receiving water and sediment quality assessments. It is proposed that water quality is completed annually until sufficient data are collected to determine the achieved dilutions. Sediment quality is to be completed annually until adequate data are collected to assess contamination within sediments.

8.4 Water quality assessment

Spatial estimates of dilution during the surveys 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 PFW. Due to the high level of mixing predicted, multiple sampling events over time may be required to confirm the minimum dilution achieved.

To ensure the objectives of the survey are met, key characteristics of the receiving environment and PFW 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.

Table 8.3 Targeted characteristics for survey

Characteristic	Condition	Rationale
PFW	500 m^3 of PFW in discharge event	A 500 m^3 discharge event over 7 hours is suggested to carry out the survey design during the desired range of tides to meet the model validation objective.
Tides and Currents	Two stages of tide during a neap tide (flood and slack)	Receiving water sampling will occur during three stages of the tide. Slack tides with low currents (~0.05-0.1 m/s) allow easiest validation of the predicted dilution from near-field modelling. It is predicted that the plume will surface within the mixing zone under low currents. Sampling of flood stages may experience moderate (0.1-0.2 m/s) to relatively high currents (~0.4-0.6 m/s) and considered interpretation of the data may be necessary in terms of a mid-water column plume intersection or near the seabed as interpreted by the modelling (Section 7.7).
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.

8.5 Receiving waters sampling locations

The spatial design of the field survey is comprised of the following sites and depths to be carried out during three sampling events based on tidal cycle (ebb, flood and slack), as depicted in Figure 8-1

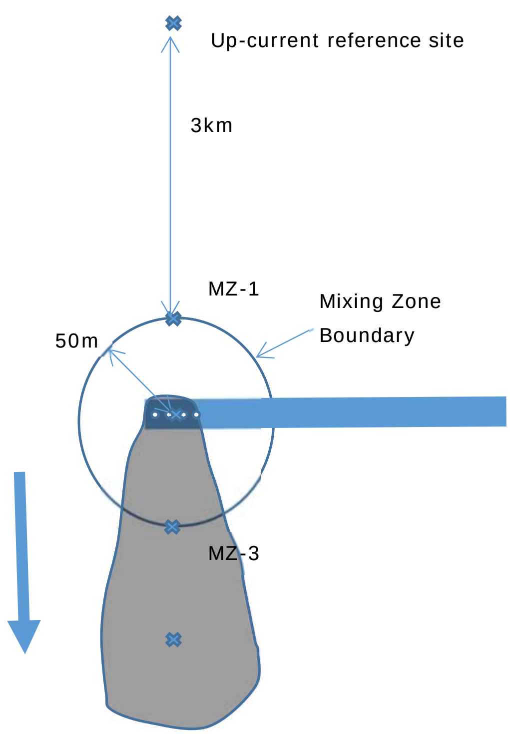
- A drogue will be deployed overhead the discharge point at the beginning of each tidal range to determine the direction of water flow. The drogue will be approximately 2 m below the surface to allow for an accurate assessment of the current flow (i.e. if against wind directions).
- PFW discharge pump at the YGP on an hourly basis over the 7 hours discharge of ~500 m^3 (if practicable) to accurately characterise the PFW discharge over the entire event;
- Water sampling and profiling at
    - an up-current reference site 3 km from the diffuser to characterise the ambient background marine water quality immediately prior to or after each of the 3 tidal cycles in the vicinity of the mixing zone;
    - the boundary of the mixing zone, 50 m from the outfall in the four cardinal directions from the current;
    - 100 m downstream of the outfall along current to allow estimation of further dilution beyond the mixing zone.

Idealised target locations have been identified in Table 8.4 and Figure 8-1 for different tidal scenarios but may vary based on actual direction of water flow.

Table 8.4 Indicative receiving water sampling points

Location ID	Easting	Northing
PW-02 – Discharge Pump (at YGP)	546947	8425312
PW Outfall	542277	8425557
Mixing zone boundary sites		
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
Reference sites		
Ref-1 (default 1.3 km north)	542277	8428557
Ref-2 (default 1.3 km south)	542277	8422557

(a) Flood tide



(b) Slack water

Location ID	Easting	Northing

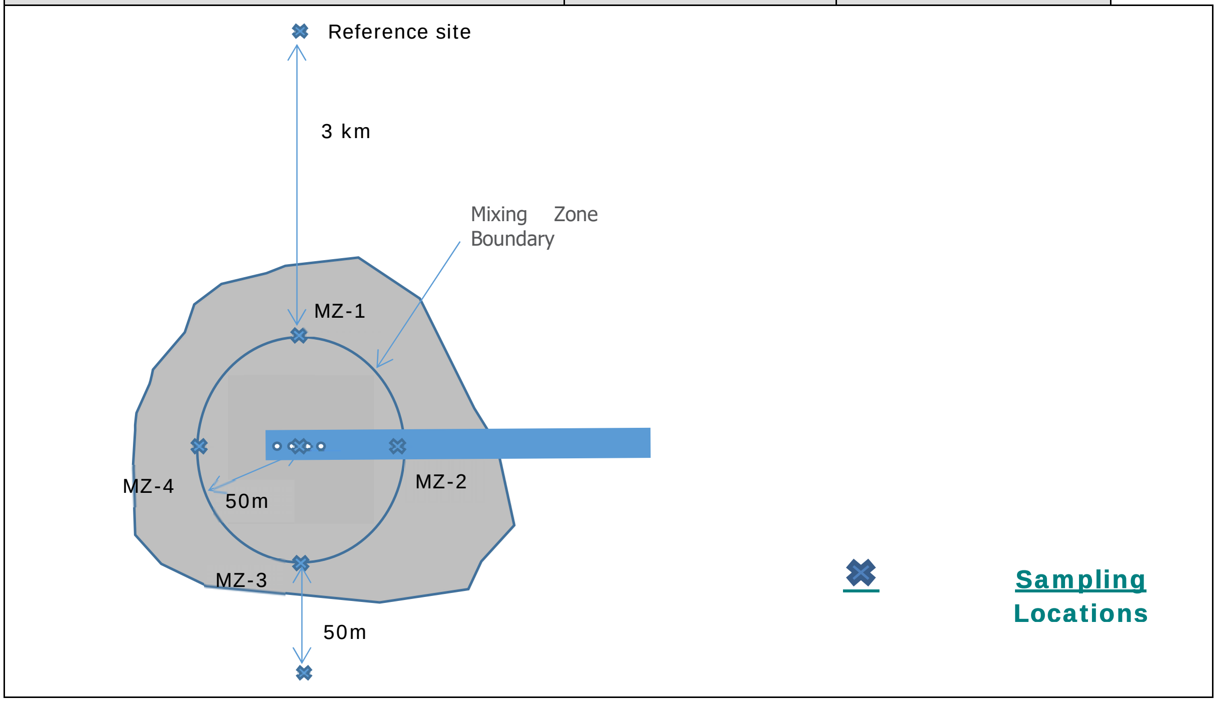


Figure 8-1 Indicative water sampling sites

The plume depth will vary as a function of the tidal stage and current speed. To ensure samples are collected from within the plume, a small vessel (<10 m) will be utilised to allow accurate positioning and to follow the drogue direction. A GPS will be used to precisely locate the outfall, mixing zone boundary and sampling sites during the survey.

8.6 Sediment quality assessment

Sediment quality will be assessed in conjunction with shoreline sediment and biota assessments. The sampling design allows for collection of sediments within the mixing zone and in proximity to sensitive ecological areas. This will assist to determine the long-term impact of discharge to the marine ecosystem including the Walpinhthi Reef Exclusion Zone.

8.7 Sediment sampling locations

Sediment sampling within the proposed mixing zone has been problematic historically due to limited sediment and a dominate fraction of rock and shell (0, 0). It is proposed that three sediment samples are taken within the mixing zone, and two samples are collected at the 50 m boundary along the long-term prevailing current directions (or nearest location sediment is available). A further two samples may be collected between the southern 50 m mixing boundary and the Walpinhthi Reef Exclusion zone.

8.8 Sample collection overview

All sample processing will be in accordance with AS/NZS 5667.1:1998 at NATA-certified laboratories. Samples will be stored and transported in accordance with the analytical laboratory requirements and required preservation techniques and holding times.

Receiving water samples will be collected only from the surface depth. For both tidal events the following number of samples are anticipated:

Table 8.5 Sample numbers per site when collecting from surface depth (assumes flood = southern current, slack = southern current (but could be either))

Sample numbers	Flood	Slack
PW-02 – Discharge Pump (at YGP)	3	3
PW outfall	3	3
Mixing zone boundary sites		
MZ-1 (north 50 m)	3	3
MZ-2 (east 50 m)	3	3
MZ-3 (south 50 m)	3	3
MZ-4 (west 50 m)	3	3
Outside mixing zone sites		
MZ-5 (north 100 m)		
MZ-6 (south 100 m)	3	3
Reference sites		
Ref-1 (default 3 km north)		
Ref-2 (default 3 km south)	3	3
QA/QC samples		
Splits	2	2
Triplicates	2	2
Rinsate (laboratory supplied)	1	1
Blanks (laboratory supplied)	1	1
Subtotals	30	30
Total		60

Water quality CTD profiles will be completed at each site for temperature and conductivity through the water column.

A total of seven sediment samples will be collected using a grab sampler.

8.9 Physio-chemical parameters

A key objective of the field surveys 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 analytes known to be in the produced formation water listed in Table 8.2.

Table 8.6 Physio-chemical parameters to be measured in receiving water samples

Analyte	Units	LoR
Physio-Chemical		
Salinity	psu	0.1
Conductivity	mS/cm	0.1
Total Dissolved Solids	mg/L	5.0
Total Suspended Solids	mg/L	1.0
Turbidity	NTU	0.1
Nutrients		
Total Organic Carbon	mg/L	1.00
Total Oxidised Nitrogen	mg/L	0.01
Ammoniacal Nitrogen	mg/L	0.01
Total Nitrogen	mg/L	0.05
Metals		
Antimony (Sb)	µg/L	0.5
Arsenic (As)	µg/L	0.5
Barium (Ba)	µg/L	1.0
Beryllium (Be)	µg/L	0.1
Boron (B)	µg/L	100
Cadmium (Cd)	µg/L	0.2
Chromium (Cr)	µg/L	0.5
Cobalt (Co)	µg/L	0.2
Copper (Cu)	µg/L	1.0
Iron	µg/L	5.0
Lead (Pb)	µg/L	0.2
Manganese (Mn)	µg/L	0.5
Mercury (Hg)	µg/L	0.04
Molybdenum (Mo)	µg/L	0.1
Nickel (Ni)	µg/L	0.5
Selenium (Se)	µg/L	2.0
Tin (Sn)	µg/L	5.0
Zinc (Zn)	µg/L	5.0
Other		
Phenol	ug/L	0.1

Analyte	Units	LoR
Total Petroleum Hydrocarbons	µg/L	50
Volatile TPH C6 to C9	µg/L	20
Benzene	µg/L	1
Toluene	µg/L	2
Ethylbenzene	µg/L	2
Xylene	µg/L	2
Polycyclic Aromatic Hydrocarbons	µg/L	2

A key objective of the survey is to determine if accumulation of contaminants is occurring in sediments to determine the long-term impact of discharge to the marine ecosystem including the Walpinhthi Reef Exclusion Zone.

Sediment samples will be analysed for analytes known to be in the produced formation water listed in Table 8.7.

Table 8.7 Physio-chemical parameters to be measured in sediment samples

Analyte	Units	LoR
Nutrients		
Total Organic Carbon	%	0.05
Ammoniacal Nitrogen	mg/kg	1.00
Total Nitrogen	mg/kg	0.05
Metals		
Aluminium (Al)	mg/kg	10
Arsenic (As)	mg/kg	0.2
Barium (Ba)	mg/kg	0.1
Cadmium (Cd)	mg/kg	0.05
Chromium (Cr)	mg/kg	0.05
Cobalt (Co)	mg/kg	0.5
Copper (Cu)	mg/kg	0.1
Iron	mg/kg	5.0
Lead (Pb)	mg/kg	0.5
Manganese (Mn)	mg/kg	0.2
Mercury (Hg)	mg/kg	0.01
Nickel (Ni)	mg/kg	0.1
Selenium (Se)	mg/kg	0.05
Zinc (Zn)	mg/kg	0.25
Other		
Phenols	mg/kg	0.5
Total Recoverable Hydrocarbons	mg/kg	250

Analyte	Units	LoR
Benzene	mg/kg	0.1
Toluene	mg/kg	0.1
Ethylbenzene	mg/kg	0.1
Xylene	mg/kg	0.1
Polycyclic Aromatic Hydrocarbons	mg/kg	8.0
Physical		
Particle size distributions	%	1

8.10 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. Salinity profiles from the CTD measurements may be used to provide an estimate of dilutions 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 7.7 for validation.

8.11 Schedule

Once this report is accepted by NT EPA, a detailed sampling and analysis plan will be developed and sampling undertaken as soon as possible, subject to operational and logistical constraints.

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

8.12 Ongoing receiving water and sediment monitoring

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

9 PERFORMANCE IMPROVEMENT

Eni has implemented several measures to improve PFW quality, detailed in the following sections.

9.1 Plant trial of lamella clarifier

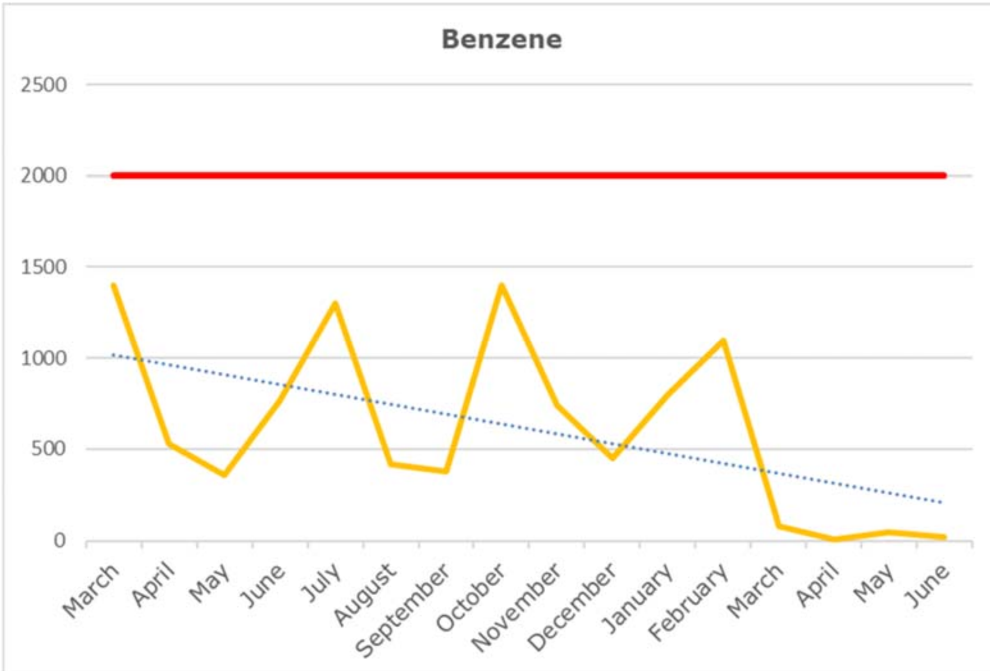
Eni has proposed a plant trial of a lamella clarifier to reduce EPL230-01 parameters from the treated PFW. The objective of the plant trial is to validate if an alternate PWT process involving a lamella plate clarifier (LPC) can treat the produced water to the EPL parameters for safe discharge and identify potential improvements should a permanent LPC be pursued in the future. The parameters of concern, exceeding their respective discharge limits are TSS, toluene, ethylbenzene, m+p xylenes and copper. The trial equipment includes the following.

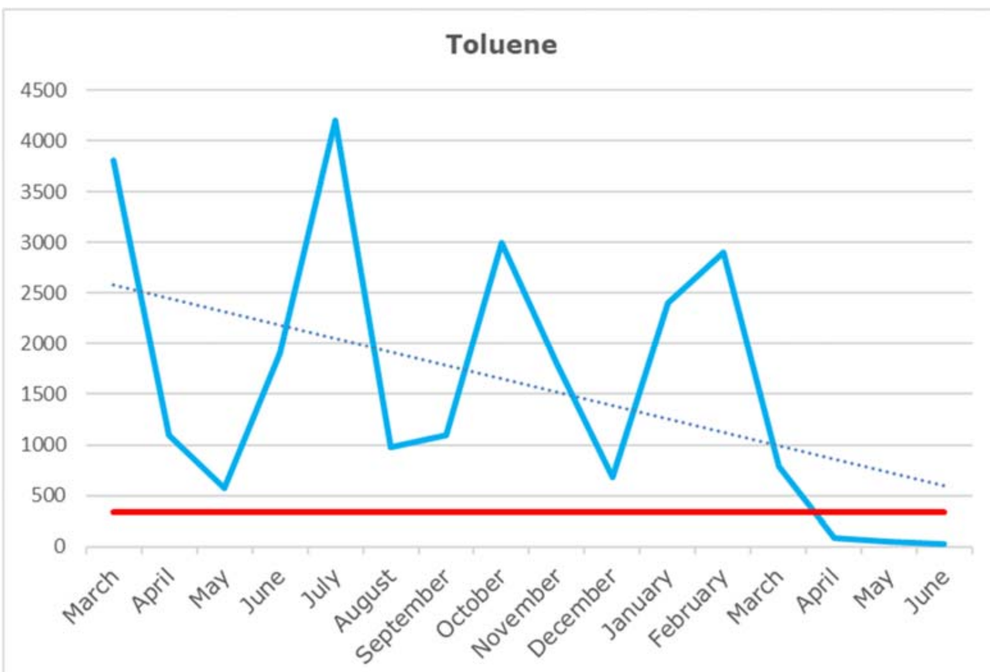
- Two chemical dosing units will be supplied, one for pre-treatment with caustic and the other for post treatment pH correction with citric acid. Each comes complete with magnetic flow metering, pH controller and a digital metering pump for automatic dosing of chemicals.
- The oil water separator (OWS) is designed for bulk removal of oil should carryover occur. This unit also has an air sparging connection for oxidation of metals in the water to enhance their removal.
- A LPC will be operated downstream of the oil water separator. This has inclined plates to increase the surface area for solids removal, and hoppers to collect the solids.

This support includes scoping up all the rental equipment, hoses, fittings etc., developing start/shutdown and operating procedures, and attending site to commission the equipment and fine tune the process. Site operators will then operate the equipment for a 12-week trial period, then it will be decommissioned and demobilized. After a 12-week trial period by the site operators, the equipment will be decommissioned and demobilised (Ref. **Error! Reference source not found.**).

9.2 PFW - BTEX removal progress

Trial procedures to reduce BTEX parameters from the PFW are performed by recirculating the water through baseline PW system to provide full exposure to N_2 sparging at the PW tank. This treatment is provided as a single pass system prior to discharge. The effects of the plant trial on BTEX parameters are shown in Figure 9-1. The treatment trial commenced from March 2023 and lasted until June 2024. The resultant BTEX levels from the treatment trial were recorded monthly and are summarised in Figure 9-1.


Benzene
2500
2000
1500
1000
500
0
March
April
May
June
July
August
September
October
November
December
January
February
March
April
May
June


Toluene
4500
4000
3500
3000
2500
2000
1500
1000
500
0
March
April
May
June
July
August
September
October
November
December
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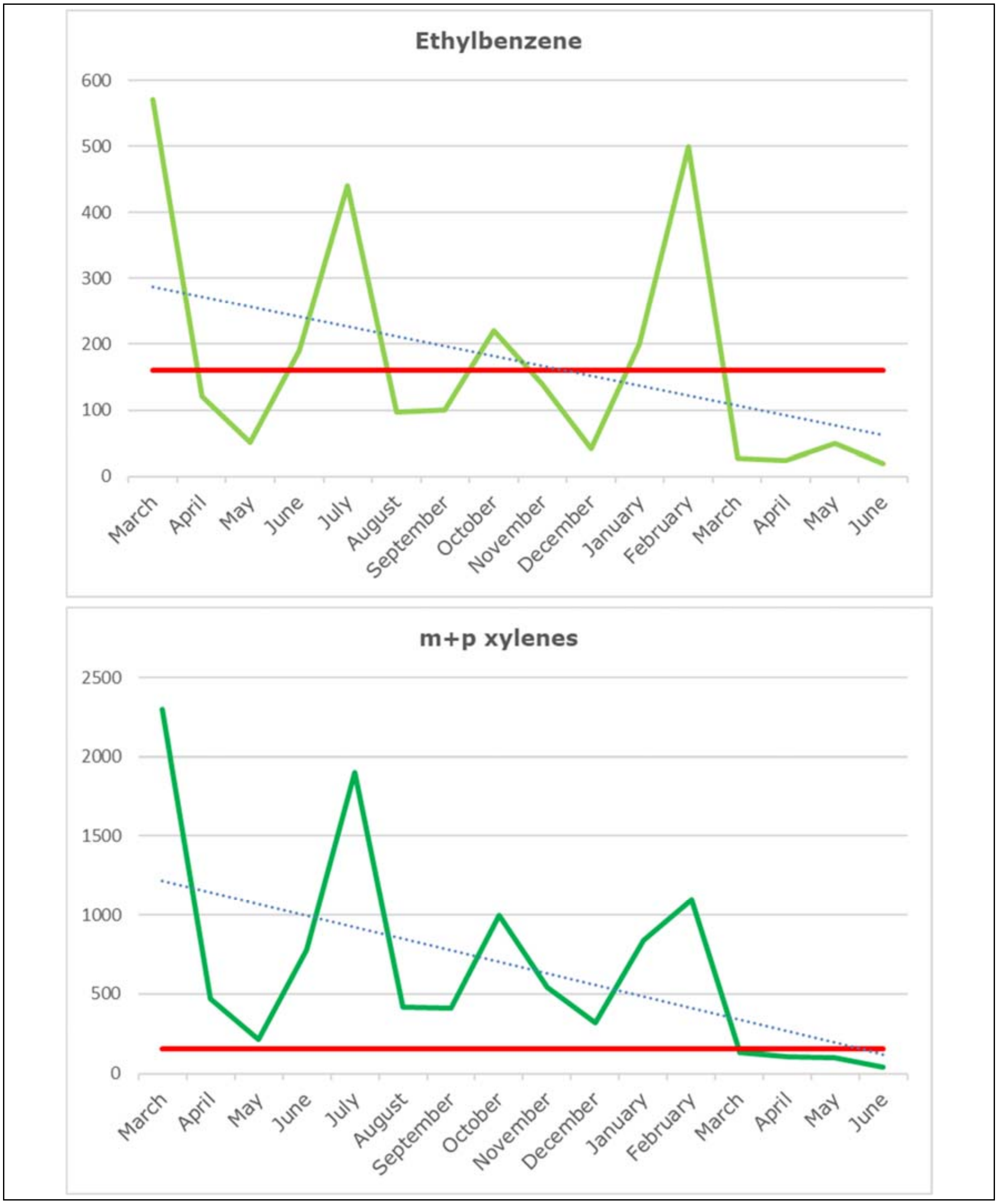

Figure 9-1 Effect of the plant trial operation on BTEX parameters

The treatment trial have showed significant reduction in BTEX levels from March 2023 to June 2024. Previous four discharge results since March 2024 have shown that BTEX results were within current EPL230-

01 limits (Figure 9-1). The most recent results indicate the achievement of 99% level of marine species protection (highest level).

Benzene levels were below its licence limits (2000 µg/l) prior to the treatment trial at 1400 µg/l. However, the treatment trial has demonstrated significant reduction in benzene levels, especially between February and June 2024 where the concentrations dropped from 1100 µg/l to 40 µg/l.

Toluene, ethylbenzene and m+p xylenes levels on the other hand, were significantly exceeding their licence limits (330 µg/l, 160 µg/l and 150 µg/l respectively) prior to the treatment trial at 3800 µg/l, 570 µg/l and 2300 µg/l respectively. Subsequently, the treatment trial have significantly reduced these parameters below their respective licence limits. The achievement of toluene levels below the licence limit was observed from April 2024 onwards, while that of ethylbenzene and m+p xylene levels was observed earlier, from March 2024 onwards.

By the end of the trial in June, the final recorded values of all parameters were at most 40 µg/l. Benzene levels demonstrated 98% reduction from its pre-trial levels and 99% reduction from its licence limit. Toluene levels demonstrated 99% reduction from its pre-trial levels and 93% reduction from its licence limit. Ethylbenzene levels demonstrated 96% reduction from its pre-trial levels and 87% reduction from its licence limit. Finally, m+p xylene levels demonstrated 98% reduction from its pre-trial levels and 73% reduction from its licence limit.

9.3 Temporary trial of water clean-up equipment

A temporary trial of a proposed water clean-up process was conducted to test for metalloids and solids reduction. The process includes flocculation of metalloids and other solids by using a high pH coagulant. The process flow remains as a single pass system but reduced to 10-13 m^3/hr.

Table 9.1 represents the results of the trial operation. The parameters below the license limit are depicted in 'green' text, while the parameters exceeding the license limit are depicted in 'red' text. Cells with "<" before the value indicate the concentration was below detection limits. The results show that manganese levels have been reduced to undetectable levels at a pH of 10.5.

The next phase of the trial will include an intermediate process where the pH increase is temporarily halted at a pH of 8.8 to facilitate zinc and copper reduction. The pH is then finally raised to 10.5 to facilitate manganese removal.

Table 9.1 Results of coagulant-based plant trial operation

Parameter	EPL230-01 Limit (µg/l)	1st Run		2nd Run		3rd Run	
		Pre-treatment	Post-treatment	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
		18/06/2024	24/06/2024	28/08/2024	2/09/2024	3/10/2024	21/10/2024
BTEX Parameters							
Benzene	2000	450	78	130	9.4	<50	<20
Toluene	330	1400	290	630	83	<50	<20
Ethylbenzene	160	180	28	130	24	<50	<20
m+p xylene	150	820	135	580	110	<100	<40
Metals							
Copper	8	15	11	9.7	15	18	27
Manganese	80	910	160	500	52	53	<5
Zinc	43	250	100	72	100	78	100

9.4 Produced water tank modifications

Eni has suspected that a buildup of material is occurring in the base of PW tank, resulting in leaching of metals as the water level decreases during treatment. An investigation of the sparging system in base of PW Tank with off-the-shelf materials, has been proposed. The investigation will aid in identifying appropriate modifications to the PW tank, which facilitates solids removal by keeping them "suspended" during storage prior to treatment. As a result, heavy materials are separated, and the PW system is kept clear of material that generally builds up in the vessels.

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APPENDIX A SUMMARY OF PRODUCED WATER MONITORING RESULTS 2023-2024

kent

Calculation of Dilution Factors 2017-2024
Project: Blacktip Operations
Client: Eni Australia B.V.

Date of Review
17/12/2024

Parameters flagged in the 2017 PFW-MP
Parameters exceeding 100 dilutions
Parameters exceeding ANZG (2018) values but below 100 dilutions
Parameters below ANZG (2018) values

Parameter	Unit	2024 Monitoring Triggers	ANZG (2018) Values at 99% LOSP	*Measured Concentrations* Measured Conc. 2017	Measured Conc. 2018	Measured Conc. 2019	Measured Conc. 2020	Measured Conc. 2021	Measured Conc. 2022-	Measured Conc. 2023-	*Dilution Factors* Dilution Factor 2023-	Max Dil. Factor	Notes
pH	unitless	8.5	8.5	6.92	7.60	7.60	7.92	8.06	7.91	8.07	3	38	
Electrical Conductivity	uS/cm			995.33	879.00	1,251.67	3,763	39,080	64,183	68,027			
DO	%Sat			9.73	6.00	6.93	7.19	7.75	7.42	9.50			
Temperature	°C												
Turbidity	NTU			22.33	13.00	14.00	7.20	11.08	15.25	23.49			
BOD	mg/l			24.53	59.00	90.00	46.81	72.52	47.31	311.04			
COD	mg/l			1,653.33	2,340.00	2,653.33	4,771	2,667	2,642	2,823			
TSS	mg/l	10	10	519.33	10.00	23.33	14.45	17.50	38.33	29.31	3	52	
TDS	mg/l			681.00	795.00	1,113.33	3,716	27,092	46,850	49,400			
TOC	mg/l			496.67	1,195.50	834.33	1,338	652.33	499.67	628.75			
OiW	mg/l	6	6	10.89	22.12	15.40	13.91	15.51	17.83	27.84	5	5	
Total Phos	mg/l			2.21	22.55	0.05	0.05	0.05	0.05	0.17			
Total Nitro	mg/l			3.38	6.10	7.67	7.26	19.76	43.18	42.26			
Oxid. Nitro (NOx)	mg/l			0.07	0.02	0.02	0.02	0.01	0.03	0.02			
Ammon. N (NH3-N)	mg/l		500	3.60	2.30	6.17	7.20	16.76	42.43	39.60	0	0	
Nitrate (NO3-)	mg/l			0.05	0.02	0.02	0.01	0.01	0.03	0.02			
Nitrite (NO2-)	mg/l			0.01	0.01	0.02	0.02	0.01	0.01	0.03			
Al_F	µg/L								35.85	105.81			
Al_T	µg/L			60.00	55.00	96.67	1,069	45.01	26.40	130.20			
Ar				1.33	1.00	1.00	1.86	0.92					
As_F	µg/L								3.96	1.98			
As_T	µg/L								4.28	2.09			
Ba_F	µg/L								100.174	101.250			
Ba_T	µg/L			653.33	640.00	153.00	7.386	68.437	91.350	106.850			
Be_F	µg/L								1.65	1.25			
Be_T	µg/L			0.50	0.50	0.50	0.50	0.46	2.00	1.25			
B_F	µg/L								2.945	3.726			
B_T	µg/L			70.00	65.00	63.33	211.25	1.440	3.360	3.679			
Cd_F	µg/L		0.7						0.69	0.44	1	1	
Cd_T	µg/L		0.7	1.07	0.10	0.13	0.13	0.09	0.80	0.45	1	2	
Co_F	µg/L		0.005						0.58	1.30	260	260	
Co_T	µg/L		0.005	1.00	1.00	1.00	1.00	1.00	0.40	1.30	260	260	
Cu_F	µg/L		0.3						3.68	9.41	31	31	
Cu_T	µg/L	3	0.3	1.00	1.00	1.00	1.25	1.51	11.05	10.30	34	37	Trigger value has varied from that given in the 2024 annual monitoring report (3ug/L)
Cr_F	µg/L								4.68	3.03			
Cr_T	µg/L			1.67	1.50	1.33	1.50	2.36	4.00	2.89			
Cr III	µg/L		7.7						33.35	31.26	4	4	
Cr VI	µg/L		0.14						33.35	31.26	223	238	
Fe_F	µg/L								3.353	2.226			
Fe_T	µg/L			1,833.33	445.00	4,410.33	7.857	29.708	6.110	2.681			
Hg_F	µg/L		0.1						1.08	0.61	6	11	
Hg_T	µg/L		0.1	0.74	0.70	0.30	0.37	0.71	2.03	0.93	9	20	
Mg_F	µg/L								143,090	63,896			
Mg_T	µg/L			0.53	2.05	0.50	47.00	31.00	84,650	97,721			
Mn_F	µg/L	80	80						189.19	109.19	1	2	
Mn_T	µg/L	80	80	109.67	230.00	111.33	166.22	324.01	161.50	113.82	1	4	
Mo_F	µg/L								2.08	1.86			
Mo_T	µg/L			1.67	1.00	1.00	1.00	1.08	2.00	1.88			
Pb_F	µg/L		2.2						0.76	1.45	1	1	
Pb_T	µg/L		2.2	1.00	1.00	1.67	1.00	0.92	1.29	1.49	1	1	
Ni_F	µg/L		7						3.56	3.46	0	1	
Ni_T	µg/L		7	7.67	9.50	18.67	7.56	6.01	4.54	3.68	1	3	
Se_F	µg/L								7.45	3.88			
Se_T	µg/L			1.00	1.00	3.33	1.00	1.00	8.00	3.89			
Sn_F	µg/L								3.50	3.98			
Sn_T	µg/L			1.00	1.00	1.00	1.00	1.00	4.00	2.78			
Sr_T				273.33	215.00	69.67							
Zn_F	µg/L	23	3.3						452.93	44.80	14	137	Trigger value has varied from that given in the 2024 annual monitoring report (23ug/L)
Zn_T	µg/L	23	3.3	66.33	7.50	153.00	21.22	66.01	80.60	56.84	17	46	Trigger value has varied from that given in the 2024 annual monitoring report (23ug/L)
Radium Isotopes (Ra 226)	mBq/L				30±10	4.00	30		6.800				
Radium Isotopes (Ra 228)	mBq/L				100.00	9.00	40		14.000				
MBAS	ug/L								0.10	0.10			
Phenol	µg/L	1200	270	323.33	230.00	723.33	651.11	552.58	175.36	132.50	0	3	Discharge limit has varied from that given in the 2024 annual monitoring report (1200ug/L)
Pentachlorophenol	µg/L	55	11	170.00	252.50	200.00	140.56	12.50	21.36	23	2	23	Discharge limit has varied from that given in the 2024 annual monitoring report (55ug/L)
2-Chlorophenol	ug/L			34.00	50.50	40.00	29.22	2.50	4.27	7.40			
2-Methylphenol (O-Cresol)	ug/L			486.67	270.00	1,550.00	974.44	893.33	337.27	223			
3/4-Methylphenol	ug/L			456.67	375.00	1,486.67	1,170	731.67	224.67	174.60			
2-Nitrophenol	ug/L			34.00	50.50	40.00	30.0	2.50	4.27	7.40			
Ethyl/Dimethylphenols	ug/L			353.33	135.00	696.67	672.29	418.42	335	301			
Benzoic acid	ug/L												
2,4-Dichlorophenol	ug/L			34.00	50.50	330.00	28.22	2.50	4.27	7.40			
2,6-Dichlorophenol	ug/L			34.00	50.50	40.00	28.22	3.50	4.27	7.40			
4-Chloro-3-Methylphenol	ug/L			170.00	252.50	200.00	145.56	16.25	21.36	37.00			
2,4,6-Trichlorophenol	ug/L		3	34.00	50.50	40.00	29.00	155.58	4.27	7.40	2	52	
2,4,5-Trichlorophenol	ug/L			34.00	50.50	40.00	29.00	190.58	4.27	7.40			
2,4-Dinitrophenol	ug/L			680.00	1,010.00	800.00	558.11	45.25	85.45	148.00			
4-Nitrophenol	ug/L			680.00	1,010.00	800.00	558.89	179.17	74	92.00			
2,3,4,5-Tetrachlorophenol	ug/L								10	16.10			
2,3,4,6-Tetrachlorophenol	ug/L			34.00	50.50	40.00	28.22	2.42	4.27	4.08			
4,6-Dinitro-o-cresol	ug/L								10.00	58.20			
TPH	mg/L								10.82	8.16			
PAH	ug/L			24.07	10.00	117.33	25.35	20.23	20.06	29.41			
Benzene	µg/L	1300	500	433.33	470.00	1,500.00	2,123	1,731	1,712	846	2	4	Trigger value has varied from that given in the 2024 annual monitoring report (1300ug/L)
Toluene	µg/L	330	110	700.00	345.00	2,866.67	3,688	3,617	3,446	2,110	19	34	Discharge limit has varied from that given in the 2024 annual monitoring report (330ug/L)
Ethyl benzene	µg/L	160	50	190.00	160.00	320.00	345.38	661	406.15	221.46	4	13	Discharge limit has varied from that given in the 2024 annual monitoring report (160ug/L)
Xylene (m+p)	µg/L	150	50	644.67	665.00	1,333.33	1,443	1,401	1,541	928.46	19	31	Discharge limit has varied from that given in the 2024 annual monitoring report (150ug/L)
Naphthalene	µg/L	120	50	107.33	55.50	59.00	32.89	15.58	50.15	44.08	1	2	Discharge limit has varied from that given in the 2024 annual monitoring report (120ug/L)
Anthracene	µg/L	7	0.01	1.00	5.50	4.00	1.00	0.93	1.00	1.86	186	550	Discharge limit has varied from that given in the 2024 annual monitoring report (7ug/L)
Fluoranthene	µg/L	2	1	1.00	5.50	4.00	1.00	0.93	1.00	1.87	2	6	Discharge limit has varied from that given in the 2024 annual monitoring report (2ug/L)
Benzo(a)pyrene	µg/L	0.7	0.1	1.00	5.50	4.00	1.00	0.93	1.40	1.93	19	55	Discharge limit has varied from that given in the 2024 annual monitoring report (0.7ug/L)
Xylene (o)	ug/L			776.67	255.00	503.33	507.78	491.67	461.11	327.46			
TRH C6-C9	ug/L			5,966.67	4,200.00	8,500.00	11,013	13,442					
TRH C6-C10	ug/L			7,933.33	5,500.00	9,966.67	15,922	15,083					
TRH C6-C10 less BTEX	ug/L			4,733.33	3,600.00	3,430.00	8,111	7,522					
TRH C10-C14	ug/L			15,450.00	187,550.00	11,333.33	95,078	50,250					
TRH C15-C28	ug/L			291.00	1,010.00	813.33	8,900	5,325					
TRH C29-C36	ug/L			62.00	100.00	100.00	304.44	91.75					
TRH >C10-C16	ug/L			12,500.00	167,350.00	10,733.33	25,411	8,942					
TRH >C10-C16 less Napth	ug/L			9,436.67	167,300.00	10,333.33	14,289	8,917					
TRH >C16-C34	ug/L			123.33	460.00	350.00	6,283	1,109					
TRH >C34-C40	ug/L			3,733.33	100.00	100.00	228.89	100					
TPH >C16-C35 Aliphatic	ug/L			3,700.00	100.00	113.33	96.25	250.83					
TPH >C35 Aliphatic	ug/L			470.00	100.00	100.00	100	216.67					
TPH C16-C35 Aromatic	ug/L			83.33	90.00	131.67	51.25	1,106					
Napththalene	ug/L		50	22.67	55.00	115.33	61.67	38.67			0	2	
Acenaphthylene	ug/L			1.00	5.50	4.00	1.00	1.68					
Acenaphthene	ug/L			1.00	5.50	4.00	1.00	0.93					
Fluorene	ug/L			1.33	5.50	4.67	1.50	0.93					
Phenanthrene	ug/L		0.6	1.00	5.50	4.33	1.00	0.93			0	9	
Pyrene	ug/L			1.00	5.50	4.00	1.00	0.93					
Benzo(a)anthracene	ug/L			1.00	5.50	4.00	1.00	0.93					
Chrysene	ug/L			1.00	5.50	4.00	1.00	0.93					
Benzo(b,j+k)fluoranthene	ug/L			2.00	11.00	8.00	2.00	1.59					
Indeno(1,2,3- c,d)pyrene	ug/L			1.00	5.50	4.00	1.00	0.93					
Dibenzo(a,h)anthrace ne	ug/L			1.00	5.50	4.00	1.00	0.93					
Benzo(g,h,i)perylene	ug/L			1.00	5.50	4.00	1.00	0.93					
Benzo(a)pyrene TEQ	ug/L			5.00	5.00	20.00	5.00	4.59					
2-Methyl-4,6-Dinitrophenol	ug/L			340.00	505.00	400.00	279.22	25					
MBA	ug/L			0.10	0.30			0.10					

ANNUAL MONITORING REPORT – YGP EPL230-01 (10/2/2023 – 9/2/2024)

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PR-OP	01	03/05/2024	Issued for Information					
PR-OP	00	07/03/2024	Issued for Information	SALL	JCO	GPA		
Validity Status	Rev. Number	Date	Description	Prepared by	Checked by	Approved by	Contractor Approval	Company Approval
Revision index								

eni australia	Project name **BLACKTIP OPERATIONS**	Company identification 000036_DV_PR.HSE.1210.000 Job N. ____
		Contractor identification Contract ____
(Vendor logo and business name)		Vendor identification .... Order N..........................
Facility Name BLACKTIP	Location AUSTRALIA WA-33-L	Scale: 1:1 / Sheet of Sheets: 1 / 103
Document Title **ANNUAL MONITORING REPORT – YGP EPL230-01 (10/2/2023 – 9/2/2024)**		Supersedes N................. Superseded by N......... Plant Area / Plant Unit

REVISION HISTORY

Rev.	Date	Nr. of sheets	Description
00	07/03/24	93	Issued for Information
01	03/05/24	103	Issued for Information Updated to address NT EPA comments

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1. EXECUTIVE SUMMARY

The Blacktip Annual Monitoring Report 2023 summarises the environmental performance of the Blacktip Yelcherr Gas Plant (YGP) for the reporting period 10 February 2023 to 9 February 2024. It makes this comparison against the Environmental Protection Licence (EPL) 230-01.

At times, this Report provides information required for licence anniversary reporting, with a 10 Feb 2023 to 9 Feb 2024 period. At other times, information is reported in Financial Year terms, based on NGER reporting (July to June). Where anniversary or financial year reporting is used, it is clearly marked.

This Report accompanies the Annual Return, which provides a summary of the compliance against the EPL.

1.1 Production

Production output for the reporting period (Calendar year) was:

- Gas production was 390.6 MSCM;
- Annual Gas production was 297.976 ktonnes; and
- Condensate production was 4,355 tonnes.

1.2 Discharges to Water

- Offshore produced water monitoring (in part for model validation) was conducted in June 2023;
- Annual shellfish and sediment monitoring was conducted in November 2023 with the results consistent across sampling sites, with little variation between the control and monitoring sites, providing confidence that there are no adverse impacts from produced water discharge to the environment;
- Increased volume of PW discharge occurred in 2023; and
- Non-compliances with limits and trigger values are outlined in Table 10.1. This includes Produced Water limits for Oil in Water, Manganese, Zinc, Copper, Naphthalene, Benzene, Toluene, Ethylbenzene, and Xylene (m+p);

1.3 Discharges to Air

- Total greenhouse gas emissions from Yelcherr Gas Plant calculated in the latest NGER reporting period (July to June) were 28,550 tCO2-e; and
- Total volume of gas flared was 2,140 KSCM, with an average daily rate of 8.5 KSCM/d, compared with 5.86KSCM/d in the previous licence period.

1.4 Discharges to Land

<u>Liquid waste discharges – treated wastewater</u>

- A total of 2.9ML of treated wastewater effluent was reused for irrigation; and
- Non-compliances with limits and trigger values are outlined in Table 10.1. This includes trigger values for Oil in Water, pH, E.coli, BOD and TSS.

Liquid waste discharges – stormwater

- Non-compliances with the trigger value for oil in water, occurred on 6 occasions; and
- Oil in water typically ranged between 0-4.8 mg/l.

1.5 Groundwater

- A total of 15.3ML was abstracted for potable water use; and
- All quarterly monitoring results were within the Australian Drinking Water Guidelines and ANZECC guidelines.

1.6 Waste Management

- Blacktip operations generated an approximate total of 225.92 tonnes of hazardous waste, and 30.83 tonnes of non-hazardous waste.

1.7 Non-Conformances

Non-Conformances recorded in 2023/2024 are reported in the Annual Return and recorded below in Table 1.1.

Table 1.1: 2023/2024 Non Conformances

Date of NC	Date detected	Licence Number	Clause breached	Agency	Case Description	Case Number	NC Description / remarks
14-Feb-23	04/04/23	EPL230-01	Condition 28	NTEPA	Blacktip - YGP - Non-compliance with EPL230-01 - Produced Water and Wastewater Discharge	186534	PW above EPL Limit for OiW, Copper (Filtered), Copper (Total), Toluene, Ethylbenzene, Xylene,
28/03/23	15/05/23	EPL230-01	Condition 28	NTEPA	Blacktip - YGP - Non-compliance with EPL230-01 - Produced Water and Wastewater Discharge	182863	PW above EPL Limit for TSS, Copper (Filtered), Copper (Total), Toluene, Ethylbenzene, Xylene, PW above trigger values over three consecutive samples for OiW, Benzene, and Zinc (Total). WW above EPL Limit for TSS and OiW.
12/04/23	27/06/23	EPL230-01	Condition 28	NTEPA	Blacktip - YGP - Non-compliance with EPL230-01 - Waste Water Discharge	186514	WW above EPL limits for BOD, TSS and E. Coli
16/04/23	27/06/23	EPL230-01	Condition 28	NTEPA	Blacktip - YGP - Non-compliance with EPL230-01 - Produced Water Discharge	186526	PW above EPL Limits for Toluene, Xylene, Naphthalene and Total Copper, PW above Trigger Values for 3 consecutive periods for Zinc (Total and Filtered) and Copper (Filtered)
14/05/23	29/05/23	EPL230-01	Condition 28	NTEPA	Blacktip - YGP - Non-compliance with EPL230-01 - Produced Water and Wastewater Discharge	186689	PW above EPL Limits for Toluene, Xylene, and Copper (Total and Filtered), WW below pH and above OiW limits.
15/06/23	20/07/23	EPL230-01	Condition 28	NTEPA	Blacktip - YGP - Non-compliance with EPL230-01 - Waste Water Discharge	189300	WW above EPL limits for TSS
19/06/23	20/07/23	EPL230-01	Condition 28	NTEPA	Blacktip - YGP - Non-compliance with EPL230-01 - Produced Water Discharge	189305	PW above EPL Limits for OiW, Mn (Dissolved and Total), Toluene, Ethylbenzene, and Xylene (m+p)
13/07/23	18/08/23	EPL230-01	Condition 28	NTEPA	Blacktip - YGP - Non-compliance with EPL230-01 - Waste Water Discharge	191247	WW above EPL limits for BoD
16/07/23	18/08/23	EPL230-01	Condition 28	NTEPA	Blacktip - YGP - Non-compliance with EPL230-01 - Produced Water Discharge	191246	PW above EPL Limits for OiW, Toluene, Ethylbenzene, and Xylene (m+p), Copper (dissolved and total), Mn (dissolved and total), Toluene, Ethylbenzene, and Xylene (m+p)
05/08/23	18/09/23	EPL230-01	Condition 28	NTEPA	Blacktip - YGP - Non-compliance with EPL230-01 - Produced Water Discharge	193306	PW above EPL Limits for Toluene, Xylene (m+p), Zinc (dissolved and total), pH
15/08/23	18/09/23	EPL230-01	Condition 28	NTEPA	Blacktip - YGP - Non-compliance with EPL230-01 - Waste Water Discharge	193307	Blacktip - YGP - Non-compliance with EPL230-01 - Waste Water monitoring parameters measured above limits.
12/09/23	27/10/23	EPL230-01	Condition 28	NTEPA	Blacktip - YGP - Non-compliance with EPL230-01 - Produced Water Discharge	196767	PW above EPL Limits for Toluene, Xylene (m+p), Zinc (dissolved and total), Manganese (dissolved and total), Copper (dissolved and total), and OiW
07/11/23	30/11/23	EPL230-01	Condition 28	NTEPA	Blacktip - YGP - Non-compliance with EPL230-01 - Produced Water Discharge	200146	PW above EPL Limits for Toluene, Xylene (m+p), Zinc (total), Manganese (dissolved and total)
08/11/23	30/11/23	EPL230-01	Condition 28	NTEPA	Blacktip - YGP - Non-compliance with EPL230-01 - Waste Water Discharge	200151	WW above EPL limits for TSS
10/10/23	21/11/23	EPL230-01	Condition 28	NTEPA	Blacktip - YGP - Non-compliance with EPL230-01 - Produced Water Discharge	199410	PW above EPL Limits for Toluene, Ethyl benzene, Xylene (m+p), Zinc (dissolved and total), Manganese (dissolved and total)
10/11/23	10/11/23	EPL230-01	Condition 19.1 & 19.2	NTEPA	Blacktip-YGP-LOPC-[Reported to NTEPA] During transfer of sludge from main tank to ISO tanks the transfer hose parted and sludge spilled to grade	198443	During transfer of sludge from main tank to ISO tanks the transfer hose parted, and sludge spilled to grade
13/12/23	19/01/24	EPL230-01	Condition 28	NTEPA	Blacktip - YGP - Non-compliance with EPL230-01 - Waste Water Discharge	206992	Wastewater monitoring parameters measured above limits for TSS, 50 mg/l (EPL limit = 30mg/l)
18/12/23	19/01/24	EPL230-01	Condition 28	NTEPA	Blacktip - YGP - Non-compliance with EPL230-01 - Produced Water Discharge	206993	Produced Water monitoring parameters measured above limits for copper (filtered), Copper (total), Zinc (total), Toluene and Xylene.
17/01/24	16/02/24	EPL230-01	Condition 28	NTEPA	Blacktip - YGP - Non-compliance with EPL230-01 - Waste Water Discharge		Wastewater above EPL limits for E. Coli
22/01/24	16/02/24	EPL230-01	Condition 28	NTEPA	Blacktip - YGP - Non-compliance with EPL230-01 - Produced Water Discharge		Produced Water above EPL Limits for OiW, Toluene, Ethylbenzene, and Xylene (m+p), Copper (dissolved and total), Mn (dissolved and total), Toluene, Ethylbenzene, and Xylene (m+p).

1.8 Community initiatives

Eni continues to maintain a positive and engaging relationship with the Thamarrurr Rangers, who deliver local environmental monitoring services such as, but not limited to:

- Monitoring of offshore assets (e.g. Single Point Mooring (SPM) and hose);
- Wild fire management;
- Controlled burning;
- Weed and pest monitoring and eradication;
- Marine monitoring;
- Sea turtle monitoring;
- Fauna monitoring and relocation;
- Provision of vessel and crew for offshore environmental sampling;
- Emergency Response: Initial Oil Spill Monitoring Capabilities;
- PW-01 (Produced Water discharge point) monitoring; and
- Containers for Change (plastic bottle recycling).

1.9 Continuous improvement

The following activities were completed during the reporting period to continually improve compliance to EPL230-01 requirements:

- A Comprehensive annual fugitive emissions survey to monitor for gas leaks across YGP was conducted in November 2023;
- A Comprehensive annual venting validation survey to monitor venting sources at YGP was conducted in November 2023;
- A hydrogeological survey was undertaken at YGP (November 2023) to establish an assessment of potential risk to groundwater and provide a third monitoring location to allow improved assessment of groundwater;
- Thamarrurr Rangers participated water outfall sampling training to be used for future sampling exercises;
- A trial skid to remove metalloids from Produced Water has been engineered in preparation for installation in Q2 2024;
- An emergency exercise has been carried out at YGP involving and assessing the Thamarrurr Rangers in first responder capabilities in the event of a hydrocarbon spill in the offshore area (off shore water sampling and monitoring);
- An in depth energy efficiency assessment in accordance with the requirements of ISO50001 was completed;
- Engaged a new third party contractor to conduct site based EPL230-01 monitoring and analysis programme;
- In accordance with Section 48(1), a third party consultant was engaged to conduct an independent environmental audit of the Yelcherr Gas Plant (YGP) on behalf of the NT EPA; and
- Company conducted an Environmental Audit and a 5 Yearly Performance Review of the wastewater treatment plant.

2. INTRODUCTION

This Report summarises the environmental performance of the Blacktip YGP for the reporting period 10th February 2023 to 9th February 2024, as required by condition 63 of the EPL.

Eni Australia Limited (Eni) is Operator of the Blacktip Gas Project in the Northern Territory. The development 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 Yelcherr Gas Plant (YGP) near Wadeye. The processed gas is exported via an onshore export pipeline, by Australian Pipeline Trust, to the customer, Power and Water Corporation.

Blacktip YGP commenced production on 26 August 2009. The operation of the YGP is licensed under the Environmental Protection Licence (EPL), EPL230-01, issued by the former Department of Natural Resources, Environment, The Arts and Sport (NRETAS) (now Northern Territory Environment Protection Authority (NT EPA) on 11th August 2009.

EPL230-01 (the current license) was issued to Eni as the most recent amendment to the EPL.

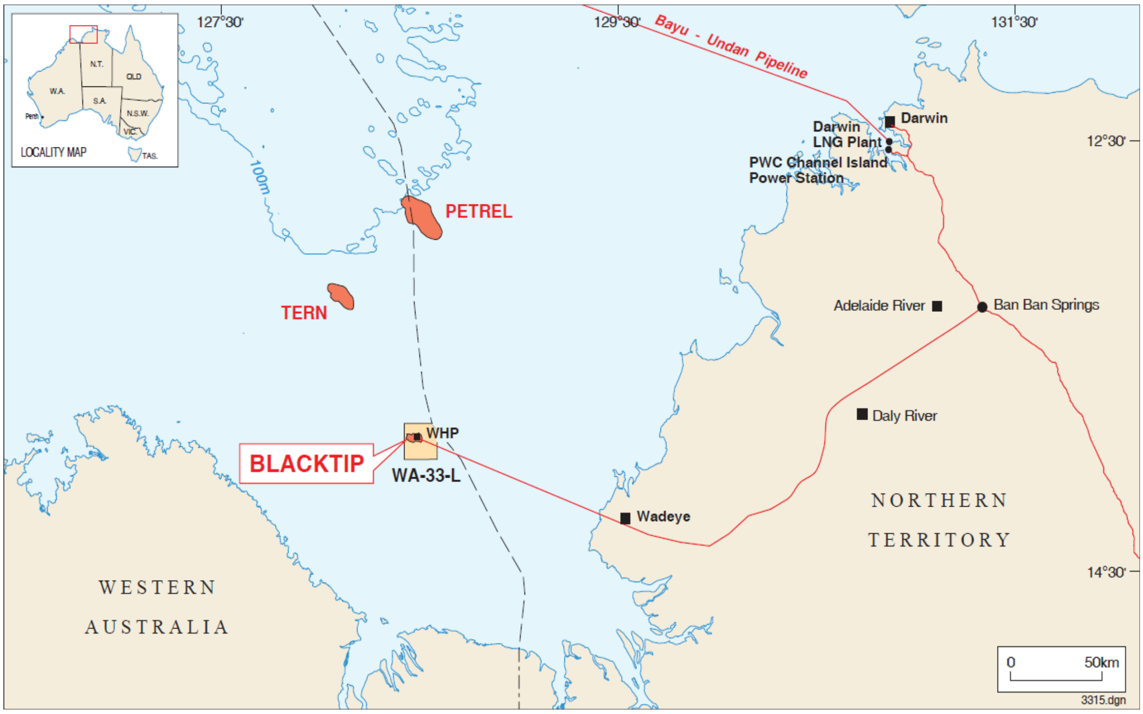


Figure 2.1: Blacktip Project locality map

2.1 Condition 64 requirements

This Report has been prepared in accordance with NT EPA 'Guideline for Reporting on Environmental Monitoring' and the requirements under condition 64 of the EPL, outlined below.

Table 2.1: EPL Condition Clause 64

Clause	EPL condition	Refer Section
64.1	include an updated description of gas plant infrastructure and processes	3.0
64.2	reports on total condensate produced and total gas processed by the gas plant;	4.0
64.3	reports on the quality of gas received by the plant;	4.4
64.4	includes a tabulation of all monitoring data required as a condition of this licence;	Appendices
64.5	includes a trend analysis and interpretation of all monitoring data required as a condition of this licence;	5.0, 6.0, 7.0, 8.0
64.6	includes a long-term trend analysis of monitoring data to demonstrate any environmental impact associated with the activity over a minimum period of three years;	5.0, 6.0, 7.0, 8.0
64.7	reports the total annual emissions for each emission point, as well as for condensate tanks and fugitive emissions.	7.0
64.8	reports the frequency and volume of wastewater discharges for the reporting period;	6.0
64.9	identifies the number of exceedances of trigger values and limits that have occurred during the reporting period, which includes a record of trigger value exceedances in accordance with condition 61;	1.7, Appendices
64.10	is prepared in accordance with the requirements of the NT EPA *Guideline for Reporting on Environmental Monitoring;*	
64.11	demonstrates continuous improvement in air emissions from the authorised air emissions points identified in Attachment 4;	7.0
64.12	demonstrates continuous improvement in wastewater quality from the authorised discharge points identified in Attachment 2.	5.0, 6.0

2.2 Program objectives

Wastewater streams emanating from the YGP include:

- Produced water;
- Sewage wastewater;
- Stormwater runoff from the utilities area; and
- Stormwater runoff from the Open Drains System (ODS).

The above streams may contain pollutants, which, if not properly managed, can enter the groundwater or surface waterways and result in soil and groundwater contamination. Therefore, wastewater must be managed appropriate in accordance with the Onshore Gas Plant Environmental Management Plan 000036_DV_EX.HSE.0684.000, and discharges are to be monitored for pollutants.

2.3 Site information

2.3.1 Site layout

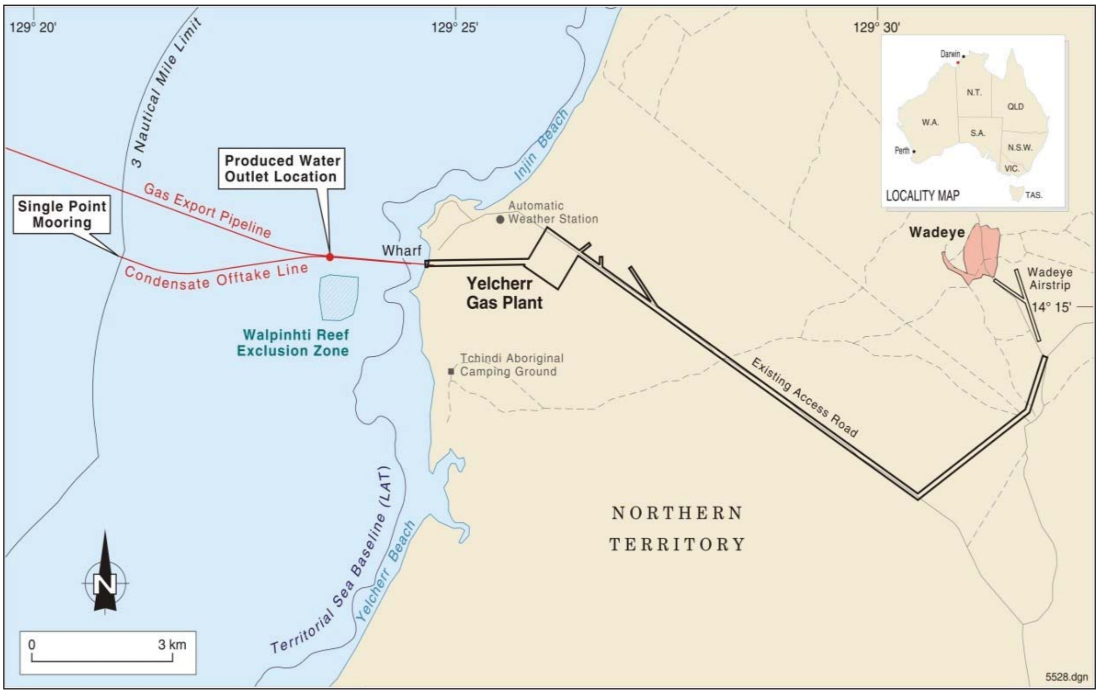


Figure 2.2: Blacktip Project layout

2.3.2 Environmental Context

Wadeye is located in the eastern (onshore) part of the Bonaparte Gulf Basin. The key geological/aquifer unit in the region is the Hyland Bay Formation, of Upper Permian age, which dips to the west (Laws & Brown, 1976). The unit is about 400m thick and was deposited in a deltaic environment during a period of marine transgression. Overlying the Hyland Bay Formation are undifferentiated sediments that have been heavily leached/altered to form a blanket cover of laterite and laterised clays and sandstones (Jamieson, 1991).

The uppermost sediments (in the Hyland Bay Formation) comprise weathered, fine to coarse, clean to clayey sandstone and rounded quartz gravels with interbeds of clay and siltstone. Fracturing within the Hyland Bay Formation sediments has resulted in the development of secondary permeability and highly permeable dual-porosity aquifers in this unit, which have been exploited by bores utilised for water supply by the Wadeye community (Jamieson, 1991). The aquifers are semi-confined to semi-unconfined, with pumping typically resulting in a delayed yield from surrounding sediments (Jamieson, 1991).

The lowermost sediments comprise pink to dark grey clays which are at least 50m thick. This clay unit sub-crops immediately to the east of Wadeye.

Geotechnical investigations undertaken by Advanced Geomechanics (AG, 2005) have confirmed that the general lithological sequence of sandstones, clayey/silty sands and gravels at the plant site is fairly consistent with the sequence found at Wadeye, although no gravels have been encountered at Wadeye.

Interpretation of a 10-day pumping test undertaken by AG (2005) (Figure 5) indicates that the aquifer in the area of the plant site has a transmissivity of around 1,300 m2/day, although the lack of measurement precision with which the test was undertaken causes some uncertainty in the estimated transmissivity. The groundwater level (elevation) at the time of the test in October 2004 was not provided but is estimated to be around +4 mAHD (based on section drawings showing bore elevations). Pumping at around 190kL/day resulted in a final drawdown of 0.2m. Jamieson (1991) reports a typical transmissivity of around 4,000m2/day in the Wadeye area and a specific yield of 10%.

Groundwater flows to the Northwest toward the Bonaparte Gulf coast and discharges as small springs in coastal creek/swamp areas. The hydraulic gradient is low and estimated to be about 0.1% (Jamieson, 1991). Based on the results of bore test data, Jamieson (1991) estimates that groundwater throughflows, (and hence coastal discharges to the sea and creek/wetland systems) are of the order of 1.5Mm3/yr/km.

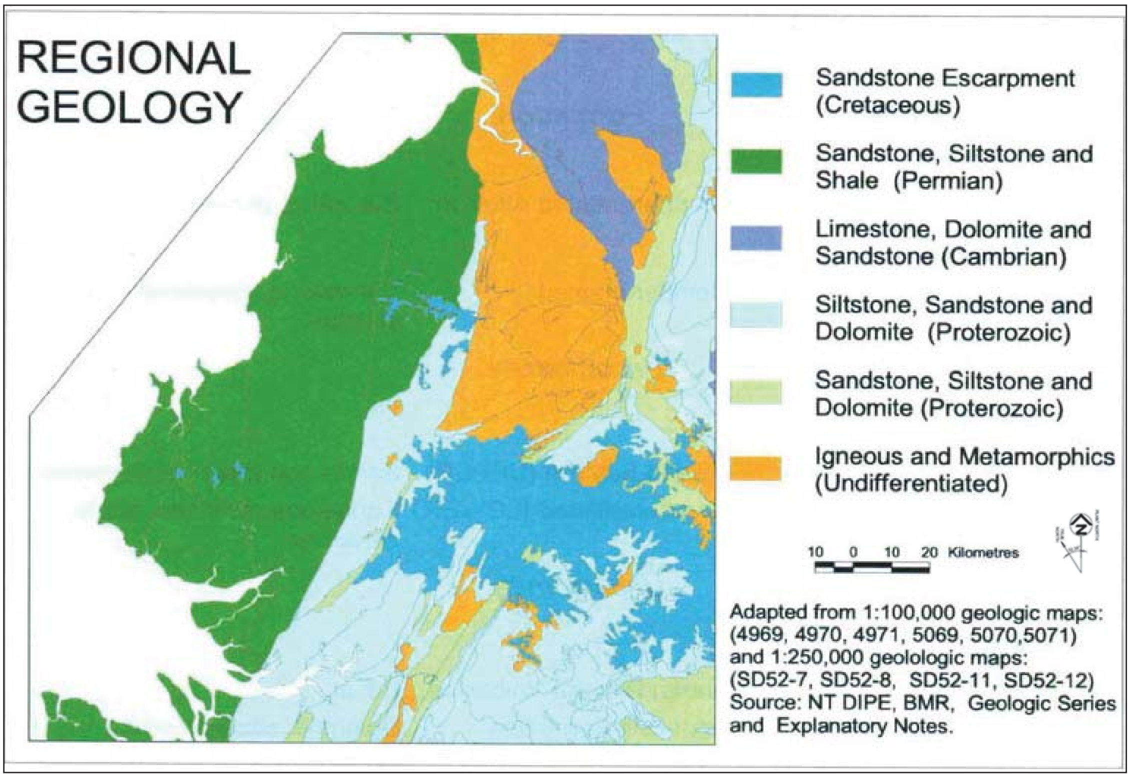


Figure 2.3: Regional Geology layout

Source of above information is Groundwater Management Plan - Blacktip Gas Project (Phase 1 Civil Works), EcOZ Environmental Services Pty Ltd, Sept 2006

3. OVERVIEW OF YELCHERR GAS PLANT

3.1 General overview

In accordance with condition 64.1 of EPL230-01, this section provides a description of the gas plant infrastructure and processes. Infrastructure at the YGP includes:

- A gas processing plant consisting of separation, gas dehydration, compression, condensate storage and produced water 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; and
- 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.

3.2 Plant Configuration

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 120 TJ/day.

Stabilised condensate is stored on site at the YGP before being exported to the SPM for offload via tankers.

The production life of the field is planned to be 25 years based on initial gas sales contract. The design life of the Blacktip YGP is 30 years.

The entire YGP site occupies an area of 750m by 750m, with the main process facility located to the south of the site (occupying an area of approximately 250m by 380m) and the accommodation, warehouse, offices, and control room to the north (see Figure 3.1). The coordinates of the YGP are shown in Table 3.1.

Table 3.1: YGP Coordinates

Corner	GDA 1994		GDA 1994 MGA Zone 52	
	East	North	mE	mN
W	129°25'52.09"	14°14'33.60"	546 510	8 425 393
N	129°26'05.87"	14°14'13.22"	546 924	8 426 018
E	129°26'26.77"	14°14'26.66"	547 549	8 425 604
S	129°26'12.99"	14°14'47.04"	547 135	8 424 979

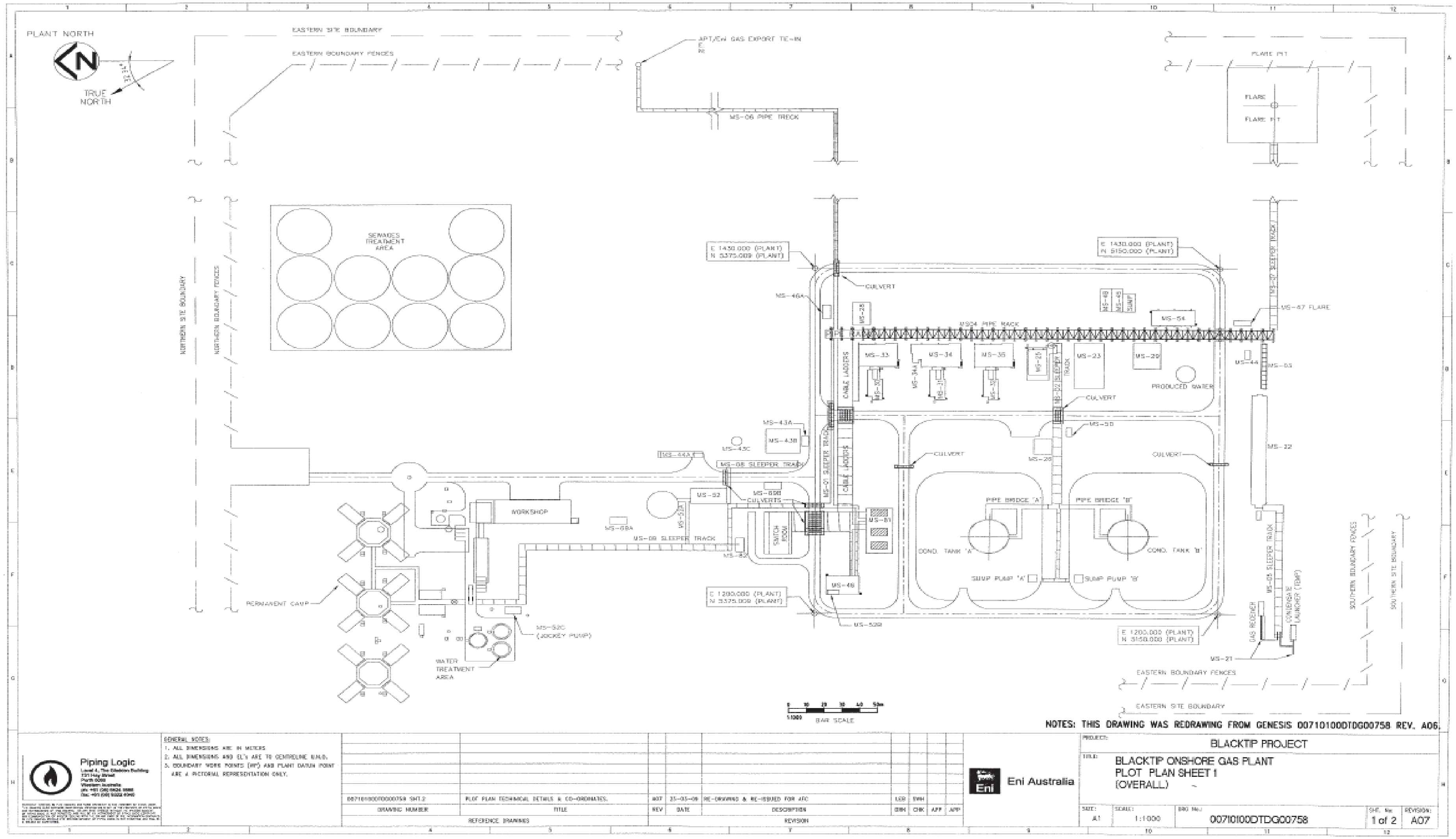


Figure 3.1: Blacktip YGP layout

3.3 Other facilities

Other key facilities on site include:

- Utilities system – including:
  - Power generation;
  - Compressed air system;
  - Potable water system;
  - Chemical injection;
  - Stormwater drainage;
  - Sewage treatment plant and effluent reuse; and
  - Firewater.
- Ancillary buildings – including:
  - Accommodation;
  - Laboratory, workshop and stores; and
  - Cyclone rated emergency response shelter.
- Hazardous chemicals storage; and
- Lighting, security and perimeter fencing.

4. PRODUCTION

4.1 Overview

The annual production is provided in Table 4.4.1.

Blacktip is licensed for a maximum scale of 1,055,300 tonnes of gas and 50,900 tonnes of condensate per annum.

Table 4.4.1: Overview of production

	2021	2022	2023
Annual gas production (KSCM)	881,400	543,814	390,558
Annual gas production (t)	673,000	415,240	297,976
Condensate production (t)	10,521	7,476	4,355
Total production (t)	683,521	422,716	302,331

Notes: Reporting period is from 1 January – 31 December

4.2 Condensate

One condensate offtake occurred on 29th November 2023. Volume was 27,511bbl.

4.3 Gas production

Total gas production in 2023 was 390 MSCM, a decrease from 2022.

4.4 Gas composition

The reservoir fluid properties and contaminants are shown in Table 4.2 and Table 4.4.3.

Table 4.4.2: Blacktip reservoir fluid properties

Component	Percentage
CO_2	0.62 mol%
N2	5.88 mol%
Methane	89.06 mol%
Ethane	2.82 mol%
Propane	1.00 mol%
Ibutane	0.12 mol%
Butane	0.23 mol%
Ipentane	0.06 mol%
Pentane	0.05 mol%
Hexanes	0.02 mol%
Heptanes	0.01 mol%
Octanes	0.02 mol%
Nonanes	0.03 mol%
Decanes	0.04 mol%
Undecanes	0.02 mol%
C_{12+}	0.01 mol%

Source: Ref. [3], [5]

Table 4.4.3: Contaminants in Blacktip Gas

Component	Maximum measured
H_2S	3.0 ppmv
Mercaptan	<0.5 ppmv
Mercury	0.2 µg/m³
Radon	222 Bq/m³
Argon	0.01 mol%
Oxygen	<0.01 mol%
Helium	0.06 mol%
Hydrogen	0.01 mol%
Benzene	0.002 mol%
Toluene	0.002 mol%
Ethyl Benzene	<0.001 mol%
Xylenes	0.001 mol%

Source: Ref. [3], [5]

5. MONITORING DISCHARGES TO WATER

5.1 Produced Water

Produced Formation Water (PFW) or Produced Water (PW) separated from the liquid stream is further processed in the PFW system to remove free and entrained oil prior to disposal at sea.

The key design functions of the PFW Treatment System are to:

- Handle a maximum flow rate of 9,400bwpd (1,500 m3/day);
- Reduce the oil in water concentration to below 25ppm; and
- Maintain pH of discharged water to between 6.5 and 8.5.

The main components include:

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

The licence limit for OiW is 25mg/l, so a sodium hydroxide solution is added to remove the final hydrocarbon components to ensure specification. pH balance is returned by adding Citric Acid once the OiW readings have steadied below the limit. This information is gathered from site testing using the Horriba method to confirm suitability (within specification) prior to discharge.

Produced water discharge in this reporting period was 40.9ML.

Offshore produced water monitoring (in part for model validation) was conducted in June 2023.

Annual shellfish and sediment monitoring was conducted in November 2023 with the results consistent across sampling sites, with little variation between the control and monitoring sites, providing confidence that there are no adverse impacts from produced water discharge to the environment;

Table 5.1 presents the annual produced water discharges for the past three years.

Table 5.1: Produced water discharge annually.

	2021	2022	2023
Volume of PW discharged (m^3)	10,503	31,440	37,458
Number of discharge days	57	237	158

Notes: Reporting period is from 10 February 2023– 09 February 2024
Produced water volumes increased in 2023

5.1.1 Monitoring Objective

The objective of the Produced Water discharge monitoring program is to:

- Characterise the quality of the discharge stream; and
- Assess compliance with the limits and trigger values in the licence.

5.1.2 Monitoring Methods

Produced water is sampled and tested prior to discharge to ensure certain parameters are within the limits stipulated in the EPL. Samples are taken during discharge to ensure water quality remains within the licence limits. These samples are tested both in the site laboratory and/or transferred to the company's laboratory services provider.

EPL230-01 requires quarterly characterisation of PW. Sampling has been undertaken as per the sampling plan.

Samples are taken from PW-02. These samples are analysed for the parameters as specified in EPL230-01. The samples are generally taken on the Tuesday, which are stored appropriately, prior to transfer to the company's laboratory services provider Caleb Brett, a subsidiary of Intertek. The samples travel by charter flight from Wadeye to Darwin on a Wednesday morning. On arrival in Darwin, company logistics team moves the samples to Caleb Brett. Chemists at Caleb Brett distribute the samples to laboratories within their network. NATA accredited laboratories are used.

Routine and periodic produced water samples are collected by the process operators in line with the Water Sampling Procedure [000036_DV_PR.HSE.1013.000_03] and EPL230-01 requirements. The monitoring regime is further detailed in the document Environmental Monitoring Requirements [000036_DV_PR.HSE.1020.000_03].

5.1.3 Monitoring Results

In 2023, lower frequencies of PW discharge events occurred with increased discharge volumes compared to 2022. However, in late 2023 (from November) the volume of PW discharge reduced significantly and is expected to remain largely reduced throughout 2024 due to shutting of the water source.

The table outlining the results is available in the relevant Appendix.

For simplicity, trend analysis for the monitoring parameters discussed below are for total, not filtered samples as these results correlate. Refer to Attachment B for specific filtered sample results where required for certain analytes.

Laboratory analysis indicates a sustained increase in Barium, Boron, Copper, Mercury, and Lead in the majority of data between November 2020 and early 2023. Levels of these metalloids showed some decrease in late 2023, though remain somewhat inconsistent in measurement.

Increased levels of metals in identified in PW are likely due to the wells watering out, bringing greater concentrations of these metals to the surface. YGP does not yet have any metals removal process in the PWT system, so these metals are discharged to sea. Coagulant injection along with engineered equipment will be field trialled in 2024 to manage this.

Key trends identified during the reporting period are shown below.

Table 5.2: YGP Ba_T Trending Data

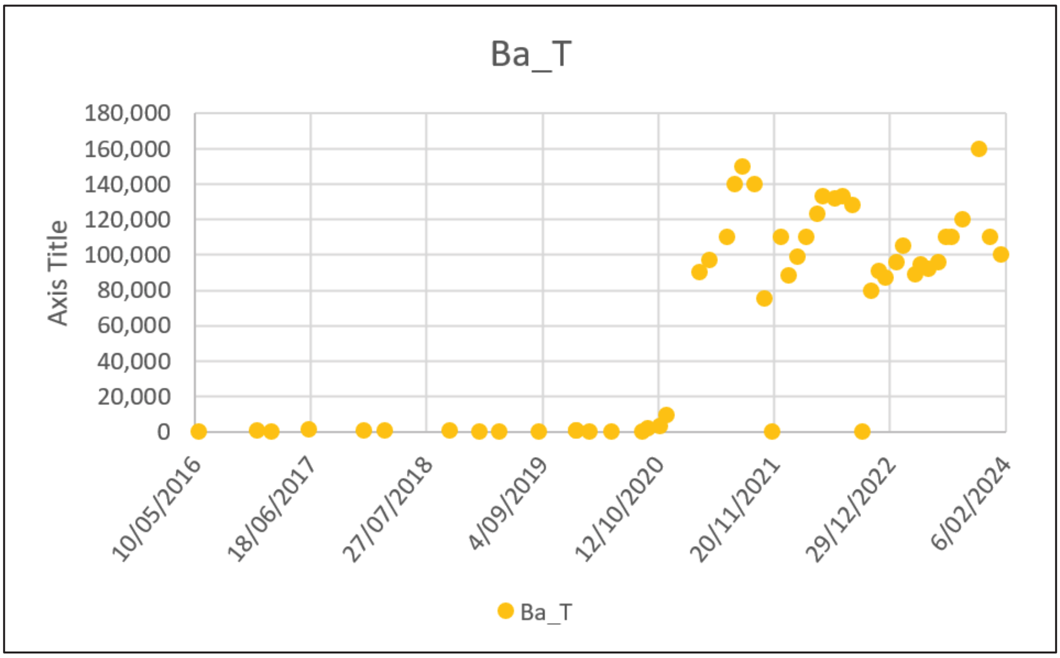
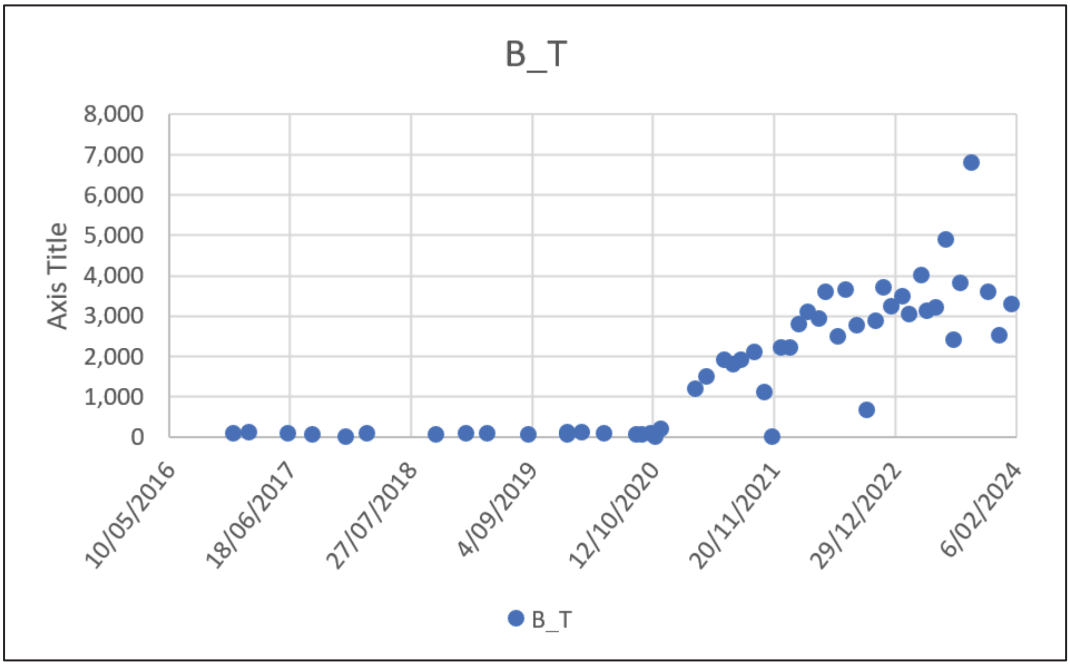


Table 5.3: YGP B_T Trending Data



[µg/l]

Table 5.4: YGP Cu_T Trending Data

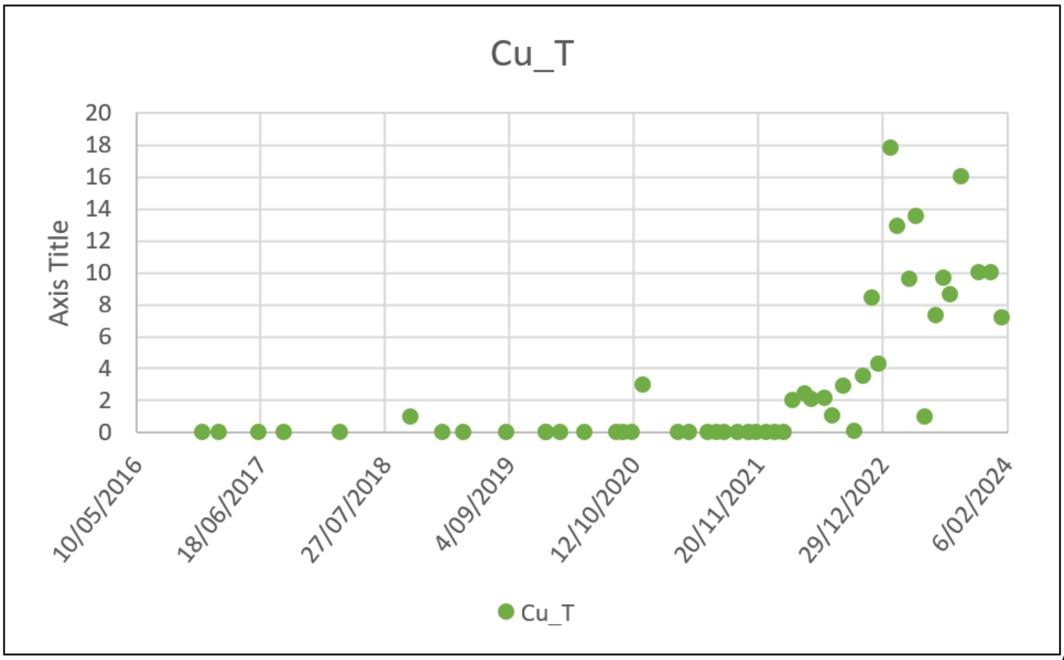


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Table 5.5: YGP Cu_T Trending Data

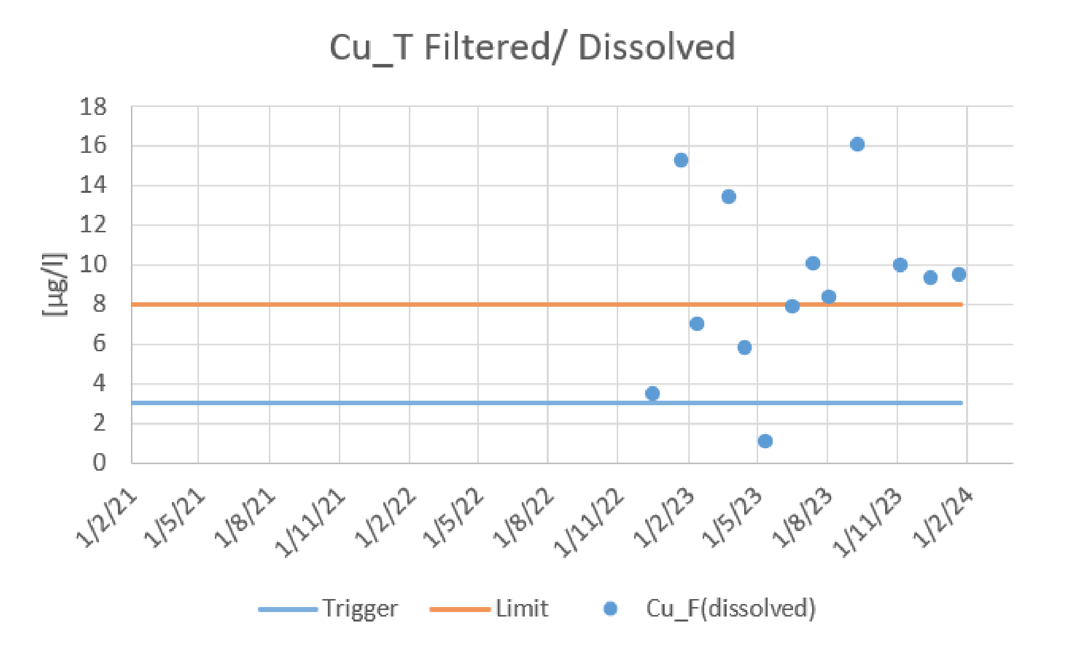
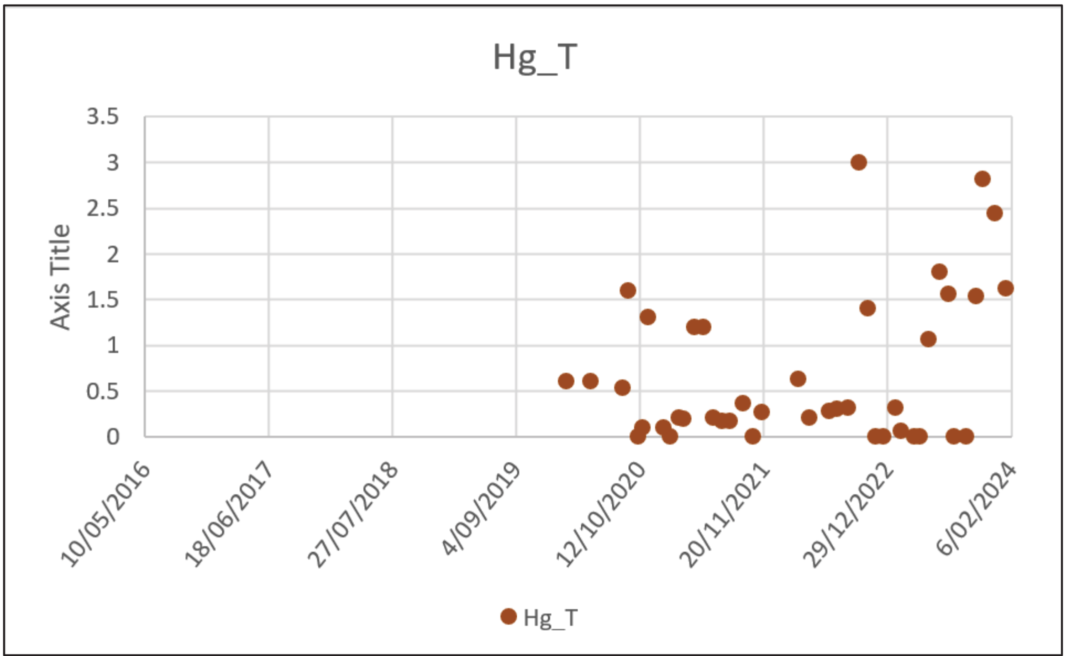
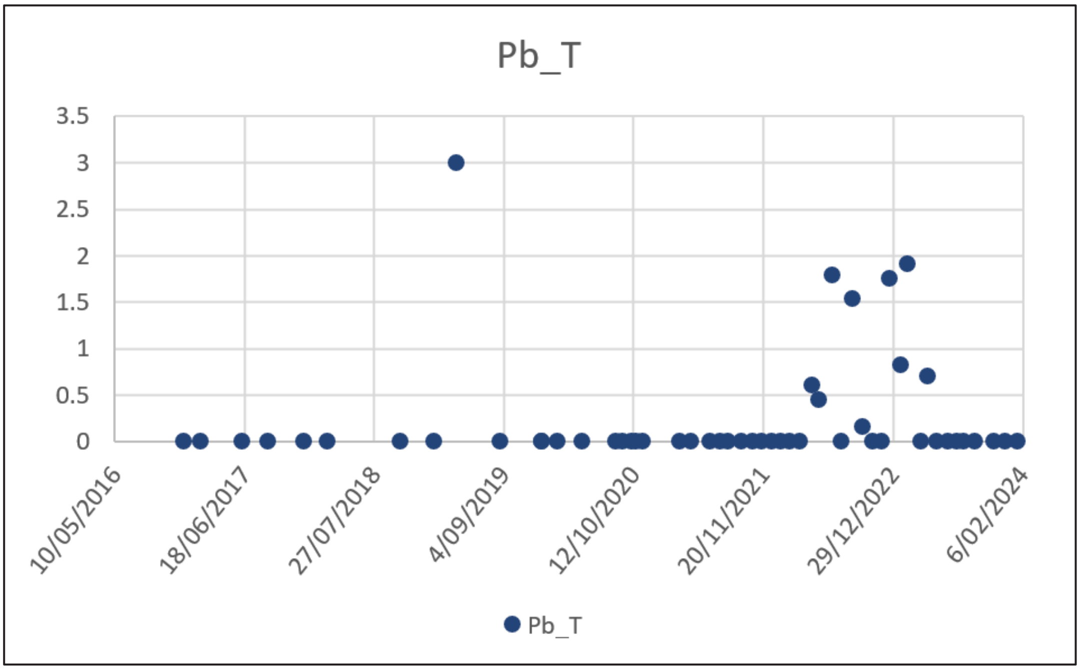


Table 5.6: YGP Hg_T Trending Data



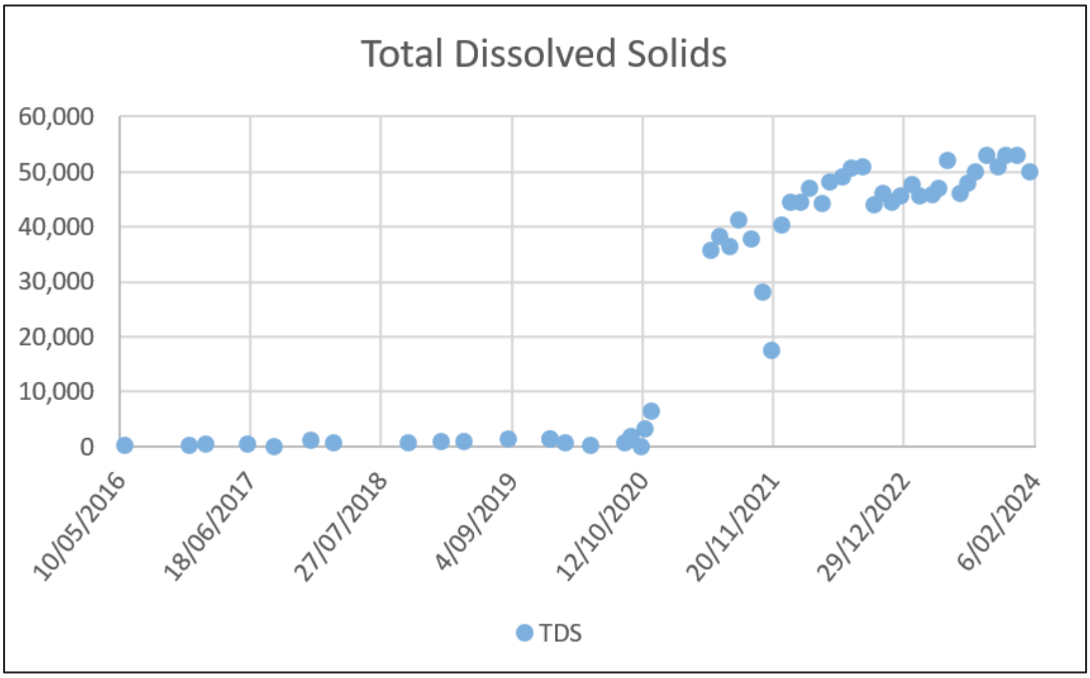
µg/l]

Table 5.7: YGP Pb_T Trending Data



[µg/l]

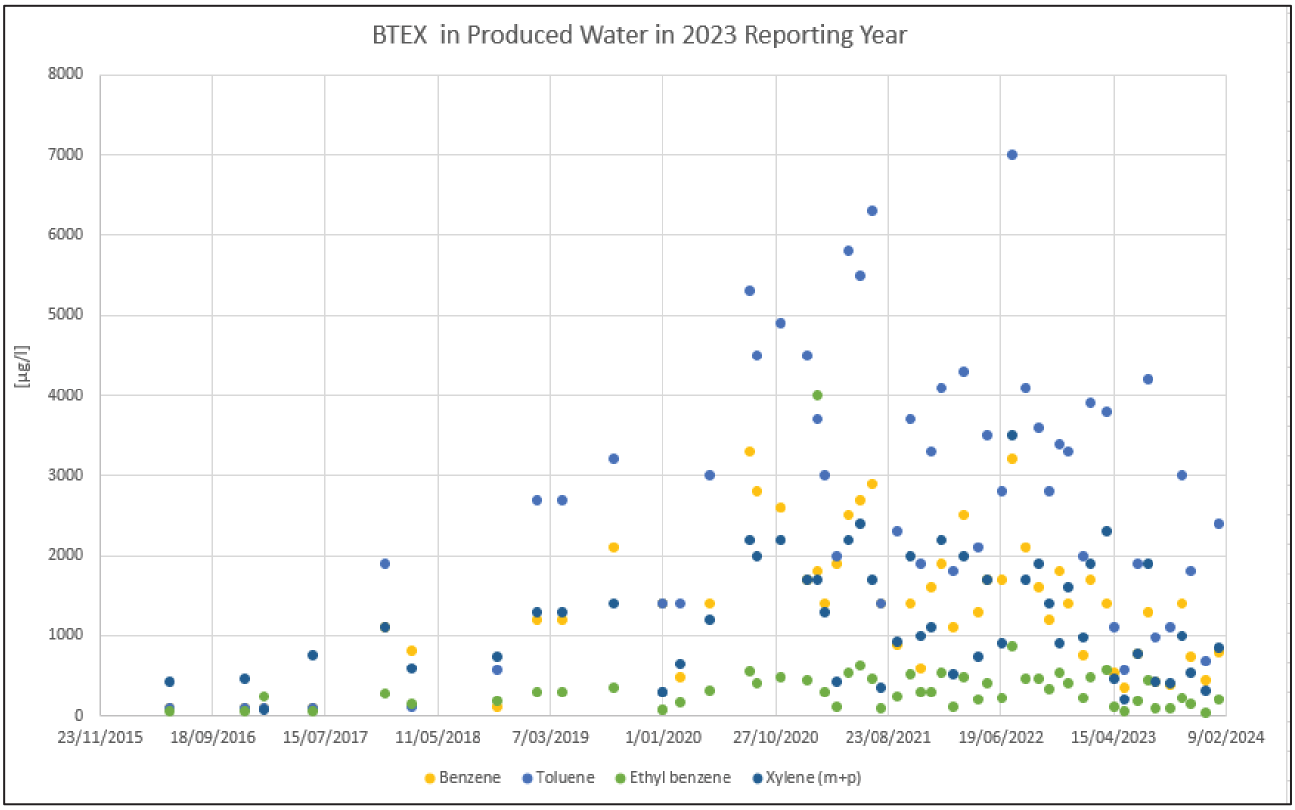
Table 5.8: YGP Total Dissolved Solids _ Trending Data



For hydrocarbon samples there has been a gradual increase in Benzene, Toluene, Ethyl benzene and Xylene (BTEX), since 2016. This is likely due to entrained hydrocarbon passing through the system. Furthermore, increased production of PW in recent years has limited residence time during treatment which affects BTEX removal.

The use of Nitrogen sparging and activated carbon filters to extract the entrained hydrocarbon in PW has been ongoing through 2023. The use of this correlates with a decrease in levels of BTEXs observable in late 2023 data. This indicates that Nitrogen sparging is showing signs of effectiveness in reducing BTEX levels in PW, despite ongoing exceedances. Hence, further refinements to this process will be ongoing throughout 2024 in order to keep BTEXs trending down towards EPL230-01 defined thresholds and trigger limits.

Table 5.5: BTEX in Produced Water Trending Data



The BTEX units are [µg/l].

5.1.4 Data Management and Quality Control

The quality assurance/quality control (QA/QC) procedures specific to the collection and analysis of samples from sample location include:

- NATA accredited analytical laboratories were used for all analysis or a test method managed under a NATA accredited quality management system;
- Laboratory designated sample holding times;
- Chain of custody forms completed and accompanied the samples; and
- Calibration of all field-testing equipment using standard method(s) was undertaken.

5.1.5 Annual Marine Monitoring

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.

Sediment and Shellfish Sampling was undertaken in November 2023 in accordance with the *Australian Government National Assessment Guidelines*. Sampling in 2023 was conducted late due to restricted beach access. Sampling is typically undertaken at the end of the wet season in May when shellfish are still relatively abundant.

2023 sampling demonstrated that all metal concentration in mangrove sediments were below the Australian and New Zealand default guideline values. All hydrocarbon concentration were below detection limits in mangrove sediment samples. Metal concentrations were all within the historical ranges across the various locations.

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

5.1.6 Produced water model validation

Eni has a commitment in the Produced Formation Water Plan (000036_DV_PR.HSE.1056.000_04) to validate the near field and far field produced water dispersion model. In working towards this, Eni is revising the Produced Formation Water Plan (000036_DV_PR.HSE.1056.000_04) with finalisation expected in 2024.

Offshore monitoring at the produced water outfall was undertaken in November 2020, for the purposes of validating the produced water dispersion model in accordance with the Produced Formation Water Plan. The study report was delivered on the 25th of March 2021. The assessment concluded that within the proposed 50m mixing zone, no laboratory parameters exceeded the ANZG (2018) Marine water 99% toxicant DGVs.

This report was submitted to the NT EPA on 30th April 2021 to support the licence amendment of Eni to increase the allowable discharge concentration of BTEX, Zn, and Mn parameters in the Produced Water Discharge stream.

Following up on the above-mentioned Study Report, Thamarrurr Rangers also participated in an Eni endorsed AIMS water outfall sampling training programme to support future sampling and monitoring of the mixing zone. A targeted campaign of PW outfall data was collected during the monitoring training in June 2023 which demonstrated similar results to the November 2020 Study Report, further validating harm to the environment is not evident.

5.1.7 Discussion and Interpretation of Results

In respect to wells management, in late 2020, a new water layer was broken into. This brought additional produced water inclusive of metals to the surface and to the YGP. This was later capped to reduce water flow rates in early 2024.

BTEX is light entrained hydrocarbon. These levels have exceeded parameters for TEX for several years, so appear unlinked to the new water source in the formation.

5.1.8 Conclusions and Proposed Actions

To align the quality of discharged PFW with specifications, Company has developed a PFW Project roadmap towards EPL230-01.

As part of PFW Project, Nitrogen sparging has been used in the Produced Water Treatment tank to remove the light hydrocarbons, which has showed some effectiveness and will be further refined throughout 2024.

The Project has also trialled and implemented inline oil separation using activated carbon filters to further remove entrained hydrocarbons.

Additionally, trials for the use of a coagulant injection system utilising engineered equipment to reducing metals in PW will be carried out in Q2 2024.

It is acknowledged that due to dilution in the mixing zone to contaminant concentrations below ANZG Default Guideline Values (DVG), the risk of negative environmental receptor impact is deemed low.

6. MONITORING DISCHARGES TO LAND

6.1 Wastewater disposal

Domestic wastewater, including wastewater originating from showers, wash basins, toilet facilities, laundries, and kitchens, is treated by the Wastewater Treatment Plant (WWTP). The WWTP is an ABACO Jacana Sequencing Batch Reactor (SBR). The SBR includes primary treatment by settlement and secondary treatment by activated sludge. Treated effluent is discharged through an irrigation system to the designated area shown. The irrigation system has a flow rate capacity of 3.5m3 /hr and consists of 10 sprinklers, each with a 40m radius.

Wastewater generated at Blacktip YGP is treated in an ABCO Water System 150 EP. Effluent is reused through an irrigation system to land, and a total of 1.8ML was discharged over the reporting period.

Table 6.1: Treated wastewater effluent reuse

	2021	2022	2023
Effluent reuse (ML)	1.7	1.4	1.8

Notes:
Reporting period is from 1 February to 31 January.

In accordance with the EPL, treated discharged wastewater is sampled and analysed for constituents monthly by an external laboratory to verify compliance against the contaminant limits. The results are presented in the relevant Appendix.

Volumetric flowrates of wastewater are up slightly from 2022 discharges.

A new effluent discharge flowmeter was installed in March 2023 due to lightning strike impacting the old meter.

Improvements to chorine dosing methods to reduce levels of E.coli as well as aeration methods to minimise BOD have been made to the WWTP in 2023.

6.1.1 Monitoring Objective

Wastewater monitoring includes:

- Routine testing on site prior to discharge; and
- Periodic (monthly, quarterly, or annually) monitoring of discharge water for detailed chemical analysis.

Routine sampling and testing prior to discharge allow water quality to be assessed to determine whether it meets the EPL limits for discharge. The tests are typically carried out on site in the site laboratory using portable bench top instruments such as the Horiba and PC700 and are described in the Blacktip Operations Water Sampling Procedure 000036_DV_PR.HSE.1013.000.

Periodic monitoring of discharge water is undertaken to monitor the chemical composition of the wastewater stream and assess water quality across a full suite of parameters. Samples are sent to an external laboratory for analysis of chemical composition.

Sewage wastewater samples are collected by the Process Operators. Sewage wastewater is treated by the Wastewater Treatment Plan (WWTP) and discharge to a nearby irrigation spray field (authorised discharge point WW-01).

6.1.2 Monitoring Methods

Samples are taken from sample point WW-02. These samples are analysed for the parameters as specified in EPL230-01. The samples are taken on the Tuesday and are stored appropriately. Samples are transferred to Darwin and Chain of Custody transferred to company's laboratory services provider Caleb Brett, a subsidiary of Intertek. The samples travel by charter flight from Wadeye to Darwin on a Wednesday morning. On arrival in Darwin, company logistics team moves the samples to Caleb Brett. Chemists at Caleb Brett distribute the samples to laboratories within their network. NATA accredited laboratories are used where required.

In 2023, following a recommendation of the S48 Audit and in an attempt to improve wastewater testing quality, Company engaged external Technicians to conduct water sampling for a period. This transferred responsibility from in house to an external provider. However, due to longer transfer times and exceedances in sample holding times, Company reverted back to the original sampling methodology. This was caused by restrictions on logistics associated with set charter flight schedules.

Routine and periodic water samples are collected by the process operators in line with the Water Sampling Procedure [000036_DV_PR.HSE.1013.000_03] and EPL230-01 requirements.

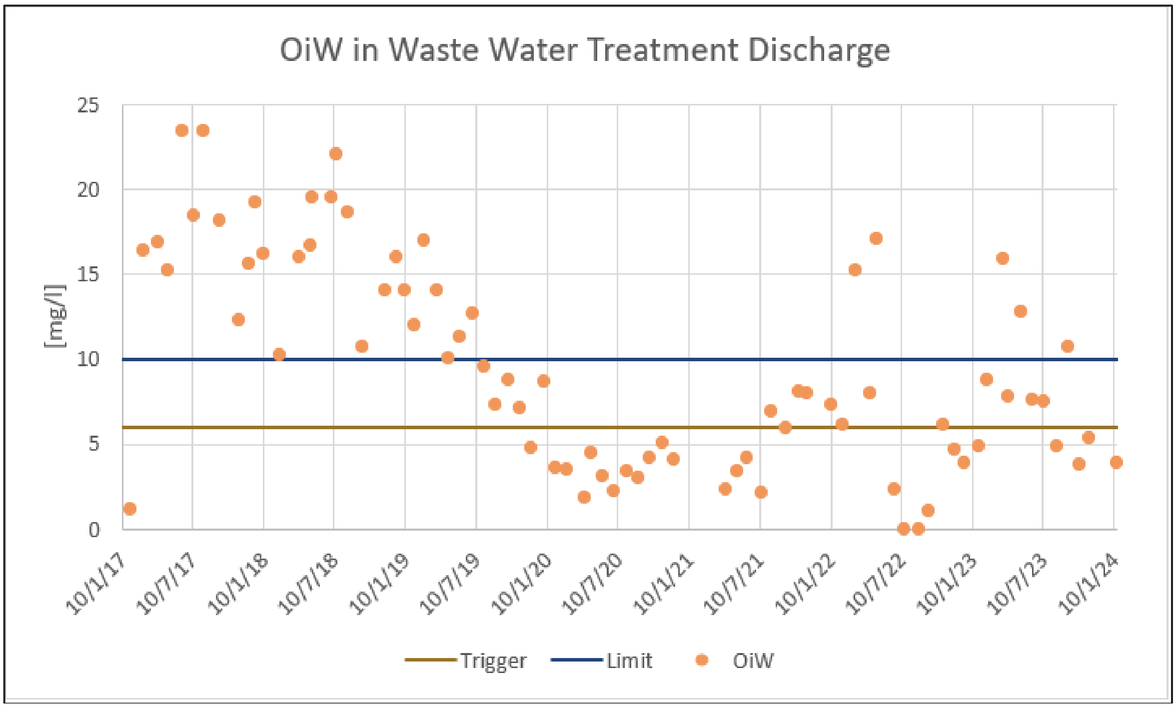
The monitoring regime is further detailed in the document Environmental Monitoring Requirements [000036_DV_PR.HSE.1020.000_03].

6.1.3 Monitoring Results

The table outlining the monitoring results of WW-02 is available in the relevant Appendix.

Graphs indicating trending according to parameters with EPL limitations and parameters to be monitored, are presented below.

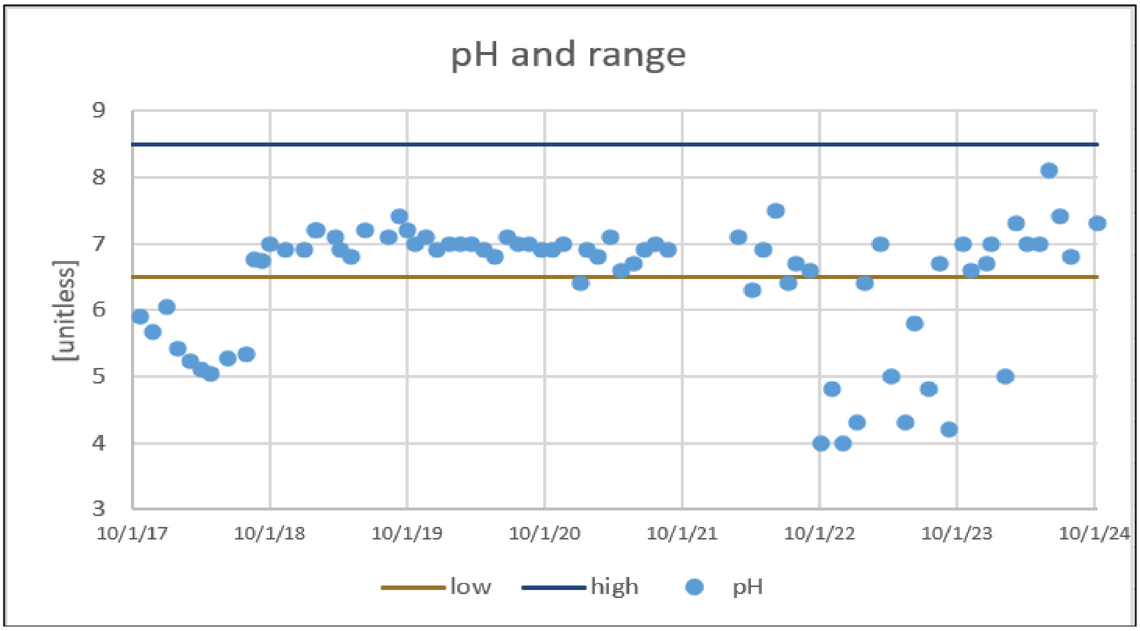
Table 6.2: YGP Treated wastewater effluent reuse Trending Data



Higher values of OiW have historically been associated with inappropriate use of the grease trap in the kitchen. Awareness and discipline on this issue is maintained on site to ensure kitchen hands and chefs dispose the waste oil into the grease trap, which is then transported to Darwin for disposal. These initiatives have been well received and implemented by the new catering contractors (TCLH) engaged in Q3 2023.

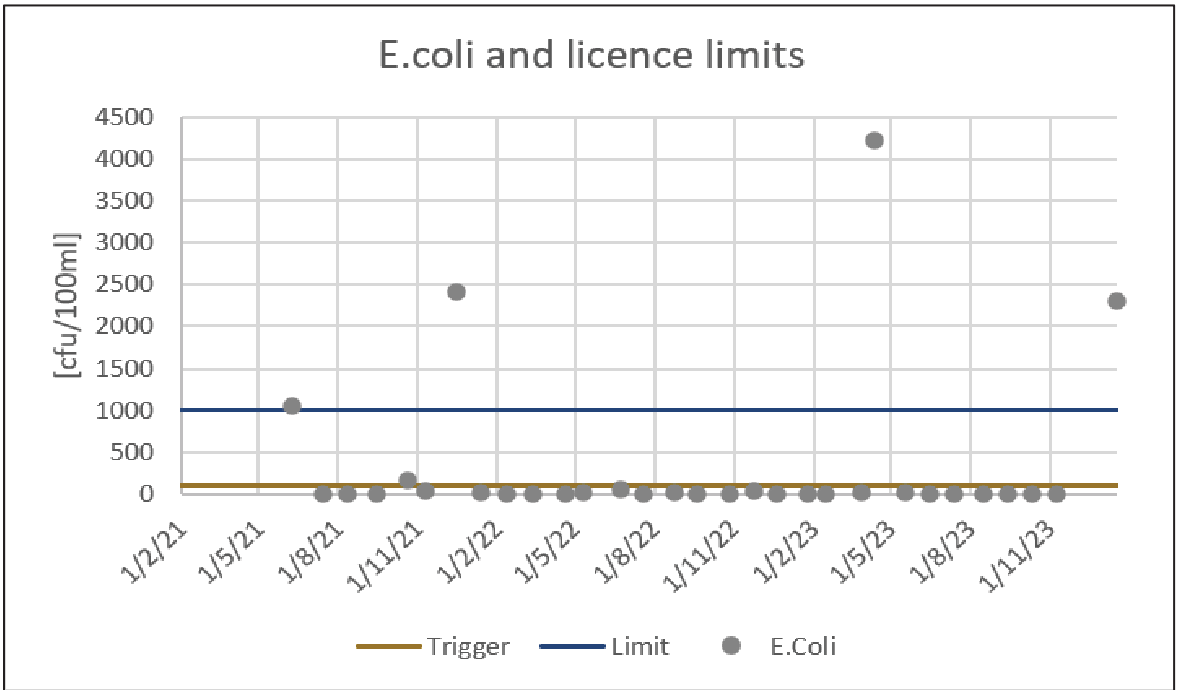
Exceedances of OiW limits in wastewater occurred in March, April and August 2023. Company will continue to communicate importance of proper waste disposal to staff and maintain acceptable levels of OiW in wastewater as observable in late 2023 data.

Table 6.3: YGP pH and Range Trending Data



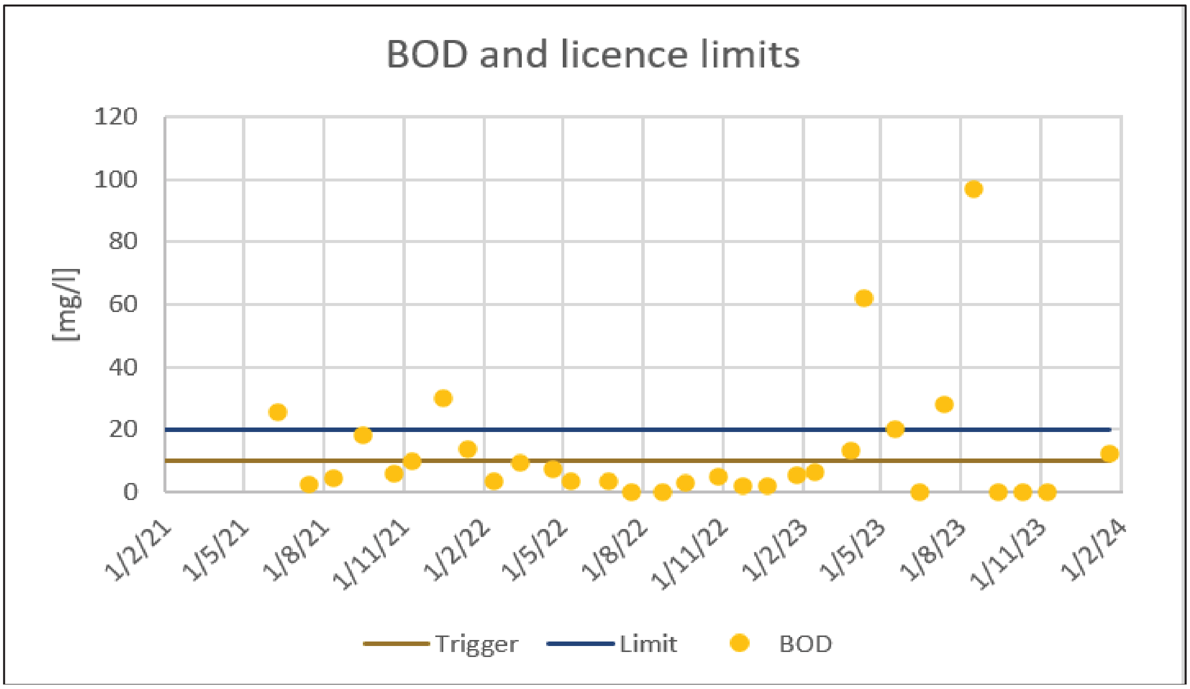
In May 2023, treated wastewater pH levels fell below pH6.5 briefly before returning to acceptable limits.

Table 6.4: YGP E.coli and licence limits Trending Data



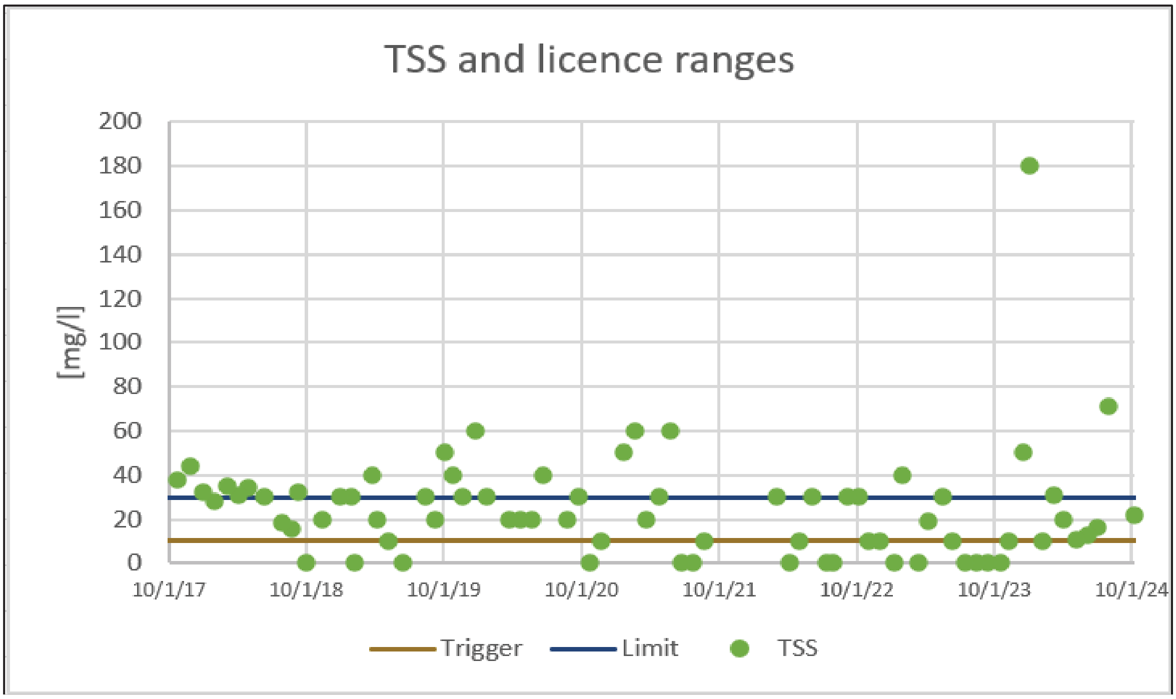
In April 2023 and January 2024 levels off E.coli exceeded licence conditions.

Table 6.5: YGP BOD and licence limits Trending Data



Several exceedances of BOD in treated wastewater can be observed in monitoring data throughout 2023.

Table 6.6: YGP TSS and licence ranges Trending Data



In November an exceedance of acceptable limits for TSS occurred alongside higher levels of TDS.

Table 6.7: YGP Total Dissolved Solids Trending Data

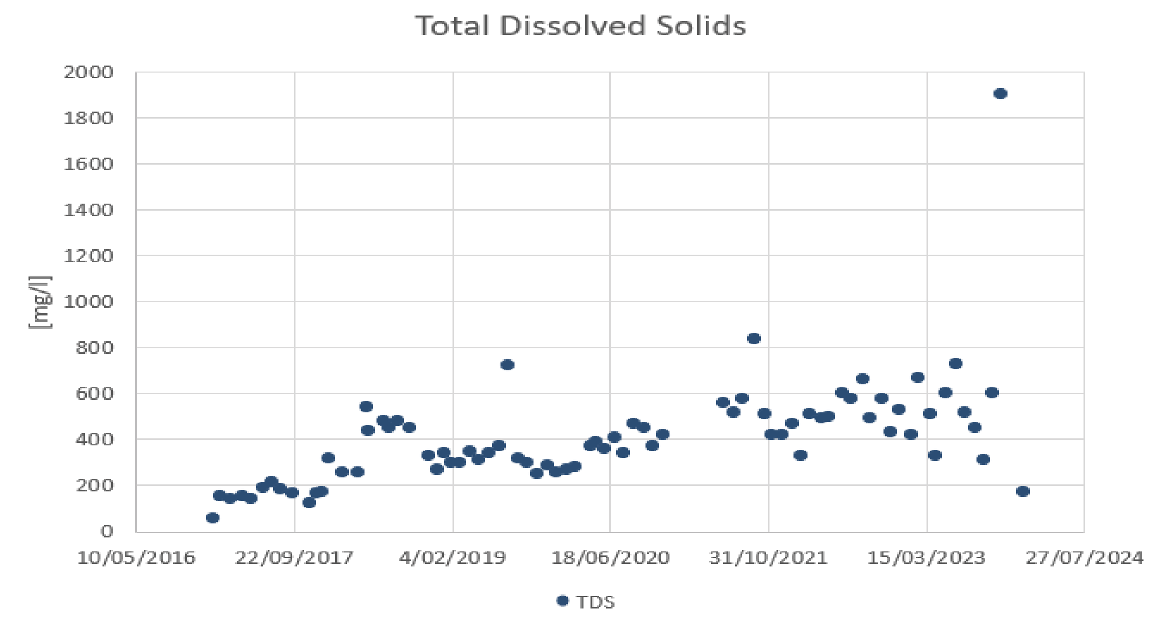


Table 6.8: YGP Electricity Conductivity Trending Data

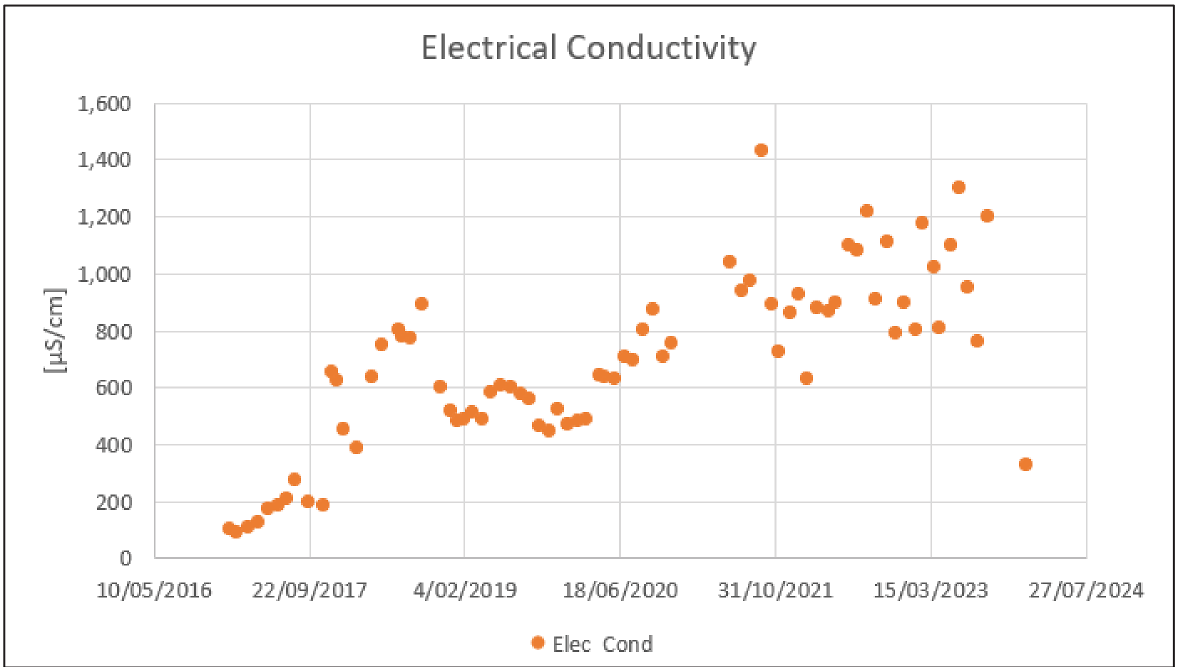
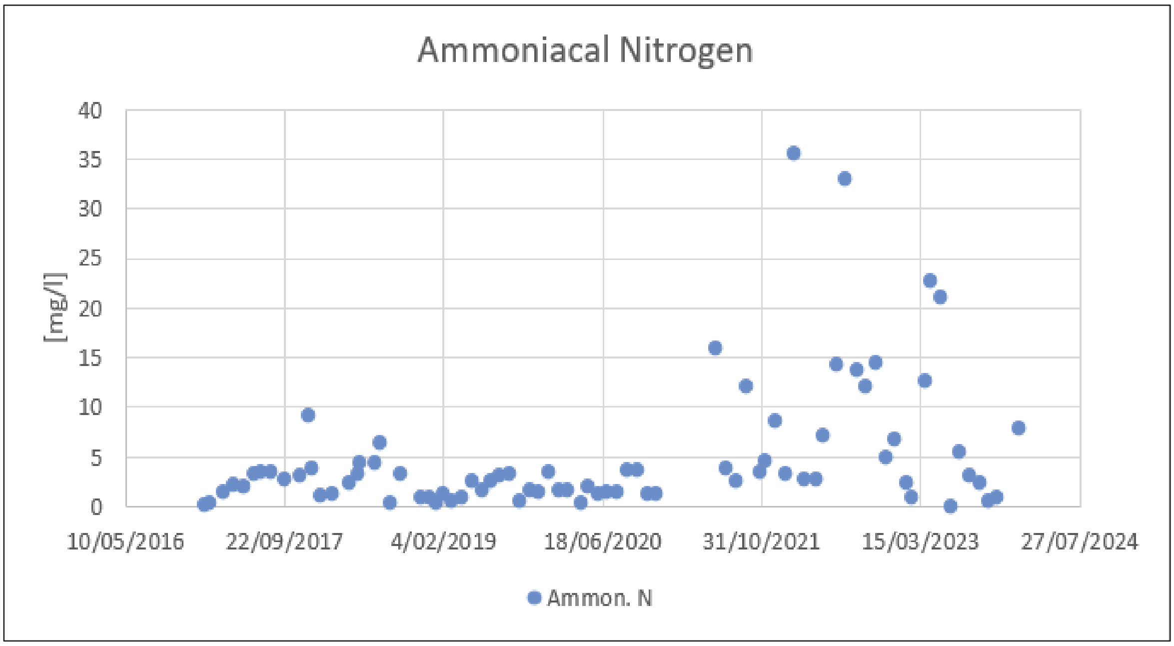


Table 6.9: YGP Ammoniacal Nitrogen Trending Data



Reducing levels of Ammoniacal Nitrogen throughout 2023 can be observed in monitoring data.

6.1.4 Data Management and Quality Control

Samples are obtained as per the Sampling Plan.

Single samples are taken and distributed to participating laboratories.

Duplicates, Triplicates, Blanks and Controls are not used as the number of bottles required to achieve this level of QA/QC is unrealistic knowing the logistics challenges at YGP.

6.1.5 Discussion and Interpretation of Results

Aeration pump trials have initiated the reduction of BOD levels in treated wastewater in the reporting period.

The spike in TSS observable in November monitoring data can be attributed to the carry-over of solids during Aeration pump trials.

In response to exceedances of E.coli levels during the reporting period an automatic chlorine dosing system has been installed on the wastewater treatment system and brought online.

Levels of TDS and electrical conductivity have been reduced in late 2023/ early 2024.

The table outlining the monitoring results of WW-02 is available in the relevant Appendix. The following provides a summary of trends observable in this data.

6.1.6 Conclusions and Proposed Actions

The wastewater treatment plant is considered over-sized for its throughput. It is designed for a 120-person camp, and generally is only processing the waste of 20 persons. This brings with it operational challenges that need to be managed.

In addition to recent chlorine dosing and aeration improvements, Company are looking to further options for performance improvements to the wastewater treatment system. Monitoring of data and implementation of recommendations from recent Audits and Performance Reviews of the wastewater treatment plant will continue to inform any such refinements.

6.2 Stormwater disposal

The open drains on the YGP are designed to collect stormwater, washdown water, fire test water and any accidental spills from equipment. During the wet season, a large volume of water will enter the drains. The main contaminant of concern in the equipment bund will be residual hydrocarbons related to equipment leaks or maintenance. The flow is highly variable and minimal in the dry season and up to the design capacity of 130m3 /hr during the wet season. The plant drains are split into two separate systems:

- Hazardous; and
- Non-hazardous.

Stormwater discharge to the environment includes cooling water from the fire pump testing and stormwater collected from the process skids. Fire pump cooling water is potable water used in a tubular design heat exchanger, where the other medium is coolant. The cooling water does not come into direct contact with the coolant or any other contamination sources and is discharged directly from the utilities area run off sump (monitoring point SW-01) or via the Hazardous open drains pit (monitoring point SW-03) if further treatment is required. This source of stormwater was diverted from SW-02 in 2023 to allow treatment prior to discharge.

Process skid stormwater is collected in the Open Drain Sump (ODS) for treatment and sampling prior to manual discharge to grade at SW-03. The ODS typically remains closed for much of the dry season and is only opened to grade when rainfall increases during the wet season.

6.2.1 Monitoring Objective

To determine the contaminants in the storm-water run-off stream before being discharged to grade.

There is no flow meter on this discharge, the fluids flow to grade after a sample is taken and analysed.

6.2.2 Monitoring Methods

Treated storm water samples are collected by the process operators in line with the Water Sampling Procedure [000036_DV_PR.HSE.1013.000_03] and EPL230-01 requirements.

Treated storm water includes runoff from the utilities area (authorised discharge point SW-01) and stormwater runoff from the Open Drains System (authorised discharge point SW-03).

6.2.3 Monitoring Results

Results are provided in relevant Appendices.

The following trends are available.

Table 6.7: YGP SW-03 pH and licence limits Trending Data (2017 – 2024)

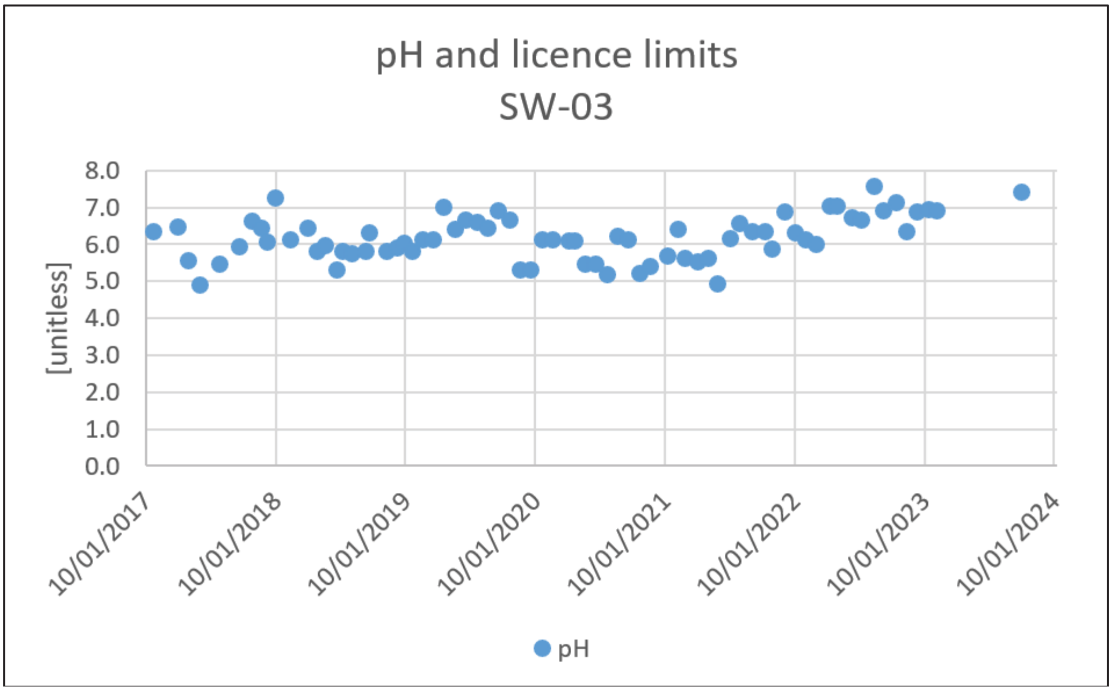


Table 6.8: YGP SW-03 Electrical Conductivity Trending Data

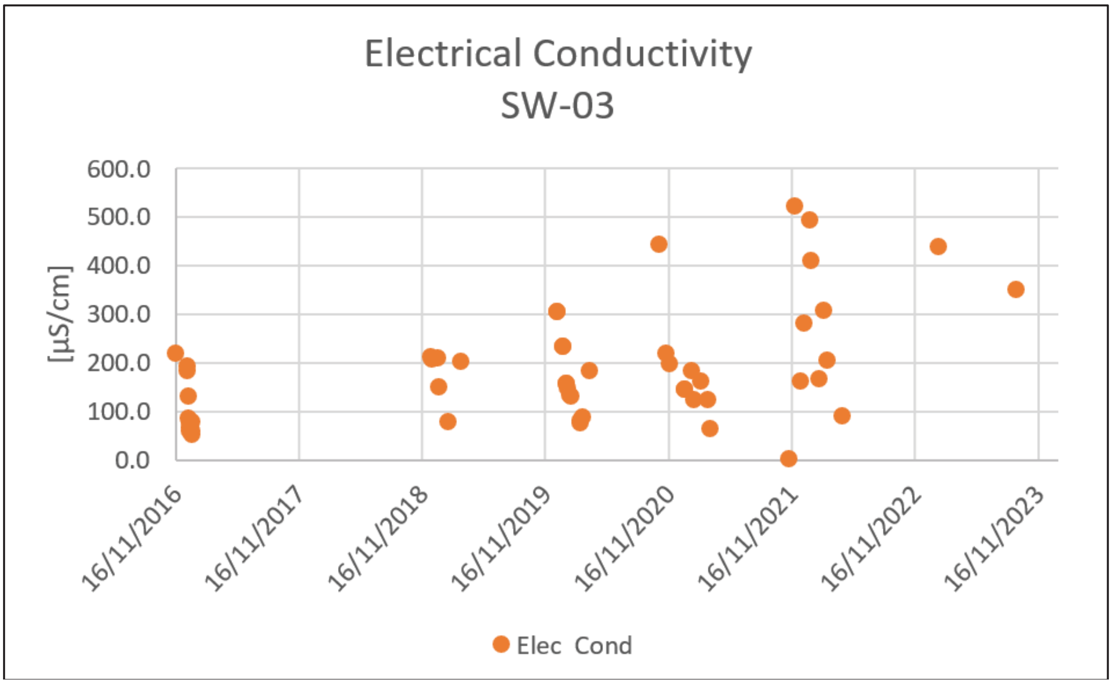
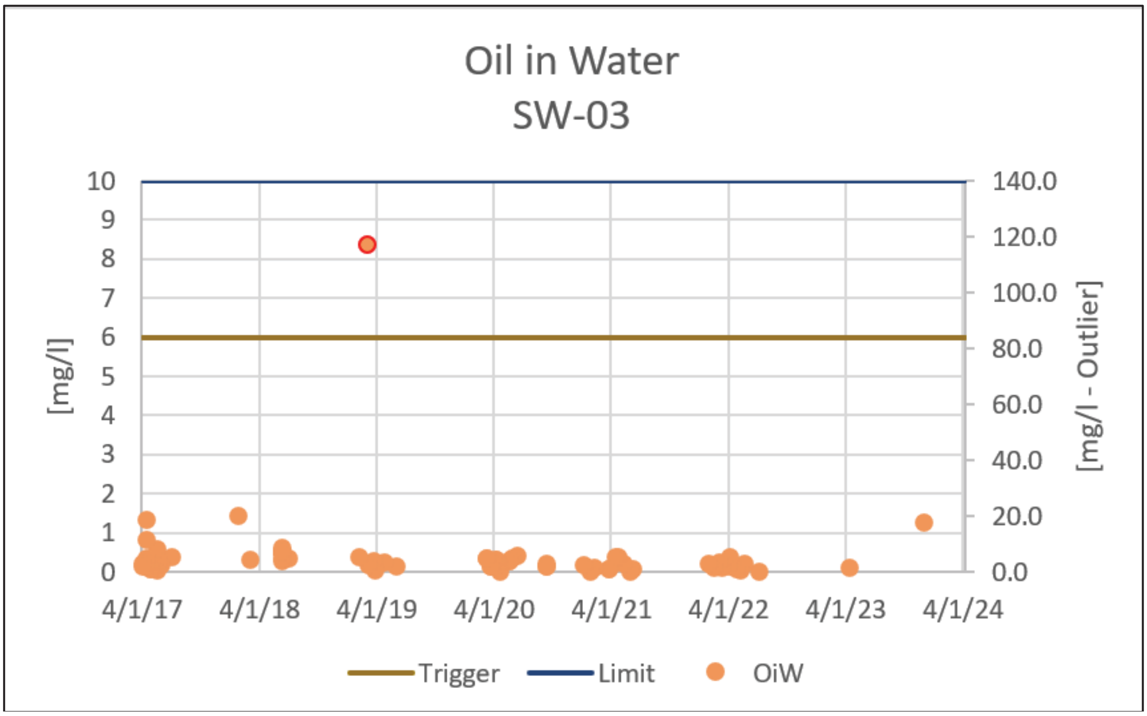


Table 6.9: YGP SW-03 Oil in Water Trending Data



6.2.4 Data Management and Quality Control

As explained in earlier sections, there are logistical challenges with meeting required QA/QC expectations in sampling methods due to the remoteness of the site.

6.2.5 Discussion and Interpretation of Results

The conversion of data from the previous reporting structure to the new format requested by NT EPA to communicate information in the latest structure (April 2022) is still ongoing. For storm water the historical data has not been brought up to present requirements, due to the significant extra work required to complete the transformation.

Three stormwater sampling events including lab analysis were conducted at monitoring point SW-01 over the reporting period. These were conducted in February and September 2023 as well as in January 2024 (Annual monitoring event). Results for these are in the appendices of this report.

Site testing of discharge points at the utilities area (authorised discharge point SW-01) and stormwater runoff from the Open Drains System (authorised discharge point SW-03) was also conducted throughout the year (see appendices).

Eni is continuing to collate historical stormwater data for the last two years.

6.2.6 Conclusions and Proposed Actions

In 2024 Company will continue to monitor OiW results in site and lab testing to prevent further exceedances. Company will also explore options for stormwater discharge outlets to be fitted with flow meters in order to improve monitoring data.

7. MONITORING DISCHARGES TO AIR

Air emission monitoring is performed by the external laboratory services provider.

Most air emissions emanating from the YGP are from the following key sources:

- Flares;
- Gas turbine compressors;
- Gas engine generators; and
- Emergency diesel generator.

Fuel usage for the compressors and gas engines is monitored continuously, as are gas quantities flared. Table 7.7.1 lists the flow meters used for measuring the various gas streams.

Table 7.7.1: Gas flow meters

Emission Source	Gas Flow Meter	Reference Number
Turbine Compressor	Compressor A Compressor B Compressor C	420.1 FIT 161 420.1 FIT 261 420.1 FIT 361
Engine Generators	LP Fuel Gas	420.1 FIT 004
Flare	HP Flare	230.1 FIT 008
	LP Flare	230.1 FIT 002
	Fuel Gas Distribution	420.1 FIT 007

Total greenhouse gas emissions from Yelcherr Gas Plant calculated in the latest NGER reporting period were 28,550 tCO_2-e (Ref. [2]).

7.1.1 Monitoring Objective

The objective of this monitoring objective is to determine the contaminants in the exhaust stream of the compression units.

There is a flow meter on this fuel gas input. Multiplication with flow rate and concentration from the Ektimo analysis provide the final contaminant flow.

Ektimo is brought to site twice annually. For the visits they obtain the following information:

Air Emissions Monitoring Programme

Atmospheric Emission Points		Monitoring location height	Parameter						
Emission point code	Description		CO	CO_2	CH_4	NOx	SO_2	Solid particles	VOC
A01	High Pressure Flare	-	NR	NR	NR	NR	NR	NR	NR
A02	Low Pressure Flare	-	NR	NR	NR	NR	NR	NR	NR
A03	Gas Turbine Compressor A	13 m	B	A	A	B	A	A	B
A04	Gas Turbine Compressor B	13 m							
A05	Gas Turbine Compressor C	13 m							
A06	Gas Engine Generator A	8 m	B	A	A	B	A	A	B
A07	Gas Engine Generator B	8 m							
A08	Gas Engine Generator C	8 m							
A09	Emergency Diesel Generator	-	NR	NR	NR	NR	NR	NR	NR

A = Annually; B = biannually (i.e. every 6 months); NR = Not Required;

The NGERS reporting approach has been used in this report.

NGERS and NPI reporting data was externally validated for correctness in 2023.

7.1.2 Monitoring Methods

NGERS and NPI reports form the basis of the analysis.

Ektimo investigations and reports ensure that the discharge concentration of contaminants is known.

Fuel and gas flow must also be measured and recorded to determine the overall pollutant mass loading and ensure mass limits are not exceeded. Fuel and gas flow are measured by flow meters, shown below. Pollutant loads are calculated and reported annually under the National Greenhouse and Energy Reporting Scheme (NGERS) and the National Pollutant Inventory (NPI) reporting scheme.

Frequency	Sample Location	Monitoring Methodology	Parameter	Analysis	Concentration Limit
Adhoc	A01 A02	Visual monitoring for visible smoke using a Ringelmann chart	Smoke	Visual observation by site personnel	No visible emission other than for a total period of no more than 5 minutes in any 2 hours
Bi-annual	A03 A04 A05 A06 A07 A08	A sample must be collected by a qualified technician and sent to an external laboratory for analysis	CO*	External laboratory	100-1600 mg/m
			NOX*		350-2000 mg/m
			VOC		40 mg/m
Annual			C02	External laboratory analysis	
			CH4		
			SO2		100 mg/m
			Solid Particles		

Dry, 273K, 101.3 kPa, 15% O2 or at manufacturers specified level
ARingelmann chart is provided in Appendix D
Source: EPL 230-01, Attachment 4 Air Emission Monitoring programme

Table above taken from Blacktip Operations Environmental Monitoring Requirements [000036_DV_PR.HSE.1020.000].

7.1.3 Monitoring Results

Atmospheric parameters in the licence have been on specification through 2023/2024.

7.1.4 Data Management and Quality Control

Intertek managed the Ektimo contract for the Annual Emission Testing Report (2023) during the reporting period. Calibration certificates for this report can be found in Attachments F and QA/QC checks are available on request. For Ektimo's full QA/QC details, search for Ektimo at NATA's website www.nata.com.au.

7.1.5 Discussion and Interpretation of Results

An assumed LP flare flowrate has been estimated and used in the cumulative flaring figure. The meter involved was returned to service on the 24$^{th\ of}$ April 2023.

Exhaust emissions from the above equipment contains contaminants, which at high levels can contribute to air pollution including greenhouse emissions and smog.

The YGP operates a high pressure (HP) and low pressure (LP) ground flare system. These are in a 'pit' at the southeast corner of the plant. The locations of the solar gas turbine compressors and the gas engine generator packages are also shown in Figure 3.8. The compressors operate on a 1 x 100% basis and generators on a 2 x 100% basis.

7.2 Fuel gas consumption

The two main consumers of high pressure (HP) and low pressure (LP) fuel gas are the gas turbine compressors and power generators. The volume of gas consumed as fuel during the reporting period is summarised in Table 7.7.2.

Table 7.7.2: Gas consumption at YGP

	2021	2022	2023
Daily fuel gas consumption (KSCM)	76.9	55.8	41.3
Total annual fuel gas consumption (MSCM)	28.1	20.3	15.1
Emissions (tCO_2-e)	56,800	46,618	32,228

Notes:
Reporting period is from 1 January – 31 December
Emissions number for 2022 taken from Eni's internal GHG recording program, SHERPA.

7.3 Flaring

The annual volume of gas flared from the past three years is summarised in Table 7.3.

Table 7.3: Gas flared at YGP

	2021	2022	2023
Daily volume of gas flared (KSCM/d)	6.98	6.2	8.5
Total volume of gas flared (KSCM)	2,549	2,262	3,103
Estimated emissions (t CO_2-e)[1]	5503[2]	4,775	6,671

Notes:

Estimate to nearest 100 tonnes.
[1] Reporting period is from 1 January – 31 December, recorded in SHERPA

For the 2023 period, the Total equivalent greenhouse gas (GHG) emissions for flaring were calculated using Eni's internal emissions reporting program Sherpa.

7.4 Diesel Usage

Diesel usage over the reporting period was 102m^3. This equates to GHG emissions of approximately 276 tonnes CO_2-e. This information is drawn from SHERPA 2023. SHERPA is Eni's GHG data entry program.

Table 7.4: Annual diesel consumption and GHG emissions

	2021[2]	2022[3]	2023[1]
Diesel – stationary energy (m^3)	125	64	90
Diesel – mobile plant and transport (m^3)	4	7	12
Emissions (t CO_2-e)	350	192	276

Notes:
[1] Reporting period is from 1 January – 31 December using SHERPA
[2] Reporting period as per NGER from 1 July to 30 June
[3] Reporting period is from February 2022 to January 2023. It assumes mobile plant and transport is 7m3. The fuel records show a total diesel usage of 71m^3, so the stationary energy is calculated by subtracting mobile usage from total (71-7m^3). The Emissions is calculated using interpolation with the 2020 and 2021 relationship.

7.5 Stack emission monitoring

Emissions from the export gas turbine compressors are shown in the relevant Appendix.

All pollutant emissions measured were within the EPL limits.

7.6 Fugitive emission monitoring

During November 2023, a fugitive emissions survey was undertaken at the Blacktip Yelcherr Gas Plant. The following conclusions were drawn:

Table 7.5: Fugitive Emissions Data

Classification	Gas Leak	Number of Leaks at Source	
	[Concentration / Volume]	Preliminary Reading	Validation Reading
< Minor	< 500 ppm	4	4
Minor	≥ 500 ppm to < 5000 ppm	2	2
Significant	≥ 5000 or LEL% > 10%	1	1
Total		**7**	**7**

All leaks were quantified and Tag numbers for the affected equipment was recorded. These leaks are listed in the report Bureau Veritas - ENI Australia - Fugitive Emissions Survey 2023 (November).

Work orders have been raised for inspection and repair of remaining fugitive emission sources.

7.7 Pollutant inventory reporting

Eni reports emissions to atmosphere and the environment via the National Pollutant Inventory (NPI) and the National Greenhouse and Energy Reporting Scheme (NGERS).

Eni submitted the annual NPI reporting figures via the NPI Online Reporting System on 13 September 2023. NPI details available on request.

The annual NGERS reporting figures were submitted to the Department of Climate Change on 15 September 2023. Total emissions from Yelcherr Gas Plant during the July 2022 to June 2023 NGER reporting period were 28,550 tCO_2-e.

7.8 Flaring

The HP flare header is designed for inventories above 1000kPag. The system is sized to blowdown the Hydrocarbon inventory in the YGP to achieve the required 690kPag or 50% of operating pressure (whichever is lower) within 15 minutes.

The LP flare is designed to safely dispose of regeneration offgas, and control pressure regulation during normal operation. The annual volume of gas flared from the past three years is summarised in the following table.

Table 7.6: Gas flared at YGP

	2021	2022	2023
Daily volume of gas flared (KSCM/d)	6.98	6.2	8.5
Total volume of gas flared (KSCM)	2,549	2,262	3,103
Estimated emissions (t CO_2-e)[1]	5503[2]	4,775	6,671

Notes:
Estimate to nearest 100 tonnes.
[1] Reporting period is from 1 January – 31 December, recorded in SHERPA

For the 2023 period, the total equivalent greenhouse gas (GHG) emissions for flaring was calculated using Eni's internal emissions reporting program SHERPA.

8. UNPLANNED DISCHARGES TO LAND

8.1 Groundwater Quality

Groundwater is abstracted for potable water use and ancillary equipment at Yelcherr Gas Plant. The annual groundwater abstraction volumes are summarised in Table 8.8.1

There are also three monitoring bores, BH5, BH7 and BH1 located at YGP. The location of the abstraction and monitoring bores are shown in Figure 8.1

Table 8.8.1: Total annual volume of groundwater abstracted

	2021	2022	2023
Groundwater use (ML)	22	11	15.3

Notes: Reporting period is from 1 January to 31 December.

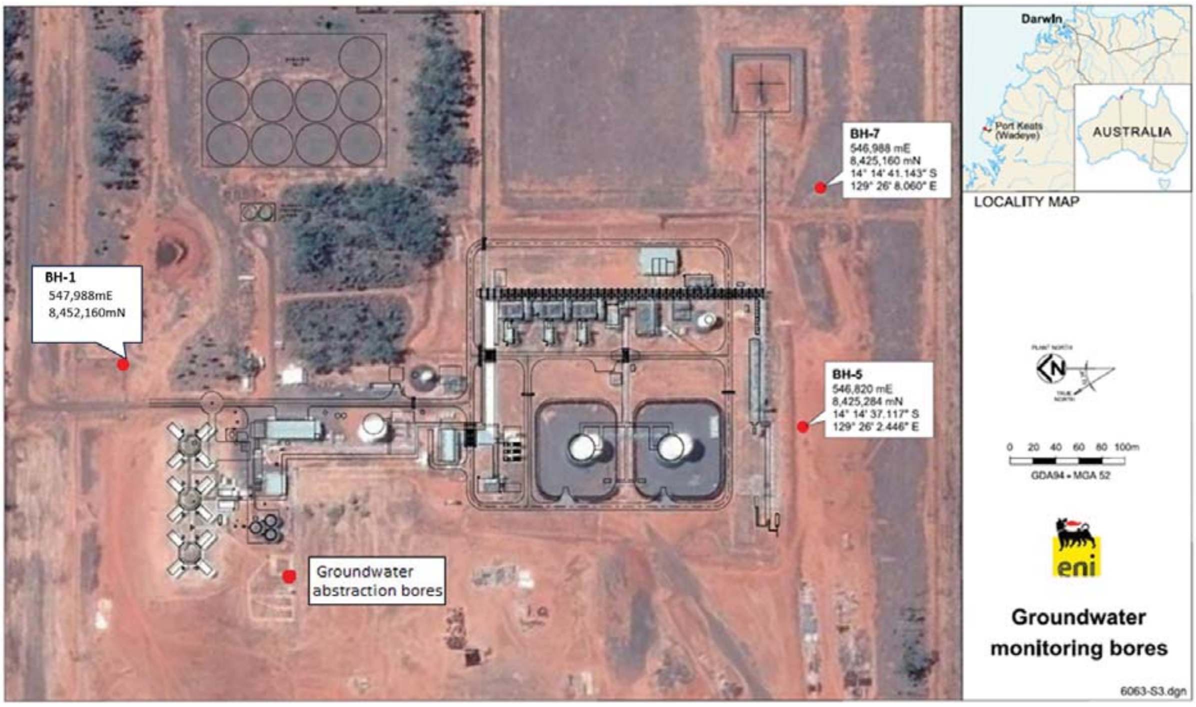


Figure 8.1: Groundwater abstraction and monitoring bores

Groundwater monitoring bore BH-1 was reinstated during a recent Hydrogeological Survey undertaken (November 2023). These works provided a third groundwater monitoring location to allow assessment of groundwater flow direction and gradient.

An additional 2 monitoring bores (BH-Nike and PH-Sierra) were installed in late 2023 and Company will consider including these in regular groundwater sampling and monitoring events in 2024.

Volumetric flowrates are up slightly on 2022 usage, though are lower than 2021 figures.

Two ground water extraction bores (BH-1 and BH-2) draw water from the aquifer for potable and plant use.

Groundwater monitoring (BH-5 and BH-7) was conducted on 13 February 2023, 15 June 2023 and 13 July 2023. Monitoring also conducted on 7 November 2023 and 21 January 2023 included recommissioned BH-1 bore.

The results and trend analysis are presented in Attachment E.

Elevated levels of total coliforms is evident in results form in April sampling which is likely attributed to a holding time breach of samples allowing proliferation of this contaminant. Results for total coliforms returned to normal levels in subsequent sampling.

All results were within the Australian Drinking Water Guidelines and ANZECC guidelines for 80% species protection. Quarterly monitoring at both bores measured pH between 4.9 and 5.8.

8.1.1 Monitoring Objective

A Groundwater Monitoring plan is being developed. The Environmental Management Plan requires samples to be drawn from the wells. Depths of water from surface are also required to be measured.

Sampling has been ongoing. Depth measurements are returning to practice.

8.1.2 Monitoring Methods

Groundwater monitoring was undertaken by the operators and coordinated by the Environmental Advisor through 2023.

Groundwater is monitored to determine whether wastewater discharges are impacting groundwater quality. The groundwater monitoring boreholes are BH5, BH7 and BH1.

Groundwater monitoring for BH1 commenced in November 2023 after being brought online post the Hydrogeological Survey.

Sampling and monitoring will be carried out in line with EPL230-01 requirements and in accordance with procedures defined in BTP Operations Environmental Monitoring Requirements [000036_DV_PR.HSE.1020.000].

8.1.3 Monitoring Results

The following key trends have been captured:

Table 8.2: YGP pH Trending Data

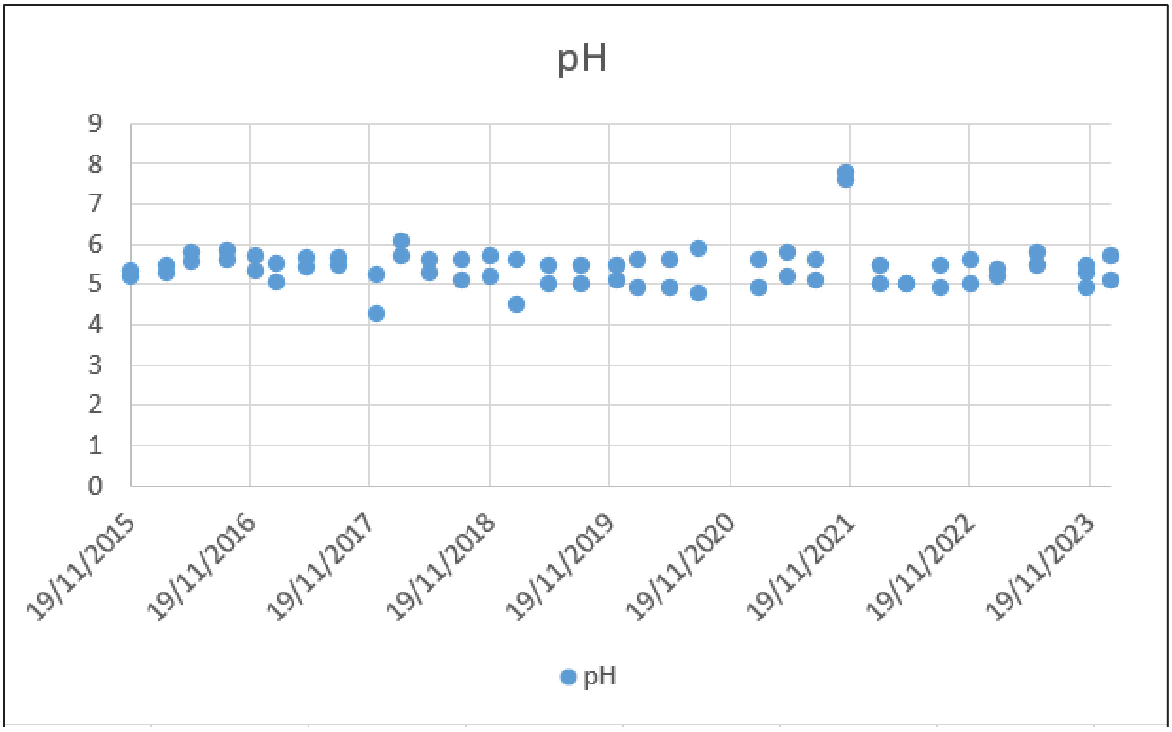


Table 8.3: YGP Electricity Conductivity (BH5/BH7) Trending Data

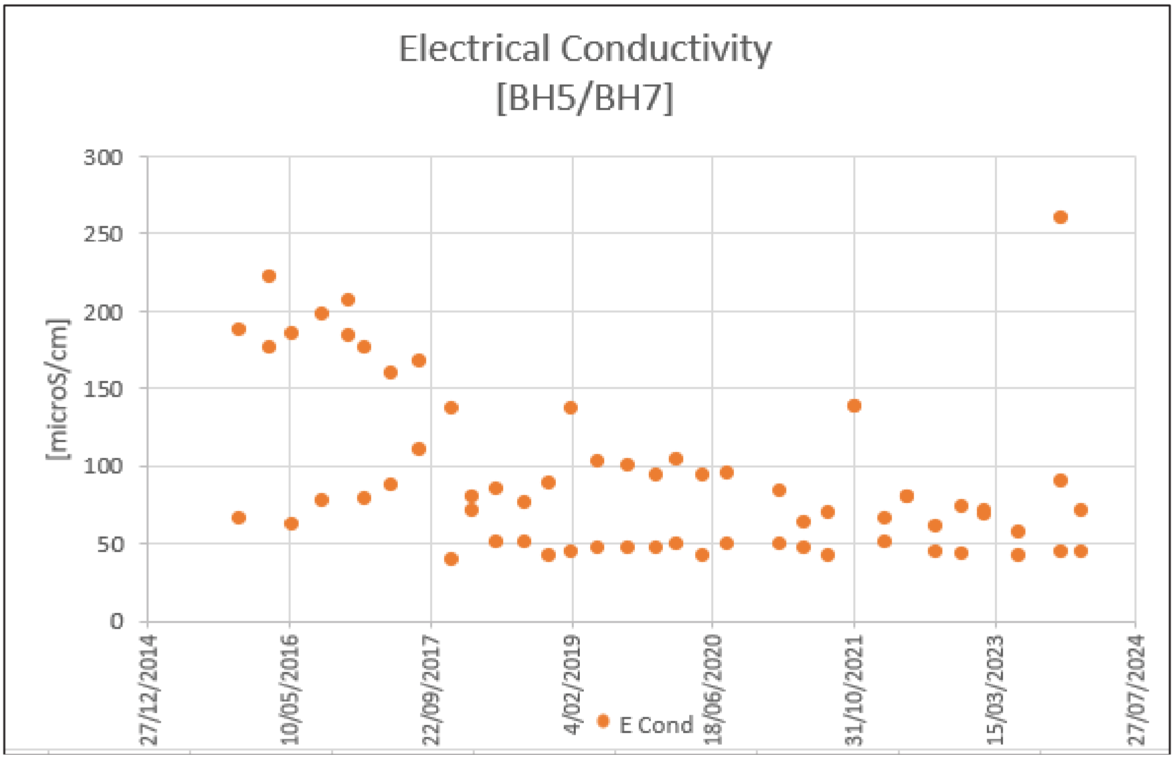


Table 8.4: YGP Dissolved Oxygen (BH5/BH7) Trending Data

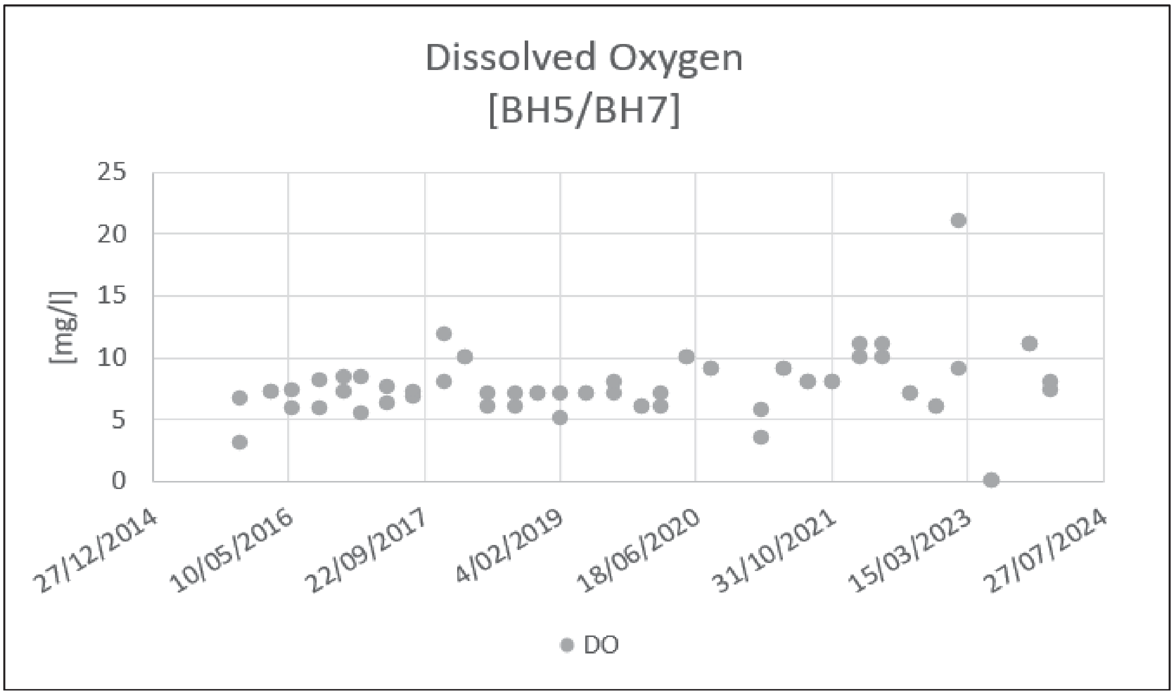


Table 8.5: YGP OiW and TPH (BH5/BH7) Trending Data

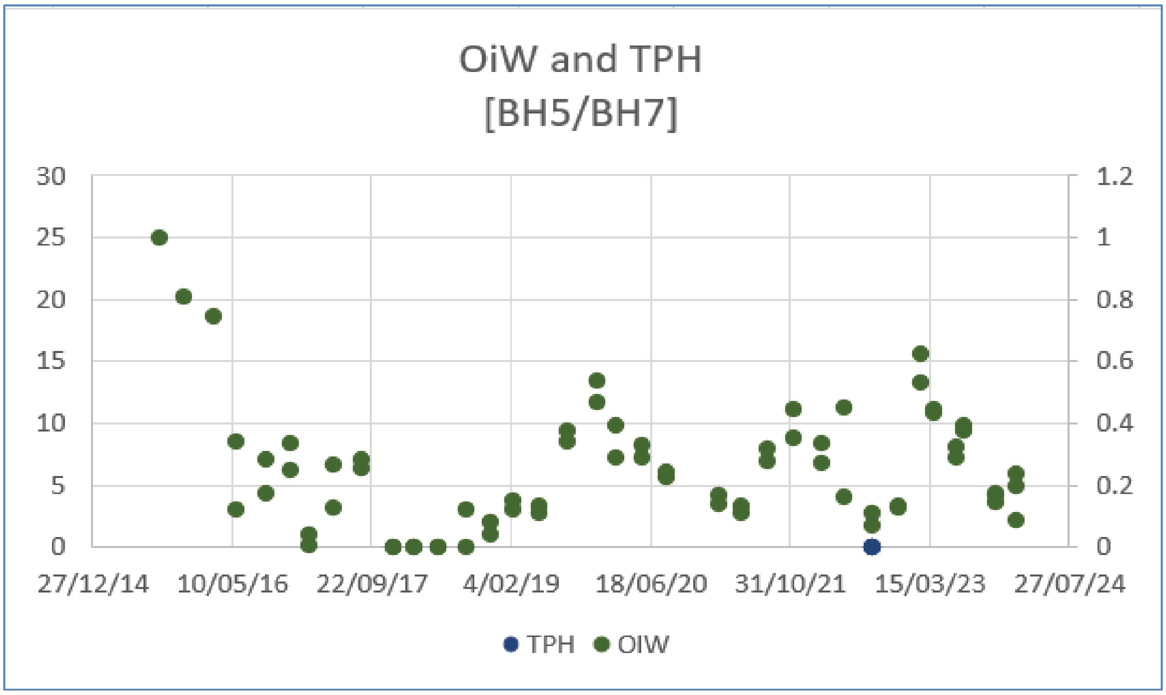
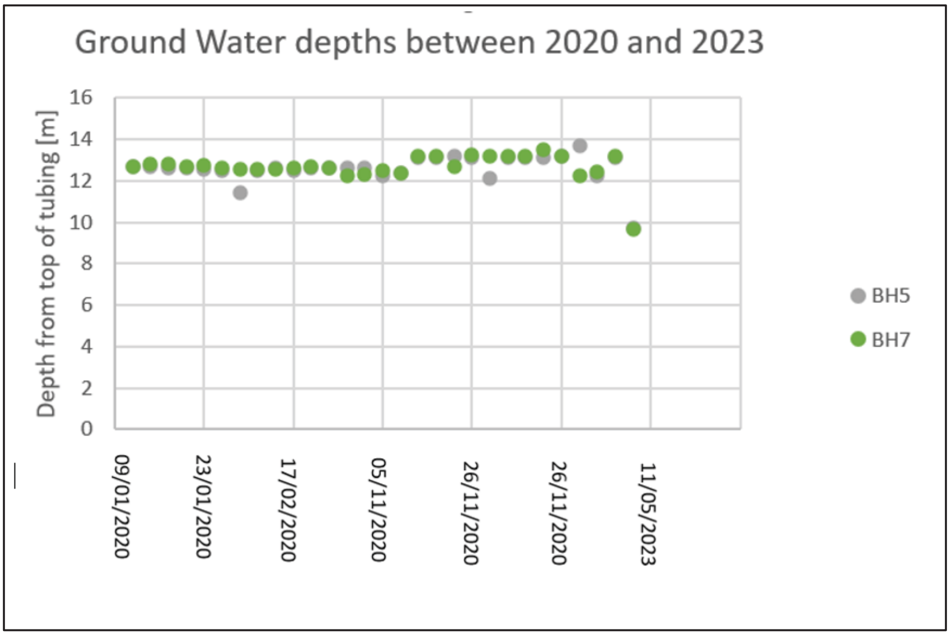


Table 8.6: Ground Water depths (BH5/BH7) Trending Data



No concerning trends or notable behaviours were identified in the other parameters. Groundwater depths (water levels) measured during the recent Hydrogeological Survey (November 2023) for BH-1, BH-5 and BH-7 were 11.71m, 11.01m and 10.95m retrospectively. More groundwater depths are available, which indicate a depth ranging between 13 meters and 9 meters. Depth data stretching back longer is available on request.

8.1.4 Data Management and Quality Control

The quality assurance/quality control (QA/QC) procedures specific to the collection and analysis of samples from sample location included:

- NATA accredited analytical laboratories were used for all analysis or a test method managed under a NATA accredited quality management system;
- Laboratory designated sample holding times met;
- Chain of custody forms was completed and accompanied the samples; and
- Calibration of all field-testing equipment using standard method(s) was undertaken.

8.1.5 Discussion and Interpretation of Results

Low level values for Oil in Water (OiW) have been present in the bore water samples. Indications Oil in Water present are suspected to be due to the analysis method (Horiba OCMA500) identifying naturally occurring Total Organic Carbon (TOC).

Total Petroleum Hydrocarbons (TPH) monitoring of bores continued in 2023 after commencing in 2022. TPH was not detected in groundwater for the majority of 2023 except for a single low level reading at BH-5 in June. This is seen as a one off event with no impact to the environment or any sensitive receivers. PH levels at this bore have since returned to baseline levels. Company will continue monitoring of TPH in bores throughout 2024.

8.1.6 Conclusions and Proposed Actions

There is no indication that negative environmental impacts are being experienced in the monitoring bores.

9. WASTE MANAGEMENT

Solid waste is managed onsite according to the Blacktip Waste Management Plan (000036_DV_PR.HSE.0832.000).

Domestic waste from the accommodation village and crib room is taken to the local West Daly Regional Shire Council Landfill. General industrial waste and hazardous waste from the plant is transported by a licensed contractor to Darwin for disposal, treatment, recycling, or destruction.

Table 9.1: Waste disposal

	2021	2022	2023
Domestic waste to local landfill (t) • Kitchen waste • Accommodation waste • Office waste	1	1	3
Darwin recycling (t) E.g. Scrap metal	3	4	6
Darwin disposal – non-hazardous (t) E.g. spent chemicals, cooking oil	22.7	58	30.83
Darwin disposal – hazardous (t) E.g. waste oil, oily rags, chemical drums and filters	85.6	63	225.92

Notes: Reporting period is from 1 January to 31 December.

A higher volume of hazardous waste was produced in 2023, much of this resulted from a spill incident that involved the cleanup and recovery of sludge material in November as well as increased use of filters needed to remove BTEX and metals from the Produced Water.

Volume of recycled materials increased, and non-recyclables decreased reporting period.

10. INCIDENTS AND NON-COMPLIANCES

The Waste Management and Pollution Control Act (NT) and EPL require all non-compliances with the EPL and any potential or actual environmental harm or pollution event to be recorded and reported to NT EPA.

Pollution is defined in the Waste Management and Pollution Control Act (NT) as:

- A contaminant or waste that is emitted, discharged, deposited or disturbed or that escapes; or
- A contaminant or waste, effect, or phenomenon, that is present in the environment because of an emission, discharge, deposition or escape or disturbance of a contaminant or waste.

Incidents and Non-Compliances are submitted to NT EPA within 24 hours of the site being made aware of the issue.

10.1 Incidents and non-compliances

The Annual Return outlines the compliance assessment against the Environment Licence EPL230-01.

Table 10.1 lists the environmental non-compliances recorded between 10 February 2023 and 9 February 2024. These have been raised in the non-compliance register and actions are tracked to closure.

Table 10.1: Environmental non-compliances

Date of NCR	Date detected	Clause breached	Description / remarks
14/02/23	04/04/23	Condition 28	• PW above EPL Limit for OiW, Copper (Filtered), Copper (Total), Toluene, Ethyl-Benzene, Xylene,
28/03/23	15/05/23	Condition 28	• PW above EPL Limit for TSS, Copper (Filtered), Copper (Total), Toluene, Ethyl-Benzene, Xylene, • PW above trigger values over three consecutive samples for OiW, Benzene, and Zinc (Total). • WW above EPL Limit for TSS and OiW.
12/04/23	27/06/23	Condition 28	• WW above EPL limits for BOD, TSS and E.Coli
16/04/23	27/06/23	Condition 28	• PW above EPL Limits for Toluene, Xylene, Naphthalene and Total Copper, • PW above Trigger Values for 3 consecutive periods for Zinc (Total and Filtered) and Copper (Filtered)
14/05/23	29/05/23	Condition 28	• PW above EPL Limits for Toluene, Xylene, and Copper (Total and Filtered), • WW below pH and above OiW limits.
15/06/23	20/07/23	Condition 28	• WW above EPL limits for TSS
19/06/23	20/07/23	Condition 28	• PW above EPL Limits for OiW, Mn (Dissolved and Total), Toluene, Ethylbenzene, and Xylene (m+p)
13/07/23	18/08/23	Condition 28	• WW above EPL limits for BoD
16/07/23	18/08/23	Condition 28	• PW above EPL Limits for OiW, Toluene, Ethylbenzene, and Xylene (m+p), Copper (dissolved and total), Mn (dissolved and total), Toluene, Ethylbenzene, and Xylene (m+p)
05/08/23	18/09/23	Condition 28	• PW above EPL Limits for Toluene, Xylene (m+p), Zinc (dissolved and total), pH

Date of NCR	Date detected	Clause breached	Description / remarks
15/08/23	18/09/23	Condition 28	• Blacktip - YGP - Non-compliance with EPL230-01 - Waste Water monitoring parameters measured above limits.
12/09/23	27/10/23	Condition 28	• PW above EPL Limits for Toluene, Xylene (m+p), Zinc (dissolved and total), Manganese (dissolved and total), Copper (dissolved and total), and OiW
07/11/23	30/11/23	Condition 28	• PW above EPL Limits for Toluene, Xylene (m+p), Zinc (total), Manganese (dissolved and total)
08/11/23	30/11/23	Condition 28	• WW above EPL limits for TSS
10/10/23	21/11/23	Condition 28	• PW above EPL Limits for Toluene, Ethyl benzene, Xylene (m+p), Zinc (dissolved and total), Manganese (dissolved and total)
10/11/23	10/11/23	Condition 19.1 & 19.2	• During transfer of sludge from main tank to ISO tanks the transfer hose parted and sludge spilled to grade
13/12/23	19/01/24	Condition 28	• Waste Water monitoring parameters measured above limits for TSS, 50 mg/l (EPL limit = 30mg/l)
18/12/23	19/01/24	Condition 28	• Produced Water monitoring parameters measured above limits for Copper (filtered), Copper (total), Zinc (total), Toluene and Xylene.
17/01/24	16/02/24	Condition 28	• Waste Water above EPL limits for E.coli
22/01/24	16/02/24	Condition 28	• Produced Water above EPL Limits for OiW, Toluene, Ethylbenzene, and Xylene (m+p), Copper (dissolved and total), Mn (dissolved and total), Toluene, Ethylbenzene, and Xylene (m+p).

10.2 Complaints

No complaints were received during the reporting period.

10.3 Audits and inspections

An onsite monitoring event by NT EPA Authorised Officers was conducted in June 2023 which included the collection of water samples from PW-02 to be analysed for BTEX and heavy metals. These samples were taken during a time when no discharge was occurring (preparation only)

Senversa Pty Ltd was engaged to conduct an environmental audit of certain aspects of operation at the Yelcherr Gas Plant (YGP) in response to being issued with a Section 48(1) Notice by NT EPA. The site inspection component of the audit was undertaken from 22nd to the 25th of February 2023 with the Audit being finalised for submission on the 13th October 2023.

Company conducted an Environmental Audit at the wastewater treatment plan against Yelcherr Gas Plant (YGP) EPL 230-01 Licence Conditions in May 2023.

Company conducted a 5 yearly Wastewater Treatment Plant Performance Review in July 2023.

CONTINUOUS IMPROVEMENT AND OTHER ACTIVITIES

The following activities were completed during the reporting period to continually improve compliance to EPL230-01 requirements:

- A Comprehensive annual fugitive emissions survey to monitor for gas leaks across YGP was conducted in November 2023;
- A Comprehensive annual venting validation survey to monitor venting sources at YGP was conducted in November 2023;
- A hydrogeological survey was undertaken at YGP (November 2023) to establish an assessment of potential risk to groundwater and provide a third monitoring location to allow improved assessment of groundwater;
- Thamarrurr Rangers participated water outfall sampling training to be used for future sampling exercises;
- A trial skid to remove metalloids from Produced Water has been engineered in preparation for installation in Q2 2024;
- An emergency exercise has been carried out at YGP involving and assessing the Thamarrurr Rangers in first responder capabilities in the event of a hydrocarbon spill in the offshore area (off shore water sampling and monitoring);
- An in depth energy efficiency assessment in accordance with the requirements of ISO50001 was completed;
- Engaged a new third party contractor to conduct site based EPL230-01 monitoring and analysis programme;
- In accordance with Section 48(1), a third party consultant was engaged to conduct an independent environmental audit of the Yelcherr Gas Plant (YGP) on behalf of the NT EPA; and
- Company conducted an Environmental Audit and a 5 Yearly Performance Review of the wastewater treatment plant.

11. COMMUNITY INITIATIVES

Eni and the Thamarrurr Rangers continue to work closely to identify opportunities for local engagement and achieve positive environmental outcomes.

Eni continues to maintain a positive and engaging relationship with the Thamarrurr Rangers, who deliver local environmental monitoring services such as, but not limited to:

- Monitoring of offshore assets (e.g. Single Point Mooring (SPM) and hose);
- Wild fire management;
- Controlled burning;
- Weed and pest monitoring and eradication;
- Marine monitoring;
- Sea turtle monitoring;
- Fauna monitoring and relocation;
- Provision of vessel and crew for offshore environmental sampling;
- Emergency Response: Initial Oil Spill Monitoring Capabilities;
- PW-01 (Produced Water discharge point) monitoring; and

Containers for Change (plastic bottle recycling).

The SPM monitoring conducted by the Rangers includes inspection of the SPM equipment as well as inspection of the surrounding waters for surface sheen and possible spills. This provides a valuable contribution to the safe offtake of condensate and is an important part of Eni's scheduled maintenance. The Rangers also support the YGP groundwater monitoring, marine monitoring and weed management programs.

In 2023, Thamarrurr Rangers participated in training for water outfall sampling and monitoring to be used in the future. This will support validation of the mixing zone at PW-01.

The regular monitoring by the rangers allows our site-based personnel to engage with local indigenous community members, providing a greater appreciation of the region and the importance of caring for country.

12. ABBREVIATIONS

Abbreviation	Description
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
BOD	Biological Oxygen Demand
EPL 230-01	Environmental Protections Licence (EPL230-01)
Kscm	Thousands of standard cubic meters
ML	Mega-litres
Mn	Manganese
NGER	National Greenhouse and Energy Regulator
NPI	National Pollutant Inventory
NT EPA	Northern Territory Environment Protection Authority
OiW	Oil in Water
tCO2-e	Tonnes of Carbon Dioxide equivalent
TSS	Total Suspended Solids
YGP	Yelcherr Gas Plant
Zn	Zinc

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ATTACHMENTS

ATTACHMENT A:

AIR EMISSIONS MONITORING PROGRAMME

Attachment A.1: Summary of stack emission monitoring results from the compressors

	CO	NOx[1]	SOx	Solid particles	VOCs
EPL limit	**100 mg/m³**	**350 mg/m³**	**100 mg/m³**	**-**	**40 mg/m³**
October 2021					
Compressor A	<8	210	*<8*	*27*	0.55
Compressor B	<9	230	*<8*	*4.1*	0.18
Compressor C	<8	240	*<8*	*20*	1.8
April 2022					
Compressor A	<7	320	*NT*	*NT*	<0.2
Compressor B	<8	250	*NT*	*NT*	0.18
Compressor C	<7	320	*NT*	*NT*	<0.2
November 2022					
Compressor A	<9	210	*21*	*<2*	0.17
Compressor B	NT	NT	NT	NT	NT
Compressor C	NT	NT	NT	NT	NT
November 2023					
Compressor A	NT[6]	NT [6]	NT [6]	NT [6]	NT [6]
Compressor B	NT [6]	NT [6]	NT [6]	NT [6]	NT
Compressor C	25	320	<2	<2	1.8

Notes:
[1] NOx presented as NO_2 equivalent.
[2] SOx presented as the cumulative concentration of SO_2 and SO_3.
[3] All measurements reported on a dry basis at NTP and corrected to 15% O_2 in accordance with the EPL.
[4] Measurements above the EPL limit are indicated in red, and measurements above the trigger value are indicated in orange.
[5] NT = Not tested.
[6] Compressor A & B were not operational at time of testing due to unplanned maintenance.

Attachment A.2: Summary of stack emission monitoring results from the generators

	CO	NOx[1]	SOx	PM	VOCs
EPL limit	**1600 mg/m^3**	**2000 mg/m^3**	**100 mg/m^3**	**-**	**40 mg/m^3**
October 2021					
Generator A	770	1500	*<20*	*8.9*	11
Generator B	750	1500	*<20*	*3.4*	36
Generator C[8]	NT[8]	NT[8]	*NT[8]*	*NT[8]*	NT[8]
April 2022					
Generator A	1100	2000	NT	NT	0.38
Generator B	1100	2000	NT	NT	0.58
Generator C	NT[8]	NT[8]	NT[8]	NT[8]	NT[8]
November 2022					
Generator A	730	1400	<2	NT	4.8
Generator B	610	1400	<4	NT	0.42
Generator C	520	1200	<2	NT	9.2
November 2023					
Generator A	NT[8]	NT[8]	NT[8]	NT[8]	NT[8]
Generator B	1200	2000	<2	<3	1.3
Generator C	860	1700	<2	<2	0.85

Notes:
[1] NOx presented as NO_2 equivalent.
[2] SOx presented as the cumulative concentration of SO_2 and SO_3.
[3] All measurements reported on a dry basis at NTP and corrected to 15% O_2 in accordance with the EPL.
[4] Measurements above the EPL limit are indicated in red, and measurements above the trigger value are indicated in orange.
[5] Emissions sampling provider advised that levels of methane (160-200mg/m^3) can cause an interference with the SO_2 cell of the analyser
[6] NT = Not tested.
[7] June 2020 emissions testing was deferred due to COVID travel restrictions.
[8] Gas Engine Generator was not operational due to unplanned maintenance

Attachment A.3: Air emissions annual pollutant mass inventory (Source – NPI (Appendix C) and 2023 NGER report – Info only)

Atmospheric Emission Points			Annual Pollutant Mass (t)								
Point ID	Description		SO_2	NOx	CO	VOC	PM_{10}	CO_2	CH_4	N_2O	CO_2-e
A03 A04 A05	Gas Compressor A Gas Compressor B Gas Compressor C	2018-2019	0.2	125	40	1	0.9	35,165	3	0.07	35,254
		2019-2020	0.3	160	48	1	1.1	42,388	3	0.08	42,496
		2020-2021	0.3	172	48	1.2	1.1	40,691	79	23	40,794
		2022-2023	4.06	76	4.5	0.23	1.8	19,074	37.11	11.13	19,074
A06 A07 A08	Engine Generator A Engine Generator B Engine Generator C	2018-2019	0.03	347	19	4	<0.003	3,653	0.28	0.007	3,663
		2019-2020	0.02	191	19	4	<0.003	3,661	0.28	0.007	3,670
		2020-2021	0.02	130	19.7	4.2	2.7	3,682	7	2	3,691
		2022-2023	0.07	52	27.9	0.07	0.04	2,978	5.79	1.74	2978

[1] SOx, NOx and CO figures are as per the NPI reports and associated estimation techniques, and CH_4, N_2O and CO_2 are as per NGER reports and associated estimation techniques.

[2] Not available or below threshold (i.e. for NPI substances, SO_2, NOx, CO).

ATTACHMENT B:

PRODUCED WATER MONITORING

Routine produced water discharge sampling and analysis

DATE	Quantity	Average OiW	pH	EC	Dissolved Oxygen	Temp	Turbidity
Units	m3/d	mg/l	unitless	µS/cm	% saturation	˚C	NTU
Limit		6 to 25	6.5-8.5				
13-Feb-23	222	21.3	8.1	69.76		29.5	19.6
14-Feb-23	98.2	22.4	8.3	71.8		30.2	21
15-Feb-23	216.5	15	7.49	68.9		29.8	30
16-Feb-23	255.1	15	7.49	68.4		32.1	40.1
17-Feb-23	103	17.8	7.62	67.9		31	29
18-Feb-23	108.6	14.7	8.1	68.94		33	15.6
19-Feb-23	78.8	18.2	8.47	68.92		32.1	26.8
20-Feb-23	116.2	17.2	8.34	68.75		32.5	19
21-Feb-23	165	19.3	8.3	68.4		30.6	21.2
24-Feb-23	146	21	8.2	69.75		23.6	46.2
26-Feb-23	269	20	7.3	68.1		28.2	31.3
27-Feb-23	150	24	8.4	68		23.8	36.4
28-Feb-23	407.1	19.5		65.8		27.8	67.8
01-Mar-23	207	11.2	7.3	68.77		29.1	30.2
02-Mar-23	203	10.3	7.4	66.3		31	67.1
03-Mar-23	185	8.2	8.4	41.9		30.1	19.9
05-Mar-23	180	6.5	7.6	155.7		28.9	3.6
06-Mar-23	151.4	10.1	8.4	43.71		27.9	28.1
07-Mar-23	78.5	15	7.8	481.2		30.2	5.43
08-Mar-23	102.23	16.9	7.82	69.49		33.7	16.9
09-Mar-23	147.1	24	8.28	29.2		25.8	15.8
10-Mar-23	144.5	11.2	7.35	70.09		30.9	17
11-Mar-23	85.9	16.8	8.2	222.6		24.6	16.1
12-Mar-23	142.2	11.8	7	67.46		31.3	11.9
13-Mar-23	128	15.9	8.25	96.24		30	15.8
14-Mar-23	133	23.4	8.36	115.3		29	16.4
15-Mar-23	127.6	19.2	6.8	127.3		29	5.4
18-Mar-23	80	16.1	6.78	11.94		31	9.8
19-Mar-23	95.8	13.7	7.29	304.3		30	14.6
20-Mar-23	67.1	21.8	6.71	71.34		31	13
23-Mar-23	447	7.9	7.1	630		30	13.4
24-Mar-23	73.1	16.4	8.13	754.1		32	13.3
31-Mar-23	85.1	10.1	7.89	3.58		31.1	21.1
02-Apr-23	218.8	8.7	8.3	70	3	32	22
03-Apr-23	11.3	18.2	7.4				
04-Apr-23	100.1	18.2	7.4	70	3.3	30.1	24.8
07-Apr-23	434.9	10.3	7.8	70.5		29.1	17
08-Apr-23	148.1	10.5	7.9				
11-Apr-23	99.2	1.1	7.9				
13-Apr-23	75	8.7	6.91				
16-Apr-23	101.1	13.7	7.7	69.51	0.1	29.2	37.1
18-Apr-23	474.6	12.67	7.3	71.1		28.7	41.2
23-Apr-23	284.4	21.8	6.6	68.87		29.7	87
24-Apr-23	115.9	9.4	8.39	72.3		29.8	62
28-Apr-23	332.2	23.9	8.3	125.6	2	22.8	71
01-May-23	579.6	14.6	8.2	67.65		30	79.4
05-May-23	10	12.4	8				
06-May-23	118.9	12.4	8	69.7	1.2	28.9	134
07-May-23	378.4	16.9	8.2	70.74	2.7	30.2	22
09-May-23	216.5	2.2	8.5	71		28	55
10-May-23	199.8	15.9	7.2	69.17		29.4	72.3
11-May-23	87.7	18.1	8.4	76	2	29.1	16.5
14-May-23	388.74	5.6	7.9	68.9		28.1	2.5
16-May-23	81.8	5.8	8.3	69.5		28.7	3.9
17-May-23	46.9	8.8	8.4	72.3	1.7	28.6	10.9
18-May-23	303.5	12.9	8.28	68.9		28.1	20.5
19-May-23	121.2	5.4	8.49	71.65	1	28.7	7.95
20-May-23	203.1	5.6	7.9	69.64	2	26.7	19

DATE	Quantity	Average OiW	pH	EC	Dissolved Oxygen	Temp	Turbidity
Units	m3/d	mg/l	unitless	µS/cm	% saturation	˚C	NTU
Limit		6 to 25	6.5-8.5				
21-May-23	147.7	6.3	8.4	70.5	7.2	26	185
22-May-23	133.3	11.5	8.38	69.1		24.2	9.1
23-May-23	175.7	11.8	8.3	72.4	6.4	27.2	24
24-May-23	206.2	16	7.9	66.49	7.1	24.5	4.8
26-May-23	53	10.8	6.94	68.24	1.9	26.5	3.81
29-May-23	257.6	10.4	8	66.7	6.1	25	44.7
31-May-23	108	21.6	8.3				
01-Jun-23	108	21.6	8.3	67.2	3.1	25	275
02-Jun-23	277.8	12.1	8.4	69.5	6.8	25	78
03-Jun-23	221.6	7.6	8.116	72	3.1	31.2	42.4
04-Jun-23	510	4.9	7.4	68.4	3.4	32	8.05
05-Jun-23	108.9	15.4	8.3	66.9	5	24	61
06-Jun-23	588.6	6	7.2	70	6	26	71
09-Jun-23	640.2	22.8	7.179	69.4	3.5	28	39.3
14-Jun-23	426	6	8.35	70.3	6.1	28.9	43.9
19-Jun-23	557	2	8.4	72.9	5.2	28.1	6.4
22-Jun-23	551.8	16.7	8.49	68	0	26	67.4
27-Jun-23	579.1	1.4	8.08	71	5.8	23	85
30-Jun-23	632	5.7	8.38	69.12	5.9	29	68.9
06-Jul-23	530.2	0	8.39	69.12	175	30.7	2.08
06-Jul-23	125.7	0.1	8.4	67.72	124	25.3	3.38
09-Jul-23	386	9.3	6.85	48.29	167	26.6	31.9
14-Jul-23	536.2	16.3	8.417	68.96	2.5	28.1	9.94
16-Jul-23	405.4	9.6	8.47	1.87	0.2	29.8	42.4
17-Jul-23	380.4	13	7.02	72.03	1.9	29.9	10.1
19-Jul-23	203.3	12.6	8	69.1	1.9	24.4	14.1
24-Jul-23	236.4	13.1	7	69.1	5.4	26	69
24-Jul-23	552.27	5.4	8.04	68.25	0.3	24.8	51.3
26-Jul-23		7.8	8.3	68.21	3.1	21	32.9
29-Jul-23	381.3	13.3	8.37	83		28.1	9.1
02-Aug-23	483.6	18	8.41	0.789	5.4	28.1	6.8
05-Aug-23	429.86	4.8	8.25	69.4	4.6	22.1	42.6
08-Aug-23	301.11	2.2	8.315	70	0.9	25	77.4
10-Aug-23	45.4	4.3	6.5	78	0.9	27	71.5
18-Aug-23	150.7	11.9	7.27	71	2.6	26	68
20-Aug-23	391.4	13.3	7.17	79	2.1	27	55
22-Aug-23	402.5	21.1	6.7	68	4.1	26	23.5
24-Aug-23	414.9	3.35	7.2				
26-Aug-23	550	5.6	7.4	71.65	4.6	26.8	8.51
29-Aug-23	207.2	12.9	6.602	69.63	2.5	32.3	14
30-Aug-23	428	10.5	6.75	71.6	4.1	29.8	9.1
02-Sep-23	412.53	7.5	6.95	71.1	6.2	30.5	8.1
03-Sep-23	202.39	9.85	6.92				
05-Sep-23	502.3	20.9	6.793	975.8	182	22.3	7.28
07-Sep-23	288	5.1	6.568	71.12	4.6	28.4	6.27
08-Sep-23	164.37	8.3	8.434	69.89	5.2	24.9	23.9
09-Sep-23	136.9	7.2	6.85				
10-Sep-23	306.22	8.8	6.87				
12-Sep-23	277.16	9.375	6.79				
14-Sep-23	281.6	5.1	7				
18-Sep-23	341.6	8.3	8.43				
19-Sep-23	310.3	9.9	7.984	70.03	4	29.5	36
22-Sep-23	54.03	17.9	8.1				
24-Sep-23	312.63	15.9	8.4				
25-Sep-23	272.43	11.1	8.67				
27-Sep-23	246.2	17.8	8.27	69.4	3.8	31.5	4.1
28-Sep-23	194.25	5	8.15				
29-Sep-23	73.47	21.9	8.027	72.02	121	26.4	22.9
30-Sep-23		6.7	8.08	72.01	20	28.5	12.3
02-Oct-23	348.6	9.5	8.2	71	4.2	28	31

DATE	Quantity	Average OiW	pH	EC	Dissolved Oxygen	Temp	Turbidity
Units	m3/d	mg/l	unitless	µS/cm	% saturation	˚C	NTU
Limit		6 to 25	6.5-8.5				
04-Oct-23	193.7	11	7.87	72.31	49.1	28.9	14.4
05-Oct-23	112.18	11	7.87				
10-Oct-23	407.94	4.7	8.14	71.05	73.8	30	7.2
11-Oct-23	36	7.55	7.58				
12-Oct-23	287	16.8	6.61	71.64	7.94	29.8	5.81
13-Oct-23	57.55	16.8	6.99				
14-Oct-23	377.13	4.1	7.69	71.1	21.8	29.6	4.1
16-Oct-23	297.2	5.4	8.47	71.54	10.1	29.9	20.4
17-Oct-23	64.67	6.05	8.27				
18-Oct-23	438.11	8.4	8.4	70.13	N/A	30.3	12.2
21-Oct-23	400.02	7.7	7.85	69.77	N/A	33.3	13.8
24-Oct-23	578.8	2	7.02	70.83	N/A	29	5.16
26-Oct-23	201.55	8	6.8	70.22	N/A	31.7	9.7
28-Oct-23	364.96	3.7	8.4	71	3.5	31	36
29-Oct-23	230.3	20	8.24	69	3.4	31	24
30-Oct-23	164.37	16	8.45	61	3.9	31	29
01-Nov-23	214.22	17.9	8.31	71	N/A	29.6	32
02-Nov-23	185.1	17.9	7.8				
03-Nov-23	121.3	23	8.2	75	N/A	31	29
04-Nov-23	147.2	18	8.3	79	N/A	32	38
07-Nov-23	201.84	7	8	65	N/A	32	31
08-Nov-23	269.61	15.4	8.39	71.74	0.29	29.4	12.2
09-Nov-23	128.1	5.1	7.6	71.61	0.24	28.8	17.9
11-Nov-23	241.29	5.4	7.7	70.2	1.2	23.7	5.26
13-Nov-23	226.9	9.4	8.44	70.04	0.6	31.8	0.81
18-Nov-23	311.5	10	7.78	78.32	85	29.8	18.5
19-Nov-23	158.94	11.3	6.84	72.32	14.8	26.9	34.7
20-Nov-23	269.2	13.1	7.3	72.45	28	31.7	11.7
22-Nov-23	74	8.2	8.2				
23-Nov-23	74	8.2	8.2	71.24	17.9	32.8	4.52
27-Nov-23	57.9	21.9	8.26	70.91	3.2	32.8	5.13
28-Nov-23	171.8	23.5	7.9	72.14	2	30.1	28
07-Dec-23	118.3	6.1	8.3	71.17	3.3	29.1	11.3
08-Dec-23	118.3	6.1	8.3				
18-Dec-23	149.7	10	8.1	69	3.8	34	31
30-Dec-23	12.7	17.3	8.29				
03-Jan-24	300.18	16.8	8.01	8.46	62	22.5	13.2
05-Jan-24	180.1	15.6	8.1	70.8	1.5	33.9	12.8
09-Jan-24	253.99	7.6	7.8	71.99	2	33	23.7
10-Jan-24	120.8	6.3	7.5	70.35	18	29	40.6
22-Jan-24	128	0.3	7.8	70.94	47	30.8	1.8

Produced water sampling and analysis

Sample Date	pH	Elec Cond	DO	Temp	Turbidity	BOD	COD	TSS	TDS	TOC	OiW
	unitless	µS/cm	%Sat	˚C	NTU	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Trigger Value	6.5 -8.5							10			6
Limit								50			25
22/01/2024	8.3	75,000			0.82	520	3,100	10	50,000	740	34.4
15/12/2023	8.2					270	4,400	8	53,000	720	22.8
7/11/2023	8.2	73,000						<5	53,000		22.4
15/10/2023	7.8					240	1,400	<5	51,000	330	12.3
12/09/2023	7.2	77,000			38	190	1,100	14	53,000	280	25.4
5/08/2023	8.8	73,000			2	360	920	<5	50,000	210	20.1
16/07/2023	8.3	67,000			12	150	2,400	13	48,000	490	88.1
19/06/2023	7.9	70,000			10	160	3,000	<5	46,000	1000	25.5
14/05/2023	7	63,000			1.1	180	5,100	6	52,000	1400	19.3
16/04/2023	8.1	63,100	9		13	857	3,380	20	47,000	724	18.6
28/03/2023	8.8	62,200	9		76	795	2,780	110	45,900	564	20.7
14/02/2023	8.2	61,700	10		6	5.3	2,660	20	45,700	471	31.9
24/01/2023	8.1	63,300	10		76	5.2	3,640	160	47,600	616	20.4

Produced water sampling and analysis continued…..

Sample Date	Total Phos	Total Nitro	Oxid. Nitro (NOx)	Ammon. N (NH3-N)	Nitrate (NO3-)	Nitrite (NO2-)	Al_F	Al_T	As_F	As_T
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/L	µg/L	µg/L	µg/L
Trigger Value										
Limit										
22/01/2024	<0.50	38	<0.0050	33	<0.0050	<0.0050	130	100	<2.0	<2.0
15/12/2023	<0.25	44	<0.005	38	<0.005	<0.005	<20	130	<2.0	<2.0
7/11/2023							<20	<20	<2	<2
15/10/2023										
12/09/2023	<0.1	42	<0.05	38	<0.05	<0.2	21	81	<2	<2
5/08/2023							<20	29	<2	<2
16/07/2023	<0.25	42	0.0077	40	<0.005	<0.005	<10	97	<1	<1
19/06/2023	<0.25	47	0.01	42	<0.02	0.029	540	490	<2	<2
14/05/2023	<0.25	40	<0.005	39	<0.005	<0.005	330	340	<1	<1
16/04/2023	<0.025	37.8	0.01	37.7	0.01	<0.005	86.1	123	<2	<2
28/03/2023	<0.025	43.5	<0.025	41.6	<0.025	<0.005	49.1	52.3	<2	<2
14/02/2023	<0.025	45.5	<0.005	44.3	<0.005	<0.005	41.5	71.9	3.8	4.5
24/01/2023	<0.025	42.8	0.045	42.4	0.045	<0.005	2	28.2	<2	2.6

Produced water sampling and analysis continued.....

Sample Date	Ba_F	Ba_T	Be_F	Be_T	B_F	B_T	Cd_F	Cd_T	Co_F	Co_T
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Trigger Value										
Limit										
22/01/2024	100,000	100,000	<1.0	<1.0	3,900	3,300	<0.2	0.24	<2	<2
15/12/2023	120,000	110,000	<1.0	<1.0	3,700	2,500	<0.2	0.22	<2	<2
7/11/2023	110,000	160,000	<1	<1	4,200	3,600	<0.2	<0.2	<2	<2
15/10/2023										
12/09/2023	120,000	120,000	<1	<1	4,800	6,800	0.26	0.32	<2	<2
5/08/2023	100,000	110,000	<1	<1	4,100	3,800	<0.2	0.84	<2	<2
16/07/2023	110,000	110,000	<0.5	<0.5	2,400	2,400	0.66	<0.1	<1	<1
19/06/2023	97,000	96,000	<1	<1	4,400	4,900	<0.2	<0.2	<2	<2
14/05/2023	99,000	92,000	<0.5	<0.5	3,500	3,200	<0.1	<0.1	<1	<1
16/04/2023	88,200	94,300	<2	<2	3,010	3,120	<0.8	<0.8	<0.4	<0.4
28/03/2023	90,800	88,900	<2	<2	4,360	4,010	<0.8	<0.8	<0.4	<0.4
14/02/2023	92,400	105,000	<2	<2	2,760	3,040	<0.8	<0.8	<0.4	<0.4
24/01/2023	87,600	96,000	<2	<2	3,580	3,480	<0.8	<0.8	<0.4	<0.4

Produced water sampling and analysis continued.....

Sample Date	Cu_F	Cu_T	Cr_F	Cr_T	Cr III	Cr VI	Fe_F	Fe_T	Hg_F	Hg_T
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Trigger Value	3	3								
Limit	8	8								
22/01/2024	9.4	7.2	<2	<2	<50	<50	4,400	4,800	0.68	0.7
15/12/2023	9.3	10	<2	<2	<25	<25	470	510	0.21	0.23
7/11/2023	9.9	10	<2	<2	<25	<25	370	680	0.12	0.1
15/10/2023										
12/09/2023	16	16			<25	<25	140	3,800	0.05	0.06
5/08/2023	8.3	8.6	<2	<2	<25	<25	69	110	<0.05	0.095
16/07/2023	10	9.7	2.5	2.1	<25	<25	23	1,400	0.18	0.18
19/06/2023	7.8	7.3	4.8	3.7	<0.05	<0.05	7,300	7,500	<0.5	0.26
14/05/2023	1	1	2	2	<0.05	<0.05	950	980	0.67	1.1
16/04/2023	5.72	13.5	<4	<4	<50	<50	156	188	2.46	2.9
28/03/2023	13.4	9.6	<4	<4	<50	<50	7,740	5,930	<0.8	3.14
14/02/2023	6.94	12.9	<4	<4	<50	<50	350	412	<0.8	<0.8
24/01/2023	15.2	17.8	<4	<4	<50	<50	4,740	5,860	<0.8	1.62

Produced water sampling and analysis continued.....

Sample Date	Mg_F	Mg_T	Mn_F	Mn_T	Mo_F	Mo_T	Pb_F	Pb_T	Ni_F	Ni_T
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Trigger Value										
Limit			80	80						
22/01/2024	41,000	41,000	99	85	<2	<2	<2	<2	6.4	6.1
15/12/2023	67,000	70,000	22	22	<2	<2	<2	<2	5	5.9
7/11/2023	110,000	150,000	110	120	<2	<2	<2	<2	2.1	2
15/10/2023			240	240						
12/09/2023	140,000	140,000	280	280	<2	<2	<2	<2	2.9	3.6
5/08/2023		120,000	29	30	<2	<2	<2	<2	2.2	3.3
16/07/2023	0	110,000	100	140	1.3	1.5	<1	<1	5.4	2.3
19/06/2023		260,000	280	270	<2	<2	<2	<2	<2	2.7
14/05/2023	61	56	26	28	<1	<1	<1	<1	3	3
16/04/2023	45,400	45,900	5.7	6.6	<2	<2	0.73	0.7	5.48	7.7
28/03/2023	67,300	65,800	41.4	47.5	<2	<2	<0.4	<0.4	4.46	2.14
14/02/2023	68,400	72,400	41.4	47.5	<2	<2	1.58	1.91	0.86	2.24
24/01/2023	99,800	97,500	145	163	<2	<2	0.69	0.82	1.66	3.23

Produced water sampling and analysis continued.....

Sample Date	Se_F	Se_T	Sn_F	Sn_T	Zn_F	Zn_T	Radium Isotopes (Ra 226)	Radium Isotopes (Ra 228)	MBAS	Phenol
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mBq/L	mBq/L	µg/L	µg/L
Trigger Value					23	23				
Limit					43	43				1200
22/01/2024	<2	<2	17	2.4	59	42				180
15/12/2023	<2	<2	<2	<2	40	120				110
7/11/2023	2.3	2.5	<2	<2	42	49				78
15/10/2023					55	49				150
12/09/2023	2.2	2.2	<2	<2	58	62				210
5/08/2023	<2	<2	<2	<2	45	51				
16/07/2023	1.1	<1	<1	<1	36	39			<0.1	190
19/06/2023	<2	<2	<2	<2	31	42			<0.1	140
14/05/2023	<1	<1	<1	<1	70	74			<0.1	92
16/04/2023	<8	<8	<4	<4	29.9	32.9			<0.1	110
28/03/2023	<8	<8	<4	<4	33.5	31.7			<0.1	110
14/02/2023	<8	<8	6.7	7	12.2	68.2			<0.1	110
24/01/2023	<8	<8	<4	<4	70.8	78.1			<0.1	110

Produced water sampling and analysis continued.....

Sample Date	Pentachlorophenol	2-Chlorophenol	2-Methylphenol (O-Cresol)	4-Methylphenol	2-Nitrophenol	Ethyl/Dimethylphenols	Benzoic acid	2,4-Dichlorophenol	2,6-Dichlorophenol	4-Chloro-3-Methylphenol
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Trigger Value										
Limit	55									
22/01/2024	<5.0	<20	220	200	<20	650		<20	<20	<100
15/12/2023	<5.0	<10	180	170	<10	250		<10	<10	<50
7/11/2023										
15/10/2023										
12/09/2023	<5	<1	330	240	<1	380		<1	<1	<5
5/08/2023										
16/07/2023	<50	<10	280	200	<10	310		<10	<10	<50
19/06/2023	<5	<1	260	200	<1	270		<1	<1	<5
14/05/2023	<50	<10	160	96	<10	<10		<10	<10	<50
16/04/2023	<50	<10	200	120	<10	330		<10	<10	<50
28/03/2023	<50	<10	180	270	<10	190		<10	<10	<50
14/02/2023	<5	<1	200	120	<1	290		<1	<1	<5
24/01/2023	<5	<1	220	130	<1	330		<1	<1	<5

These samples are only required Quarterly as NTEPL230-01.

Produced water sampling and analysis continued.....

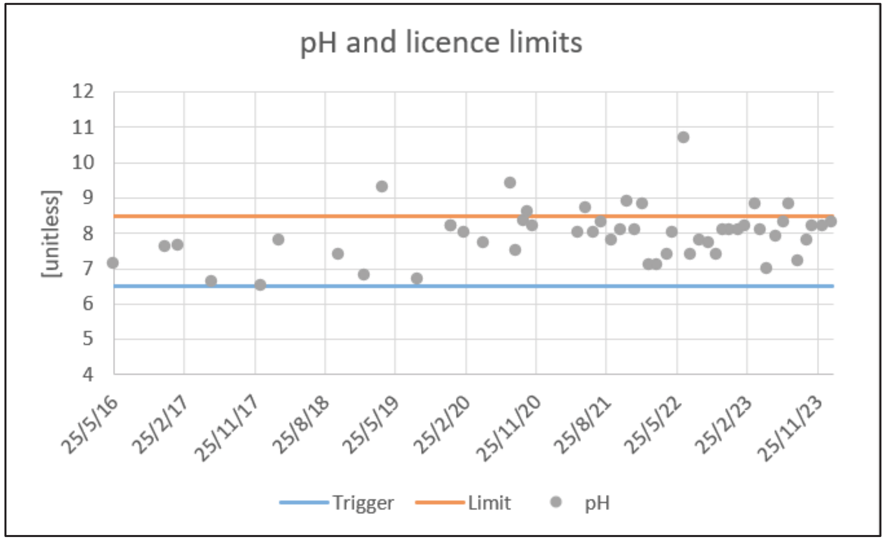
Sample Date	2,4,6-Trichlorophenol	2,4,5-Trichloro-phenol	2,4-Dinitrophenol	4-Nitrophenol	2,3,4,5-Tetrachlo-rophenol	2,3,4,6-Tetrachlo-rophenol	4,6-Dinitro-o-cresol	TPH	PAH
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L
Trigger									
Limit									
22/01/2024	<20	<20	<400	<20	<2.0	<2.0	<20		71
15/12/2023	<10	<10	<200	<20	<2	<2	<2		13
7/11/2023								4	14
15/10/2023								5.5	66
12/09/2023	<1	<1	<20	<20	<0.4	<0.4	<20	67.9	35
5/08/2023								0.43	28
16/07/2023	<10	<10	<200	<200	<4	<4	<200	2.4	44
19/06/2023	<1	<1	<20	<20	<0.4	<0.4	<20	0.1	22
14/05/2023	<10	<10	<200	<200	<100	<10	<100	0.15	4.3
16/04/2023	<10	<10	<200	<200		<10	<100	0.35	14
28/03/2023	<10	<10	<200	<200		<10	<100	4.75	25
14/02/2023	<1	<1	<20	<20	<10	<1	<10	0.84	26
24/01/2023	<1	<1	<20	<20	<10	<1	<10	3.35	20

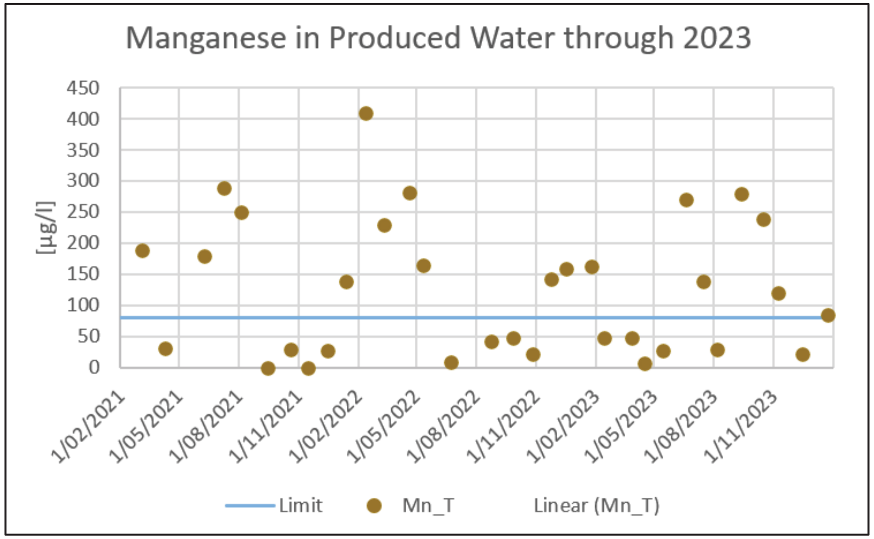
All samples, except TPH and PAH are required Quarterly.
TPH and PAH are required Monthly. As has been previously discussed with the NT EPA, the TPH and OiW sampling definition has been misunderstood. Since November 2022 Eni has taken samples for TPH analysis.

Produced water sampling and analysis continued…..

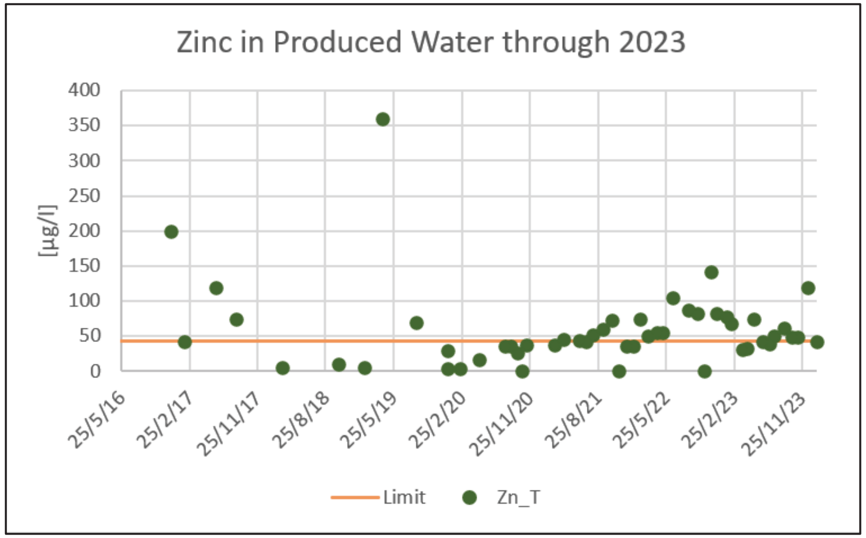
Sample Date	Benzene	Toluene	Ethyl benzene	Xylene (m+p)	Naphthalene	Anthracene	Fluoranthene	Benzo (a) pyrene	Xylene (O)
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Trigger	1300								
Limit	2000	330	160	150	120	7	2	0.7	
22/01/2024	800	2400	200	840	65	<0.1	<0.5	<0.1	320
15/12/2023	450	680	41	320	12	<0.1	<0.1	<0.1	120
7/11/2023	740	1800	140	540	<20	<0.1	<0.1	<0.1	220
15/10/2023	1400	3000	220	1000	28	<0.1	<0.1	<0.1	380
12/09/2023	380	1100	100	410	32	<0.1	<0.1	1	170
5/08/2023	420	980	97	420	26	<0.1	<0.1	<0.5	180
16/07/2023	1300	4200	440	1900	51	<0.5	<0.2	<0.1	660
19/06/2023	770	1900	190	780	25	<0.1	<0.1	<0.1	300
14/05/2023	360	570	51	210	12	<1	<1	<1	77
16/04/2023	530	1100	120	470	180	<10	<10	<10	180
28/03/2023	1400	3800	570	2300	48	<10	<10	<10	670
14/02/2023	1700	3900	480	1900	40	<1	<1	<1	640
24/01/2023	750	2000	230	980	34	<1	<1	<1	340

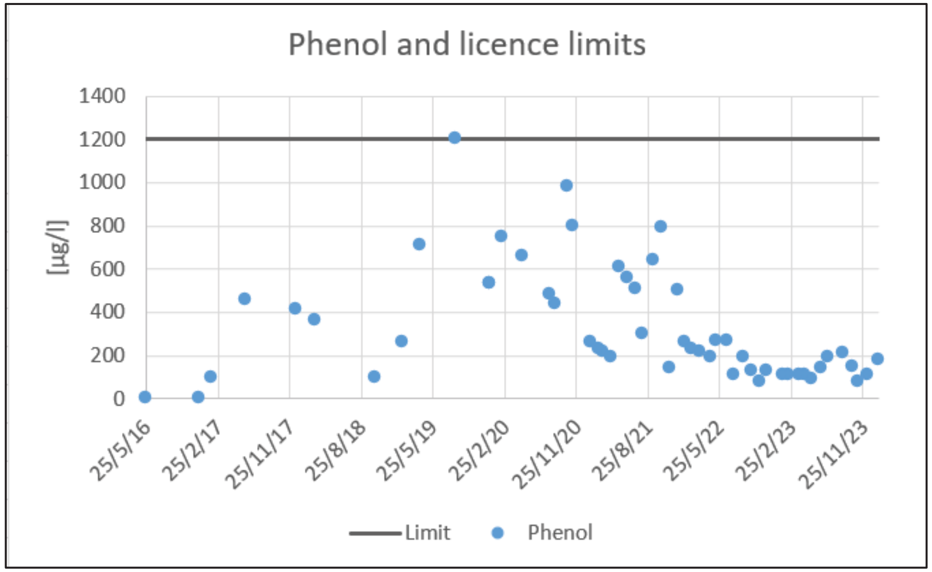
Produced water sampling and analysis continued…..

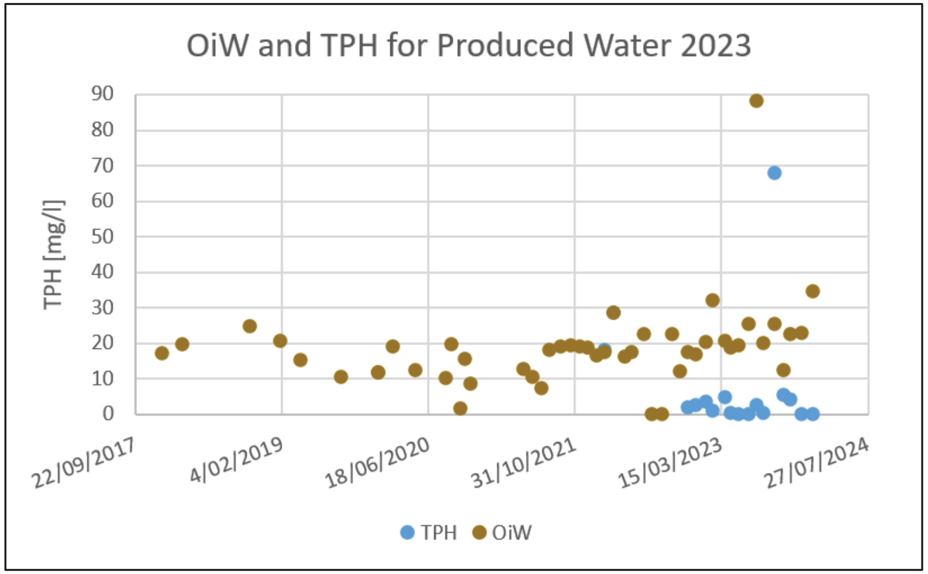




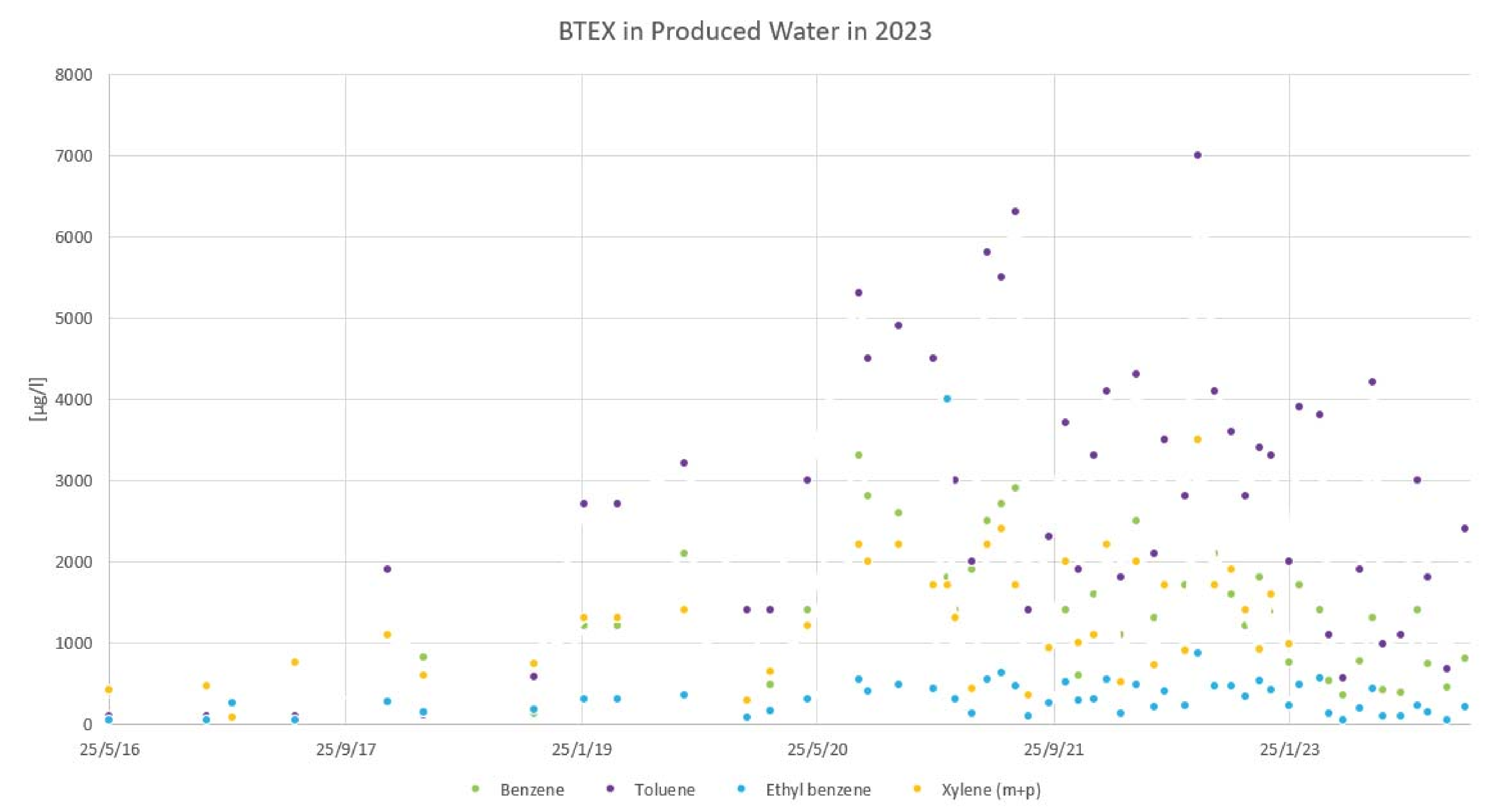
Units - pH : unitless, Manganese and Zinc : µg/L. Phenol : µg/L, OiW : mg/l, TPH : µg/L







Units - pH : unitless, Manganese and Zinc : µg/L. Phenol : µg/L, OiW : mg/l, TPH : µg/L



Units - BTEX : µg/L

ATTACHMENT C:

WWTP SAMPLING

Treated wastewater effluent monitoring results

Sample Date	pH	Elec Cond	Turbidity	DO	BOD	COD	TSS	TDS	TOC	OiW
Units	unitless	µS/cm	NTU	% sat	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Threshold	6.5 -8.5				10		10			6
Limits					20		30			10
17/01/2024	7.3	330	4.6	7.4	12	89	22	170	<1.0	3.9
15/12/2023										
8/11/2023	6.8				<5	130	71	1900	44	5.3
11/10/2023	7.4				<5	29	16	600	10	3.8
13/09/2023	8.1	1,200	5.8	10	<5	30	13	310	11	10.7
15/08/2023	7	760	5	3	97	320	11	450	48	4.9
13/07/2023	7	950	14	8.8	28	120	20	520	22	7.5
15/06/2023	7.3	1,300	6.4	10	<5	56	31	730	22	7.6
17/05/2023	5	1,100	4.8	7.8	20	220	10	600	17	12.8
12/04/2023	7	810	120	<1	62	620	180	330	36	7.8
28/03/2023	6.7	1,020	19	8	13	40	50	510	14	15.9
15/02/2023	6.6	1,180	5	9	6.4	40	10	670	14	8.8

Treated wastewater effluent monitoring results continued...

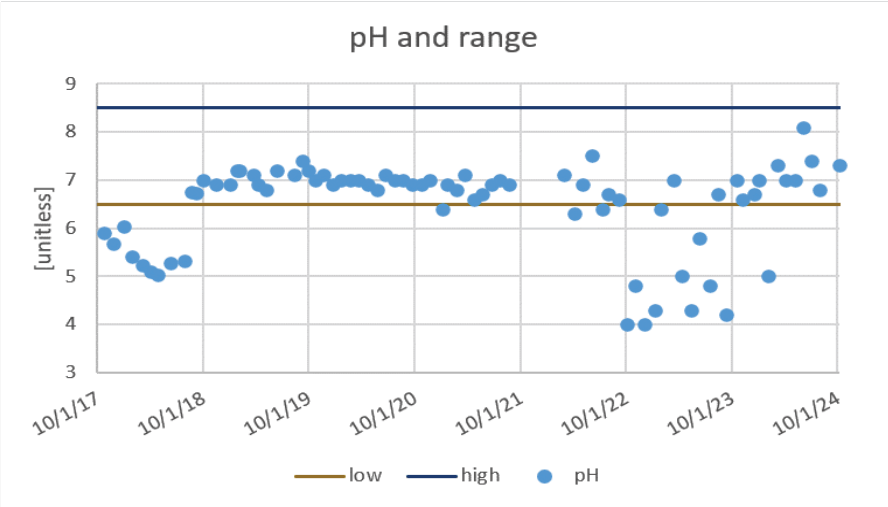
Sample Date	Tot. Phos	Tot. Dissolv Phos	Tot. Nitro	Tot. Dissolv Nitro	Ammon. N	Nox-N (Oxid. N)	NO3-N (nitrate)	NO2-N (nitrite)	E.Coli	Ent Cocci	Total Coliforms
Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	cfu per100ml	cfu per 100ml	
Threshold									100		
Limits									1000		
17/01/2024	0.71	0.22	13	11	8	2.2	2.2	0.029	2300	720	86000
15/12/2023											
8/11/2023	2.8	0.33	30	28	1				<10	<10	
11/10/2023	1	0.59	8.1	7.8	0.7				<10	40	
13/09/2023	1.4	0.95	11	11	2.5	4.9	4.8	0.14	<10	780	
15/08/2023	3.8	0.74	28	20	3.1	14	14	0.13	<10	430	
13/07/2023	1.5	0.32	19		5.5	7	6.9	0.067	<10	<10	10
15/06/2023	1.3	0.24	8.5	6.7	0.012	5.6	5.6	<0.005	<10	<10	<10
17/05/2023	0.4		58		21	35	35	0.24	10	<10	250
12/04/2023	8.95	1.22	38.9	26.2	22.9	0.06	0.055	<0.005	4,220	4,220	4,220
28/03/2023	0.245		37.7		12.7	4.05	4.02	0.035	13	2,420	2,420
15/02/2023	0.455		9.82		0.86	7.13	7.13	<0.005	1	53	

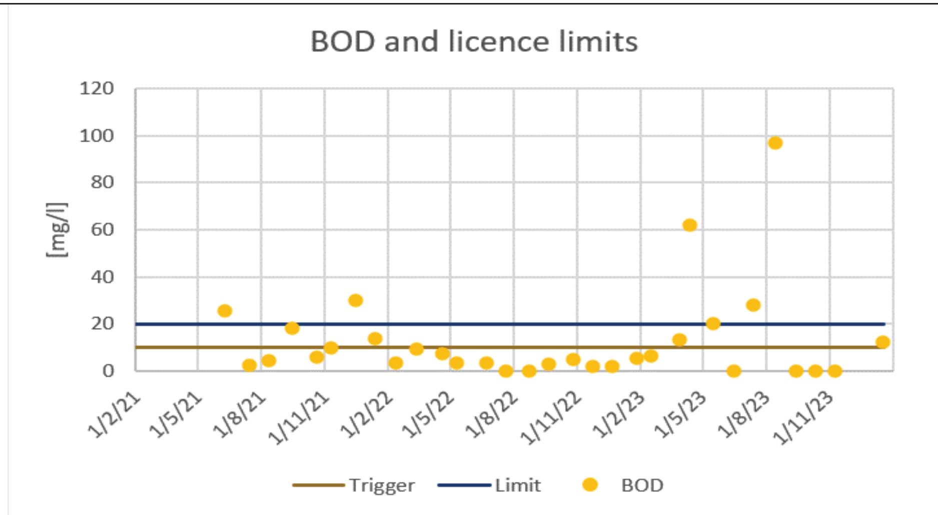
Treated wastewater effluent monitoring results continued...

Sample Date	Al	As	Ba	Be	B	Cd	Co	Cu	Cr	Cr III	Cr VI	Fe	Hg	M	Mn	Mo	Pb	Ni	Se	Sn	Zn
Units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg /L	µg/ L	µg/ L	µg/	µg/L	µ	µg/	µg/	µg/	µg	µg/	µg	µg/L
Threshold																					
Limits																					43
17/01/2024																					
15/12/2023																					
8/11/2023																					
11/10/2023																					
13/09/2023																					
15/08/2023	61	1.2	7	<0.5	250	0.43	<1	14	<1	<5	<5	<10	<0.05		110	1	<1	6.7	<1	<1	120
13/07/2023																					
15/06/2023																					
17/05/2023																					
12/04/2023																					
28/03/2023																					
15/02/2023																					

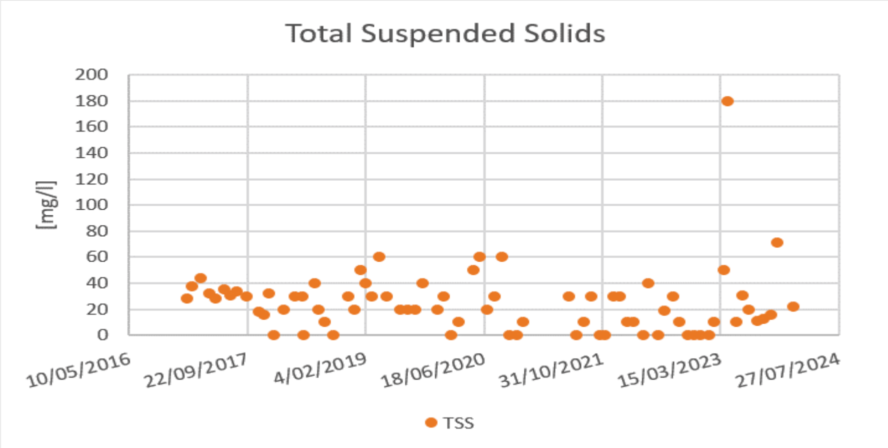
Treated wastewater effluent monitoring results continued...

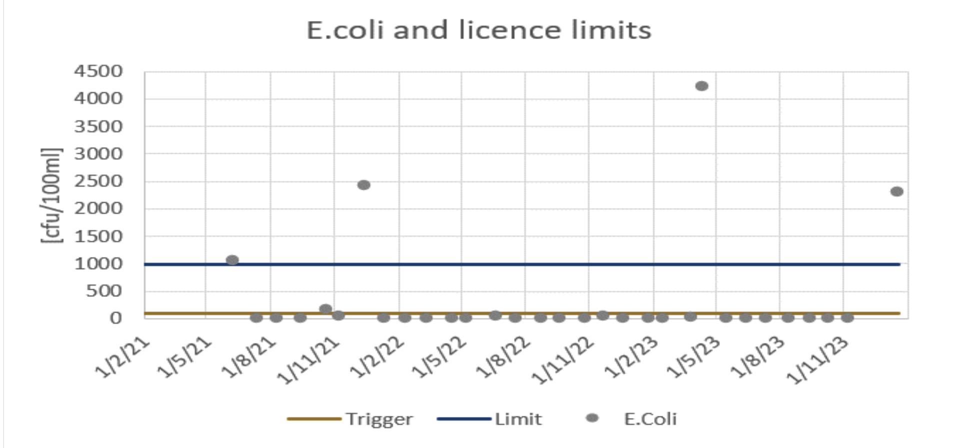
Sample Date	TPH	PAH	Benzene	Toluene	Ethyl benzene	Xylene (m+p)	Naphthalene	Anthracene	Fluoranthene	Benzo (a) pyrene	Xylene (o)
Units	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	
Threshold											
Limits			2000	330	160	150	120	7	2		
17/01/2024		<0.1	<1.0	1.2	<1.0	<2.0	<1.0	<0.1	<0.1	<0.1	<0.1
15/12/2023											
8/11/2023	<0.1	<0.1	<5	<5	<5	<10	<5	<0.1	<0.1	<0.1	<5
11/10/2023											
13/09/2023	1.4	<0.1	<1	<1	<1	<2	<1	<0.1	<0.1	<0.1	<1
15/08/2023	<0.1	<0.1	<1	<1	<1	<2	<1	<0.1	<0.1	<0.5	<1
13/07/2023	0.19	<0.1	<1	<1	<1	<2	<0.1	<0.1	<0.1	<0.1	<1
15/06/2023	0.29	<0.1	<1	<1	<1	<2	<0.1	<0.1	<0.1	<0.1	<1
17/05/2023	TBA	0	<1	<1	<1	<2	<1	<0.1	<0.1	<0.1	<1
12/04/2023	0.25	0	<1	<1	<1	<2	<1	<1	<1	<5	
28/03/2023	<0.1		<1	1	<1	<2	<2	<1	<1	<1	<1
15/02/2023	0.24	0	<1	2	<1	<2	<1	<1	<1	<1	<1

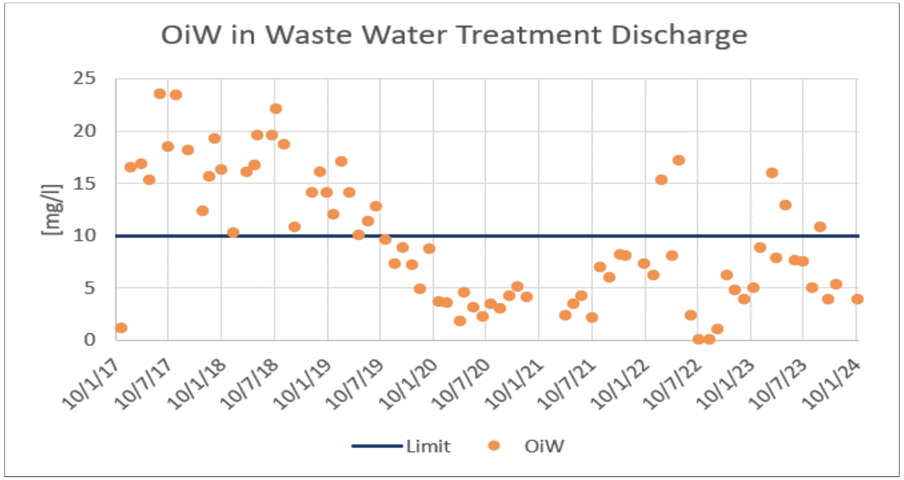


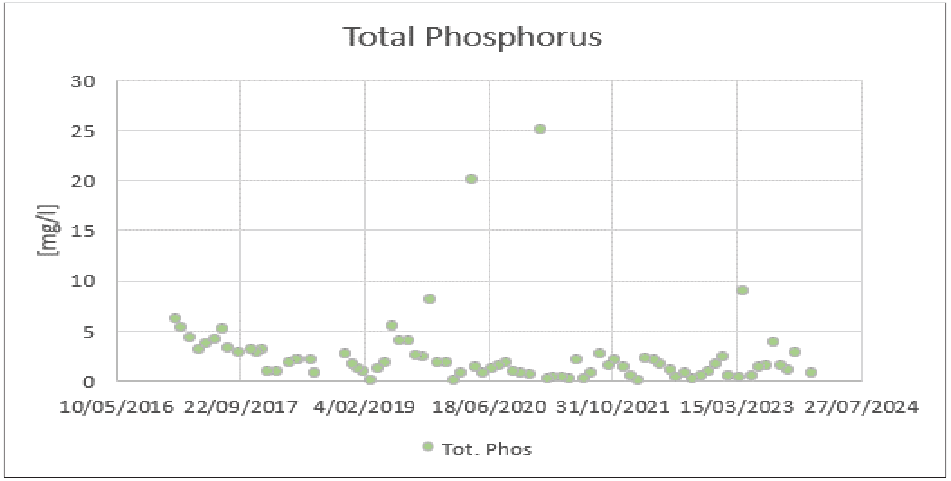


Units – pH : Unitless, BOD : mg/l, TSS : mg/l, E.Coli : cfu/100ml,

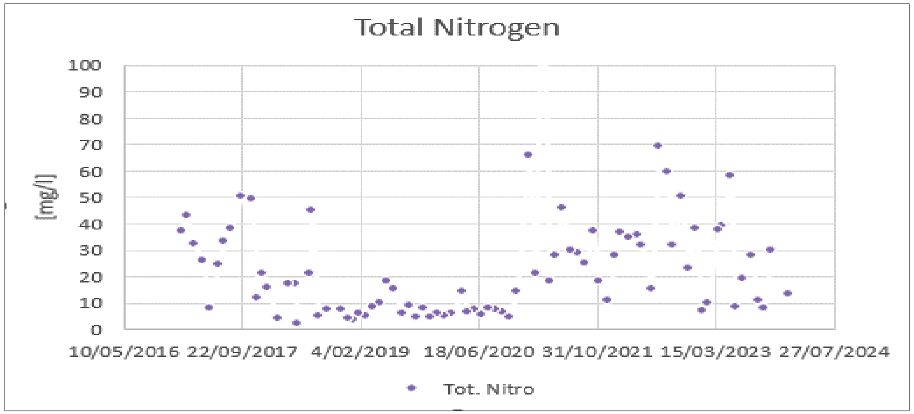


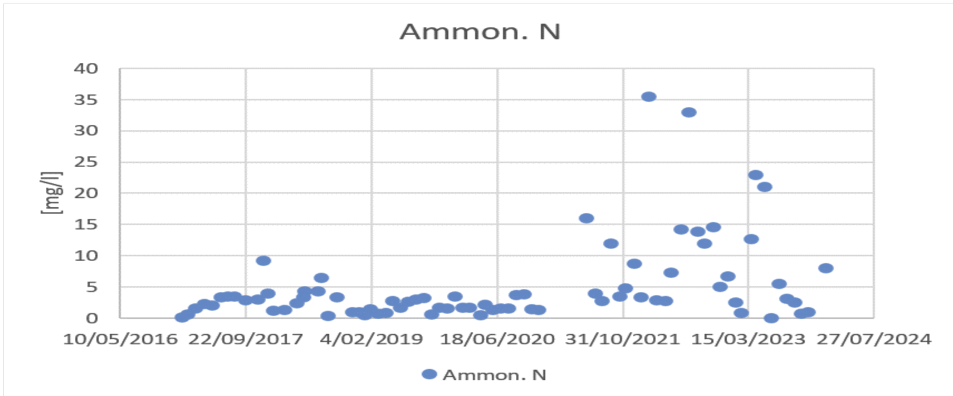






Units – OiW : mg/l, Total Phosphorus : mg/l, Total Nitrogen : mg/l, Total Ammonia : mg/l





ATTACHMENT D:

STORMWATER MONITORING

Utilities stormwater discharge monitoring (SW-01)

Date & time	pH	EC	Oil in Water (HORIBA)
	pH	µs/cm	mg/L
Trigger			1
Limit			6
4/3/2023	5.98	87	1.9
3/04/2023	5.9	-	-
2/05/2023	6.12	-	2.7
11/06/2023	6.19	86	0.7
26/07/2023	5.51	184.5	0.9
27/07/2023	5.69	131.5	0.5
7/09/2023	5.74	149.8	0.4

Table – Site measurements during discharge

Open drains sump stormwater discharge monitoring (SW-03)

Date & Time	pH	EC	Oil in Water (HORIBA)
	pH	µs/cm	mg/L
Trigger			1
Limit	-	-	6
23/02/2023	6.8	-	1.2
25/03/2023	6.32	-	0.8
15/04/2023	6.93	558.1	0.5
9/07/2023	7.337	9.371	0.8
01/10/2023	7.08	3.35	4.1
13/11/2023	6.55	1.53	1.5
20/11/2023	6.538	1.633	4.8
10/12/2023	-	-	0.9

Notes:

[4] Values above the EPL limit are shown in red text. Values above the trigger value or outside ANZECC 80% species protection guideline value are shown in orange text.
[5] All routine analyses conducted in the site laboratory, using the PC700 bench meter for pH and EC, and the Horiba OCMA500 with Florisil solvent for oil in water, unless otherwise stated

Annual stormwater monitoring

Parameter	Unit	Value
pH	unitless	6.7
Elec Cond	µS/cm	67
OiW	mg/l	3.6
Al	µg/L	32
As	µg/L	<1
Ba	µg/L	170
Be	µg/L	<0.5
B	µg/L	36
Cd	µg/L	4.4
Co	µg/L	<1
Cu	µg/L	<1
Cr	µg/L	<1
Cr III	µg/L	<0.5
Cr VI	µg/L	<0.5
Fe	µg/L	180
Hg	µg/L	<0.050
Mg	µg/L	<500
Mn	µg/L	12
Mo	µg/L	1.5
Pb	µg/L	<1
Ni	µg/L	4.4
Se	µg/L	<1
Sn	µg/L	<1
Zn	µg/L	94

Notes:
[1] This table summarises the discharge monitoring between 10 February 2023 – 9 February 2023.
[2] NT = not tested.
[3] Trigger value for 80% species protection from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Volume 1. Updated values (2018) have been used where available.
[4] Values above the EPL limit are shown in red text. Values above the trigger value or outside ANZECC 80% species protection guideline value are shown in orange text.
[5] All routine analyses conducted in the site laboratory.

Sample Date	pH	Elec Cond	OiW	Al	As	Ba	Be	B	Cd	Co	Cu	Cr	Cr III	Cr VI
	unitless	µS/cm	mg/l	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
21/01/2024	6.7	67	3.6	32	<1	170	<0.5	36	4.4	<1.0	<1.0	<1.0	<0.5	<0.5
12/09/2023	7.4	350	17.7	42	1.3	250	<0.5	190	0.16	<1.0	<1.0	<1.0	<0.5	<0.5
13/02/2023	7.0	543	9.0	4.5	0.3	896	<0.5	33.5	0.12	0.18	0.63	0.2	<0.5	<0.5

Sample Date	Fe	Hg	Mg	Mn	Mo	Pb	Ni	Se	Sn	Zn
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
21/01/2024	180	<0.050	<500	12	<1	<1.0	4.4	<1.0	<1.0	530
12/09/2023	2000	<0.050	840	74	13	<1.0	23	<1.0	<1.0	42
13/02/2023	8	<0.020	1.5	49.1	1.3	0.13	3.99	<0.2	<1.0	94

Stormwater outlet- SW-01- Annual Laboratory analysis results - Intertek

ATTACHMENT E:

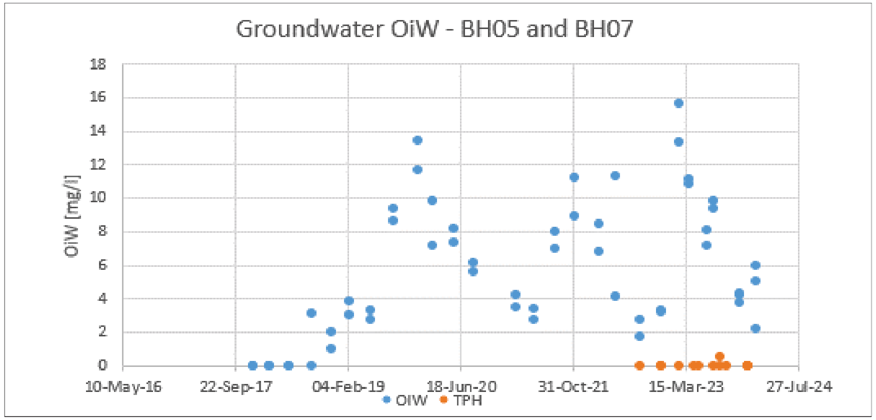
GROUNDWATER MONITORING

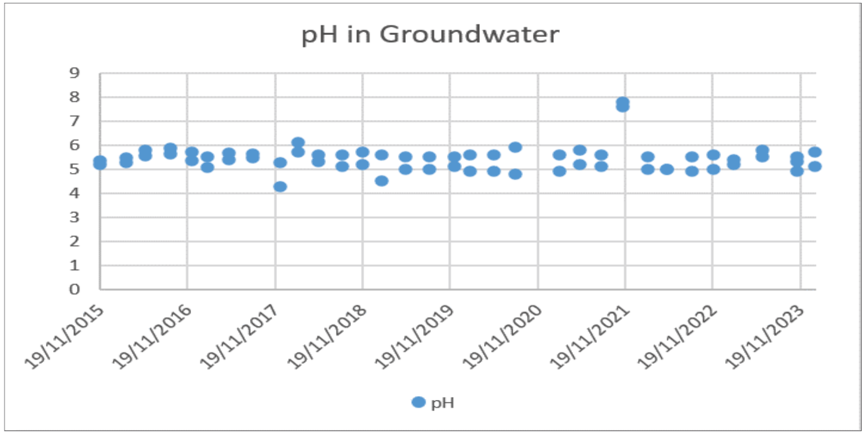
Quarterly groundwater monitoring data

Sample Date		pH	E Cond	Turbidity	DO	BOD	Total Phos	Total Nitro	NOx (Oxid. N)	NH3 (Amm)	NO3 (Nitrate)	NO2 (Nitrite)
		-	microS/cm	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
21/01/24	BH-01	5.3	260	78	6.5							
21/01/24	BH-05	5.1	71	1.4	7.3							
21/01/24	BH-07	5.7	44	6.1	8							
7/11/23	BH-01	5.3	260	110	11	<5	<0.05	0.43	0.15	<0.005	0.15	<0.005
7/11/23	BH-05	4.9	89	180	11	<5	<0.05	3.2	2.8	0.066	2.8	<0.005
7/11/23	BH-07	5.5	44	320	11	12	<0.05	1.9	1.8	<0.005	1.8	<0.005
13/07/23	BH-05					20	<0.05	3.7	3.5	0.019	3.5	<0.005
13/07/23	BH-07					11	<0.05	2.5	2.2	0.017	2.2	<0.005
15/06/23	BH-05	5.5	56	31	HT breach	14	<0.05	3.7	3.1	0.016	3.1	<0.005
15/06/23	BH-07	5.8	42	68	HT breach	<5	<0.05	2.6	2.2	0.015	2.1	<0.005
15/05/23	BH-05											
15/05/23	BH-07											
18/04/23	BH-05											
18/04/23	BH-07											
27/03/23	BH-05											
27/03/23	BH-07											
13/02/23	BH-05	5.2	68	56	21	6.5	0.025	4.19	3	0.02	3	<0.005
13/02/23	BH-07	5.4	71	100	90	7	0.085	3.51	3	0.05	3	<0.005

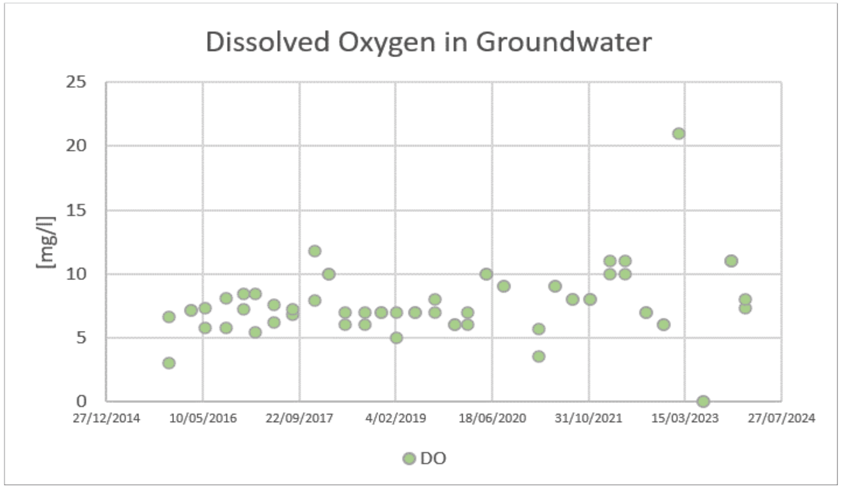
Quarterly groundwater monitoring data

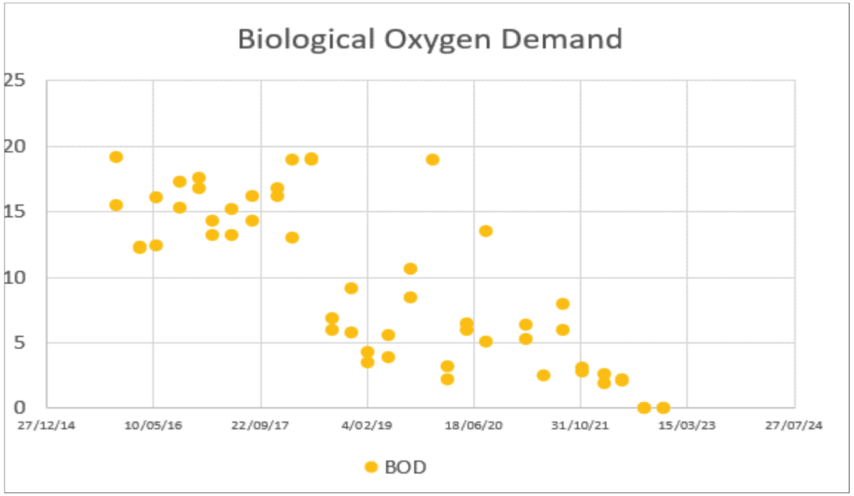
Sample Date	E. coli	Ent-Cocci	Total Coliforms	TPH	OIW	TSS	TDS	TOC	COD
	cfu per 100ml	cfu per 100ml	per 100ml MPN	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L
21/01/2024				<0.1	6				
21/01/2024				<0.1	5				
21/01/2024				<0.1	2.2				
7/11/23	<10	<10	<10	<0.1	4.3	110	65	1.8	20
7/11/23	<10	<10	<10	<0.1	3.7	230	51	1.6	25
7/11/23	<10	<10	<10	<0.1	4.2	220	39	5.5	220
13/07/23	<10	<10	<10	<0.1	9.8	320	30	1.4	74
13/07/23	<10	<10	10	<0.1	9.4	580	48	1.3	85
15/06/23	<10	<10	<10	0.49	7.2	110	42	1.2	<20
15/06/23	<10	<10	10	<0.1	8.1	320	35	<1	52
15/05/23									
15/05/23									
18/04/23	3	<1	>2419.9						
18/04/23	1	<1	1990						
27/03/23	<1	<1	<1	<0.1	10.8				
27/03/23	<1	<1	<1	<0.1	11.1				
13/02/23	<1	260	56		13.3	30	50	<1	<20
13/02/23	1	461	517		15.6	160	60	<1	<20

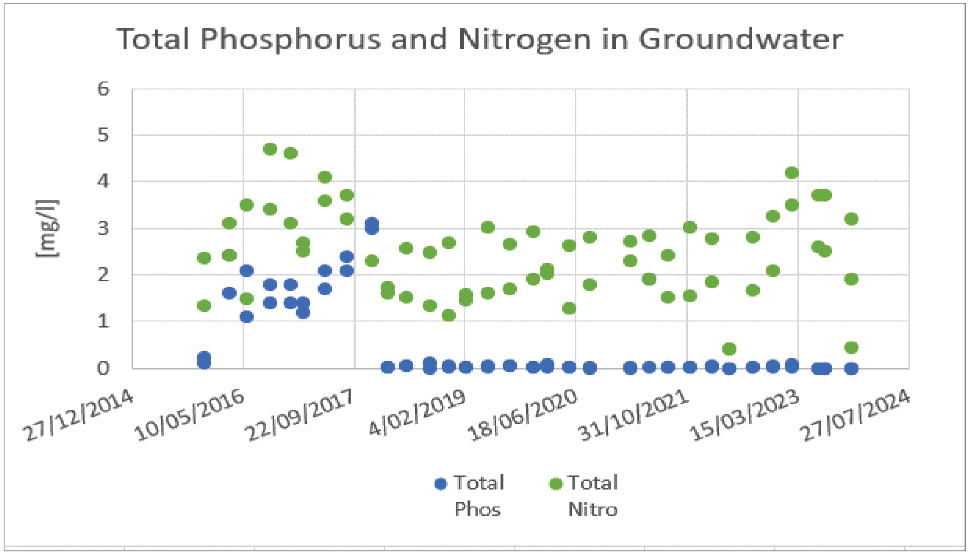




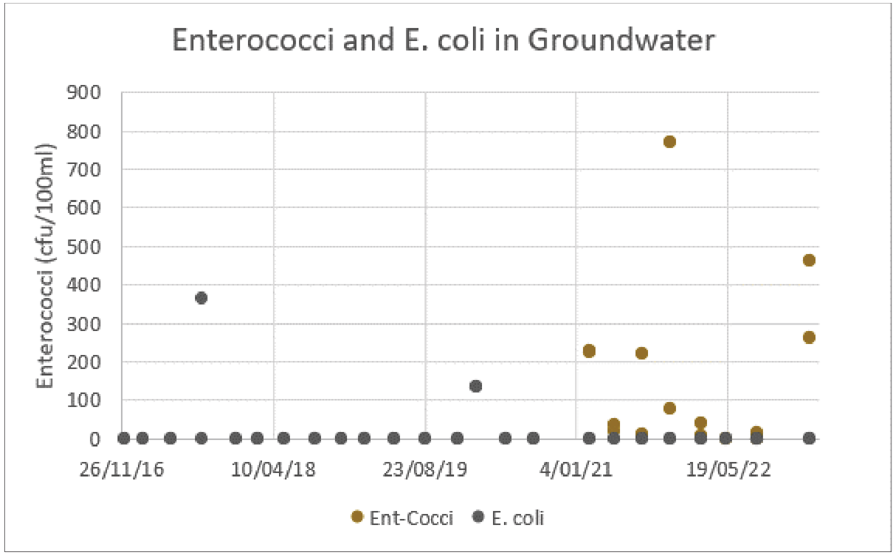
Units – OiW : mg/l, TPH : µg/L, pH : unitless, DO : mg/l, BOD : mg/l







Total Phosphorus and Nitrogen in Groundwater
[mg/l]
6
5
4
3
2
1
0
27/12/2014
10/05/2016
22/09/2017
4/02/2019
18/06/2020
31/10/2021
15/03/2023
27/07/2024
Total Phos
Total Nitro



Enterococci and E. coli in Groundwater
Enterococci (cfu/100ml)
900
800
700
600
500
400
300
200
100
0
26/11/16
10/04/18
23/08/19
4/01/21
19/05/22
Ent-Cocci
E. coli

ATTACHMENT F:

CALIBRATION CERTIFICATES

intertek
Total Quality. Assured.

VERIFICATION REPORT

Client: ENI Australia, Blacktip YGP
Instrument: HORIBA OCMA-500
Serial Number: T9EHWHDT
Date Calibrated: 10th February 2024
Next Calibration: 10th August 2024

Method

1. Zero Calibration
    a. Pure S-316 Solvent is measured in measurement mode, and result should be 0.0 mg/L if not replace internal filters and re measure.
    b. Change instrument into Zero Calibration and run S-316 Solvent.
2. Span Calibration
    a. Prepared known sock sample is measured to obtain steady reading. Concentration of standard is twice the value of measured sample.
3. Verify with Standard or Stock Samples.

Maintenance:

Were Internal Filter / O-ring replaced : Yes
Were repairs carried out : No

Calibration Results:

Following readings were obtained against Pure S-316 & Standard.

Mode	Expected Reading (mg/L)	Instrument Reading (mg/L)
Zero Calibration	0.0	0.0
Span Calibration	200.0	200.0
Stock Sample 1	50.0	50.3
Stock Sample 2	25.0	24.1

Remarks:

The Instrument is acceptable for use as per the standard operating test procedure (ASTM D 7066).

Verified by: Pasan Mihijaya
Title: Chemist
Date: 10th February 2024

intertek caleb brett

e 1 of 1

Other calibration certificates of third party laboratories are assumes to be incorporated by NATA accreditation. Certificates may be requested.

Intertek Calibration Certificates – Annual Emission Testing Report 2023_RO14853

9 Appendix 3: Equipment Calibration Certificates

Ektimo

Equipment Assurance Certificate

6 Monthly Pitot Tube Checks

Equipment ID: 1862

Date of certification: 11/01/2023

Performed by: JAr

Acceptance criteria	
Visual inspection	Pass
Measurments meet specifications outlined in USEPA Method 2.	Pass

This equipment has been deemed fit for purpose in accordance with Ektimo's Equipment Assurance Program developed based upon the National Association of Testing Authorities (NATA) document *General Accreditation Criteria - Equipment assurance, in-house calibration and equipment verification May 2019*.

Ektimo's Equipment Assurance Program is audited by NATA on a routine basis to assess ongoing conformance to *ISO/IEC 17025:2017 General requirements for the competency of testing and calibration laboratories*.

Ektimo

Equipment Assurance Certificate

6 Monthly Barometer Checks

Equipment ID: 1998

Date of certification: 04/01/2023

Performed by: Manipal Singh

Acceptance criteria	
Within the required accuracy of ±10 hPa outlined by ISO10780.	Pass

This equipment has been deemed fit for purpose in accordance with Ektimo's Equipment Assurance Program developed based upon the National Association of Testing Authorities (NATA) document *General Accreditation Criteria - Equipment assurance, in-house calibration and equipment verification May 2019*.

Ektimo's Equipment Assurance Program is audited by NATA on a routine basis to assess ongoing conformance to *ISO/IEC 17025:2017 General requirements for the competency of testing and calibration laboratories*.

Ektimo

Equipment Assurance Certificate

12 Monthly Manometer Calibrations

Equipment ID: 1932

Date of certification: 04/01/2023

Performed by: V.Domadiya

Acceptance criteria	
Readings within 5% of the reference manometer readings.	Pass

This equipment has been deemed fit for purpose in accordance with Ektimo's Equipment Assurance Program developed based upon the National Association of Testing Authorities (NATA) document *General Accreditation Criteria - Equipment assurance, in-house calibration and equipment verification May 2019*.

Ektimo's Equipment Assurance Program is audited by NATA on a routine basis to assess ongoing conformance to *ISO/IEC 17025:2017 General requirements for the competency of testing and calibration laboratories*.

Ektimo

Equipment Assurance Certificate

6 Monthly / Initial Temperature Device Checks

Pyrometer ID: 1963
Thermocouple ID: 2186
Date of certification: 04/01/2023
Performed by: JRi

Acceptance criteria	
Error (°C) must be less than 2 or Error (%) must be less than 1.5	Pass

This equipment has been deemed fit for purpose in accordance with Ektimo's Equipment Assurance Program developed based upon the National Association of Testing Authorities (NATA) document *General Accreditation Criteria - Equipment assurance, in-house calibration and equipment verification May 2019*.

Ektimo's Equipment Assurance Program is audited by NATA on a routine basis to assess ongoing conformance to *ISO/IEC 17025:2017 General requirements for the competency of testing and calibration laboratories*.

Ektimo

Equipment Assurance Certificate

6 Monthly TPM kit and M5 Console Calibrations

Equipment ID: 1886
Date of certification: 03/01/2023
Performed by: VDo

Acceptance criteria	
Gas meter achieves a standard error of ≤ ±2%	Pass
Rotameter setting vs flowrate = R^2>0.99	Pass

This equipment has been deemed fit for purpose in accordance with Ektimo's Equipment Assurance Program developed based upon the National Association of Testing Authorities (NATA) document *General Accreditation Criteria - Equipment assurance, in-house calibration and equipment verification May 2019*.

Ektimo's Equipment Assurance Program is audited by NATA on a routine basis to assess ongoing conformance to *ISO/IEC 17025:2017 General requirements for the competency of testing and calibration laboratories*.

Ektimo

Equipment Assurance Certificate

12 Monthly Nozzle Diameter Check

Equipment ID: 1833
Date of certification: 05/01/2023
Performed by: HMa

Acceptance criteria	
Percentage error of the diameter <1%	Pass

This equipment has been deemed fit for purpose in accordance with Ektimo's Equipment Assurance Program developed based upon the National Association of Testing Authorities (NATA) document *General Accreditation Criteria - Equipment assurance, in-house calibration and equipment verification May 2019*.

Ektimo's Equipment Assurance Program is audited by NATA on a routine basis to assess ongoing conformance to *ISO/IEC 17025:2017 General requirements for the competency of testing and calibration laboratories*.

Ektimo

Equipment Assurance Certificate

6 Monthly Analyser Linearity Checks (Multi Gas Analyser)

Equipment ID: 2111

Date of certification: 13/01/2023

Performed by: Jri

Acceptance criteria					
Each point of the linearity check for the following gases, was within 2% of the anticipated value.					
Low Range Linearity					
NO:	Pass	NO_2:	Pass	SO_2:	Pass
CO:	Pass	CO_2:	Pass	O_2:	Pass
High Range Linearity					
NO:	Pass	SO_2:	Pass	CO:	Pass

This equipment has been deemed fit for purpose in accordance with Ektimo's Equipment Assurance Program developed based upon the National Association of Testing Authorities (NATA) document *General Accreditation Criteria - Equipment assurance, in-house calibration and equipment verification May 2019.*

Ektimo's Equipment Assurance Program is audited by NATA on a routine basis to assess ongoing conformance to *ISO/IEC 17025:2017 General requirements for the competency of testing and calibration laboratories.*

Ektimo

Equipment Assurance Certificate

6 Monthly Non-Isokinetic Kit Check

Equipment ID: 3083/3084

Date of certification: 23/01/2023

Performed by: Hardik Mavani

Acceptance criteria	
Reference gas meter & temperature devices external	Pass
Volume ±2% at 2L/min:	Pass
Volume ±2% at 0.5L/min:	Pass
Leak check <5kPa over 1 minute	Pass
Error (°C) must be less than 2 or Error (%) must be less than 1.5	Pass

This equipment has been deemed fit for purpose in accordance with Ektimo's Equipment Assurance Program developed based upon the National Association of Testing Authorities (NATA) document *General Accreditation Criteria - Equipment assurance, in-house calibration and equipment verification May 2019.*

Ektimo's Equipment Assurance Program is audited by NATA on a routine basis to assess ongoing conformance to *ISO/IEC 17025:2017 General requirements for the competency of testing and calibration laboratories.*

Bureauveritas Calibration Certificates – Venting Validation Survey Report 2023_ 4072C3-18587148-FE-03

All equipment was calibrated; physically and internally inspected prior to the survey.

Table 2 defines the equipment type, serial number, calibration schedule and brief description.

Table 1: Equipment properties

Equipment	Serial Number & Calibration	Brief Description
Heath RMLD CS	S/N - 8211919005 (Internal calibration)	- Tuneable diode laser absorption spectroscopy device. - The RMLD CS is a handheld laser and the analysis unit, providing an audible response to any detected source of methane plume emissions. Up to 30 metres in detection distance. - Leaks are quantified as ppm-m readings.
Health DPIR +	S/N – 9001233010 (Internal calibration)	- Infrared optical gas detection utilising a pumped sample gas via a probe and bellows [8]. - The Heath DPIR has a greater sensitivity and suction rate than the GMI Leaksurveyor 500s.
OPGAL EyeCGas 2.0 Camera	S/N – TGC-131100089 (Internal Calibration)	- The OPGAL EyeCGas is an optical gas imaging camera capable of detection, and thermographic and digital imaging to quickly detect methane, carbon monoxide, carbon dioxide and VOC leaks.

Bureauveritas Calibration Certificates – Fugitive Emissions Survey Report 2023_ 072C3-18587148-FE-01

12. APPENDIX C - EQUIPMENT SPECIFICATIONS

12.1 GMI Leaksurveyor Technical Specifications

As extracted from the GMI Leaksurveyor operating manual:

Measuring Ranges

PPM 0 – 499ppm
PPM 500 – 10000ppm
LEL 0 – 10%
LEL 10 – 100%
VOL 0 – 100%
ppm – Semiconductor Sensor
LEL – Catalytic Sensor

Volume Gas – Thermal Conductivity Sensor Certification

IEC Ex d ia IIB T3 ATEX II 2G Eex ia d IIB T3 UL913 Class 1 Div 1 Groups CD CE

Physical Properties

Dimensions: 180 (H) x 95 (W) x 105 (D) mm, 7.1 (H) x3.7 (W) x 4.1 (D) in Weight: 1.7 kg

Environment

Humidity: 0 to 95% R.H. non-condensing Temperature: -20ºC to +50ºC (-4ºF to +122ºF)

Sampling System

Integral pump with semiconductor pressure sensor for flow fail detection. Sample path is protected by hydrophobic filter.

Power Supply

Alkaline: Approx. 21 hours' run-time Rechargeable: Approx. 18 hours' run-time

Enclosure

High impact rubberized polycarbonate case

IP Rating

IP54

12.2 Heath RMLD Technical Specifications

As extracted from the Heath RMLD operating manual:

Detection Method

Tunable Diode Laser Absorption Spectroscopy (TDLAS)

Measurement Range

0 to 99,999 ppm-m

Sensitivity

- 5 ppm-m at distances from 0 to 50 ft (15 m)
- 10 ppm-m or better at distances from
- 50 to 100 ft (15 to 30 m)

Intrinsic Safety

Class 1 Division 1 Group D, T4 in accordance with UL 913 & CSA C22.2 No 157, MetLab Listing #E112840

Detection Distance

100 ft (30 m) nominal. Actual distance may vary due to background type and conditions.

Beam Size

Conical in shape with a 22" diameter at 100 ft (56 cm at 30 m)

Detection Alarms Modes

Digital Methane Detection (DMD): Audible tone relative to concentration when detection threshold exceeded Adjustable Detection Alarm Level from 0 to 255 ppm-m

Pure Tone

Continuous audio tone relative to concentration

Adjustable Volume

8 Levels

System Fault Warning
Unique audible tone and indication on the display
Self-Test & Calibration
Built-in Self-Test and Calibration function verifies operation and adjusts laser wavelength for maximum sensitivity. Test gas cell integrated within carrying case.
Compliance
EMC (EN61000-6-2, EN6100-6-4)
Laser Eye Safety
IR Laser: Class I (CDRH, ANSI and IEC)
Green Spotter Laser
Class IIIa; Do not stare into beam or view directly with optical instruments
Communications
RS232 and Bluetooth Standard Display: Large, easy to read backlit LCD (.75" Numeric)
Operating Temperature
0 to + 122° F (-17° to 50° C)
Humidity
5 to 95% RH, non-condensing
Enclosure
IP54 (Water splash and Dust resistant)
Instrument Weight
10 lbs (Transceiver 3 lbs, Controller 7 lbs); (4.5 kg; 1.3 kg , 3.2 kg)
Carry Case
14 lbs; 34" x 9 ½" x 14" (6.4 kg; 86 cm x 24 cm x 36 cm)
Battery
Internal, rechargeable, Li ion battery pack, 11.1 VDC
Battery Run Time
8 hours at 32° F without backlight on, minimum
Battery Charging
External, in-line, 110-240 Vac, 50 / 60 hertz, international, 19 Vdc power supply

12.3 EyeCGas V2.0 OGI Camera Technical Specifications

As extracted from the OPGAL EyeCGas OGI Camera operating manual:
Thermal Imager
Thermal Sensitivity 20mK@ 25˚C
F #
1.1
Field of View
18° with 30 mm lens
Focus near
<0.5m
Focusing
Manual
Digital Zoom
x2, x4
Embedded Digital Camera
VGA, fixed focus, for situational awareness
Type
Cooled High Sensitivity , 320x240 pixels
Spectral range
3-5µm
Voltage
12 VDC
Power consumption
14.4 W
Battery Life
4 hours continuous
Weight (with battery and lens)
2.5 kg (5.5 lbs.)

Color

Grey and Black

Size in (LxHxW)

9" x 4.3" x 5.1" (230 x 110 x 130)mm

Interface

Tripod mounting UNC 1/4", rotation safe

Display Unit

3.5" Color LCD 640X480

Operating temperature range

-20°C to + 50°C

Storage temperature range

-40° to + 70°C

Temperature and Humidity

IEC 60068-2-30 Temp. +25°C / +40°C Humidity 95% RH

EMC/ EMI

FCC 47 CFR part 15 subpart B - Radiated Emissions
EN 610000-6-4 : 2007 class A - Radiated Emissions
EN 610000-6-2 : 2005 class A - Immunity to Electrostatic Discharge (ESD)
EN 610000-6-2 : 2005 class A - Radiated Immunity to RFE
EN 610000-6-2 : 2005 class A - Radiated Immunity to Power Frequency magnetic field

Vibration

2.4 GRMS Random Vibration - Mil Std 810F 514.5

Water and Dust Protection

IP65 - Blowing Dust test - MIL-STD-810F, Method 510.4, Procedure I, IP65 - Jetting Water
HALT - High Accelerated Life Test
Vibration level: Max temp : 55 deg, Min temp : -20 deg

Safety

EN60950-1:2006

12.4 Heath DPIR Technical Specifications

As extracted from the Heath DPIR operating manual:

Detection Method

Infrared Controlled Interference Polarization Spectrometer

Measurement Range

0 to 10,000 PPM; 1 to 100% Gas

Display Range

Auto Ranging Manual Ranging

PPM: 0-10,000 PPM scale: 0-10,000

%Gas: 1-100% %Gas scale: 0-100%

Sensitivity

1 PPM

Resolution

0-1000 PPM: 1 PPM 1000-10,000 PPM: 5 PPM 1-100%Gas: 0.1%

Accuracy

Greater of ±0.5% or ±10% of reading (normal temperature and pressure, % gas on manual mode)

Response Time

PPM Mode: T10< 0.7s, T50< 1.3s PPM Mode with Survey Probe: T10< 1.2s, T50< 1.8s %Gas Mode with Method 21 Probe: T50< 1.8s, T90< 2.5s; Recovery Time T10< 2.0s

Sample Flow Rate

2.0 LPM (with Survey Probe attached)

Connectivity

Bluetooth 5 Low Energy (BLE) (compatible with iOS, Android and Windows devices)

Detection Alarms Modes

Digital Methane Detection (DMD): Audible tone when detection threshold exceeded. Adjustable Alarm Level from 1 to 9,000 PPM. Tick: Continuous audio tone relative to concentration

System Fault Warning
Audible tone and indication on the display

Self-Test & Calibration
Built in Self-Test and Calibration function verifies operation and adjusts calibration for maximum sensitivity. Test gas cell integrated within the instrument.

Compliance
EN 61326-1 Conducted Emissions Class B EN 61326-1 Radiated Emissions Class B EN 61000-4-2 4kV/8kV ANSI C63.4 Class B EN 61000-4-3 3 V/M FCC 47 CFR Part 15 Class B

Dust Filter
Replaceable filter provides dust protection. Easy change-out quick disconnect filter cap.

Display
Large easy to read backlit LCD (0.75" Numeric)

Operating Temperature
0 to + 122 F (-17 to 50 C) (nominal battery voltage)

Humidity
5 to 95% RH, non-condensing

Enclosure
IP54 (Water splash and Dust resistant)

Instrument Weight
5.6 lbs.

Carry Case
13 lbs empty; 21 lbs filled 24.5" x 21" x 9"

Power Supply
Internal rechargeable Li-ion battery or External 12 Vdc car battery with power conditioner

Battery Operating Life
8 hours at 32º F without backlight on

Battery Charger
External, in-line, 110 - 240 VAC, 50 / 60 hertz. 10 hours to 90% charge

Shoulder Strap
Single over the shoulder padded strap

Alarm Volume
108 dBs @ Alarm port (A-fast)

Survey Probe
Quick connect fitting with locking clasp. Adjustable length from 25" to 41"

Bar hole Probe
Std: 20"; Optional 36"

Method 21 Probe (optional)
Std: 5', with quick connect fitting and locking clasp

Intrinsic Safety
Class I Division I Group D T3 UL 913, CSA 22.2 No. 157, MET Labs #E112840

APPENDIX B BLACKTIP OPERATIONS MARINE SURVEY 2024

BLACKTIP OPERATIONS MARINE SURVEY 2024

PR-OP	00	31/10/2024	Final Issue	MALL	AMA	JCO		
Validity Status	Rev. Number	Date	Description	Prepared by	Checked by	Approved by	Contractor Approval	Company Approval
Revision index								

eni australia	Project name **BLACKTIP OPERATIONS**	Company identification 710000PGRV00071_00 Job N. ___
		Contractor identification Contract ___
(Vendor logo and business name)		Vendor identification …………………………….. Order N……………………….
Facility Name BLACKTIP	Location NORTHERN TERRITORY	Scale: 1:1 / Sheet of Sheets: 1 / 82
Document Title **BLACKTIP OPERATIONS MARINE SURVEY 2024**		Supersedes N……………… Superseded by N………….. Plant Area / Plant Unit

REVISION HISTORY

Rev.	Date	Nr. of sheets	Description
00	31/10/2024	82	Final Issue

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ATTACHMENT B: Measured metal concentrations in shellfish 2010-2024

ATTACHMENT C: Laboratory Analytical Report 2024

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
DGV	Default guideline values
EIS	Environmental Impact Statement
EPL	Environment Protection Licence
GPS	Global Positioning System
GV-high	Upper guideline value
ID	Insufficient Data
ICP-OES	Inductively Coupled Plasma Optical Emission Spectroscopy
ISQG	Interim Sediment Quality Guidelines
kg	Kilograms
LOR	Limit of Reporting
mg	Milligrams
NA	Not applicable
NATA	National Association of Testing Authorities
ND	Not detected
NT	Not tested
NTEPA	Northern Territory Environmental Protection Authority
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, in line with EPL230-01 to undertake sediment and shellfish sampling in the vicinity of the produced water pipeline to monitor any impacts on sediment and biota. The sampling was conducted on 6th August and 2nd October 2024. On 6th August 2024 one site could not be reached due to tides and the beach being closed for "Sorry Business", the final sampling was taken on 2nd October 2024.

All metal concentrations in mangrove sediments were below the Australian and New Zealand default guideline values (Ref. [1]). All hydrocarbon concentrations were below detection limits in mangrove sediment samples.

Metal concentrations in shellfish samples were all within the historical ranges across the various locations and the trend is declining. All metals at locations 1 & 2 were below last year's results.

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, due to the reduction in the produced water discharge.

3. INTRODUCTION

3.1 Background

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

The field consists of an unmanned offshore wellhead platform (WHP), a subsea pipeline bringing whole well stream fluid (i.e. gas, condensate and produced water) into 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) received at the YGP is treated and discharged through a long-sea outfall offshore (PW02) (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 (Ref.[3]).

3.2 Purpose of this Document

This Document presents results for the 2024 annual marine monitoring. The samples were collected on 6th August and 2nd October 2024 from the two ends of nearby Yelcherr Beach, a control site Munda beach and an alternative control site of Kuy Beach.

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

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 potential build-up of contamination in the marine environment due to the PW discharge. The comparison between each annual dataset is included in the results and discussion section of this report.

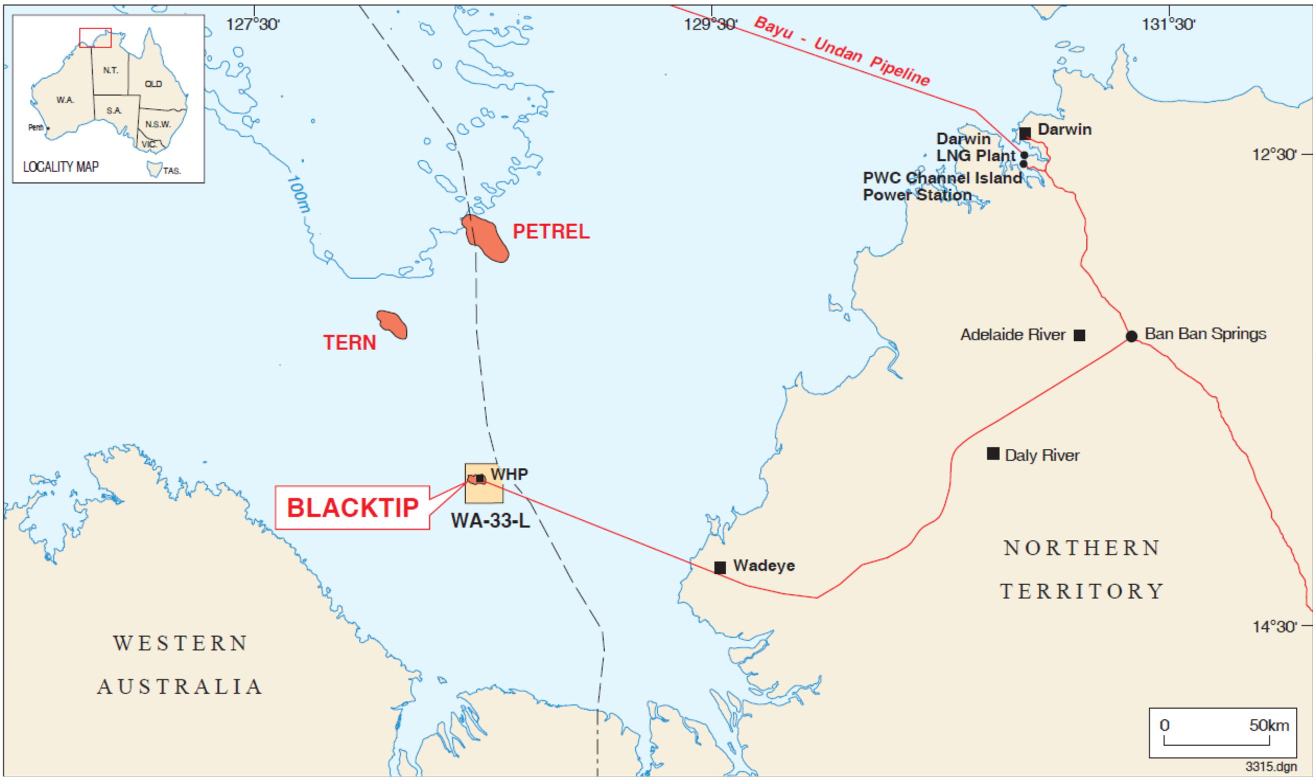

Figure 3.1: Blacktip Field location

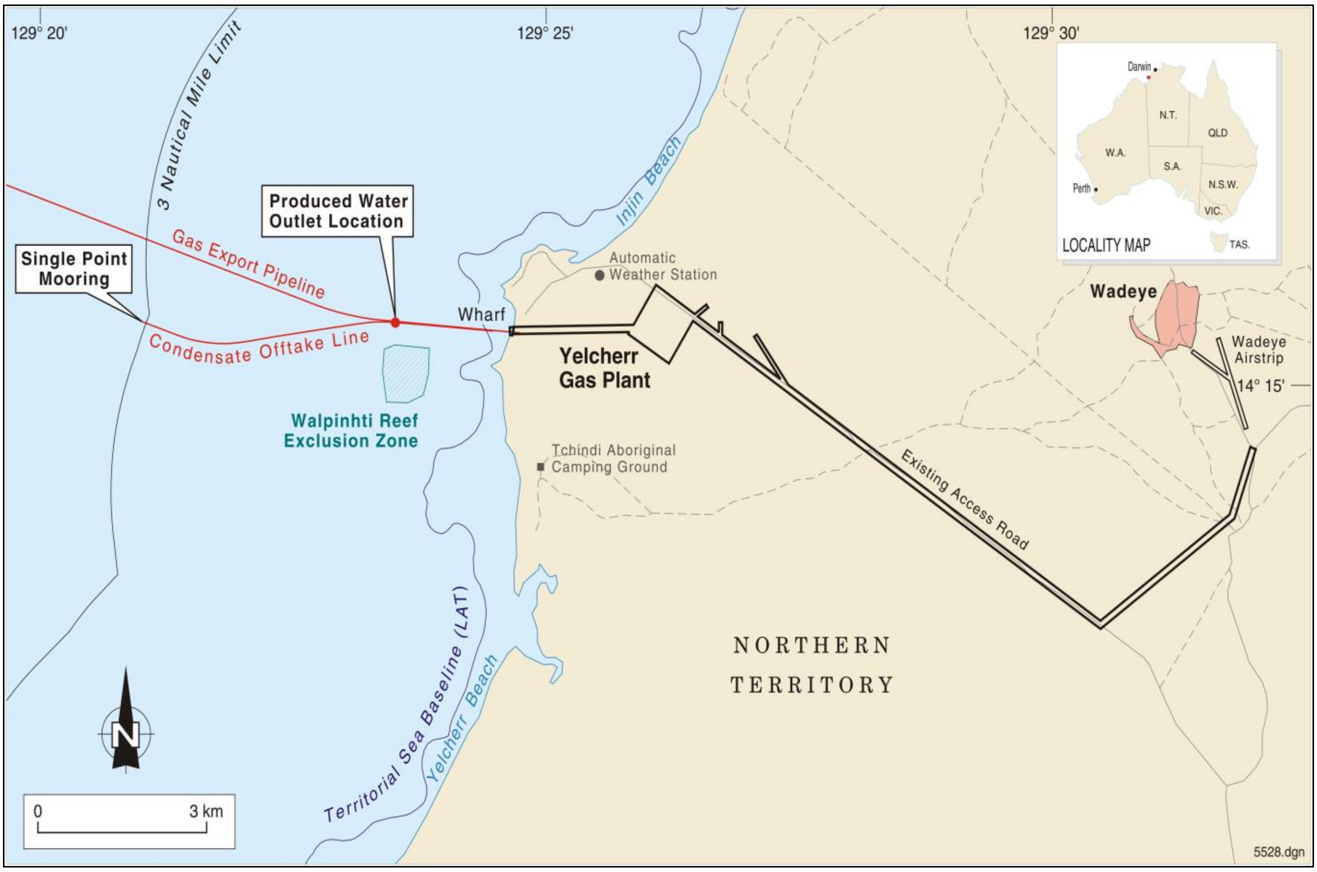

Figure 3.2: Nearshore pipelines and produced water outlet location

4. METHODS

4.1 Sampling locations

Onshore sampling locations include the southern and northern mangrove and rocky headland areas at either end of Yelcherr beach, as well as an accompanying control sample location approximately 7km north of the beach (Munda Beach). It was agreed for 2024 that an Alternative Site selected by the local rangers due to their knowledge of mud whelk's locations would be utilised, this is 53km north from the Control 1 location (Kuy Beach).

As indicated in earlier 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; and
- 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 RH: Rocky Headland	01: Southern end 02: Northern end C: Control CA: Control A	Sed: Sediment SF: Shellfish	01: Sample 1 02: Sample 2

Sample locations surveyed in 2024 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 7km north of the beach.

Table 4.2: Marine survey sample locations

Location name	Recorded sample code	Site Description	Coordinates
Location 1	BT-M-01-SED-01 BT-RH-01-SF-01 BT-M-01-SF-01	Yelcherr Beach (South)	-14.248081 129.407773
Location 2	BT-M-02-SED-01 BT-M-02-SF-01 BT-RH-02-SF-01	Yelcherr Beach (North)	-14.238457 129.411085

Location name	Recorded sample code	Site Description	Coordinates
Control 1	BT-M-C1-SED-01 BT-M-C1-SF-01 BT-RH-C1-SF-01	Control site (7km North)	-14.191592 129.454255
Control 2 (2015)	BT-M-C2-SED-01 BT-RH-C2-SF-01	Nimbe (alternative control site) Not sampled before 2015 Mangrove location is near river mouth where it meets the sea.	-14.196142 129.461886
Control A (2024)	BT-M-CA-SED-01 BT-M-CA-SF-01 BT-RH-CA-SF-01	Control site (A-Additional Control) – Mangroves (53km North) Control site (A-Additional Control) - Rocky Headland (53km North)	-14.031351, 129.598335

Figure 4.1: Marine monitoring sampling locations

4.2 Sediment sampling

Sediment samples 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 4.21). The Alternative Control site (Kuy Beach) was selected; 53km north of Control Site 1 by the Thamarrur Rangers due to the target species of Long Bottom shellfish abundance and availability in only select areas. (Figure 4.3).

Figure 4.2: Terebralia sp. in the mangrove forests (commonly Rhizophore stylosa) *(Image taken 2022)*

Figure 4.3: Types of Shells to Look for on the beach

4.4 Sample analysis

4.4.1 Overview

All samples were delivered to Intertek via Petrolab, 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 and TRH.

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 Australian and New Zealand guidelines (ANZG) (2018) where possible (Ref. [1]). Metals were analysed after acid digest (on dry weight basis) by ICP-AES/ICP-MS.

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

Metals and metalloids	Practical Quantitation Limit (PQL) (mg/kg)	Method	ANZECC and ARMCANZ (2000) guidelines (mg/kg dry weight)
Copper (Cu)	0.5	APHA 3120B	65
Lead (Pb)	0.5		50
Zinc (Zn)	0.25		200
Chromium (Cr)	0.05		80
Nickel (Ni)	0.1		21
Cadmium (Cd)	0.05		1.5
Arsenic (As)	0.2		20
Mercury (Hg)	0.02		0.15

Metals and metalloids	Practical Quantitation Limit (PQL) (mg/kg)	Method	ANZECC and ARMCANZ (2000) guidelines (mg/kg dry weight)
Manganese (Mn)	0.2		ID
Aluminium (Al)	10		ID
Cobalt (Co)	0.5		ID
Iron (Fe)	5		ID
Vanadium (V)	-		ID
Selenium	0.05		ID
Notes: ID – Insufficient Data; TBD – to be determined			

4.4.3 Hydrocarbons

Table 4.4 summarises the hydrocarbon analysis undertaken.

Organic content including BTEX were determined by Purge & Trap GC-MS. PAHs were determined by GC-MS-SIM with PTV large volume injection.

Table 4.4: Sediment and shellfish organic analyses – hydrocarbons

Parameter	Practical Quantitation Limit (PQL)	Method	Toxicant guideline values (Ref. [1])
TRH (Total Residual hydrocarbons):			
(C6-C10, C10 – C16, C16 – C34 and C34-C40)	25 - 250 mg/kg (dry weight)	USEPA 8015C	DGV 280 mg/kg GV-high 550 mg/kg
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	500 µg/kg (dry weight)	USEPA 3550B	DGV 10,000 µg/kg Total PAHs GV-high 50,000 µg/kg Total PAHs
Benzene, toluene, ethylbenzene, zylene (BTEX)	0.1-0.2 mg/kg (dry weight)		ID
Notes: ID – Insufficient Data; TBD – to be determined; DGV = Default Guideline Value; GV-high = Upper Guideline Value			

5. RESULTS AND DISCUSSION

5.1 Sediment samples

Sediment samples were taken from the mangrove muds at the southern (Location 1) and northern (Location 2) ends of Yelcherr beach, with control samples taken from a location 7km (Control site Munda Beach) and an alternative site 53km to the north (Kuy Beach) (see Figure 4.1).

Readings were well within the levels measured in previous years and consistent across the sites, Magnesium was higher in the control location (Alternative site, Kuy Beach 53km north) however this has reduced in the Southern and Northern Yelcherr Beach locations in the previous two years.

5.1.1 Metals in sediment samples

Table 5.1 and Appendix A present the measured metal concentrations in the mangrove sediment between 2010 and 2024. The key findings are summarised below:

- Overall, the readings were well within the levels measured in previous years and consistent across the sites with no significant difference between the Yelcherr beach samples and control samples;
- Results indicated no hydrocarbons were detected at any sites in 2024; and
- Results indicated there were no significant differences between readings at the control sites and monitoring sites over the duration of the monitoring program.

Comparison with Australia and New Zealand default guideline values for toxicants in sediment

All metals were measured below the relevant default guideline values (Ref. [1]).

Comparison with the 2010 baseline survey and previous survey

All readings were within tolerable measurements of the original baseline survey.

All measurements were within the historical range and did not indicate any trend or noticeable difference between the Control site and monitoring sites, indicating no adverse impacts from produced water discharge.

Table 5.1: Measured metal concentrations in mangrove sediment between 2010-2024

Metals (typical PQL mg/kg)	Year	BT-M-C1-SED-01	BT-M-C2/CA-SED-01	BT-M-01-SED-01	BT-M-02-SED-01	DGV (Ref.[1])	GV-high (Ref.[1])
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Aluminium	2010	1100	NT	950	2050	ID	ID
	2011	1800	NT	2000	8800		
	2012	1500	NT	4700	3100		
	2014	45000	NT	2200	3800		
	2015	7800	13000	3100	4100		
	2016	5700	NT	1600	11000		
	2017	1500	NT	2100	4700		
	2018	1560	NT	NT	4430		
	2019	8400	NT	NT	13700		
	2020	6530	NT	8690	10300		
	2021	2870	NT	2500	3250		
	2022	3810	NT	1520	4290		
	2023	3200	NT	2500	7200		
	2024	2900	6600	530	1800		
Arsenic	2010	9	NT	11	14.5	20	70
	2011	17	NT	8.5	22		
	2012	13	NT	13	36		
	2014	43	NT	10	23		
	2015	9.7	42	23	10		
	2016	12	NT	15	23		
	2017	16	NT	27	22		
	2018	12	NT	NT	13		
	2019	11	NT	NT	30		
	2020	14	NT	11	19		
	2021	<0.2	NT	<0.2	<0.2		
	2022	22	NT	4.5	13		
	2023	29	NT	11	37		
	2024	14	19	5.1	16		
Barium	2010	NT	NT	NT	NT	ID	ID
	2011	NT	NT	NT	NT		
	2012	NT	NT	NT	NT		
	2014	3	NT	5	4		
	2015	NT	NT	NT	NT		
	2016	7	NT	2	9		
	2017	3	NT	4	4		
	2018	6.8	NT	NT	4.9		
	2019	9.4	NT	NT	18		
	2020	6.7	NT	7.4	13		
	2021	3.2	NT	1.5	2.2		
	2022	3.4	NT	3.2	5.9		
	2023	<10	NT	<10	<10		

Metals (typical PQL mg/kg)	Year	BT-M-C1-SED-01	BT-M-C2/CA-SED-01	BT-M-01-SED-01	BT-M-02-SED-01	DGV (Ref.[1])	GV-high (Ref.[1])
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
	2024	<10	NT	<10	<10		
Cadmium	2010	0.5	NT	0.9	0.9	1.5	10
	2011	0.1	NT	NT	0.15		
	2012	0.1	NT	0.1	0.4		
	2014	1.9	NT	0.2	0.7		
	2015	<0.4	<0.4	<0.4	<0.4		
	2016	<0.4	NT	<0.1	<0.4		
	2017	<0.4	NT	<0.4	<0.4		
	2018	<0.4	NT	NT	<0.4		
	2019	<0.05	NT	NT	0.06		
	2020	<0.05	NT	<0.05	<0.05		
	2021	0.08	NT	<0.05	<0.05		
	2022	<0.05	NT	<0.05	<0.05		
	2023	<0.1	NT	<0.1	<0.1		
	2024	<0.1	<0.1	<0.1	<0.1		
Chromium	2010	120	NT	90	70	80	370
	2011	27	NT	8.9	31		
	2012	15	NT	17	33		
	2014	120	NT	10	16		
	2015	9.4	66	50	13		
	2016	16	NT	19	33		
	2017	8	NT	21	43		
	2018	9.3	NT	NT	20		
	2019	18	NT	NT	46		
	2020	13	NT	17	20		
	2021	1	NT	1	1		
	2022	4.9	NT	<0.05	6.7		
	2023	110	NT	12	58		
	2024	13	17	5.1	20		
Cobalt	2010	2.55	NT	2	3.85	ID	ID
	2011	2.2	NT	1.9	5.7		
	2012	2	NT	5	4		
	2014	4	NT	2	3		
	2015	2.9	11	6.5	3		
	2016	4	NT	2	7		
	2017	3	NT	3	6		
	2018	6.8	NT	NT	6.9		
	2019	5.9	NT	NT	5.1		
	2020	4.6	NT	5.4	5.6		
	2021	5.1	NT	4	6		
	2022	3.2	NT	1.3	2.7		
	2023	<5	NT	<5	6.6		
	2024	<5	6	<5	<5		
Copper	2010	49.2	NT	29	152	65	270

Metals (typical PQL mg/kg)	Year	BT-M-C1-SED-01 mg/kg	BT-M-C2/CA-SED-01 mg/kg	BT-M-01-SED-01 mg/kg	BT-M-02-SED-01 mg/kg	DGV (Ref.[1]) mg/kg	GV-high (Ref.[1]) mg/kg
	2011	1.2	NT	1.4	7		
	2012	3	NT	8	6		
	2014	3	NT	6	10		
	2015	2	16	1.7	2		
	2016	4	NT	<1	9		
	2017	<1	NT	1	4		
	2018	0.6	NT	NT	1.7		
	2019	2.7	NT	NT	3.7		
	2020	3.1	NT	5	5.1		
	2021	2	NT	1	1.7		
	2022	1.4	NT	0.9	2.9		
	2023	<1	NT	<1	3.6		
	2024	3.6	4	<1	2.7		
Iron	2010	3760	NT	1980	2720	ID	ID
	2011	18000	NT	8300	40000		
	2012	8600	NT	9800	24000		
	2014	55000	NT	6800	21000		
	2015	22000	24000	47000	12000		
	2016	14000	NT	14000	36000		
	2017	8000	NT	30000	54000		
	2018	8200	NT	NT	14000		
	2019	13000	NT	NT	46000		
	2020	14000	NT	15000	20000		
	2021	3300	NT	3200	3600		
	2022	12000	NT	4200	14000		
	2023	62000	NT	8700	45000		
	2024	12000	18000	3800	19000		
Lead	2010	1.6	NT	1.6	7.8	50	220
	2011	2.3	NT	1.7	5		
	2012	2	NT	3	2		
	2014	12	NT	3	6		
	2015	2.4	14	6.2	2.3		
	2016	4	NT	4	6		
	2017	3	NT	6	6		
	2018	2	NT	NT	3		
	2019	3.7	NT	NT	5.9		
	2020	4.2	NT	4.1	4.4		
	2021	<0.1	NT	<0.1	<0.1		
	2022	3.3	NT	1.4	2.8		
	2023	8.3	NT	2	7.4		
	2024	3.9	6.3	1.2	3.8		
Manganese	2010	106	NT	86.6	80.2	ID	ID
	2011	140	NT	140	210		
	2012	130	NT	220	96		

Metals (typical PQL mg/kg)	Year	BT-M-C1-SED-01	BT-M-C2/CA-SED-01	BT-M-01-SED-01	BT-M-02-SED-01	DGV (Ref.[1])	GV-high (Ref.[1])
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
	2014	420	NT	150	93		
	2015	160	190	230	120		
	2016	210	NT	180	210		
	2017	270	NT	130	180		
	2018	160	NT	NT	110		
	2019	270	NT	NT	150		
	2020	240	NT	140	190		
	2021	0.8	NT	0.7	0.8		
	2022	200	NT	89	110		
	2023	220	NT	120	100		
	2024	210	490	67	74		
Mercury	2010	<0.2	<0.2	0.4	<0.2	0.15	1
	2011	0	NT	ND	ND		
	2012	<0.02	NT	<0.02	<0.02		
	2014	0.03	NT	<0.02	<0.02		
	2015	<0.1	<0.1	<0.1	<0.1		
	2016	<0.1	NT	<0.1	<0.1		
	2017	<0.1	NT	<0.1	<0.1		
	2018	0.09	NT	NT	0.06		
	2019	0.02	NT	NT	0.02		
	2020	<0.02	NT	<0.02	<0.02		
	2021	<0.02	NT	<0.02	<0.02		
	2022	<0.02	NT	<0.02	<0.02		
	2023	<0.02	NT	<0.02	<0.02		
	2024	<0.02	<0.02	<0.02	<0.02		
Nickel	2010	35	NT	22.2	24.2	21	52
	2011	3.7	NT	2.3	9.2		
	2012	3	NT	5	6		
	2014	7	NT	2	5		
	2015	3.1	14	7.1	3.2		
	2016	5	NT	3	11		
	2017	2	NT	4	9		
	2018	2.5	NT	NT	3.1		
	2019	4.5	NT	NT	8.1		
	2020	5.0	NT	7.0	7.8		
	2021	<0.01	NT	<0.01	<0.01		
	2022	3.9	NT	2	4.7		
	2023	6.9	NT	2.9	8.4		
	2024	4.7	5.4	1.2	3.5		
Selenium	2010	NT	NT	NT	NT	ID	ID
	2011	NT	NT	ND	0.13		
	2012	NT	NT	<2	<2		
	2014	NT	NT	<2	<2		
	2015	<1.0	<1.0	<1.0	<1.0		

Metals (typical PQL mg/kg)	Year	BT-M-C1-SED-01	BT-M-C2/CA-SED-01	BT-M-01-SED-01	BT-M-02-SED-01	DGV (Ref.[1])	GV-high (Ref.[1])
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
	2016	<2	NT	<2	<2		
	2017	<2	NT	<2	<2		
	2018	0.05	NT	NT	0.06		
	2019	0.1	NT	NT	0.16		
	2020	0.15	NT	0.21	0.21		
	2021	<0.05	NT	<0.05	<0.05		
	2022	0.14	NT	<0.05	0.1		
	2023	<2	NT	<2	<2		
	2024	<2	<.2	<2	<2		
Zinc	2010	73.5	NT	55	154	200	410
	2011	6.5	NT	4.3	16		
	2012	6	NT	9	11		
	2014	9	NT	3	7		
	2015	7.3	63	18	8.7		
	2016	9	NT	5	23		
	2017	4	NT	5	15		
	2018	2.6	NT	NT	4		
	2019	6.3	NT	NT	12		
	2020	7.9	NT	10	12		
	2021	<0.25	NT	1.08	2.02		
	2022	5.4	NT	3.6	8.5		
	2023	10	NT	<5	12		
	2024	8.6	17	<5	5.1		
Magnesium	2018	5400	NT	NT	4000	n/a	n/a
	2019	6900	NT	NT	5900		
	2020	7100	NT	6400	13000		
	2021	1720	NT	1637	2015		
	2022	3500	NT	3000	3600		
	2023	2900	NT	4700	5600		
	2024	5500	13000	2400	4900		
Tin	2016	<1	NT	<1	<1	n/a	n/a
	2017	<1	NT	<1	<1		
	2018	<0.5	NT	0.5	0.5		
	2019	<0.5	NT	NT	0.5		
	2020	<0.5	NT	0.5	0.5		
	2021	<0.5	NT	0.5	0.5		
	2022	<0.5	NT	<0.5	<0.5		
	2023	<10	NT	<10	<10		
	2024	<10	<10	<10	<10		

5.1.2 Hydrocarbons in sediment samples

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

Table 5.2: Measured TRH, BTEX and PAH concentrations in mangrove sediment 2024

Chemical parameter	Limit of Reporting	Control 1 BT-M-C-SED-01	Control A BT-M-C2/CA-SED01	Location 1 BT-M-01-SED-01	Location 2 BT-M-02-SED-01	DGV trigger values (Ref.[1])	GV-high trigger values (Ref.[1])
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
BTEX							
Benzene	0.1	<0.1	<0.1	<0.1	<0.1	NA	NA
Toluene	0.1	<0.1	<0.1	<0.1	<0.1	NA	NA
Ethylbenzene	0.1	<0.1	<0.1	<0.1	<0.1	NA	NA
m+p-xylenes	0.2	<0.2	<0.2	<0.2	<0.2	NA	NA
o-xylene	0.1	<0.1	<0.1	<0.1	<0.1	NA	NA
vTRH							
C6 – C10	25	<25	<25	<25	<25	NA	NA
svTRH							
C10 – C16	25	<25	<25	<25	<25	NA	NA
C16 – C34	100	<100	<100	<100	<100	NA	NA
C34 – C40	100	<100	<100	<100	<100	NA	NA
Total TRH	250	<250	<250	<250	<250	280*	550*
PAH -Speciated							
Naphthalene	0.5	<0.5	<0.5	<0.5	<0.5	NA	NA
Acenaphthylene	0.5	<0.5	<0.5	<0.5	<0.5	NA	NA
Acenaphthene	0.5	<0.5	<0.5	<0.5	<0.5	NA	NA
Fluorene	0.5	<0.5	<0.5	<0.5	<0.5	NA	NA
Phenanthrene	0.5	<0.5	<0.5	<0.5	<0.5	NA	NA
Anthracene	0.5	<0.5	<0.5	<0.5	<0.5	NA	NA
Fluoranthene	0.5	<0.5	<0.5	<0.5	<0.5	NA	NA
Pyrene	0.5	<0.5	<0.5	<0.5	<0.5	NA	NA
Benz(a)anthracene	0.5	<0.5	<0.5	<0.5	<0.5	NA	NA
Chrysene	0.5	<0.5	<0.5	<0.5	<0.5	NA	NA
Benzo(b)fluoranthene	0.5	<0.5	<0.5	<0.5	<0.5	NA	NA
Benzo(k)fluoranthene	0.5	<0.5	<0.5	<0.5	<0.5	NA	NA
Benzo(a)pyrene	0.5	<0.5	<0.5	<0.5	<0.5	NA	NA
Indeno(1,2,3-c,d)pyrene	0.5	<0.5	<0.5	<0.5	<0.5	NA	NA
Dibenz(a,h)anthracene	0.5	<0.5	<0.5	<0.5	<0.5	NA	NA
Benzo(ghi)perylene	0.5	<0.5	<0.5	<0.5	<0.5	NA	NA
Total PAH	n/a	NIL (+)IVE	NIL (+)IVE	NIL (+)IVE	NIL (+)IVE	10	50

Notes: ID = Insufficient Data, NA = Not Applicable; DGV = Default Guideline Value; GV-high = Upper Guideline Value;
LOR = Limit of Reporting (equivalent to Practical Quantitation Limit)
*Guideline values for Total Petroleum Hydrocarbons (TPH)

5.2 Shellfish samples

5.2.1 Overview

Shellfish were collected from the mangroves and rocky headlands at either end of Yelcherr beach, with control samples taken from a location 7km to the north and an alternative site 53km north of Control 1 (see Figure 4.1).

5.2.2 Metals in shellfish samples

Table 5.3 and Appendix B present the measured metal concentrations in shellfish samples between 2010 and 2024.

All results were within the historical ranges across the various locations, and many below or near detection limits. Therefore, there is continued confidence that there are no chronic effects from produced water discharge.

Table 5.3: Measured metal concentrations (mg/kg dry weight) in shellfish samples between 2010-2024

Concentration of contaminant in shellfish tissue (mg/kg, dry weight)[1]									
Metals (PQL mg/kg)	**Year**	**Rocky headlands**				**Mangroves**			
		Control 1	**Control 2/A**	**Location 1**	**Location 2**	**Control 1**	**Control 2/A**	**Location 1**	**Location 2**
Aluminium	2010	360	NT	640	240	1660	NT	1740	2030
	2011	615	NT	350	450	220	NT	350	1050
	2012	234.5	NT	330	160	370	NT	NT	400
	2014	NT	NT	NT	NT	13000	NT	NT	2000
	2015	260	520	490	370	120	NT	220	120
	2016	62	NT	34	350	61	NT	170	530
	2017[2]	160	NT	NT	350	160	NT	66	180
	2018	NT	NT	0.55	3.4	1.8	NT	0.86	1.3
	2019	340	NT	370	26	12	NT	0.51	25
	2020	450	NT	<100	140	<100	NT	27	<100
	2021	<10	NT	<10	<10	<10	NT	<10	<10
	2022	410	NT	81	290	110	NT	230	37
	2023	1.8	NT	0.9	3.8	1	NT	1.6	5.3
	2024	<0.2	0.3	<0.2	<0.2	<0.2	0.4	<0.2	<0.2
Arsenic	2010	7.5	NT	17.5	6	8.5	NT	6.5	10
	2011	4.1	NT	14	6.4	1.7	NT	2.4	2.6
	2012	6.2	NT	8.1	3.2	2.2	NT	NT	2.4
	2014	NT	NT	NT	NT	6.9	NT	NT	8.9
	2015	1.8	2.3	3	2.7	2.3	NT	2.8	2.8
	2016	4	NT	4	5	5	NT	7	8
	2017[2]	7	NT	NT	15	4	NT	5	6
	2018	NT	NT	2.2	2.2	2	NT	3.3	2.8
	2019	10	NT	11	3.2	2.7	NT	2.1	2
	2020	2.4	NT	ND	2.9	ND	NT	3.5	ND
	2021	<0.2	NT	<0.2	<0.2	<0.2	NT	<0.2	<0.2
	2022	4.4	NT	73	3.3	4.2	NT	4.6	1

Concentration of contaminant in shellfish tissue (mg/kg, dry weight)[1]									
Metals (PQL mg/kg)	**Year**	**Rocky headlands**				**Mangroves**			
		Control 1	**Control 2/A**	**Location 1**	**Location 2**	**Control 1**	**Control 2/A**	**Location 1**	**Location 2**
	2023	0.5	NT	0.5	0.5	0.5	NT	0.5	0.5
	2024	0.5	NT	0.5	0.5	0.5	<0.5	0.5	0.5
Barium	2010	NT	NT	NT	NT	NT	NT	NT	NT
	2011	NT	NT	NT	NT	NT	NT	NT	NT
	2012	0.15	NT	0.36	0.59	0.14	NT	NT	0.14
	2014	NT	NT	NT	NT	2	NT	NT	2
	2015	NT	NT	NT	NT	NT	NT	NT	NT
	2016	6	NT	4	2	5	NT	2	1
	2017[2]	1	NT	NT	1	<1	NT	<1	<1
	2018	NT	NT	0.01	0.38	0.04	NT	0.04	0.02
	2019	5.6	NT	4.5	0.36	0.05	NT	0.05	0.15
	2020	ND	NT	<10	ND	<10	NT	ND	<10
	2021	<0.1	NT	<0.1	<0.1	<0.1	NT	<0.1	<0.1
	2022	0.81	NT	0.15	0.75	0.64	NT	3.9	0.28
	2023	0.05	NT	0.05	0.05	0.05	NT	0.05	0.05
	2024	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cadmium	2010	0.85	NT	1.55	0.9	<0.05	NT	<0.05	<0.05
	2011	1	NT	0.7	0.49	0.23	NT	0.17	0.13
	2012	0.675	NT	0.65	0.35	1.3	NT	NT	1.4
	2014	NT	NT	NT	NT	6.9	NT	NT	8.9
	2015	0.27	0.03	0.45	0.4	0.94	NT	0.17	0.12
	2016	0.4	NT	0.5	0.6	0.4	NT	0.5	0.5
	2017[2]	1	NT	NT	2	<0.4	NT	<0.4	<0.4
	2018	NT	NT	0.06	0.06	0.05	NT	0.06	0.06
	2019	1.7	NT	1.6	1.1	0.04	NT	0.09	0.18
	2020	0.13	NT	<0.1	0.18	<0.1	NT	0.15	<0.1
	2021	<0.05	NT	<0.05	<0.05	<0.05	NT	<0.05	<0.05
	2022	0.69	NT	0.88	0.55	0.13	NT	0.26	0.066
	2023	0.001	NT	0.003	0.002	0.001	NT	0.009	0.002
	2024	0.001	0.003	<0.001	0.004	0.001	0.007	0.002	0.002
Chromium	2010	30	NT	20	30	15	NT	10	20
	2011	1.74	NT	1.8	2.6	0.97	NT	0.93	3.2
	2012	0.32	NT	0.38	0.24	0.28	NT	NT	0.28
	2014	NT	NT	NT	NT	4	NT	NT	4
	2015	0.74	1.2	1	0.71	0.31	NT	0.68	0.36
	2016	1	NT	1	82	26	NT	60	66
	2017[2]	<1	NT	NT	2	<1	NT	<1	<1
	2018	NT	NT	<0.05	<0.05	<0.05	NT	<0.05	<0.05
	2019	2.9	NT	2.2	0.21	0.06	NT	<0.05	0.14
	2020	1.3	NT	<0.1	0.3	<0.1	NT	0.3	<0.1
	2021	<0.05	NT	<0.05	<0.05	<0.05	NT	<0.05	<0.05
	2022	0.6	NT	0.3	0.6	1.1	NT	0.7	0.4
	2023	0.2	NT	0.2	0.2	0.2	NT	0.2	0.2
	2024	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Concentration of contaminant in shellfish tissue (mg/kg, dry weight)[1]									
Metals (PQL mg/kg)	Year	Rocky headlands				Mangroves			
		Control 1	Control 2/A	Location 1	Location 2	Control 1	Control 2/A	Location 1	Location 2
Cobalt	2010	1.8	NT	1.5	1.25	2.2	NT	2.4	2.45
	2011	0.62	NT	0.4	0.47	0.18	NT	0.44	0.49
	2012	14.5	NT	20	8.3	12	NT	NT	10
	2014	NT	NT	NT	NT	<1	NT	NT	<1
	2015	0.26	0.39	1.5	1.1	1.8	NT	0.23	0.19
	2016	<1	NT	<1	2	3	NT	1	2
	2017[2]	<1	NT	NT	1	<1	NT	<1	<1
	2018	NT	NT	0.05	0.05	<0.01	NT	<0.01	0.04
	2019	0.98	NT	1.3	0.14	0.13	NT	0.04	0.07
	2020	0.28	NT	<0.1	0.078	<0.1	NT	0.083	<0.1
	2021	1	NT	2	2	2	NT	1	1
	2022	0.48	NT	0.11	0.29	0.088	NT	0.28	0.086
	2023	0.003	NT	0.001	0.001	0.002	NT	0.001	0.001
	2024	0.002	0.009	0.004	0.004	0.011	0.010	0.002	0.006
Copper	2010	72.4	NT	100	35.2	1.6	NT	1.6	2.8
	2011	13.5	NT	30	23	13	NT	16	11
	2012	395	NT	520	220	640	NT	NT	720
	2014	NT	NT	NT	NT	35	NT	NT	60
	2015	17	41	30	24	47	NT	13	5.9
	2016	49	NT	89	91	100	NT	62	49
	2017[2]	18	NT	NT	55	17	NT	24	19
	2018	NT	NT	5.7	9.1	8.4	NT	8.8	4.4
	2019	45	NT	49	8.3	0.97	NT	4.7	3.6
	2020	13	NT	30	11	113	NT	16	31
	2021	3.4	NT	0.8	1.8	3.3	NT	1.5	1
	2022	37	NT	30	29	7.8	NT	21	11
	2024	0.04	1.3	0.06	0.32	0.21	0.63	0.15	0.34
Iron	2010	1280	NT	1710	800	9710	NT	6450	15100
	2011	995	NT	550	670	410	NT	440	1230
	2012	0.145	NT	0.18	0.09	0.26	NT	NT	0.16
	2014	NT	NT	NT	NT	2700	NT	NT	4000
	2015	500	740	740	660	290	NT	370	290
	2016	900	NT	120	1600	510	NT	1000	220
	2017[2]	490	NT	NT	1100	610	NT	190	500
	2018	NT	NT	11	18	15	NT	24	17
	2019	640	NT	570	94	37	NT	8.9	48
	2020	780	NT	219	270	340	NT	97	42.5
	2021	3700	NT	4400	3200	8100	NT	2100	2500
	2022	430	NT	79	250	160	NT	500	52
	2023	37	NT	30	29	7.8	NT	21	11
	2024	<5	<5	<5	<5	<5	<5	<5	<5
Lead	2010	0.4	NT	0.8	0.2	3.4	NT	2.2	2.8
	2011	0.275	NT	0.2	0.22	0.11	NT	0.18	0.27
	2012	27.55	NT	14	8.4	26	NT	NT	19

Concentration of contaminant in shellfish tissue (mg/kg, dry weight)[1]									
Metals (PQL mg/kg)	**Year**	**Rocky headlands**				**Mangroves**			
		Control 1	**Control 2/A**	**Location 1**	**Location 2**	**Control 1**	**Control 2/A**	**Location 1**	**Location 2**
	2014	NT	NT	NT	NT	0.8	NT	NT	0.7
	2015	0.16	0.23	0.23	0.19	0.09	NT	0.15	0.08
	2016	9	NT	<1	<1	<1	NT	<1	<1
	2017[2]	<1	NT	NT	<1	<1	NT	<1	<1
	2018	NT	NT	0.01	0.01	<0.01	NT	0.01	<0.01
	2019	0.2	NT	0.26	0.024	0.02	NT	0.01	0.02
	2020	0.21	NT	ND	0.1	ND	NT	0.006	ND
	2021	<0.1	NT	<0.1	<0.1	<0.1	NT	<0.1	<0.1
	2022	0.16	NT	0.036	0.13	0.077	NT	0.4	0.049
	2023	0.003	NT	0.003	0.005	0.001	NT	0.001	0.009
	2024	<0.001	0.003	0.001	0.001	0.001	0.009	0.001	0.001
Manganese	2010	57.7	NT	41.8	15.9	124	NT	149	73.6
	2011	88.5	NT	7.9	13	21	NT	19	33
	2012	0.015	NT	0.02	0.01	0.01	NT	NT	0.01
	2014	NT	NT	NT	NT	160	NT	NT	85
	2015	21	15	14	11	8.9	NT	18	9.6
	2016	35	NT	11	70	42	NT	40	50
	2017[2]	2	NT	NT	74	48	NT	40	45
	2018	NT	NT	1.7	2.4	1.8	NT	1.9	3.7
	2019	32	NT	30	2	7	NT	3.3	3
	2020	15	NT	108	3.3	236	NT	3.5	44.9
	2021	<0.02	NT	<0.02	<0.02	2.7	NT	<0.02	<0.02
	2022	12	NT	2.3	9.3	5.3	NT	39	4.4
	2023	0.05	NT	0.1	0.05	0.16	NT	0.48	0.05
	2024	<0.05	0.25	<0.05	0.25	0.09	0.07	0.15	0.27
Mercury	2010	<0.2	NT	<0.2	<0.2	<0.2	NT	<0.2	<0.2
	2011	0.01	NT	0	0.01	0.01	NT	0.03	0
	2012	1.3	NT	0.89	1.2	0.48	NT	NT	0.44
	2014	NT	NT	NT	NT	<0.02	NT	NT	<0.02
	2015	0.02	0.02	0.02	0.01	<0.01	NT	0.04	0.01
	2016	<0.1	NT	<.01	<0.1	<0.1	NT	<0.1	<0.1
	2017[2]	<0.1	NT	NT	<0.1	<0.1	NT	<0.1	<0.1
	2018	NT	NT	<0.01	<0.01	<0.01	NT	0.01	<0.01
	2019	0.03	NT	0.02	<0.01	0.02	NT	<0.01	<0.01
	2020	0.01	NT	<0.02	<0.01	<0.02	NT	0.01	<0.02
	2021	<0.02	NT	<0.02	<0.02	<0.02	NT	<0.02	<0.02
	2022	0.02	NT	0.03	0.01	0.01	NT	0.05	<0.01
	2023	0.01	NT	0.01	0.01	0.01	NT	0.01	0.01
	2024	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel	2010	5.6	NT	6.8	9.2	3	NT	2.4	4.2
	2011	1.95	NT	0.9	1.1	0.54	NT	0.79	0.8
	2012	0.415	NT	0.53	0.68	0.27	NT	NT	0.27
	2014	NT	NT	NT	NT	2	NT	NT	2
	2015	0.41	0.48	0.64	0.86	0.73	NT	0.34	0.39

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

Metals (PQL mg/kg)	Year	Rocky headlands Control 1	Rocky headlands Control 2/A	Rocky headlands Location 1	Rocky headlands Location 2	Mangroves Control 1	Mangroves Control 2/A	Mangroves Location 1	Mangroves Location 2
	2016	1	NT	1	30	10	NT	24	27
	2017[2]	1	NT	NT	2	2	NT	<1	<1
	2018	NT	NT	0.07	0.17	0.049	NT	0.1	0.07
	2019	8.4	NT	11	0.88	0.16	NT	0.08	0.16
	2020	0.49	NT	<0.1	0.22	<0.1	NT	0.22	<0.1
	2021	0.1	NT	0.1	0.1	0.1	NT	0.1	0.1
	2022	3.8	NT	0.5	8.6	1	NT	0.6	3.7
	2023	0.01	NT	0.01	0.01	0.01	NT	0.01	0.01
	2024	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Selenium	2010	n/a	NT	n/a	n/a	n/a	NT	n/a	n/a
	2011	0	NT	0	0	0	NT	0	0
	2012	0	NT	0	0	0	NT	0	0
	2014	NT	NT	NT	NT	0.9	NT	NT	1
	2015	0.23	0.28	0.44	0.45	0.45	NT	0.28	0.33
	2016	<2	NT	<2	<2	<2	NT	<2	<2
	2017[2]	<2	NT	NT	<2	<2	NT	<2	<2
	2018	NT	NT	0.38	0.36	0.15	NT	0.25	0.18
	2019	1.1	NT	1.4	0.52	0.26	NT	0.19	0.17
	2020	0.3	NT	ND	0.24	ND	NT	0.26	ND
	2021	<0.05	NT	<0.05	<0.05	<0.05	NT	<0.05	<0.05
	2022	0.59	NT	0.59	0.49	0.34	NT	0.53	0.22
	2023	0.02	NT	0.01	0.01	0.01	NT	0.02	0.01
	2024	<0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
Zinc	2010	69	NT	34	24	5	NT	5.5	9
	2011	19.5	NT	21	7.9	12	NT	21	15
	2012	234.5	NT	330	160	370	NT	NT	400
	2014	NT	NT	NT	NT	69	NT	NT	70
	2015	9.6	15	19	22	39	NT	12	12
	2016	76	NT	73	40	140	NT	31	29
	2017[2]	8	NT	NT	19	23	NT	29	22
	2018	NT	NT	10	8.9	14	NT	15	13
	2019	17	NT	22	7.1	9	NT	8.8	11
	2020	13	NT	140	14	78	NT	12	15.5
	2021	0.6	NT	0.3	0.31	0.35	NT	0.3	0.33
	2022	19	NT	130	13	16	NT	88	5
	2023	1	NT	1	1	1	NT	1	1
	2024	<1	<1	<1	<1	<1	<1	<1	<1
Magnesium	2018	NT	NT	630	850	1130	NT	1420	1560
	2019	7500	NT	10400	940	2970	NT	2810	3290
	2020	5000	NT	3,300	3,600	7,300	NT	3000	1,340
	2021	48	NT	64	74	253	NT	95	20
	2022	1800	NT	1600	1800	1300	NT	7400	640
	2023	43	NT	27	68	80	NT	180	60
	2024	<0.05	190	0.05	0.25	0.09	100	0.15	0.27

Concentration of contaminant in shellfish tissue (mg/kg, dry weight)[1]									
Metals (PQL mg/kg)	Year	Rocky headlands				Mangroves			
		Control 1	Control 2/A	Location 1	Location 2	Control 1	Control 2/A	Location 1	Location 2
Tin	2016	<1	NT	<1	<1	<1	NT	<1	<1
	2017	<1	NT	<1	<1	<1	NT	<1	<1
	2018	NT	NT	<0.02	0.02	0.02	NT	0.02	0.02
	2019	0.5	NT	0.05	<0.02	<0.02	NT	<0.02	<0.02
	2020	<0.5	NT	NT	<0.5	NT	NT	<0.5	NT
	2021	<0.5	NT	<0.5	<0.5	<0.5	NT	<0.5	<0.5
	2022	<0.05	NT	<0.05	<0.05	<0.05	NT	<0.05	<0.05
	2023	0.05	NT	0.05	0.05	0.05	NT	0.05	0.05
	2024	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Notes:
[1] Composite shellfish samples
[2] Due to limited sample volumes, concentrations of contaminants in shellfish tissue were reported on an 'as received' basis, i.e. moisture content not included in the calculation.
[3] Due to small sample size, not all elements could be detected.
ND = Not Detected; NT = Not Tested; ID = Insufficient Data; NA – Not Available

5.2.3 Hydrocarbons in shellfish samples

Table 5.4 presents the TRH, BTEX and PAH concentrations measured in the shellfish samples. PAHs are responsible for most of the toxicity in oil.

All readings for petroleum compounds were below detection limits.

No abnormalities were observed in the shellfish or reported by the local community.

The results do not present an immediate concern for environmental harm or public health.

Table 5.4: Measured BTEX, TRH and PAH concentrations in shellfish 2024

	Concentration of contaminant in shellfish tissue (mg/kg, dry weight)[1]								
Parameter	LOR mg/kg	Rocky headlands				Mangroves			
		Control 1	Control 2/A	Loc1	Loc 2	Control 1	Control A	Loc 1	Loc 2
BTEX									
Benzene	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Toluene	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ethylbenzene	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
m+p-xylenes	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
o-xylene	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
vTRH									
C6 – C10	25	<25	<25	<25	<25	<25	<25	<25	<25
svTRH									
C10 – C16	25	<25	<25	<25	<25	<25	<25	<25	<25
C16 – C34	100	<100	<100	<100	<100	<100	<100	<100	<100
C34 – C40	100	<100	<100	<100	<100	<100	<100	<100	<100

	Concentration of contaminant in shellfish tissue (mg/kg, dry weight)[1]								
Parameter	**LOR mg/kg**	**Rocky headlands**				**Mangroves**			
		Control 1	**Control 2/A**	**Loc1**	**Loc 2**	**Control 1**	**Control A**	**Loc 1**	**Loc 2**
Total TRH	250	<250	<250	<250	<250	<250	<250	<250	<250
PAH -Speciated									
Naphthalene	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Acenaphthylene	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Acenaphthene	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Fluorene	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Phenanthrene	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Anthracene	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Fluoranthene	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Pyrene	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benz(a)anthracene	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chrysene	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(b)&(k)fluoranthene	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a)pyrene	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1,2,3-cd)pyrene	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dibenzo(a,h)anthracene	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(g,h,i)perylene	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a)pyrene TEQ	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

Notes: NT = Not Tested, LOR = Limit of Reporting (equivalent to Practical Quantitation Limit)

[1] Composite shellfish samples

[2] Due to limited sample volumes, concentrations of contaminants in shellfish tissue were reported on an 'as received' basis, i.e. moisture content not included in the calculation.

6. CONCLUSION

Overall, readings were within the levels measured in previous years. Action is underway to reduce the metal content of produced water through the trial wastewater treatment plant.

Since that time, additional limits for discharging Produced Water to sea have been imposed. In order to meet these limits, the facility is undergoing trails of water treatment systems to bring specific parameters within the new limits. At the time of writing, a trial produced water treatment skid is in place at the facility and is being tested and optimised to meet these parameters. Currently the system comprises of;

- Inclined Plate Lamella (IPL) (solids removal)
- Oily Water Separator (OWS) and Structure
- Produced Water Surge Tank
- 2 x Chemical Dosing Skids
- Produced Water Transfer Pump
- Scouring Pump
- Generator Set (Diesel)
- Associated hoses to connect the equipment (mixture of flanged and cam-locked)

The system has been successful in brining produced water to within limits for Benzene (introduced in 2015), Toluene, Ethylbenzene and m+p Xylene (introduced in 2020). The system has had success in reducing Copper, Manganese and Zinc (introduced in 2020), and is currently being further optimised to bring these parameters below the given limits, and to ensure consistency and repeatability for these results.

All metal concentrations in mangrove sediments were below the Australian and New Zealand default guideline values (Ref. [1]). All hydrocarbon concentrations were below detection limits in mangrove sediment samples.

Metal concentrations in shellfish samples were all within the historical ranges across the various locations.

Therefore, all results are considered satisfactory and provide continued confidence that there are no effects from produced water discharge.

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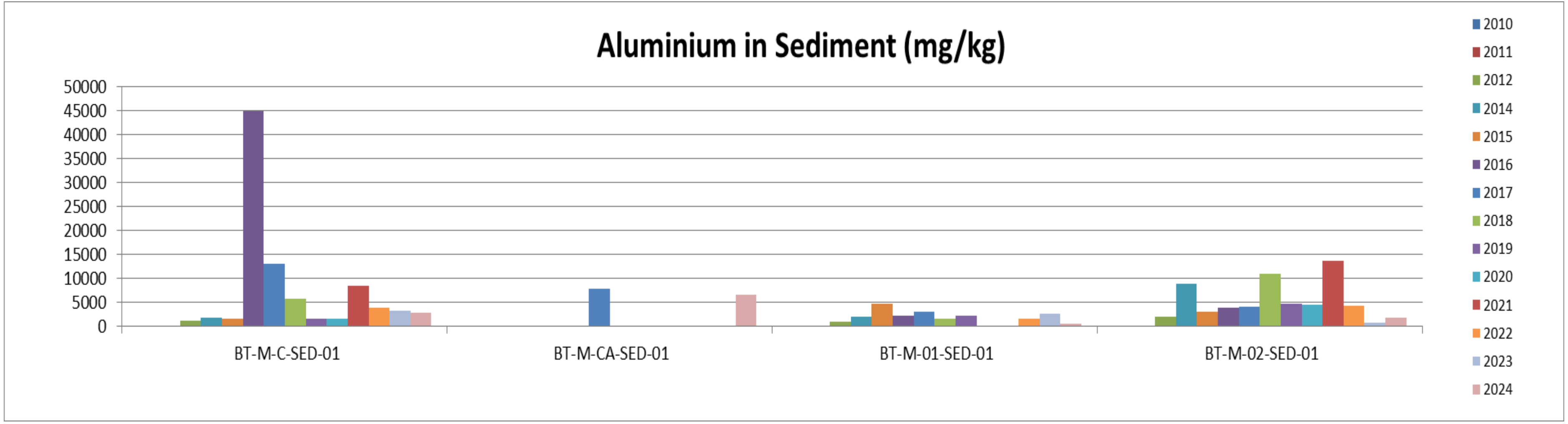
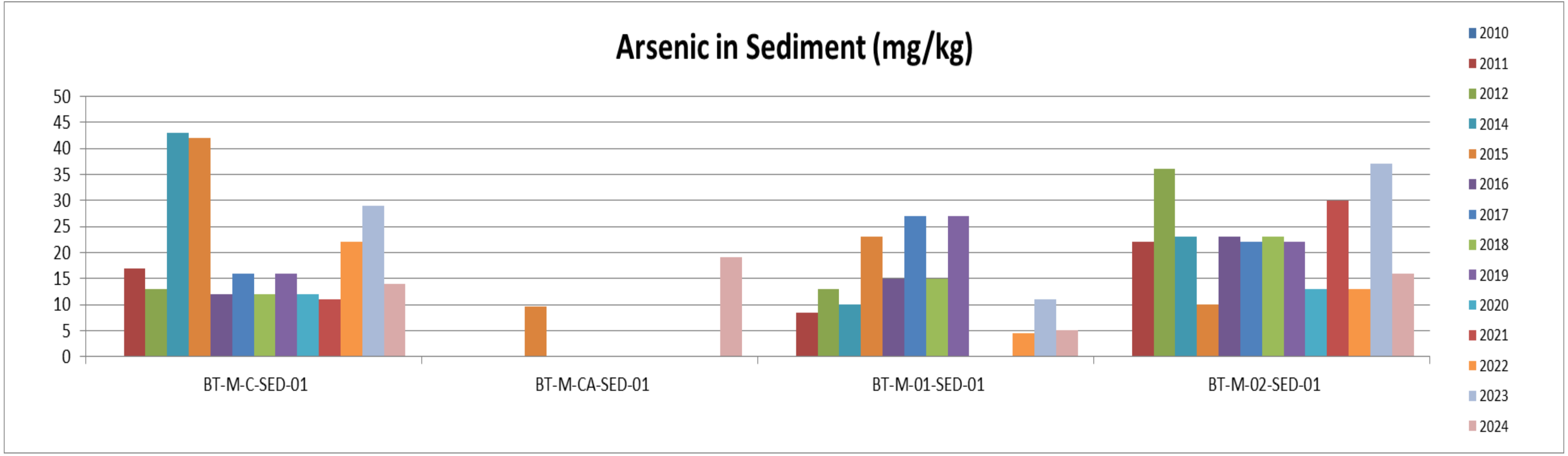
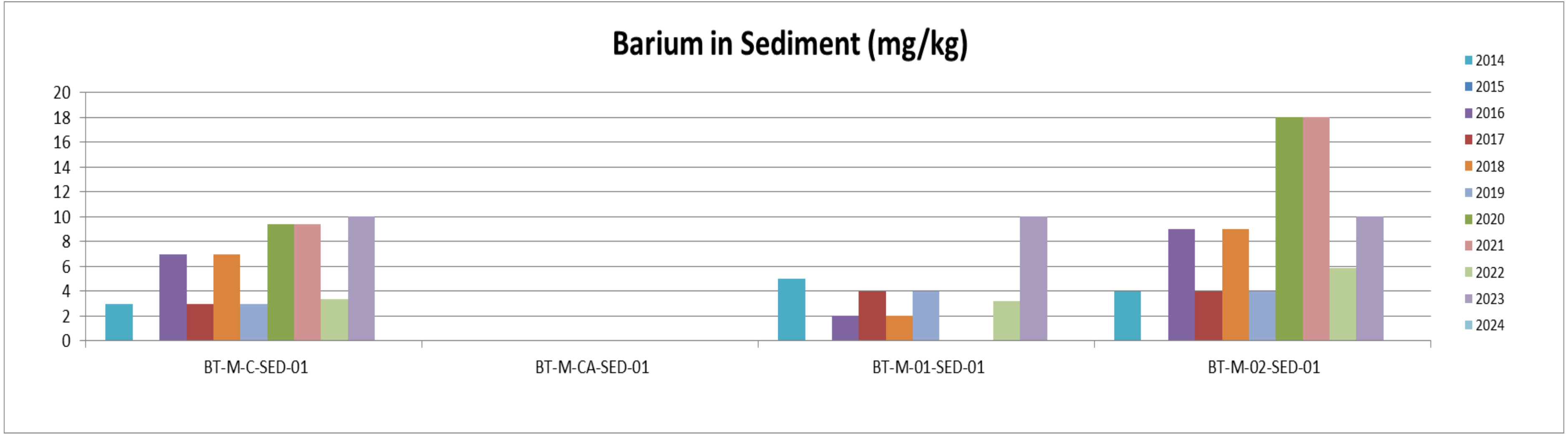
ATTACHMENTS

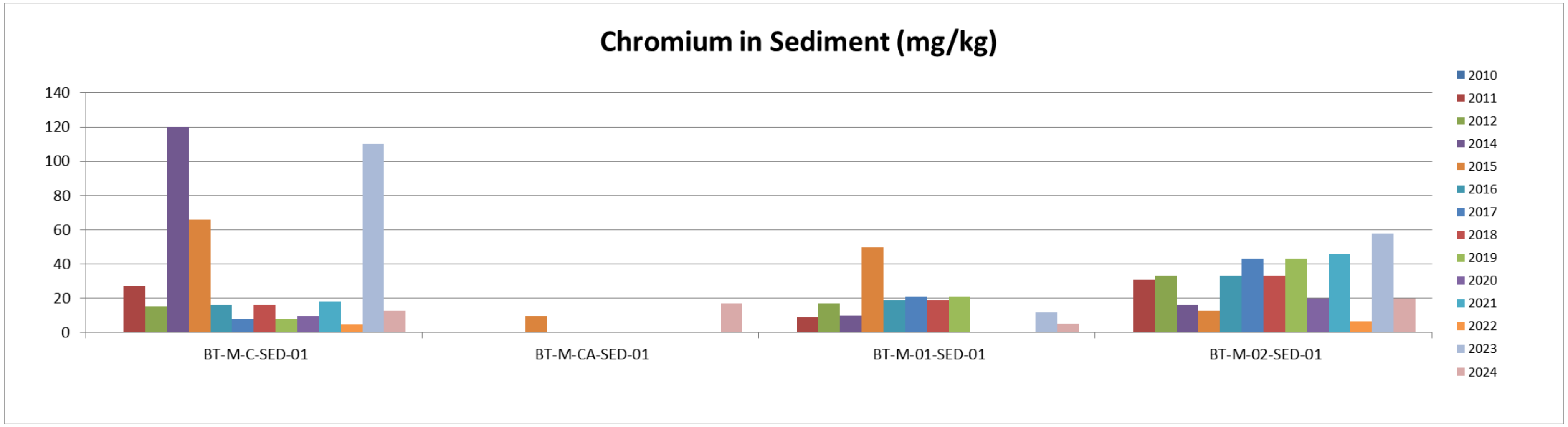
ATTACHMENT A:

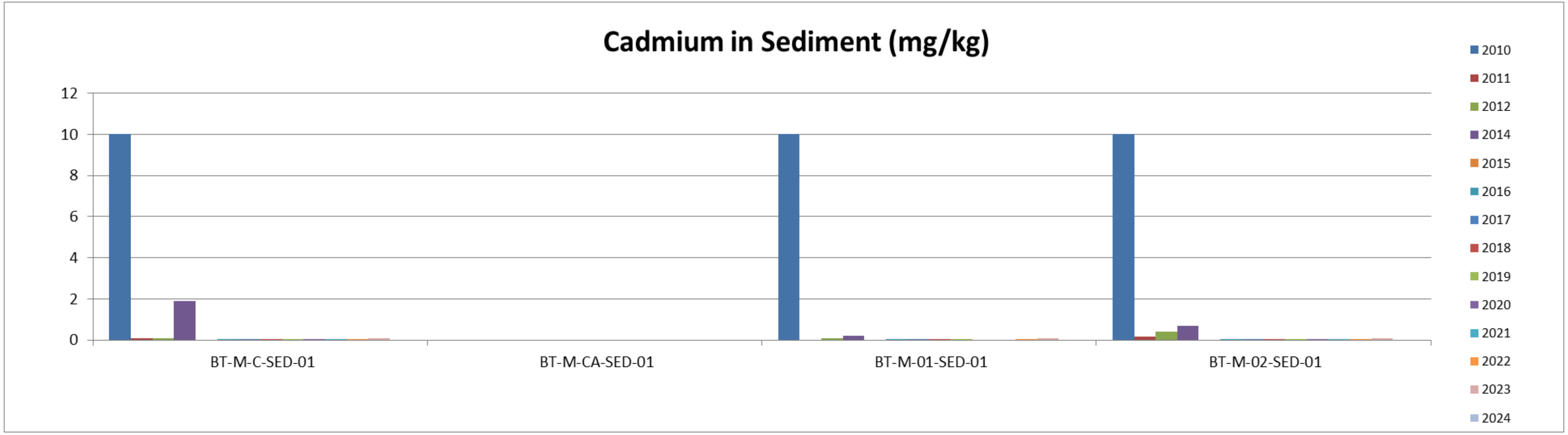
MEASURED METAL CONCENTRATIONS IN MANGROVE MUD SEDIMENT 2010–2024

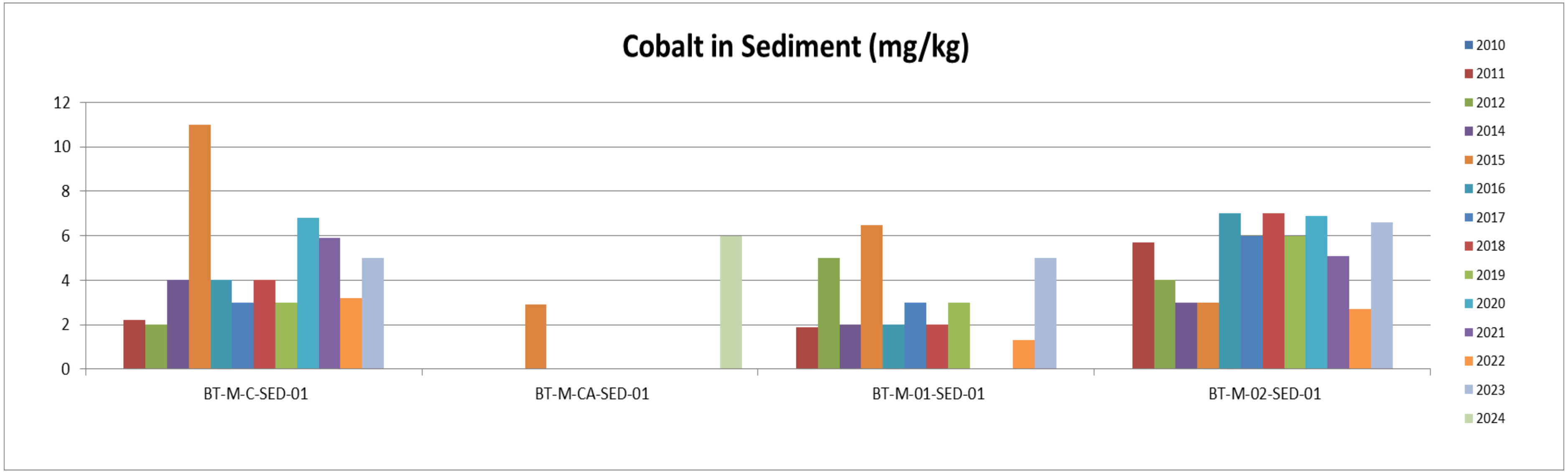

Aluminium in Sediment (mg/kg)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
BT-M-C-SED-01
BT-M-CA-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024

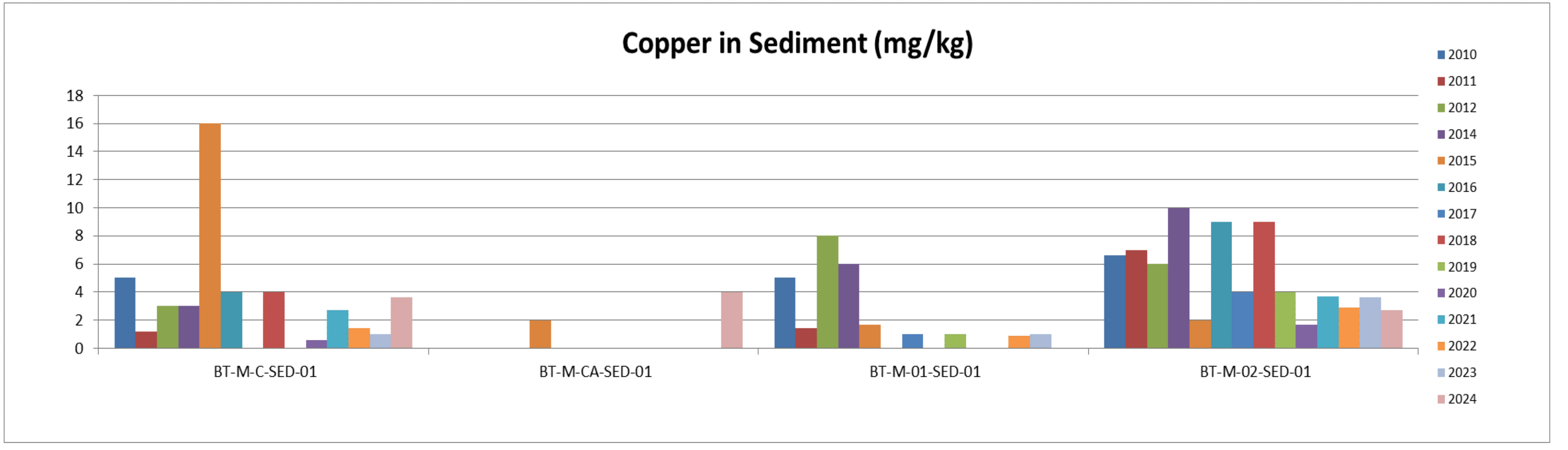

Arsenic in Sediment (mg/kg)
50
45
40
35
30
25
20
15
10
5
0
BT-M-C-SED-01
BT-M-CA-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024

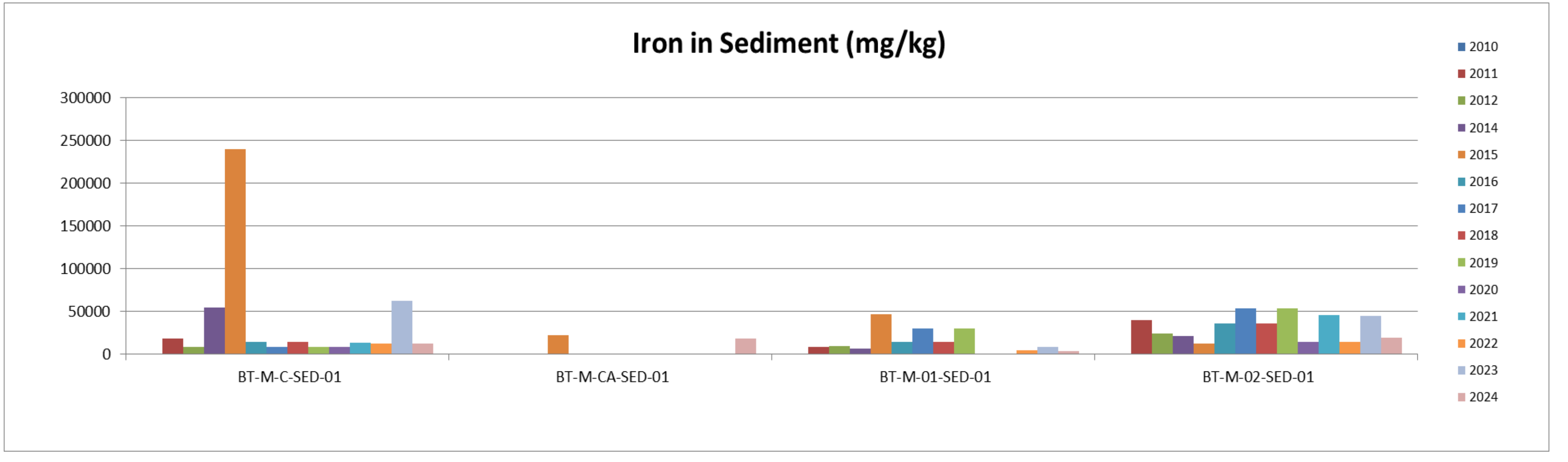

Barium in Sediment (mg/kg)
20
18
16
14
12
10
8
6
4
2
0
BT-M-C-SED-01
BT-M-CA-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024

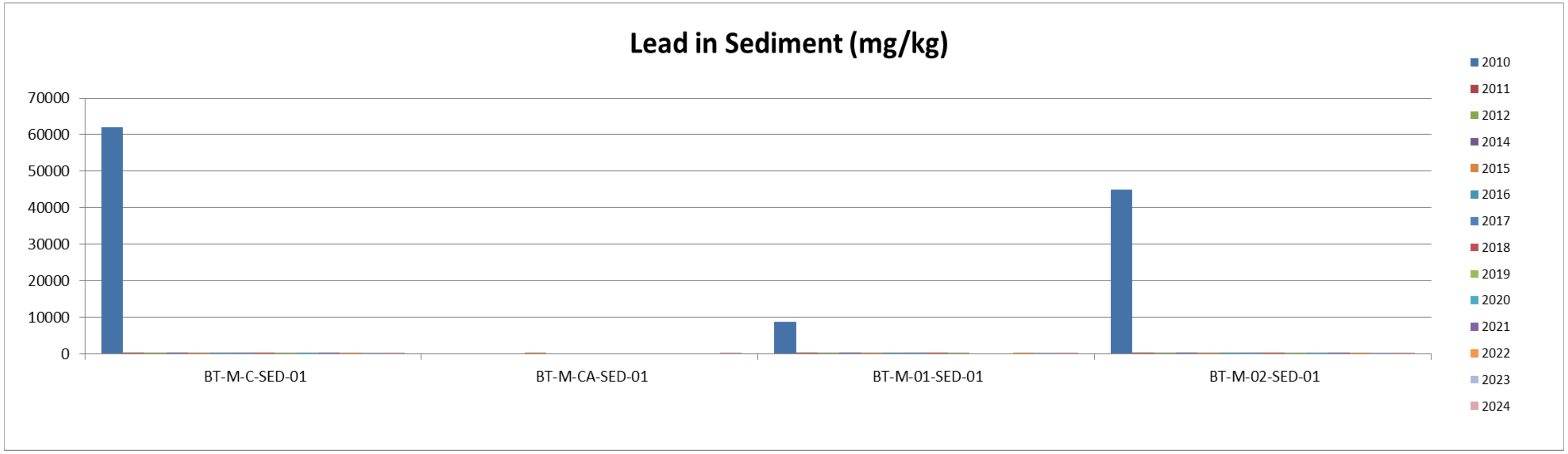

Chromium in Sediment (mg/kg)
140
120
100
80
60
40
20
0
BT-M-C-SED-01
BT-M-CA-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024

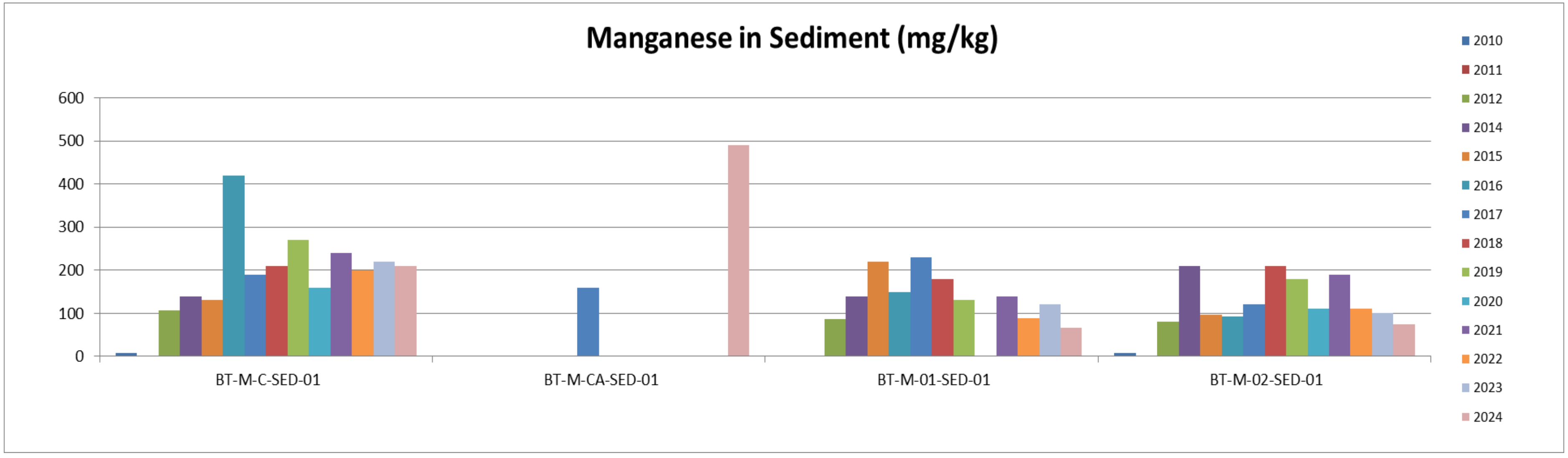

Cadmium in Sediment (mg/kg)
0
2
4
6
8
10
12
BT-M-C-SED-01
BT-M-CA-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024

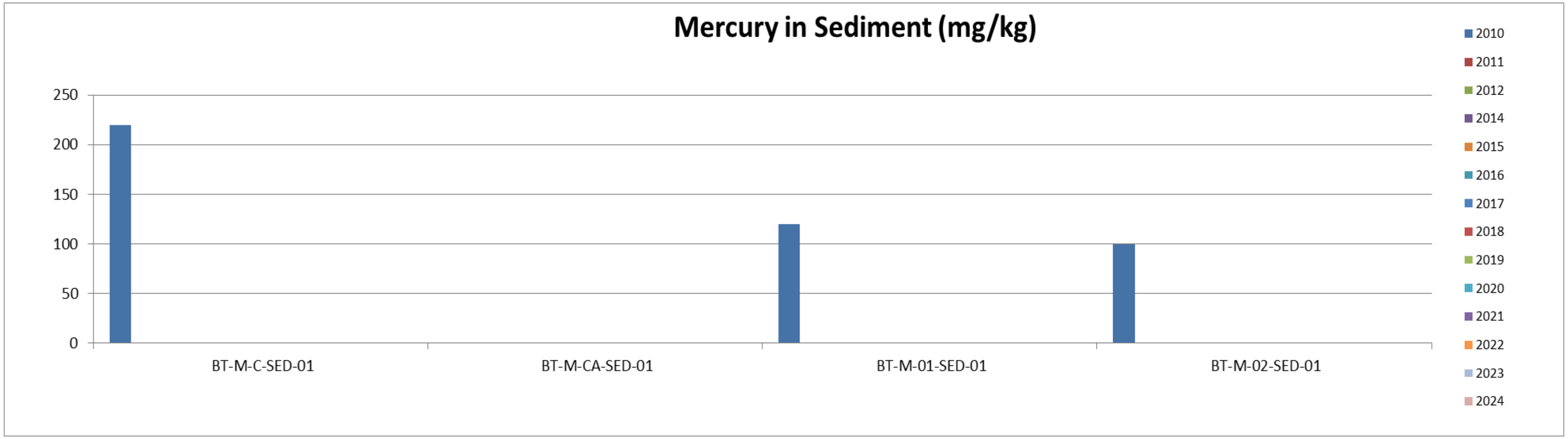

Cobalt in Sediment (mg/kg)
0
2
4
6
8
10
12
BT-M-C-SED-01
BT-M-CA-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024


Copper in Sediment (mg/kg)
18
16
14
12
10
8
6
4
2
0
BT-M-C-SED-01
BT-M-CA-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024

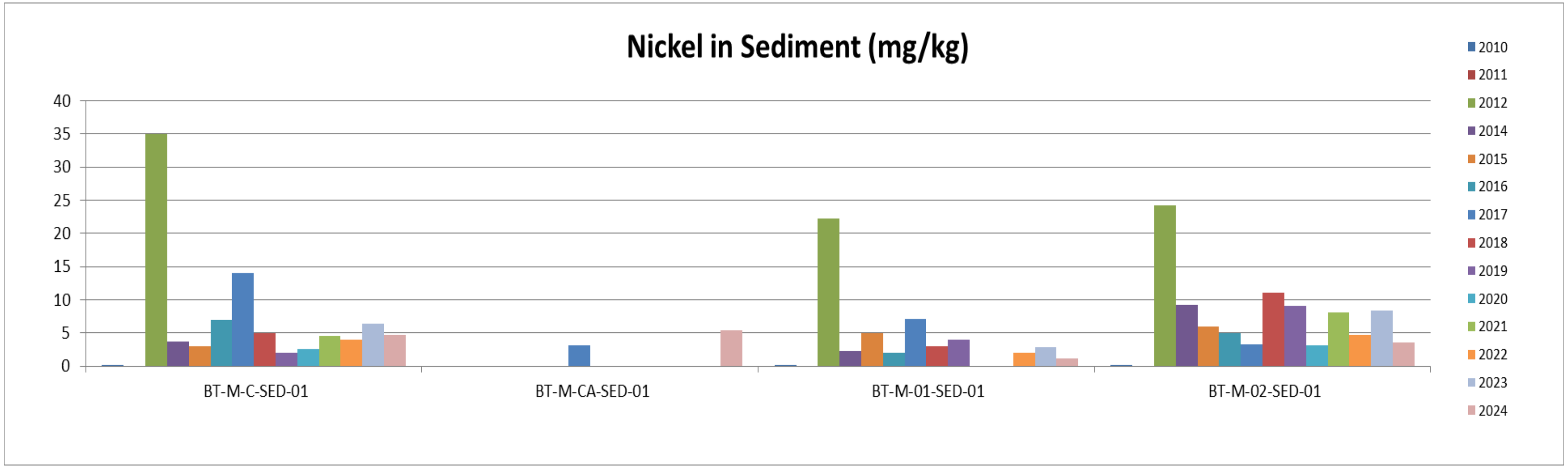

Iron in Sediment (mg/kg)
300000
250000
200000
150000
100000
50000
0
BT-M-C-SED-01
BT-M-CA-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024


Lead in Sediment (mg/kg)
70000
60000
50000
40000
30000
20000
10000
0
BT-M-C-SED-01
BT-M-CA-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024


Manganese in Sediment (mg/kg)
600
500
400
300
200
100
0
BT-M-C-SED-01
BT-M-CA-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024



Mercury in Sediment (mg/kg)
250
200
150
100
50
0
BT-M-C-SED-01
BT-M-CA-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024



Nickel in Sediment (mg/kg)
40
35
30
25
20
15
10
5
0
BT-M-C-SED-01
BT-M-CA-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
2014
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2016
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2019
2020
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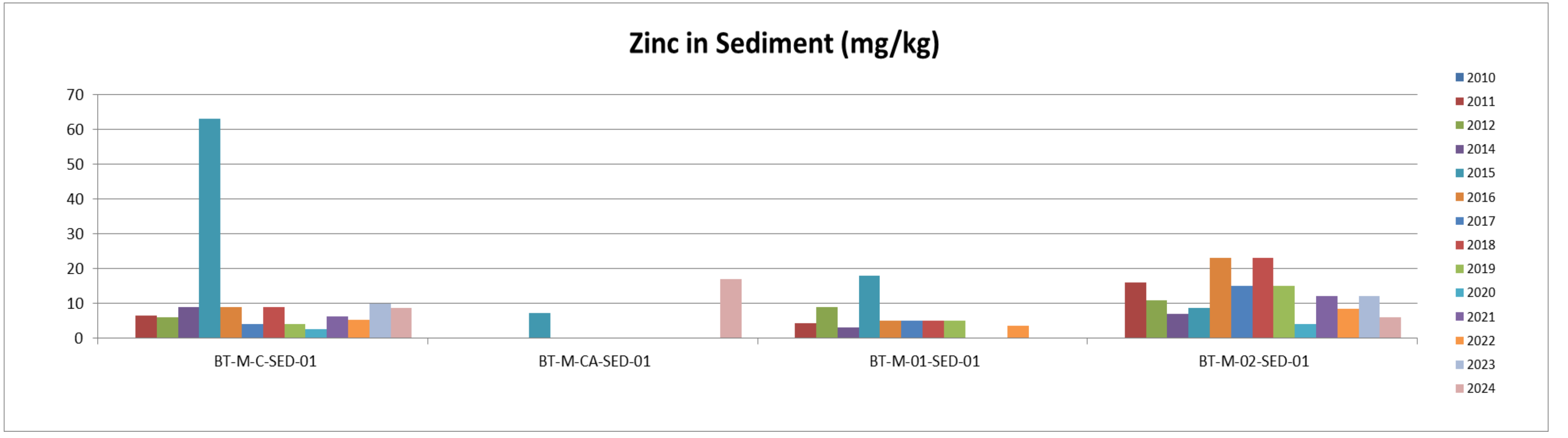
2022
2023
2024



Zinc in Sediment (mg/kg)
70
60
50
40
30
20
10
0
BT-M-C-SED-01
BT-M-CA-SED-01
BT-M-01-SED-01
BT-M-02-SED-01
2010
2011
2012
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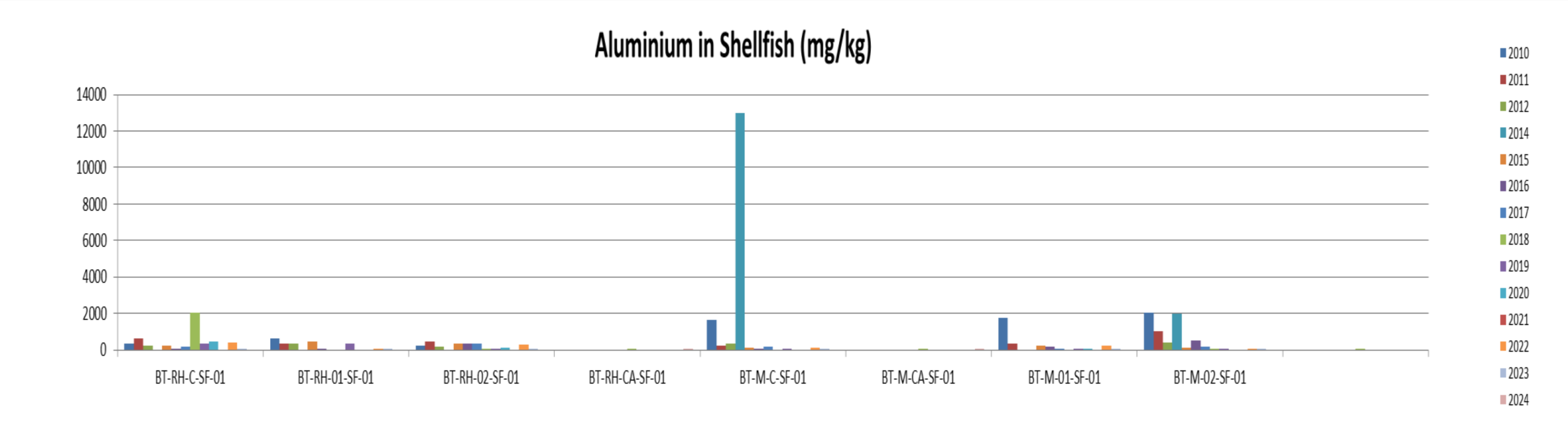
2021
2022
2023
2024

ATTACHMENT B:

MEASURED METAL CONCENTRATIONS IN SHELLFISH 2010-2024



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-RH-CA-SF-01
BT-M-C-SF-01
BT-M-CA-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
2014
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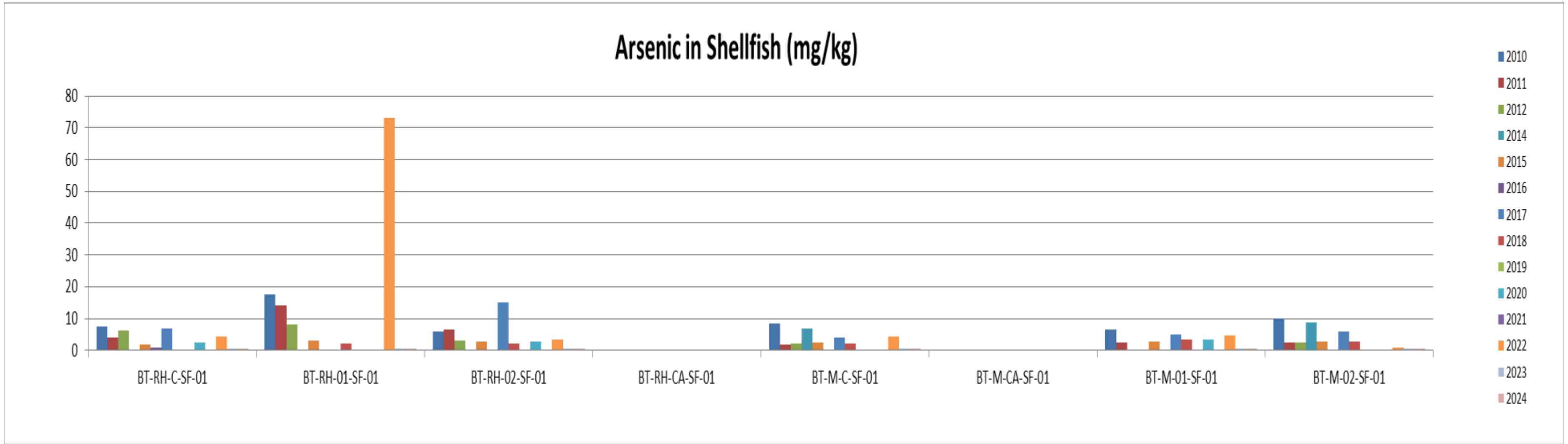
2021
2022
2023
2024



Arsenic in Shellfish (mg/kg)
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-RH-CA-SF-01
BT-M-C-SF-01
BT-M-CA-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
2014
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2021
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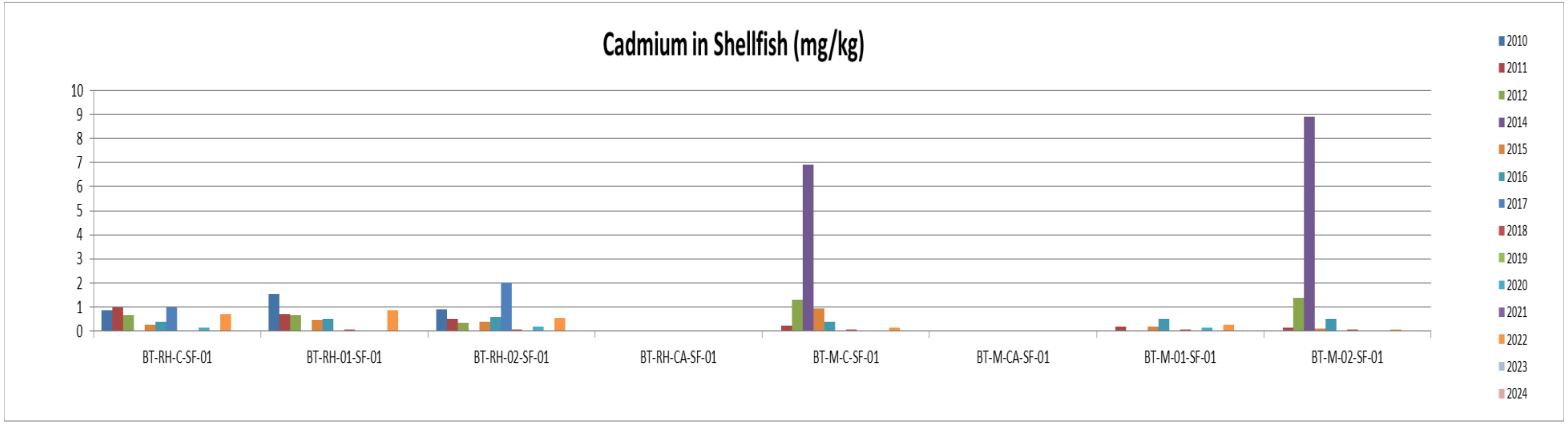
Cadmium in Shellfish (mg/kg)
0
1
2
3
4
5
6
7
8
9
10
BT-RH-C-SF-01
BT-RH-01-SF-01
BT-RH-02-SF-01
BT-RH-CA-SF-01
BT-M-C-SF-01
BT-M-CA-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
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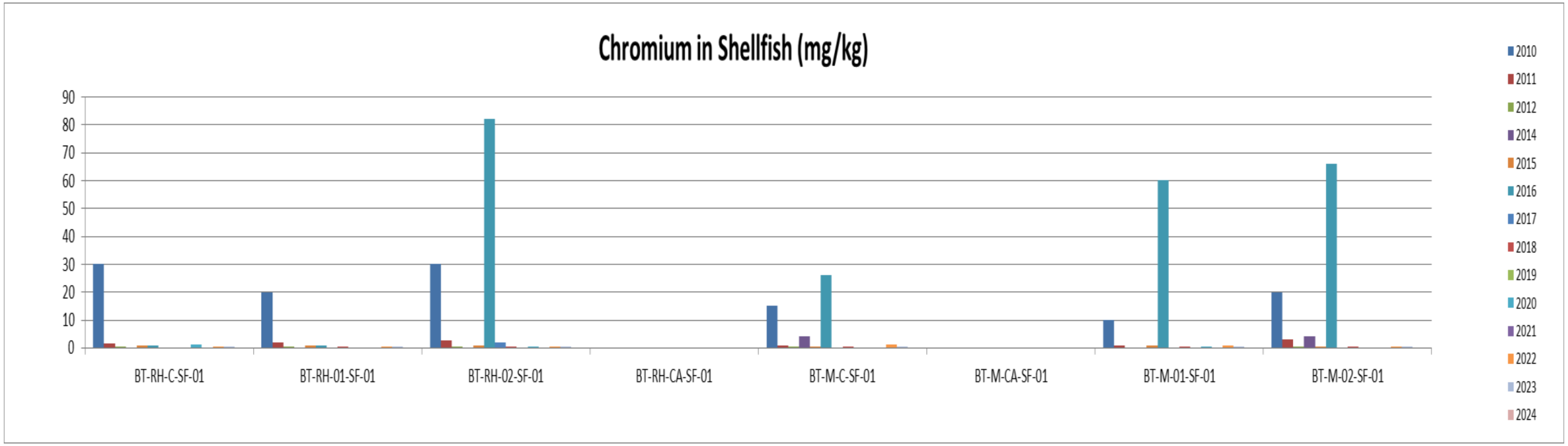
2024


Chromium in Shellfish (mg/kg)
0
10
20
30
40
50
60
70
80
90
BT-RH-C-SF-01
BT-RH-01-SF-01
BT-RH-02-SF-01
BT-RH-CA-SF-01
BT-M-C-SF-01
BT-M-CA-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
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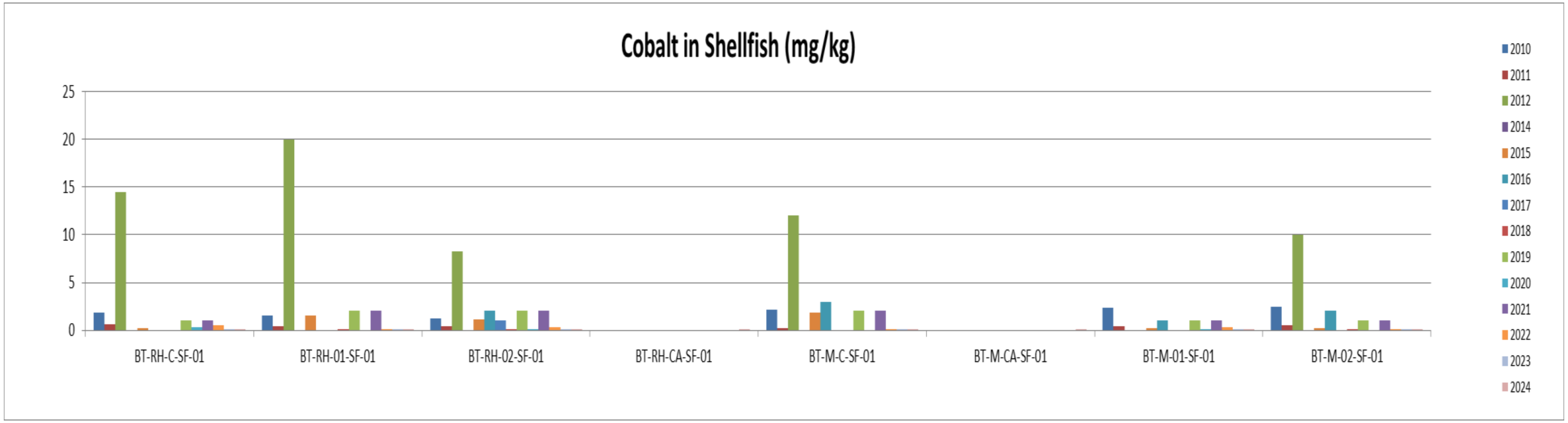
2023
2024



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-RH-CA-SF-01
BT-M-C-SF-01
BT-M-CA-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
2014
2015
2016
2017
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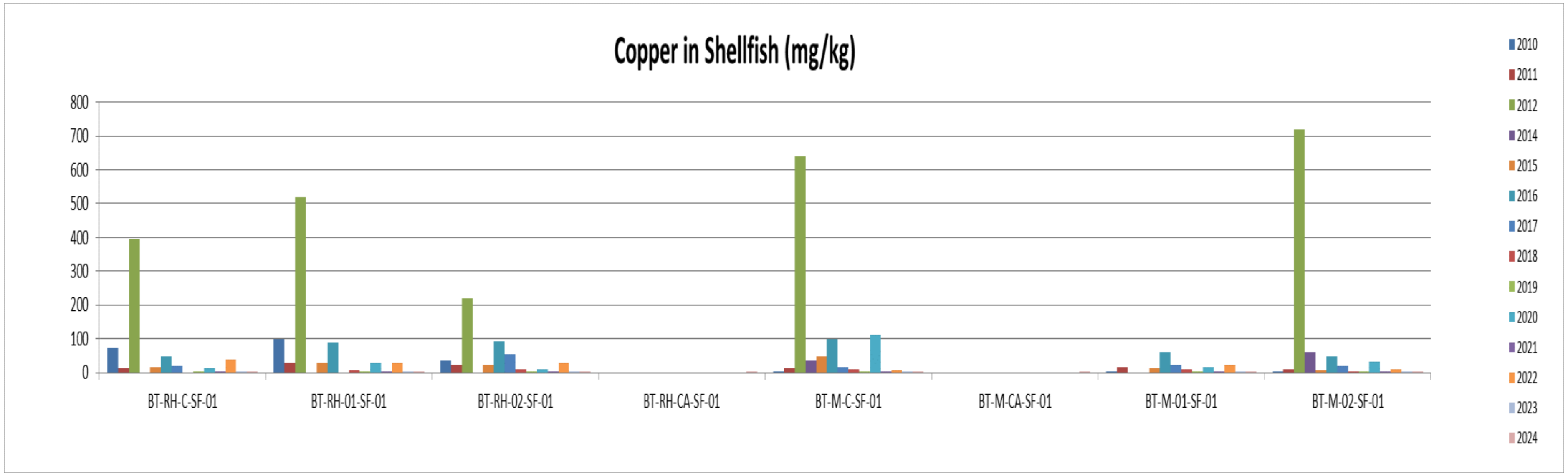
2019
2020
2021
2022
2023
2024



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-RH-CA-SF-01
BT-M-C-SF-01
BT-M-CA-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
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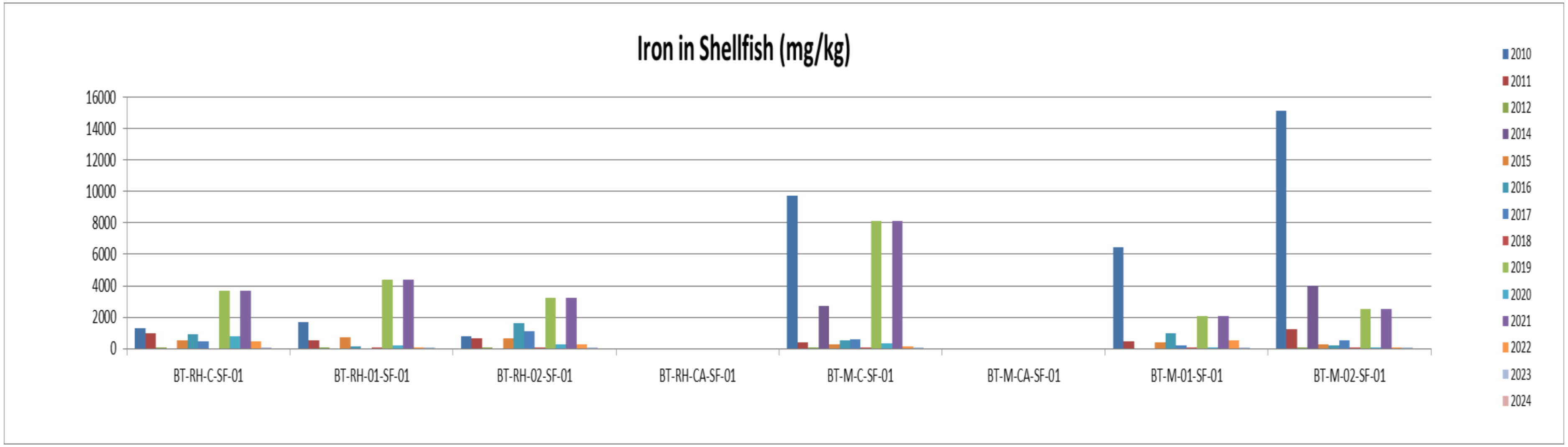
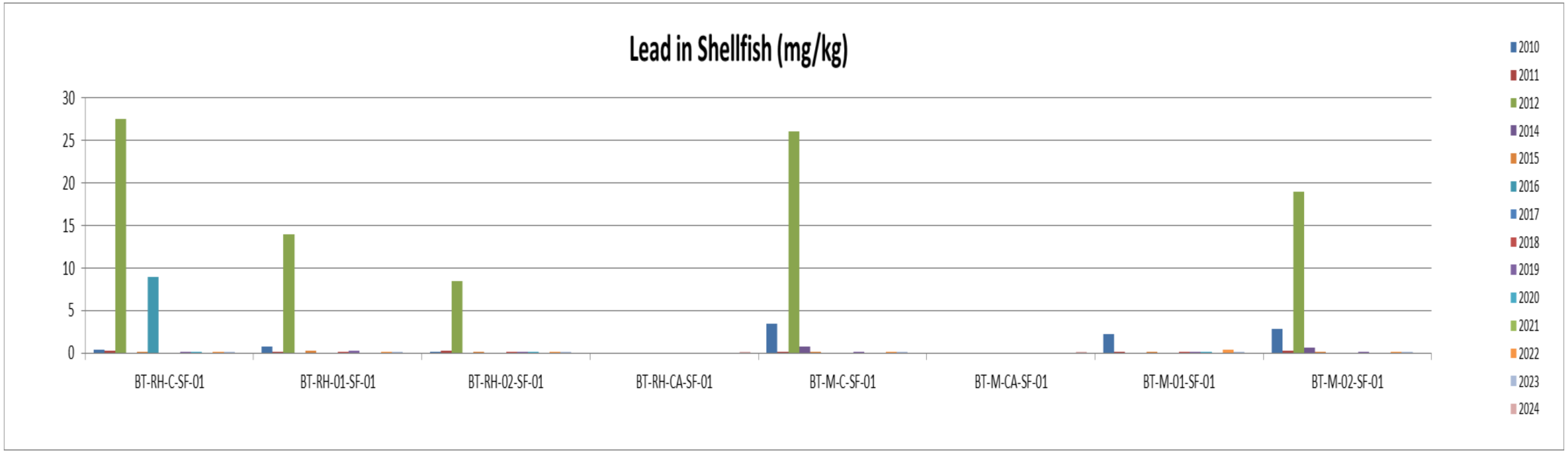
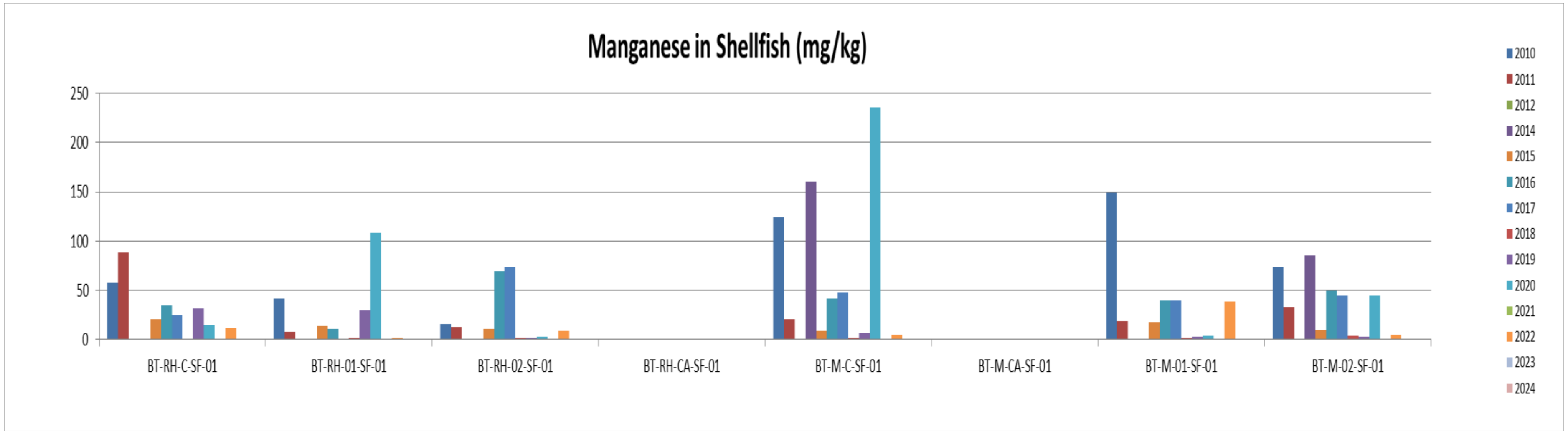
2022
2023
2024



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-RH-CA-SF-01
BT-M-C-SF-01
BT-M-CA-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024



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-RH-CA-SF-01
BT-M-C-SF-01
BT-M-CA-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024


Manganese in Shellfish (mg/kg)
250
200
150
100
50
0
BT-RH-C-SF-01
BT-RH-01-SF-01
BT-RH-02-SF-01
BT-RH-CA-SF-01
BT-M-C-SF-01
BT-M-CA-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
2012
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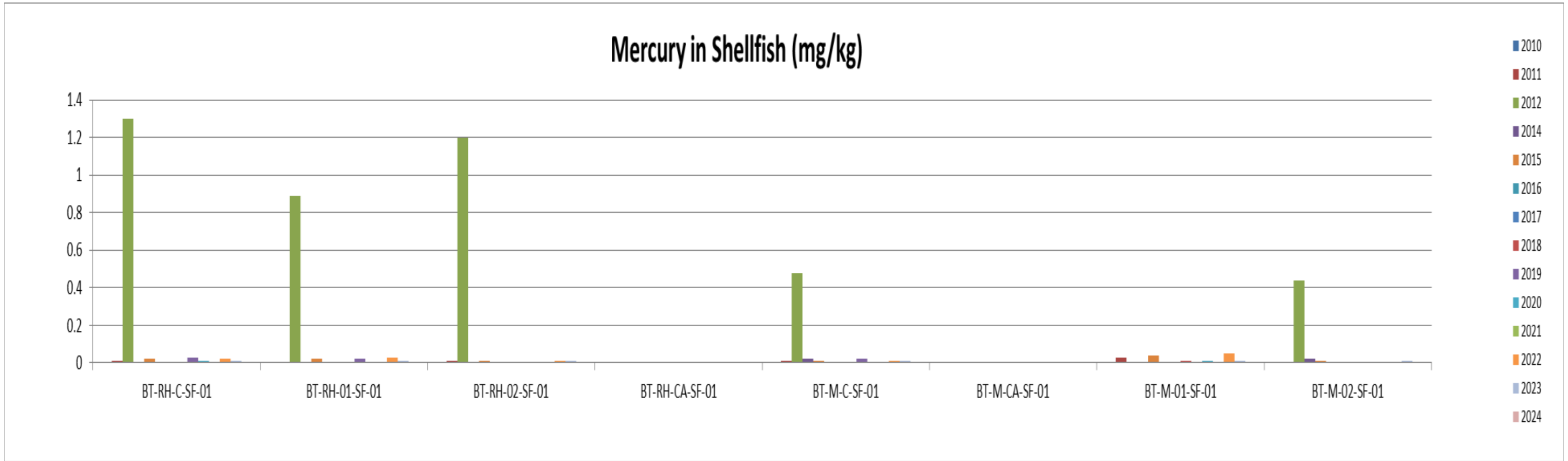
2022
2023
2024


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-RH-CA-SF-01
BT-M-C-SF-01
BT-M-CA-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
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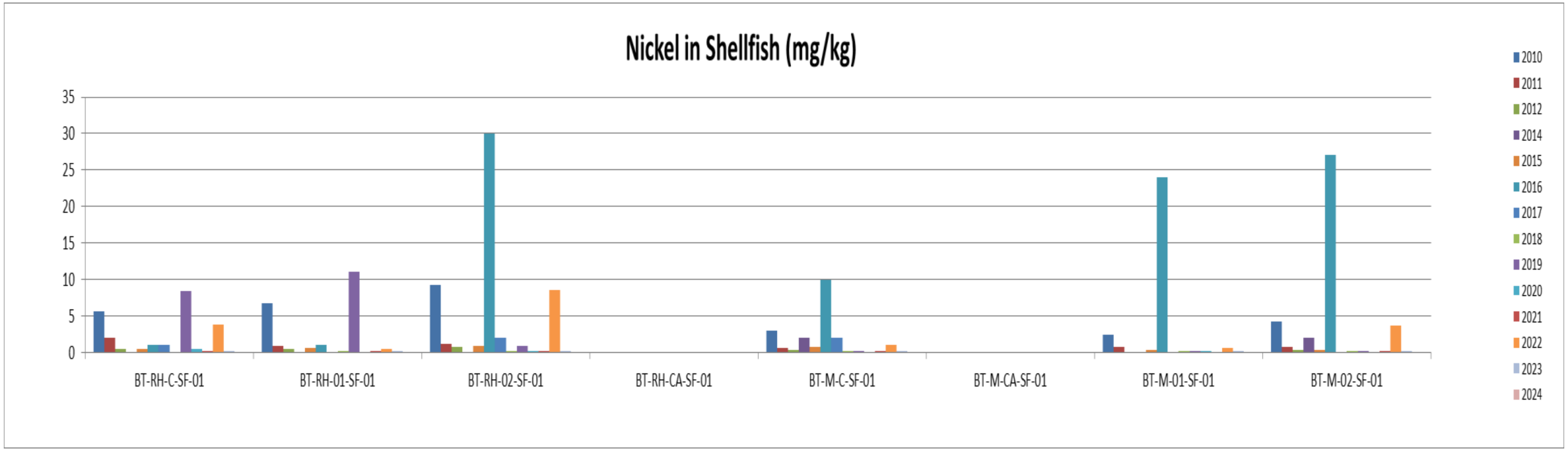
2024


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-RH-CA-SF-01
BT-M-C-SF-01
BT-M-CA-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
2011
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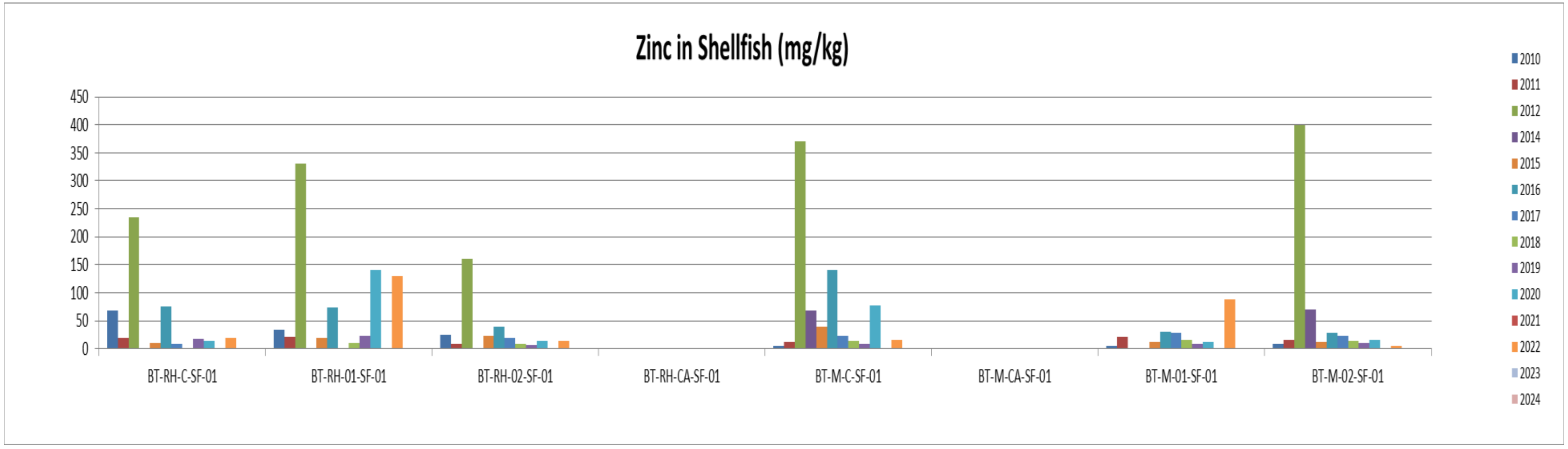
Zinc in Shellfish (mg/kg)
450
400
350
300
250
200
150
100
50
0
BT-RH-C-SF-01
BT-RH-01-SF-01
BT-RH-02-SF-01
BT-RH-CA-SF-01
BT-M-C-SF-01
BT-M-CA-SF-01
BT-M-01-SF-01
BT-M-02-SF-01
2010
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2020
2021
2022
2023
2024

ATTACHMENT C:

LABORATORY ANALYTICAL REPORT 2024

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INTERTEK GEOTECH
ANALYTICAL REPORT

CLIENT

PETROLAB Australia Pty. Ltd.
Attn. Jan Bon
45 Woodforde Road
Magill, SA 5072
Australia

JOB INFORMATION

JOB REFERENCE	:	2024-MDTN-000712 Rev.0
NO. SAMPLES	:	9
CLIENT ORDER NO.	:	24076
PROJECT	:	Sediment and Shellfish Analysis
SAMPLED ON	:	06/08/2024
DATE RECEIVED	:	16/08/2024
DATE TESTED	:	19/08/2024
DATE REPORTED	:	12/09/2024

REPORT NOTES

Samples received in good condition at a temperature of 20.0°C.
[1] – The test denotes non-NATA accredited Method.

TESTED BY

Intertek Geotech
544 Bickley Road
Maddington, Western Australia 6109

Tel: +61 8 9263 0263
Tristan.Stringer@Intertek.com

COMPANY APPROVED SIGNATORY

Noel Mellican
Laboratory Manager

NATA
WORLD RECOGNISED ACCREDITATION
ACCREDITATION No. 5646

NATA Accreditation Number: 5646
Accredited for compliance with ISO/IEC 17025 – Testing
This report shall not be reproduced, except in full.

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List of Revisions

REV.	DATE	REVISION DETAILS	AUTHOR	ISSUE
0	12/09/2024	Document created	Leanne Francisco	Noel Mellican

This document replaces and supersedes all previous versions.

Sample Information

SAMPLE REFERENCE	SAMPLE DATE	MATRIX	PRESERVATION	INTERTEK REFERENCE
BT-M-C1-SED-01 Control site (1-Original Control) - Mangroves	06/08/2024	Sediment	Refrigerated	2024-MDTN-000712-001
BT-M-C1-SF-01 Control site (1-Original Control) - Mangroves	06/08/2024	Shellfish	Refrigerated	2024-MDTN-000712-002
BT-RH-C1-SF-01 Control site (1-Original Control) – Rocky Headland	06/08/2024	Shellfish	Refrigerated	2024-MDTN-000712-003
BT-M-01-SED-01 Southern end of Yelcherr Beach - Mangroves	06/08/2024	Sediment	Refrigerated	2024-MDTN-000712-004
BT-RH-01-SF-01 Southern end of Yelcherr Beach - Mangroves	06/08/2024	Shellfish	Refrigerated	2024-MDTN-000712-005
BT-M-01-SF-01 Southern end of Yelcherr Beach - Rocky Headland	06/08/2024	Shellfish	Refrigerated	2024-MDTN-000712-006
BT-M-02-SED-01 Northern end of Yelcherr Beach - Mangroves	06/08/2024	Sediment	Refrigerated	2024-MDTN-000712-007
BT-M-02-SF-01 Northern end of Yelcherr Beach - Mangroves	06/08/2024	Shellfish	Refrigerated	2024-MDTN-000712-008
BT-RH-02-SF-01 Northern end of Yelcherr Beach - Rocky Headland	06/08/2024	Shellfish	Refrigerated	2024-MDTN-000712-009

Additional Sample Information

N/A

Methodology

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 verity of different species with varying sizes and tissue contents. Tissue samples were analyzed for metals, BTEX, TRH, and PAHs.
Metals were analyzed after acid digest (on dry wt basis) by ICP-AES/ICP-MS
Organic content including BTEX were determined by Purge & Trap GC-MS.
PAHs were determined by GC-MS-SIM with PTV large volume injection.

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RESULTS

BT-M-C1-SED-01, 06/08/2024 **Intertek Reference: 2024-MDTN-000712-001**

ANALYSIS	UNITS	LOR	RESULT
	BTEX[1]		
Benzene	mg/kg	0.1	<0.1
Ethylbenzene	mg/kg	0.1	<0.1
Toluene	mg/kg	0.1	<0.1
m,p-Xylene	mg/kg	0.2	<0.2
o-Xylene	mg/kg	0.1	<0.1
	TRH[1]		
C6-C10	mg/kg	25	<25
>C10-C16	mg/kg	25	<25
>C16-C34	mg/kg	100	<100
>C34-C40	mg/kg	100	<100
TotalTRH	mg/kg	250	<250
	PAH[1]		
Naphthalene	mg/kg	0.5	<0.5
Acenaphthylene	mg/kg	0.5	<0.5
Acenaphthene	mg/kg	0.5	<0.5
Fluorene	mg/kg	0.5	<0.5
Phenanthrene	mg/kg	0.5	<0.5
Anthracene	mg/kg	0.5	<0.5
Fluoranthene	mg/kg	0.5	<0.5
Pyrene	mg/kg	0.5	<0.5
Benz(a)anthracene	mg/kg	0.5	<0.5
Chrysene	mg/kg	0.5	<0.5
Benzo(b)fluoranthene	mg/kg	0.5	<0.5
Benzo(k)fluoranthene	mg/kg	0.5	<0.5
Benzo(a)pyrene	mg/kg	0.5	<0.5
Indeno(1,2,3-cd)pyrene	mg/kg	0.5	<0.5
Dibenzo(a,h)anthracene	mg/kg	0.5	<0.5
Benzo(g,h,i)perylene	mg/kg	0.5	<0.5

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BT-M-C1-SED-01, 06/08/2024 **Intertek Reference: 2024-MDTN-000712-001**

ANALYSIS	UNITS	LOR	RESULT
	Metals[1]		
Aluminium	mg/kg	20	2,900
Arsenic	mg/kg	2	14
Barium	mg/kg	10	<10
Beryllium	mg/kg	2	<2
Boron	mg/kg	10	23
Cadmium	mg/kg	0.1	<0.1
Chromium	mg/kg	1	13
Cobalt	mg/kg	5	<5
Copper	mg/kg	1	3.6
Iron	mg/kg	20	12,000
Lead	mg/kg	1	3.9
Magnesium	mg/kg	5	5,500
Manganese	mg/kg	5	210
Mercury	mg/kg	0.02	<0.02
Molybdenum	mg/kg	5	<5
Nickel	mg/kg	1	4.7
Selenium	mg/kg	2	<2
Tin	mg/kg	10	<10
Zinc	mg/kg	5	8.6

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BT-M-C1-SF-01, 06/08/2024 **Intertek Reference: 2024-MDTN-000712-002**

ANALYSIS	UNITS	LOR	RESULT
	BTEX[1]		
Benzene	mg/kg	0.1	<0.1
Ethylbenzene	mg/kg	0.1	<0.1
Toluene	mg/kg	0.1	<0.1
m,p-Xylene	mg/kg	0.2	<0.2
o-Xylene	mg/kg	0.1	<0.1
	TRH[1]		
C6-C10	mg/kg	25	<25
>C10-C16	mg/kg	25	<25
>C16-C34	mg/kg	100	<100
>C34-C40	mg/kg	100	<100
TotalTRH	mg/kg	250	<250
	PAH[1]		
Naphthalene	mg/kg	0.5	<0.5
Acenaphthylene	mg/kg	0.5	<0.5
Acenaphthene	mg/kg	0.5	<0.5
Fluorene	mg/kg	0.5	<0.5
Phenanthrene	mg/kg	0.5	<0.5
Anthracene	mg/kg	0.5	<0.5
Fluoranthene	mg/kg	0.5	<0.5
Pyrene	mg/kg	0.5	<0.5
Benz(a)anthracene	mg/kg	0.5	<0.5
Chrysene	mg/kg	0.5	<0.5
Benzo(b)fluoranthene	mg/kg	0.5	<0.5
Benzo(k)fluoranthene	mg/kg	0.5	<0.5
Benzo(a)pyrene	mg/kg	0.5	<0.5
Indeno(1,2,3-cd)pyrene	mg/kg	0.5	<0.5
Dibenzo(a,h)anthracene	mg/kg	0.5	<0.5
Benzo(g,h,i)perylene	mg/kg	0.5	<0.5

intertek
Total Quality. Assured.

BT-M-C1-SF-01, 06/08/2024 **Intertek Reference: 2024-MDTN-000712-002**

ANALYSIS	UNITS	LOR	RESULT
	Metals[1]		
Aluminium	mg/kg	0.2	<0.2
Arsenic	mg/kg	0.5	<0.5
Barium	mg/kg	0.05	<0.05
Beryllium	mg/kg	0.001	<0.001
Boron	mg/kg	0.2	<0.2
Cadmium	mg/kg	0.001	0.001
Chromium	mg/kg	0.2	<0.2
Cobalt	mg/kg	0.001	0.011
Copper	mg/kg	0.01	0.21
Iron	mg/kg	5	<5
Lead	mg/kg	0.001	<0.001
Magnesium	mg/kg	2	43
Manganese	mg/kg	0.05	0.09
Mercury	mg/kg	0.01	<0.01
Molybdenum	mg/kg	0.01	<0.01
Nickel	mg/kg	0.1	<0.1
Selenium	mg/kg	0.01	<0.01
Tin	mg/kg	0.05	<0.05
Zinc	mg/kg	1	<1

intertek
Total Quality. Assured.

BT-RH-C1-SF-01, 06/08/2024 **Intertek Reference: 2024-MDTN-000712-003**

ANALYSIS	UNITS	LOR	RESULT
	***BTEX*[1]**		
Benzene	mg/kg	0.1	<0.1
Ethylbenzene	mg/kg	0.1	<0.1
Toluene	mg/kg	0.1	<0.1
m,p-Xylene	mg/kg	0.2	<0.2
o-Xylene	mg/kg	0.1	<0.1
	***TRH*[1]**		
C6-C10	mg/kg	25	<25
>C10-C16	mg/kg	25	<25
>C16-C34	mg/kg	100	<100
>C34-C40	mg/kg	100	<100
TotalTRH	mg/kg	250	<250
	***PAH*[1]**		
Naphthalene	mg/kg	0.5	<0.5
Acenaphthylene	mg/kg	0.5	<0.5
Acenaphthene	mg/kg	0.5	<0.5
Fluorene	mg/kg	0.5	<0.5
Phenanthrene	mg/kg	0.5	<0.5
Anthracene	mg/kg	0.5	<0.5
Fluoranthene	mg/kg	0.5	<0.5
Pyrene	mg/kg	0.5	<0.5
Benz(a)anthracene	mg/kg	0.5	<0.5
Chrysene	mg/kg	0.5	<0.5
Benzo(b)fluoranthene	mg/kg	0.5	<0.5
Benzo(k)fluoranthene	mg/kg	0.5	<0.5
Benzo(a)pyrene	mg/kg	0.5	<0.5
Indeno(1,2,3-cd)pyrene	mg/kg	0.5	<0.5
Dibenzo(a,h)anthracene	mg/kg	0.5	<0.5
Benzo(g,h,i)perylene	mg/kg	0.5	<0.5

intertek
Total Quality. Assured.

BT-RH-C1-SF-01, 06/08/2024 **Intertek Reference: 2024-MDTN-000712-003**

ANALYSIS	UNITS	LOR	RESULT
	Metals[1]		
Aluminium	mg/kg	0.2	<0.2
Arsenic	mg/kg	0.5	<0.5
Barium	mg/kg	0.05	<0.05
Beryllium	mg/kg	0.001	<0.001
Boron	mg/kg	0.2	<0.2
Cadmium	mg/kg	0.001	0.001
Chromium	mg/kg	0.2	<0.2
Cobalt	mg/kg	0.001	0.002
Copper	mg/kg	0.01	0.04
Iron	mg/kg	5	<5
Lead	mg/kg	0.001	<0.001
Magnesium	mg/kg	2	14
Manganese	mg/kg	0.05	<0.05
Mercury	mg/kg	0.01	<0.01
Molybdenum	mg/kg	0.01	<0.01
Nickel	mg/kg	0.1	<0.1
Selenium	mg/kg	0.01	<0.01
Tin	mg/kg	0.05	<0.05
Zinc	mg/kg	1	<1

intertek
Total Quality. Assured.

BT-M-01-SED-01, 06/08/2024 **Intertek Reference: 2024-MDTN-000712-004**

ANALYSIS	UNITS	LOR	RESULT
	BTEX[1]		
Benzene	mg/kg	0.1	<0.1
Ethylbenzene	mg/kg	0.1	<0.1
Toluene	mg/kg	0.1	<0.1
m,p-Xylene	mg/kg	0.2	<0.2
o-Xylene	mg/kg	0.1	<0.1
	TRH[1]		
C6-C10	mg/kg	25	<25
>C10-C16	mg/kg	25	<25
>C16-C34	mg/kg	100	<100
>C34-C40	mg/kg	100	<100
TotalTRH	mg/kg	250	<250
	PAH[1]		
Naphthalene	mg/kg	0.5	<0.5
Acenaphthylene	mg/kg	0.5	<0.5
Acenaphthene	mg/kg	0.5	<0.5
Fluorene	mg/kg	0.5	<0.5
Phenanthrene	mg/kg	0.5	<0.5
Anthracene	mg/kg	0.5	<0.5
Fluoranthene	mg/kg	0.5	<0.5
Pyrene	mg/kg	0.5	<0.5
Benz(a)anthracene	mg/kg	0.5	<0.5
Chrysene	mg/kg	0.5	<0.5
Benzo(b)fluoranthene	mg/kg	0.5	<0.5
Benzo(k)fluoranthene	mg/kg	0.5	<0.5
Benzo(a)pyrene	mg/kg	0.5	<0.5
Indeno(1,2,3-cd)pyrene	mg/kg	0.5	<0.5
Dibenzo(a,h)anthracene	mg/kg	0.5	<0.5
Benzo(g,h,i)perylene	mg/kg	0.5	<0.5

BT-M-01-SED-01, 06/08/2024 **Intertek Reference: 2024-MDTN-000712-004**

ANALYSIS	UNITS	LOR	RESULT
	Metals[1]		
Aluminium	mg/kg	20	530
Arsenic	mg/kg	2	5.1
Barium	mg/kg	10	<10
Beryllium	mg/kg	2	<2
Boron	mg/kg	10	<10
Cadmium	mg/kg	0.1	<0.1
Chromium	mg/kg	1	5.1
Cobalt	mg/kg	5	<5
Copper	mg/kg	1	<1
Iron	mg/kg	20	3,800
Lead	mg/kg	1	1.2
Magnesium	mg/kg	5	2,400
Manganese	mg/kg	5	67
Mercury	mg/kg	0.02	<0.02
Molybdenum	mg/kg	5	<5
Nickel	mg/kg	1	1.2
Selenium	mg/kg	2	<2
Tin	mg/kg	10	<10
Zinc	mg/kg	5	<5

intertek
Total Quality. Assured.

BT-RH-01-SF-01, 06/08/2024 **Intertek Reference: 2024-MDTN-000712-005**

ANALYSIS	UNITS	LOR	RESULT
	BTEX[1]		
Benzene	mg/kg	0.1	<0.1
Ethylbenzene	mg/kg	0.1	<0.1
Toluene	mg/kg	0.1	<0.1
m,p-Xylene	mg/kg	0.2	<0.2
o-Xylene	mg/kg	0.1	<0.1
	TRH		
C6-C10	mg/kg	25	<25
>C10-C16	mg/kg	25	<25
>C16-C34	mg/kg	100	<100
>C34-C40	mg/kg	100	<100
TotalTRH	mg/kg	250	<250
	PAH[1]		
Naphthalene	mg/kg	0.5	<0.5
Acenaphthylene	mg/kg	0.5	<0.5
Acenaphthene	mg/kg	0.5	<0.5
Fluorene	mg/kg	0.5	<0.5
Phenanthrene	mg/kg	0.5	<0.5
Anthracene	mg/kg	0.5	<0.5
Fluoranthene	mg/kg	0.5	<0.5
Pyrene	mg/kg	0.5	<0.5
Benz(a)anthracene	mg/kg	0.5	<0.5
Chrysene	mg/kg	0.5	<0.5
Benzo(b)fluoranthene	mg/kg	0.5	<0.5
Benzo(k)fluoranthene	mg/kg	0.5	<0.5
Benzo(a)pyrene	mg/kg	0.5	<0.5
Indeno(1,2,3-cd)pyrene	mg/kg	0.5	<0.5
Dibenzo(a,h)anthracene	mg/kg	0.5	<0.5
Benzo(g,h,i)perylene	mg/kg	0.5	<0.5

intertek
Total Quality. Assured.

BT-RH-01-SF-01, 06/08/2024 **Intertek Reference: 2024-MDTN-000712-005**

ANALYSIS	UNITS	LOR	RESULT
	***Metals*[1]**		
Aluminium	mg/kg	0.2	<0.2
Arsenic	mg/kg	0.5	<0.5
Barium	mg/kg	0.05	<0.05
Beryllium	mg/kg	0.001	<0.001
Boron	mg/kg	0.2	<0.2
Cadmium	mg/kg	0.001	<0.001
Chromium	mg/kg	0.2	<0.2
Cobalt	mg/kg	0.001	0.004
Copper	mg/kg	0.01	0.06
Iron	mg/kg	5	<5
Lead	mg/kg	0.001	<0.001
Magnesium	mg/kg	2	26
Manganese	mg/kg	0.05	<0.05
Mercury	mg/kg	0.01	<0.01
Molybdenum	mg/kg	0.01	<0.01
Nickel	mg/kg	0.1	<0.1
Selenium	mg/kg	0.01	<0.01
Tin	mg/kg	0.05	<0.05
Zinc	mg/kg	1	<1

intertek
Total Quality. Assured.

BT-M-01-SF-01, 06/08/2024 **Intertek Reference: 2024-MDTN-000712-006**

ANALYSIS	UNITS	LOR	RESULT
	BTEX[1]		
Benzene	mg/kg	0.1	<0.1
Ethylbenzene	mg/kg	0.1	<0.1
Toluene	mg/kg	0.1	<0.1
m,p-Xylene	mg/kg	0.2	<0.2
o-Xylene	mg/kg	0.1	<0.1
	TRH[1]		
C6-C10	mg/kg	25	<25
>C10-C16	mg/kg	25	<25
>C16-C34	mg/kg	100	<100
>C34-C40	mg/kg	100	<100
TotalTRH	mg/kg	250	<250
	PAH[1]		
Naphthalene	mg/kg	0.5	<0.5
Acenaphthylene	mg/kg	0.5	<0.5
Acenaphthene	mg/kg	0.5	<0.5
Fluorene	mg/kg	0.5	<0.5
Phenanthrene	mg/kg	0.5	<0.5
Anthracene	mg/kg	0.5	<0.5
Fluoranthene	mg/kg	0.5	<0.5
Pyrene	mg/kg	0.5	<0.5
Benz(a)anthracene	mg/kg	0.5	<0.5
Chrysene	mg/kg	0.5	<0.5
Benzo(b)fluoranthene	mg/kg	0.5	<0.5
Benzo(k)fluoranthene	mg/kg	0.5	<0.5
Benzo(a)pyrene	mg/kg	0.5	<0.5
Indeno(1,2,3-cd)pyrene	mg/kg	0.5	<0.5
Dibenzo(a,h)anthracene	mg/kg	0.5	<0.5
Benzo(g,h,i)perylene	mg/kg	0.5	<0.5

intertek
Total Quality. Assured.

BT-M-01-SF-01, 06/08/2024 **Intertek Reference: 2024-MDTN-000712-006**

ANALYSIS	UNITS	LOR	RESULT
	Metals[1]		
Aluminium	mg/kg	0.2	<0.2
Arsenic	mg/kg	0.5	<0.5
Barium	mg/kg	0.05	<0.05
Beryllium	mg/kg	0.001	<0.001
Boron	mg/kg	0.2	0.2
Cadmium	mg/kg	0.001	0.002
Chromium	mg/kg	0.2	<0.2
Cobalt	mg/kg	0.001	0.002
Copper	mg/kg	0.01	0.15
Iron	mg/kg	5	<5
Lead	mg/kg	0.001	<0.001
Magnesium	mg/kg	2	75
Manganese	mg/kg	0.05	0.15
Mercury	mg/kg	0.01	<0.01
Molybdenum	mg/kg	0.01	<0.01
Nickel	mg/kg	0.1	<0.1
Selenium	mg/kg	0.01	<0.01
Tin	mg/kg	0.05	<0.05
Zinc	mg/kg	1	<1

intertek
Total Quality. Assured.

BT-M-02-SED-01, 06/08/2024 **Intertek Reference: 2024-MDTN-000712-007**

ANALYSIS	UNITS	LOR	RESULT
	BTEX[1]		
Benzene	mg/kg	0.1	<0.1
Ethylbenzene	mg/kg	0.1	<0.1
Toluene	mg/kg	0.1	<0.1
m,p-Xylene	mg/kg	0.2	<0.2
o-Xylene	mg/kg	0.1	<0.1
	TRH[1]		
C6-C10	mg/kg	25	<25
>C10-C16	mg/kg	25	<25
>C16-C34	mg/kg	100	<100
>C34-C40	mg/kg	100	<100
TotalTRH	mg/kg	250	<250
	PAH[1]		
Naphthalene	mg/kg	0.5	<0.5
Acenaphthylene	mg/kg	0.5	<0.5
Acenaphthene	mg/kg	0.5	<0.5
Fluorene	mg/kg	0.5	<0.5
Phenanthrene	mg/kg	0.5	<0.5
Anthracene	mg/kg	0.5	<0.5
Fluoranthene	mg/kg	0.5	<0.5
Pyrene	mg/kg	0.5	<0.5
Benz(a)anthracene	mg/kg	0.5	<0.5
Chrysene	mg/kg	0.5	<0.5
Benzo(b)fluoranthene	mg/kg	0.5	<0.5
Benzo(k)fluoranthene	mg/kg	0.5	<0.5
Benzo(a)pyrene	mg/kg	0.5	<0.5
Indeno(1,2,3-cd)pyrene	mg/kg	0.5	<0.5
Dibenzo(a,h)anthracene	mg/kg	0.5	<0.5
Benzo(g,h,i)perylene	mg/kg	0.5	<0.5

intertek
Total Quality. Assured.

BT-M-02-SED-01, 06/08/2024 **Intertek Reference: 2024-MDTN-000712-007**

ANALYSIS	UNITS	LOR	RESULT
	Metals[1]		
Aluminium	mg/kg	20	1,800
Arsenic	mg/kg	2	16
Barium	mg/kg	10	<10
Beryllium	mg/kg	2	<2
Boron	mg/kg	10	13
Cadmium	mg/kg	0.1	<0.1
Chromium	mg/kg	1	20
Cobalt	mg/kg	5	<5
Copper	mg/kg	1	2.7
Iron	mg/kg	20	19,000
Lead	mg/kg	1	3.8
Magnesium	mg/kg	5	4,900
Manganese	mg/kg	5	74
Mercury	mg/kg	0.02	<0.02
Molybdenum	mg/kg	5	<5
Nickel	mg/kg	1	3.5
Selenium	mg/kg	2	<2
Tin	mg/kg	10	<10
Zinc	mg/kg	5	6.1

intertek
Total Quality. Assured.

BT-M-02-SF-01, 06/08/2024 **Intertek Reference: 2024-MDTN-000712-008**

ANALYSIS	UNITS	LOR	RESULT
	***BTEX*[1]**		
Benzene	mg/kg	0.1	<0.1
Ethylbenzene	mg/kg	0.1	<0.1
Toluene	mg/kg	0.1	<0.1
m,p-Xylene	mg/kg	0.2	<0.2
o-Xylene	mg/kg	0.1	<0.1
	***TRH*[1]**		
C6-C10	mg/kg	25	<25
>C10-C16	mg/kg	25	<25
>C16-C34	mg/kg	100	<100
>C34-C40	mg/kg	100	<100
TotalTRH	mg/kg	250	<250
	***PAH*[1]**		
Naphthalene	mg/kg	0.5	<0.5
Acenaphthylene	mg/kg	0.5	<0.5
Acenaphthene	mg/kg	0.5	<0.5
Fluorene	mg/kg	0.5	<0.5
Phenanthrene	mg/kg	0.5	<0.5
Anthracene	mg/kg	0.5	<0.5
Fluoranthene	mg/kg	0.5	<0.5
Pyrene	mg/kg	0.5	<0.5
Benz(a)anthracene	mg/kg	0.5	<0.5
Chrysene	mg/kg	0.5	<0.5
Benzo(b)fluoranthene	mg/kg	0.5	<0.5
Benzo(k)fluoranthene	mg/kg	0.5	<0.5
Benzo(a)pyrene	mg/kg	0.5	<0.5
Indeno(1,2,3-cd)pyrene	mg/kg	0.5	<0.5
Dibenzo(a,h)anthracene	mg/kg	0.5	<0.5
Benzo(g,h,i)perylene	mg/kg	0.5	<0.5

intertek
Total Quality. Assured.

BT-M-02-SF-01, 06/08/2024 **Intertek Reference: 2024-MDTN-000712-008**

ANALYSIS	UNITS	LOR	RESULT
	***Metals*[1]**		
Aluminium	mg/kg	0.2	<0.2
Arsenic	mg/kg	0.5	<0.5
Barium	mg/kg	0.05	<0.05
Beryllium	mg/kg	0.001	<0.001
Boron	mg/kg	0.2	<0.2
Cadmium	mg/kg	0.001	0.002
Chromium	mg/kg	0.2	<0.2
Cobalt	mg/kg	0.001	0.006
Copper	mg/kg	0.01	0.34
Iron	mg/kg	5	<5
Lead	mg/kg	0.001	<0.001
Magnesium	mg/kg	2	87
Manganese	mg/kg	0.05	0.27
Mercury	mg/kg	0.01	<0.01
Molybdenum	mg/kg	0.01	<0.01
Nickel	mg/kg	0.1	<0.1
Selenium	mg/kg	0.01	<0.01
Tin	mg/kg	0.05	<0.05
Zinc	mg/kg	1	<1

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Total Quality. Assured.

BT-RH-02-SF-01, 06/08/2024 **Intertek Reference: 2024-MDTN-000712-009**

ANALYSIS	UNITS	LOR	RESULT
	***BTEX*[1]**		
Benzene	mg/kg	0.1	<0.1
Ethylbenzene	mg/kg	0.1	<0.1
Toluene	mg/kg	0.1	<0.1
m,p-Xylene	mg/kg	0.2	<0.2
o-Xylene	mg/kg	0.1	<0.1
	***TRH*[1]**		
C6-C10	mg/kg	25	<25
>C10-C16	mg/kg	25	<25
>C16-C34	mg/kg	100	<100
>C34-C40	mg/kg	100	<100
TotalTRH	mg/kg	250	<250
	***PAH*[1]**		
Naphthalene	mg/kg	0.5	<0.5
Acenaphthylene	mg/kg	0.5	<0.5
Acenaphthene	mg/kg	0.5	<0.5
Fluorene	mg/kg	0.5	<0.5
Phenanthrene	mg/kg	0.5	<0.5
Anthracene	mg/kg	0.5	<0.5
Fluoranthene	mg/kg	0.5	<0.5
Pyrene	mg/kg	0.5	<0.5
Benz(a)anthracene	mg/kg	0.5	<0.5
Chrysene	mg/kg	0.5	<0.5
Benzo(b)fluoranthene	mg/kg	0.5	<0.5
Benzo(k)fluoranthene	mg/kg	0.5	<0.5
Benzo(a)pyrene	mg/kg	0.5	<0.5
Indeno(1,2,3-cd)pyrene	mg/kg	0.5	<0.5
Dibenzo(a,h)anthracene	mg/kg	0.5	<0.5
Benzo(g,h,i)perylene	mg/kg	0.5	<0.5

intertek
Total Quality. Assured.

BT-RH-02-SF-01, 06/08/2024 **Intertek Reference: 2024-MDTN-000712-009**

ANALYSIS	UNITS	LOR	RESULT
	Metals [1]		
Aluminium	mg/kg	0.2	<0.2
Arsenic	mg/kg	0.5	<0.5
Barium	mg/kg	0.05	<0.05
Beryllium	mg/kg	0.001	<0.001
Boron	mg/kg	0.2	<0.2
Cadmium	mg/kg	0.001	0.004
Chromium	mg/kg	0.2	<0.2
Cobalt	mg/kg	0.001	0.004
Copper	mg/kg	0.01	0.32
Iron	mg/kg	5	<5
Lead	mg/kg	0.001	<0.001
Magnesium	mg/kg	2	140
Manganese	mg/kg	0.05	0.25
Mercury	mg/kg	0.01	<0.01
Molybdenum	mg/kg	0.01	0.01
Nickel	mg/kg	0.1	<0.1
Selenium	mg/kg	0.01	<0.01
Tin	mg/kg	0.05	<0.05
Zinc	mg/kg	1	<1

LEGEND

LOR = Limit of Reporting

NA = Not Analysed

N/A = Not Applicable

I/S = Insufficient Sample

Note [1] – Non-NATA Accredited Method

- End of Report -

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INTERTEK GEOTECH
ANALYTICAL REPORT

CLIENT	PETROLAB Australia Pty. Ltd. Attn. Jan Bon 45 Woodforde Road Magill, SA 5072 Australia

JOB INFORMATION

JOB REFERENCE	:	2024-MDTN-000865 Rev.0
NO. SAMPLES	:	3
CLIENT ORDER NO.	:	24076-2
PROJECT	:	Sediment and Shellfish Analysis
SAMPLED ON	:	01/10/2024
DATE RECEIVED	:	04/10/2024
DATE TESTED	:	07/10/2024
DATE REPORTED	:	18/10/2024

REPORT NOTES

Samples received in good condition at a temperature of 20.0°C.
[1] – The test denotes non-NATA accredited Method.

TESTED BY

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COMPANY APPROVED SIGNATORY

Noel Mellican
Laboratory Manager

NATA
WORLD RECOGNISED ACCREDITATION
ACCREDITATION No. 5646

NATA Accreditation Number: 5646
Accredited for compliance with ISO/IEC 17025 – Testing

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List of Revisions

REV.	DATE	REVISION DETAILS	AUTHOR	ISSUE
0	18/10/2024	Document created	Eder Casanova	Noel Mellican

This document replaces and supersedes all previous versions.

Sample Information

SAMPLE REFERENCE	SAMPLE DATE	MATRIX	PRESERVATION	INTERTEK REFERENCE
BT-M-CA-SED-01 Control site (A-Additional Control) - Mangroves	01/10/2024 @12:30	Sediment	Refrigerated	2024-MDTN-000865-001
BT-M-CA-SF-01 Control site (A-Additional Control) - Mangroves	01/10/2024 @12:30	Shellfish	Refrigerated	2024-MDTN-000865-002
BT-RH-CA-SF-01 Control site (A-Additional Control) – Rocky Headland	01/10/2024 @12:30	Shellfish	Refrigerated	2024-MDTN-000865-003

Additional Sample Information

N/A

Methodology

On receipt of the shellfish samples, the tissue was extracted from the shells and combined to form one composite shellfish sample for each of sample locations. Shellfish samples comprised of a variety of different species with varying sizes and tissue contents. Tissue samples were analysed for metals, BTEX, TRH, and PAHs.
Metals were analyzed after acid digest (on dry wt. basis) by ICP-AES/ICP-MS
Organic content including BTEX were determined by Purge & Trap GC-MS.
PAHs were determined by GC-MS-SIM with PTV large volume injection.

intertek
Total Quality. Assured.

Results

BT-M-CA-SED-01 Control site (A-Additional Control) - Mangroves

Intertek Reference: 2024-MDTN-000865-001

ANALYSIS	UNITS	LOR	RESULT
	BTEX[1]		
Benzene	mg/kg	0.1	<0.1
Ethylbenzene	mg/kg	0.1	<0.1
Toluene	mg/kg	0.1	<0.1
m,p-Xylene	mg/kg	0.2	<0.2
o-Xylene	mg/kg	0.1	<0.1
	TRH[1]		
C6-C10	mg/kg	25	<25
>C10-C16	mg/kg	25	<25
>C16-C34	mg/kg	100	<100
>C34-C40	mg/kg	100	<100
TotalTRH	mg/kg	250	<250
	PAH[1]		
Naphthalene	mg/kg	0.5	<0.5
Acenaphthylene	mg/kg	0.5	<0.5
Acenaphthene	mg/kg	0.5	<0.5
Fluorene	mg/kg	0.5	<0.5
Phenanthrene	mg/kg	0.5	<0.5
Anthracene	mg/kg	0.5	<0.5
Fluoranthene	mg/kg	0.5	<0.5
Pyrene	mg/kg	0.5	<0.5
Benz(a)anthracene	mg/kg	0.5	<0.5
Chrysene	mg/kg	0.5	<0.5
Benzo(b)fluoranthene	mg/kg	0.5	<0.5
Benzo(k)fluoranthene	mg/kg	0.5	<0.5
Benzo(a)pyrene	mg/kg	0.5	<0.5
Indeno(1,2,3-cd)pyrene	mg/kg	0.5	<0.5
Dibenzo(a,h)anthracene	mg/kg	0.5	<0.5
Benzo(g,h,i)perylene	mg/kg	0.5	<0.5

intertek
Total Quality. Assured.

ANALYSIS	UNITS	LOR	RESULT
	***Metals*[1]**		
Aluminium	mg/kg	20	6,600
Arsenic	mg/kg	2	19
Barium	mg/kg	10	<10
Beryllium	mg/kg	2	<2
Boron	mg/kg	10	53
Cadmium	mg/kg	0.1	<0.1
Chromium	mg/kg	1	17
Cobalt	mg/kg	5	6
Copper	mg/kg	1	4
Iron	mg/kg	20	18,000
Lead	mg/kg	1	6.3
Magnesium	mg/kg	5	13,000
Manganese	mg/kg	5	490
Mercury	mg/kg	0.02	<0.02
Molybdenum	mg/kg	5	<5
Nickel	mg/kg	1	5.4
Selenium	mg/kg	2	<2
Tin	mg/kg	10	<10
Zinc	mg/kg	5	17

intertek
Total Quality. Assured.

BT-M-CA-SF-01 Control site (A-Additional Control) - Mangroves

Intertek Reference: 2024-MDTN-000865-002

ANALYSIS	UNITS	LOR	RESULT
	BTEX[1]		
Benzene	mg/kg	0.1	<0.1
Ethylbenzene	mg/kg	0.1	<0.1
Toluene	mg/kg	0.1	<0.1
m,p-Xylene	mg/kg	0.2	<0.2
o-Xylene	mg/kg	0.1	<0.1
	TRH[1]		
C6-C10	mg/kg	25	<25
>C10-C16	mg/kg	25	<25
>C16-C34	mg/kg	100	<100
>C34-C40	mg/kg	100	<100
TotalTRH	mg/kg	250	<250
	PAH[1]		
Naphthalene	mg/kg	0.5	<0.5
Acenaphthylene	mg/kg	0.5	<0.5
Acenaphthene	mg/kg	0.5	<0.5
Fluorene	mg/kg	0.5	<0.5
Phenanthrene	mg/kg	0.5	<0.5
Anthracene	mg/kg	0.5	<0.5
Fluoranthene	mg/kg	0.5	<0.5
Pyrene	mg/kg	0.5	<0.5
Benz(a)anthracene	mg/kg	0.5	<0.5
Chrysene	mg/kg	0.5	<0.5
Benzo(b)fluoranthene	mg/kg	0.5	<0.5
Benzo(k)fluoranthene	mg/kg	0.5	<0.5
Benzo(a)pyrene	mg/kg	0.5	<0.5
Indeno(1,2,3-cd)pyrene	mg/kg	0.5	<0.5
Dibenzo(a,h)anthracene	mg/kg	0.5	<0.5
Benzo(g,h,i)perylene	mg/kg	0.5	<0.5

intertek
Total Quality. Assured.

ANALYSIS	UNITS	LOR	RESULT
	Metals[1]		
Aluminium	mg/kg	0.2	0.3
Arsenic	mg/kg	0.5	<0.5
Barium	mg/kg	0.05	<0.05
Beryllium	mg/kg	0.001	<0.001
Boron	mg/kg	0.2	0.6
Cadmium	mg/kg	0.001	0.003
Chromium	mg/kg	0.2	<0.2
Cobalt	mg/kg	0.001	0.009
Copper	mg/kg	0.01	1.3
Iron	mg/kg	5	<5
Lead	mg/kg	0.001	0.003
Magnesium	mg/kg	2	190
Manganese	mg/kg	0.05	0.25
Mercury	mg/kg	0.01	<0.01
Molybdenum	mg/kg	0.01	<0.01
Nickel	mg/kg	0.1	<0.1
Selenium	mg/kg	0.01	0.01
Tin	mg/kg	0.05	<0.05
Zinc	mg/kg	1	<1

intertek
Total Quality. Assured.

BT-RH-CA-SF-01 Control site (A-Additional Control) – Rocky Headland

Intertek Reference: 2024-MDTN-000865-003

ANALYSIS	UNITS	LOR	RESULT
	BTEX [1]		
Benzene	mg/kg	0.1	<0.1
Ethylbenzene	mg/kg	0.1	<0.1
Toluene	mg/kg	0.1	<0.1
m,p-Xylene	mg/kg	0.2	<0.2
o-Xylene	mg/kg	0.1	<0.1
	TRH [1]		
C6-C10	mg/kg	25	<25
>C10-C16	mg/kg	25	<25
>C16-C34	mg/kg	100	<100
>C34-C40	mg/kg	100	<100
TotalTRH	mg/kg	250	<250
	PAH [1]		
Naphthalene	mg/kg	0.5	<0.5
Acenaphthylene	mg/kg	0.5	<0.5
Acenaphthene	mg/kg	0.5	<0.5
Fluorene	mg/kg	0.5	<0.5
Phenanthrene	mg/kg	0.5	<0.5
Anthracene	mg/kg	0.5	<0.5
Fluoranthene	mg/kg	0.5	<0.5
Pyrene	mg/kg	0.5	<0.5
Benz(a)anthracene	mg/kg	0.5	<0.5
Chrysene	mg/kg	0.5	<0.5
Benzo(b)fluoranthene	mg/kg	0.5	<0.5
Benzo(k)fluoranthene	mg/kg	0.5	<0.5
Benzo(a)pyrene	mg/kg	0.5	<0.5
Indeno(1,2,3-cd)pyrene	mg/kg	0.5	<0.5
Dibenzo(a,h)anthracene	mg/kg	0.5	<0.5
Benzo(g,h,i)perylene	mg/kg	0.5	<0.5

intertek
Total Quality. Assured.

ANALYSIS	UNITS	LOR	RESULT
	***Metals*[1]**		
Aluminium	mg/kg	0.2	0.4
Arsenic	mg/kg	0.5	<0.5
Barium	mg/kg	0.05	<0.05
Beryllium	mg/kg	0.001	<0.001
Boron	mg/kg	0.2	0.6
Cadmium	mg/kg	0.001	0.007
Chromium	mg/kg	0.2	<0.2
Cobalt	mg/kg	0.001	0.010
Copper	mg/kg	0.01	0.63
Iron	mg/kg	5	<5
Lead	mg/kg	0.001	0.009
Magnesium	mg/kg	2	100
Manganese	mg/kg	0.05	0.07
Mercury	mg/kg	0.01	<0.01
Molybdenum	mg/kg	0.01	<0.01
Nickel	mg/kg	0.1	<0.1
Selenium	mg/kg	0.01	0.01
Tin	mg/kg	0.05	<0.05
Zinc	mg/kg	1	<1

LEGEND

LOR = Limit of Reporting
NA = Not Analysed
N/A = Not Applicable
I/S = Insufficient Sample
Note [1] – Non-NATA Accredited Method

\- End of Report -

CHAIN OF COUSTODY FORM

2024 Week 32 : beginning 5/08/2024

24076

Annual 1Y Shellfish and Sediment

Company:	Eni Australia B.V.	**PO No / Call-off No**	:	
Site:	Blacktip Yelcherr Gas Plant	**Quote No / CTR No**	:	24076
Contact:	Plant Operations Superintendent (ph : 08 9320 2697)	**Sampler (name)**	:	Thamarrurr Rangers
Senders Address:	C/- TOLL Energy & Marine Logistics Pty Ltd Attn : Darwin Logistics Warehouse Supervisor 8 Hamaura Rd East Arm NT, 0822	**Recipient laboratory address**	:	Petrolab c/o Intertek 544 Bickley Road Maddignton WA 6109 Attn: Jan Bon (0421 18 68 38)
Email:	kenny.bishell@eni.com david.mccubben@eni.com	sean.allen@external.eni.com		

Sample ID	Sample Location or Source	lindsay	Time Sampled	Type of Sample e.g. water, soil or gas	11.0 SEDIMENT AND SHELLFISH - Metals and Metalloids	11.1 SEDIMENT AND SHELLFISH - Hydrocarbons	Provide as much information about the sample as you can
BT-M-C1-SED-01	Control site (1-Original Control) - Mangroves		06/08	Sediment	✓	✓	Coordinates : -14.191592, 129.454255
BT-M-C1-SF-01	Control site (1-Original Control) - Mangroves		06/08	Shellfish	✓	✓	
BT-RH-C1-SF-01	Control site (1-Original Control) - Rocky Headland	SMALL SAMPLE	06/08	Shellfish	✓	✓	
BT-M-CA-SED-01	Control site (A-Additional Control) - Mangroves	NOT SAMPLED		Sediment	✓	✓	Coordinates : TBC
BT-M-CA-SF-01	Control site (A-Additional Control) - Mangroves	NOT SAMPLED		Shellfish	✓	✓	
BT-RH-CA-SF-01	Control site (A-Additional Control) - Rocky Headland	NOT SAMPLED		Shellfish	✓	✓	
BT-M-01-SED-01	Southern end of Yelcherr Beach - Mangroves		06/08	Sediment			Coordinates : -14.248081, 129.407773
BT-RH-01-SF-01	Southern end of Yelcherr Beach - Mangroves		06/08	Shellfish			
BT-M-01-SF-01	Southern end of Yelcherr Beach - Rocky Headland		06/08	Shellfish			
BT-M-02-SED-01	Northern end of Yelcherr Beach - Mangroves		06/08	Sediment	✓	✓	Coordinates : -14.238457, 129.411085
BT-M-02-SF-01	Northern end of Yelcherr Beach - Mangroves		06/08	Shellfish	✓	✓	
BT-RH-02-SF-01	Northern end of Yelcherr Beach - Rocky Headland		06/08	Shellfish	✓	✓	

Relinquished by:	Eni	**Received by (Company):**		*Lab use only:*
Print Name:	LINDSAY PURCE	**Print Name:**		**Samples Received: Cool or Ambient or Warm (circle one)**
Date & Time:	07/08/24. 0800	**Date & Time:**		**Temperature Received at:** (if applicable)
Signature:	LP.	**Signature:**		**Transported by: Hand delivered / courier**

NOTES : SAMPLES WERE PRESENTED TO YGP HSE SUPV @ 1600 06/08/2024. PRESERVED ON ICE FOR TRANSPORT OFFSITE BY AIR ON 07/08/2024.
Control Site (Additional Control) was NOT obtained. x 3.

SAMPLE CONTAINERS REQUIRED for Sample ID = BT-M-C1-SED-01

11.0 & 11.1 SEDIMENT - Metals and Metalloid, Hydrocarbons

1 x 600mL IsoJar

SAMPLE BOTTLE LABEL

CoC Form No :	24076
Sample ID No. :	BT-M-C1-SED-01
Sample Fluid :	Sediment
Sample Location :	Control site (1-Original Control) - Mangroves
Analysis :	11.0/11.1 SEDIMENT AND SHELLFISH

SAMPLE CONTAINERS REQUIRED for Sample ID = BT-M-C1-SF-01

11.0 & 11.1 SHELLFISH - Metals and Metalloid, Hydrocarbons

2 x 600mL IsoJar

SAMPLE BOTTLE LABEL

CoC Form No :	24076
Sample ID No. :	BT-M-C1-SF-01
Sample Fluid :	Shellfish
Sample Location :	Control site (1-Original Control) - Mangroves
Analysis :	11.0/11.1 SEDIMENT AND SHELLFISH

Document no. ENI-OPS-FR-005 *Rev : 00*

CoC 24076 Checklist

This checklist is to be filled out by the Operations person responsible for sending the sample to the required laboratory. The completed checklist is to be signed and scanned along with the front page.
- Each Orginal is to be sent with the sample/s

- Each Scanned copy is to be filed in the following folder (under the relevant year/month)
" J:\Blacktip Operations\INTERTEK_YGP LAB_COC_GLYCOL\02 Sampling Chain of custody forms "

- Each Scanned copy is to have the following file name convention
*" **CoC_** {CoC no} {date} " e.g. CoC_060 15/11/16*

1) ALL SAMPLE BOTTLES FILLED WITH THE SAMPLING FLUID — CONTROL SITE - ROCKY HEADLAND SMALL SAMPLE PRESENTED. ✓
2) ALL SAMPLE BOTTLES LABELLED ✓
3) ALL LABELS FILLED IN WITH THE CORRECT INFORMATION ✓
4) SAMPLE LOCATION / DATE / TIME & SAMPLER BEEN COMPLETED ON Page 1 ✓
5) SAMPLES BEEN ADDRESSED TO THE CORRECT LABORATORY ✓

Sampled by:	Eni
Print Name:	L. PLACE
Date & Time:	0800 07/08/24.
Signature:	[signature]

Document no. ENI-OPS-FR-005 *Rev : 00*

CHAIN OF CUSTODY FORM

24076-2

2024 Week 40 : beginning 30/09/2024

Annual 1Y Shellfish and Sediment

Company:	Eni Australia B.V.	**PO No / Call-off No**	:
Site:	Blacktip Yelcherr Gas Plant	**Quote No / CTR No**	: 24076
Contact:	Plant Operations Superintendent (ph : 08 9320 2697)	**Sampler (name)**	: Thamarrurr Rangers
Senders Address	C/- TOLL Energy & Marine Logistics Pty Ltd Attn : Darwin Logistics Warehouse Supervisor 8 Hamaura Rd East Arm NT, 0822	**Recipient laboratory address**	: Petrolab c/o Intertek 544 Bickley Road Maddignton WA 6109 Attn: Jan Bon (0421 186 838)
Email:	kenny.bishell@eni.com david.mccubben@eni.com	sean.allen@external.eni.com	

Sample information					Analysis										Comments
Sample ID	**Sample Location or Source**	**Lindsay**	**Time Sampled**	**Type of Sample e.g. water, soil or gas**	11.0 SEDIMENT AND SHELLFISH - Metals and Metalloids	11.1 SEDIMENT AND SHELLFISH - Hydrocarbons									**Provide as much information about the sample as you can**
BT-M-CA-SED-01	Control site (A-Additional Control) - Mangroves		12.30 hrs 01/10/24	Sediment	✓	✓									Coordinates : S 14° 02.1733 E 129° 35.880
BT-M-CA-SF-01	Control site (A-Additional Control) - Mangroves		12.30 hrs 01/10/24	Shellfish	✓	✓									Shellfish were difficult to find in high numbe
BT-RH-CA-SF-01	Control site (A-Additional Control) - Rocky Headland		12.30 hrs 01/10/24	Shellfish	✓	✓									Shellfish were difficult to find in high numbers and are smaller in size

Relinquished by:	Eni	**Received by (Company):**		*Lab use only:*
Print Name:	**Lindsay Place**	**Print Name:**		**Samples Received: Cool or Ambient or Warm (circle one)**
Date & Time:	**02/10/24 – 0800rs**	**Date & Time:**		**Temperature Received at: (if applicable)**
Signature:		**Signature:**		**Transported by: Hand delivered / courier**

NOTES: **Samples collected at alternative control location (Kuy Beach) at 12.30 hrs Tuesday 01/10/24 and preserved on ice immediately. Stored in chiller box and cooler until relinquished for transport to laboratory at date/time above**

SAMPLE CONTAINERS REQUIRED for Sample ID =

11.0 & 11.1 SEDIMENT - Metals and Metalloid, Hydrocarbons

1 x 600mL IsoJar

SAMPLE BOTTLE LABEL

CoC Form No :	24076-2
Sample ID No. :	0
Sample Fluid :	0
Sample Location :	0
Analysis :	11.0/11.1 SEDIMENT AND SHELLFISH

SAMPLE CONTAINERS REQUIRED for Sample ID =

11.0 & 11.1 SHELLFISH - Metals and Metalloid, Hydrocarbons

2 x 600mL IsoJar

SAMPLE BOTTLE LABEL

CoC Form No :	24076-2
Sample ID No. :	0
Sample Fluid :	0
Sample Location :	0
Analysis :	11.0/11.1 SEDIMENT AND SHELLFISH

Document no. ENI-OPS-FR-005 *Rev: 00*

CoC 24076-2 Checklist

This checklist is to be filled out by the Operations person responsible for sending the sample to the required laboratory. The completed checklist is to be signed and scanned along with the front page.
- Each Orginal is to be sent with the sample/s

- Each Scanned copy is to be filed in the following folder (under the relevant year/month)
" J:\Blacktip Operations\INTERTEK_YGP LAB_COC_GLYCOL\02 Sampling Chain of custody forms "

- Each Scanned copy is to have the following file name convention
*" **CoC**_{CoC no} {date} " e.g. CoC_060 15/11/16*

1) ALL SAMPLE BOTTLES FILLED WITH THE SAMPLING FLUID ☐
2) ALL SAMPLE BOTTLES LABELLED ☐
3) ALL LABELS FILLED IN WITH THE CORRECT INFORMATION ☐
4) SAMPLE LOCATION / DATE / TIME & SAMPLER BEEN COMPLETED ON Page 1 ☐
5) SAMPLES BEEN ADDRESSED TO THE CORRECT LABORATORY ☐

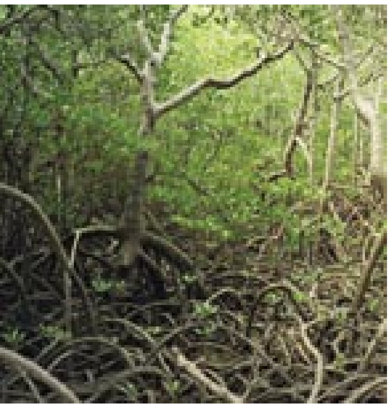
Sampled by:	Eni
Print Name:	**Lindsay Place**
Date & Time:	**02/10/24 at 08:00 hrs**
Signature:	

Document no. ENI-OPS-FR-005 *Rev.: 00*

APPENDIX C DISPERSION MODEL VERIFICATION RESULTS

Appendix J

Blacktip Produced Formation Water Assessment prepared by International Risk Consultants Environment

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Blacktip Produced Formation Water Assessment

DATE: 5 AUGUST, 2004

PROJECT: J03-187

DOC NO.: ENV-REP-03-187-001 REV 0.DOC

IRC Environment

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www.intrisk.com

DOCUMENT REVISION STATUS					
REV	DESCRIPTION	AUTHOR	REVIEW	APPROVAL	DATE
A	Internal Review	Rob Phillips	Peter Jernakoff		30 July 2004
0	Issued to client	Rob Phillips	Peter Jernakoff	Kian Feng	5 August 2004

<table>
<tr><td colspan="2" rowspan="2">Title: Blacktip Produced Formation Water Assessment</td><td colspan="2">Job Number: J03-187</td></tr>
<tr><td colspan="2">Report Number: ENV-REP-03-187-001 Rev 0.doc</td></tr>
<tr><td>Client: Woodside Energy</td><td colspan="2">Author: Rob Phillips</td><td>IRC Office: Perth</td></tr>
<tr><td colspan="4">Industry Sector: Offshore Oil and Gas</td></tr>
<tr><td colspan="4">Key words:
Woodside Energy Ltd., Blacktip, PFW, Modelling, toxicity, Initial dilution, Joseph Bonaparte Gulf</td></tr>
<tr><td colspan="4">Abstract:
Woodside Energy Ltd (WEL) is planning to develop the Blacktip Gas Field in the Joseph Bonaparte Gulf. This report provides an assessment of the environmental risk associated with disposing of produced formation water (PFW) from the development. The preferred disposal option is onshore treatment followed by discharge to the ocean through a long sea outfall.</td></tr>
<tr><td colspan="4">Country:
Northern Territory, Australia</td></tr>
<tr><td colspan="4">Reference: N/a</td></tr>
</table>

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ABBREVIATIONS

ADCIRC	Advanced Circulation Model
AGSO	Australian Geological Survey Office
ANZECC	Australian and New Zealand Environment and Conservation Council
ASTM	American Society for Testing Materials
BAF	Bioaccumulation Factor
BCF	Bio-concentration Factor
BF	Biomagnification Factor
BOD	Biochemical Oxygen Demand
BTEX	Benzene, Toluene, Ethyl benzene and Xylene
CHARM	Chemical Hazard Assessment and Risk Management
CORJET	Cornell Buoyant Jet Integral Model
CORMIX	Cornell Mixing Zone Expert System
CP	Cossack Pioneer
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DO	Dissolved Oxygen
DREAM	Dose related Risk and Effect Assessment Model
EC50	The Median Effect Concentration
EIF	Environmental Impact Factor
EPBC	Environment Protection and Biodiversity Conservation
FE	Finite Element
FEED	Front End Engineering Design
FID	Flame Ionisation Detection
GC-MS	Gas Chromatography – Mass Spectrometry
GWA	Goodwyn ‘A’
HAT	Highest Astronomical Tide
Hs	Significant Wave Height
HQ	Hazard Quotient
IC50	Median Inhibition Concentration
IR	Infra-Red
IRCE	IRC Environment

IUCN	International Union for the Conservation of Nature and Natural Resources
K_{oc}	Organic carbon/water partition coefficient
K_{ow}	Octanol/water partition coefficient
K	Diffusion coefficient
LAT	Lowest Astronomic Tide
LC50	Median Lethal Concentration
LTS	Low Temperature Separator
MAH	Monocyclic Aromatic Hydrocarbon
MFO	Mixed Function Oxygenase
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MHWS	Mean High Water Springs
MHWN	Mean High Water Neaps
MSL	Mean Sea Level
ND	Not Detected
NE	Northern Endeavour
NOAA	National Oceanic and Atmospheric Administration
NOEC	No Observed-Effect Concentration
NORM	Naturally Occurring Radioactive Material
NNE	North Northeast
NV	No Value
NPD	Naphthalene, Phenanthrene and Dibenzothiophene
NRA	North Rankin ‘A’
OGP	International Association of Oil and Gas Producers
OL	Ocean Legend
OSPAR	Oslo and Paris Commission
PAH	Polycyclic Aromatic Hydrocarbons
PSU	Practical Salinity Unit
PEC	Predicted Environmental Concentration
PFW	Produced Formation Water
PID	Photoionisation detection

PNEC	Predicted No Effect Concentration
P(SL)A	Petroleum (Submerged Land) Act
P(SL)(ME)R	Petroleum (Submerged Land)(Management of the Environment) Regulations
PWCNT	Parks and Wildlife Commission of the Northern Territory
SDH	Sorbital Dehydrogenase
SE	Southeast
Tm	Mean Spectral Period
TOC	Total Organic Carbon
UKOOA	United Kingdom Offshore Operators Association
USEPA	United States Environmental Pollution Authority
WA	Western Australia
WEL	Woodside Energy Ltd.
WET	Whole Effluent Toxicity
^{o}C	Degree Celsius

EXECUTIVE SUMMARY

This report assesses the environmental risk associated with disposing of produced formation water (PFW) from Woodside Energy Limited's (WEL's) Blacktip Gas development. The preferred disposal option is onshore treatment followed by discharge to the marine environment of the Joseph Bonaparte Gulf through a long sea outfall.

PFW discharge rates are projected to increase from 200 bbl/day at start-up to a maximum of 7,000 bbl/day five years into production. The actual toxicity of the PFW is presently unknown, however, WEL's previous ecotoxiciology studies on PFW from all its other offshore assets indicate that the lowest threshold concentration for potential environmental impact is 0.1% concentration of PFW. Blacktip PFW will be treated onshore to a higher standard than the offshore facilities and the toxic threshold is expected to be higher, ie, the PFW is likely to be less toxic.

The favoured offshore release point is in the vicinity of the Swamp Mooring, which lies three kilometres offshore in a water depth of 15m. Tidal currents in the Joseph Bonaparte Gulf are large and the assimilative capacity of the receiving waters high. Initial dilution from the discharge can be further enhanced through use of an end-of-pipe diffuser.

Pipeline hydraulics were reviewed and, based on preliminary information, a four port diffuser configuration was proposed. Dispersion modelling for this configuration predicted that at least 700 initial dilutions would be achieved for the maximum future discharge rate, reducing the PFW concentrations to 0.14%.

Far field modelling showed that the receiving waters are well flushed due to the large tidal currents. Maximum PFW concentrations occurred at slack waters with values building up to just over the 0.1% PFW threshold within 400m from the near field mixing zone. As the modelling was undertaken for worst case conditions of maximum discharge rate combined with a neap tide and low wind speed, 400m is likely to be the maximum extent of the impact. At all other stages of tide, this zone of impact would reduce substantially.

PFW also has an oxygen demand. This can be controlled by treatment prior to discharge. It was predicted that to maintain oxygen levels to within 90% of saturation levels, the biochemical oxygen demand of the effluent should be kept below 2,500mgL^{-1} for the maximum discharge rate.

The overall conclusion is that the proposed discharge should have minimal impact on the marine environment. This is based on the Blacktip PFW being no more toxic than those from other WEL assets. It is recommended that ecotoxiciology studies be undertaken once PFW becomes available to verify this assumption. As well as reducing the concentration of dispersed oil, treatment should focus on removing polycyclic aromatic hydrocarbons and reducing the toxicity of process chemicals, the compounds of most concern in PFW.

1 INTRODUCTION

1.1 Background

Blacktip is an offshore gas development located 300km South West of Darwin, Australia. The development comprises of an unmanned wellhead platform in 50m of water and a 16 inch, 120km long pipeline through which well fluids will be transported to an onshore gas treatment station (Figure 1.1 and Figure 1.2). The wet gas will be conditioned at the treatment station and then exported to Gove through the trans-territory pipeline. The favoured option for disposal of the Produced Formation Water (PFW) is treatment prior to offshore discharge to the Joseph Bonaparte Gulf through a long sea outfall.

As part of the Front End Engineering Design (FEED) for the project, IRC Environment (IRCE) was commissioned by Woodside Energy Limited (WEL) to devise an effective ocean disposal scheme and to assess the environmental risks associated with discharging PFW to the ocean.

1.2 Objective

The objective of the study is to devise an effective PFW disposal scheme for the Blacktip development and to gain a full understanding of the environmental impact associated with it.

1.3 Scope of Work

The scope of work included:

- describing the typical composition of PFW, its fate and toxicity in the marine environment;
- describing the meteorological and oceanographic conditions for the Joseph Bonaparte Gulf;
- developing a discharge model and using it to derive an effective PFW disposal scheme for the Blacktip PFW; and
- predicting the fate and effect of the PFW once it has been discharged.

1.4 IRC

IRC is an independent consultancy providing a variety of services to the mining, oil and gas exploration, production and financial industries. IRC's methods and tools have been developed to enable rapid, confident decision making, and to recognise the key decision criteria necessary to minimise risk and maximise value. IRC has an overall objective of assisting our clients improve their performance and increase the value of their assets. This is achieved by improving:

- safety performance through reducing the risk/cost associated with injury/fatality;
- environmental performance through reducing environmental damage and clean up costs;
- production performance through optimising production uptime and availability;
- health performance through implementation of organisation cultural assessment and change programs, including the Peak Performance Program; and
- information system performance through development, integration, implementation and support of stable and secure business systems.

Figure 1.1 Location of the Blacktip Gas Field and associated infrastructure (from WEL)

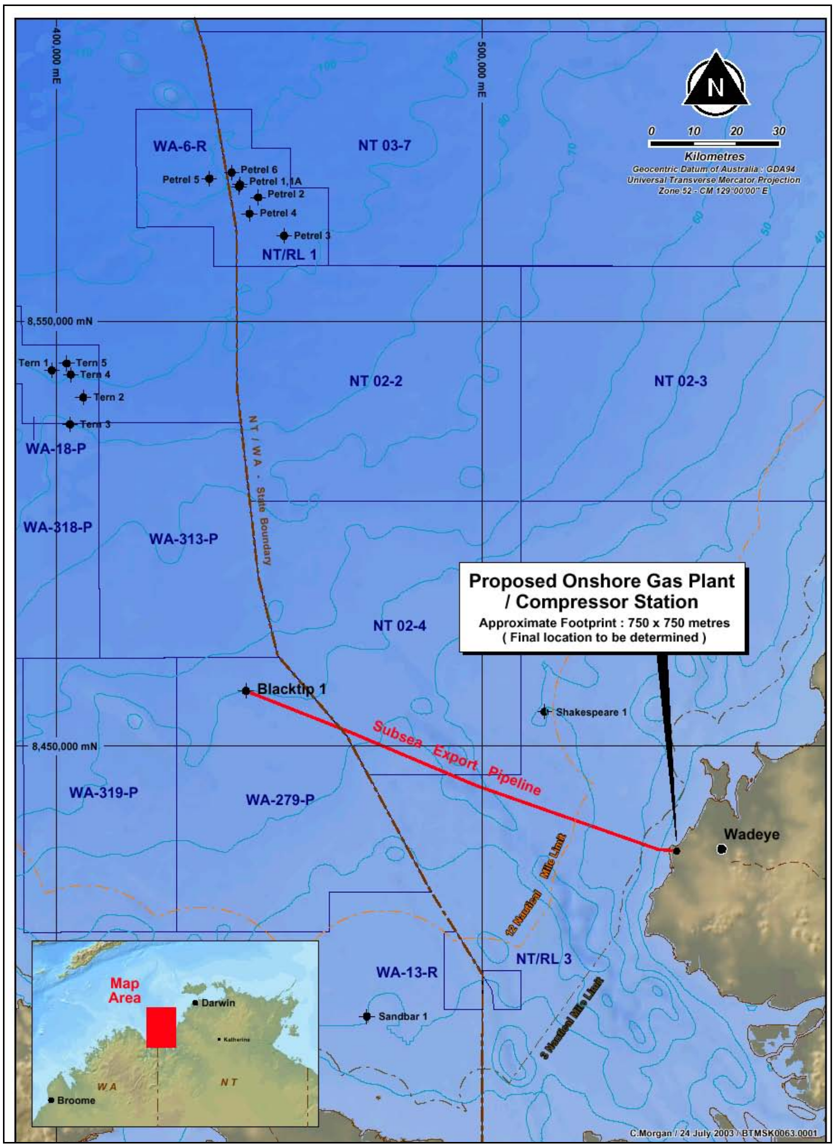
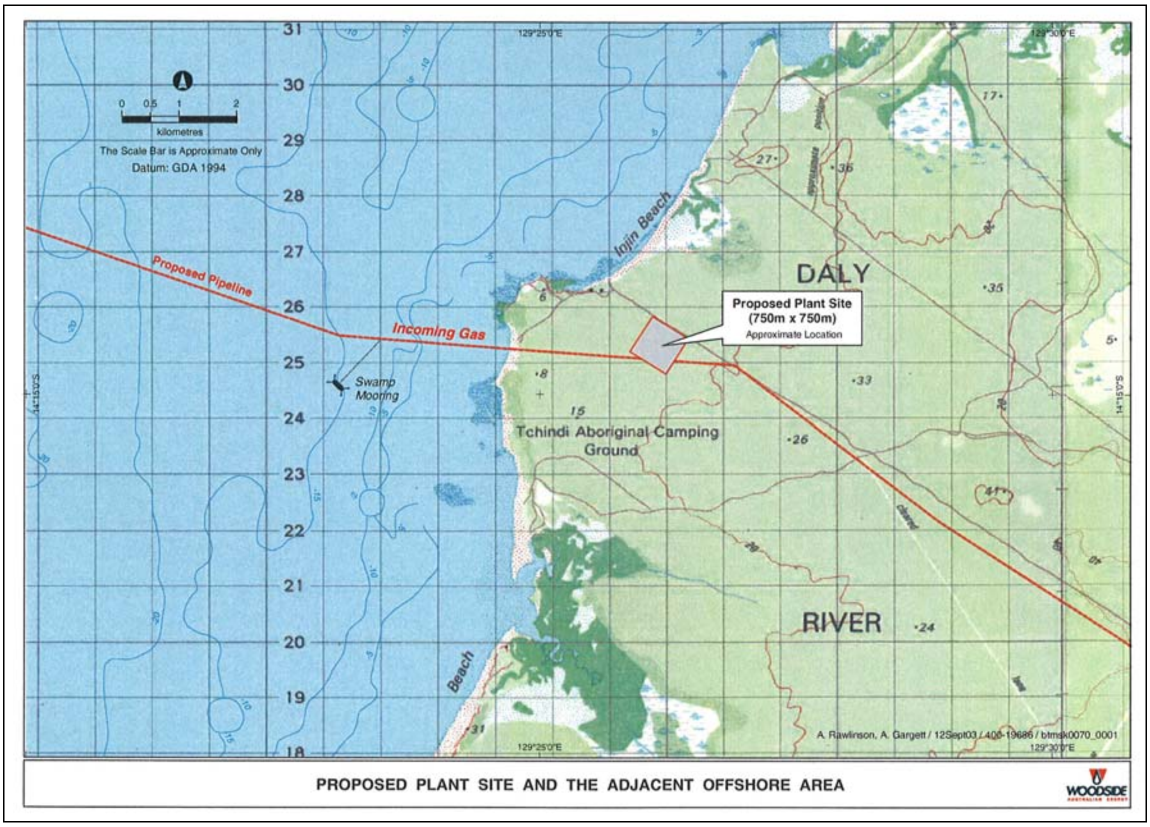


Figure 1.2 Shoreline crossing and proposed plant site (from WEL)



2 PRODUCED FORMATION WATER CHARACTERSITICS

2.1 Introduction

2.1.1 Overview

PFW (also referred to as produced water or formation water) is the waste water that is separated from the production stream during oil and gas production operations. For oil production fields the largest constituent is typically fossil water, the water found with the oil and gas inside the geological reservoir. However in gas and condensate wells, it is generally associated with saturation water that condenses due to the pressure drop between the reservoir and surface. As the reservoir matures, fossil water may be introduced and volumes of PFW tend to increase.

It is common practice throughout the offshore industry to physically separate the water from the well fluids and then dispose of the water directly to the ocean. This separation is not 100% effective and the PFW often contains small amounts of naturally occurring contaminants including dispersed oil, dissolved organic compounds (aliphatic and aromatic hydrocarbons, organic acids and phenols), inorganic compounds and residual process chemicals. Although only small concentrations of these compounds are released, the continuous discharge of large PFW volumes gives rise to environmental concern. Accordingly, most of the world’s national or regional regulatory authorities set limits on the concentration of petroleum hydrocarbons (or total oil and grease) that can remain in PFW for ocean disposal. Many regulators also require that environmental impact assessments be undertaken to fully evaluate the risk.

The chemical composition of PFW varies over a wide range and depends mainly on attributes of the reservoir geology. The composition of PFW may also change slightly through the production lifetime of the reservoir. Compared to oil production fields, PFW from gas/condensate fields generally have higher hydrocarbon contents due to technical difficulties in separating condensate and water and also due to the higher aromatic content of condensate. However, the total volume of water produced from gas fields is much smaller than from oil production fields. Many gas fields discharge less than 10m^3 of PFW per day whilst most oil fields discharge hundreds or even thousands of cubic metres per day.

2.1.2 Previous Studies

In 2002 WEL undertook a comprehensive study of PFW discharges from their assets on the North West Shelf and Timor Sea (IRCE, 2003a-e). These assets included:

- North Rankin ‘A’ (NRA);
- Goodwyn ‘A’ (GWA);
- Cossack Pioneer (CP);

- Ocean Legend (OL); and
- Northern Endeavour (NE).

The study consisted of:

- characterising the chemical composition of the PFW;
- ecotoxicology; and
- dispersion and risk assessment modelling.

The results from these studies will be applied here. There are numerous other studies in the scientific literature and excellent reviews of these are given in Swan *et al*. (1994) and, more recently, in Neff (2002).

2.2 Chemical Composition of PFW

2.2.1 Introduction

The chemical composition of PFW has been described extensively by several authors (see for example Neff, 2002; OGP, 2002; DK, 2001; Roe Utvik, 1999 and Flynn *et al.,* 1996) and operators in the North Sea report regularly on the composition and volumes of their discharges (see UKOOA, 2002; OGP, 2002 and DK, 2001).

Prior to production, it is difficult to predict the exact composition or toxicity of Blacktip PW, however, based on knowledge of other PW in the region and also worldwide, it is likely to contain trace concentrations of:

- petroleum hydrocarbons;
- phenols;
- organic acids;
- metals;
- radioisotopes; and
- residual process chemicals.

This Section introduces the chemical characteristics of each of these constituents and presents typical concentrations from oil and gas production facilities around the world.

2.2.2 Petroleum hydrocarbons

Petroleum hydrocarbons are the organic components of greatest environmental concern in PFW. These compounds contain only carbon and hydrogen atoms, with the carbon atoms linked by single or double covalent bonds to form linear branched and cyclic hydrocarbons. In aliphatic hydrocarbons all carbon-carbon bonds are single. Aromatic hydrocarbons are composed of six carbon rings in which six carbon atoms equally share nine covalent bonds.

The aqueous solubility of petroleum hydrocarbons decreases as their molecular weight increases. As oil/water separator equipment is efficient in removing oil droplets from the PFW but not dissolved oil, most of the petroleum hydrocarbons remaining after treatment are low molecular weight aromatic and aliphatic hydrocarbons that are dissolved in the PFW.

Aliphatic hydrocarbons

Aliphatic hydrocarbons are carbon structures without any aromatic nucleus. They are further divided into alkanes, alkenes and alkynes. The alkanes are the major group in crude oil. Alkanes have the general formula C_nH_{2n+2}. In crude oil they cover a broad range from methane (CH_4) which is a gas at normal conditions to heavy components like n-tetracontane ($C_{40}H_{82}$) or even heavier, which are solid compounds at normal conditions. The essential characteristic of alkane hydrocarbon molecules is that only single covalent bonds are present. In these compounds, the bonds are said to be saturated thus the alkanes are also known as the saturated hydrocarbons.

Low molecular weight alkanes are volatile whilst those with more than 16 carbons have an extremely low aqueous solubility. The most abundant alkanes found in PFW are therefore in the C13 to C16 range. It is likely that the higher molecular weight alkanes are in colloidal form or associated with dispersed oil droplets not removed by the oil/water separator.

Due to technical difficulties with separating condensate from water, aliphatic hydrocarbon concentrations in PFW are generally higher from gas/condensate fields than they are from oil fields. The average concentration from North Sea gas installations was $242mgL^{-1}$ in 2001 (UKOOA, 2002). This compared with $52mgL^{-1}$ from oil installations. However, most gas installations have concentrations of less than $40mgL^{-1}$ and the average value is enhanced by a few installations reporting very high concentrations (up to $700mgL^{-1}$).

Aromatic hydrocarbons

Aromatic hydrocarbons are carbon structures with double bonding in all positions and the carbon skeleton arranged in planar six-rings. The most typical example is benzene (C_6H_6). The structure can include more than one six-ring-structure, e.g. naphthalene which has two rings ($C_{10}H_8$), and phenanthrene, which has three rings ($C_{14}H_{10}$). In environmental investigations structures with up to six rings are included, but structures with more rings exist. The rings are often alkylated with methyl groups and in some crude oils the content of the alkylated aromatic is an order of magnitude higher than the content of the pure aromatic hydrocarbon.

The aromatic hydrocarbons are grouped into:

- monoaromatic hydrocarbons (MAHs); and
- polyaromatic hydrocarbons, (PAHs).

PAHs contain three or more aromatic rings. The two ring hydrocarbons are not included in either of these groups, however, in practice they are grouped with the PAHs.

Monocyclic aromatic hydrocarbons

MAHs have one aromatic ring that may be alkylated. The most common compounds and those of most concern in the environment are:

- benzene (C_6H_6), without any substitutes;
- toluene, (C_6H_5-CH_3) with one methyl substitute;
- ethyl benzene, (C_6H_5-C_2H_5), with one ethyl substitute; and
- xylene (C_6H_4-$(CH_3)_2$), with two methyl substitutes, which can be placed in three different positions and therefore there are three isomers.

These hydrocarbons are often named by the combined abbreviation BTEX. There are higher alkylated MAHs, with three and four carbons alkylated, but normally they are not specified or determined individually. The BTEX compounds are more soluble in water than other hydrocarbons and are generally the most abundant in PFW.

Ranges of BTEX concentrations in PFW from oil and gas facilities in the North Sea are given in Table 2.1. Concentrations may range from 0.042mgL^{-1} to as high as 2,244mgL^{-1}. PFW from gas wells usually contain higher concentrations of BTEX than oil wells due to the higher aromatic content of the condensate and gas produced. Benzene is often the most abundant BTEX compound in effectively treated PFW, followed by toluene. Ethyl benzene and the three xylene isomers are usually present at only a small fraction of the concentrations of benzene and toluene. A large number of C3- and C4- benzene isomers may also be present, usually at low concentrations.

Table 2.1 Concentration ranges of BTEX compounds in PFW from oil and gas fields in the North Sea (1999 – 2001) (from OGP, 2002)

	Oil (mgL^{-1})	Gas (mgL^{-1})
Norway	0.7 – 24.1	1.9 – 36
UK	<0.5 - 34	0.5 – 2,244
Holland	0.042 – 4.8	0.01 – 1,164
Denmark	8.7 - 14	N/A

N/A – Not available

Table 2.2 presents the concentrations measured in the PFW from WEL's production facilities on the North West Shelf and Timor Sea. Values range from 29.4mgL^{-1} at NRA to 3.3mgL^{-1} at GWA.

Table 2.2 BTEX concentrations measured in PFW from Woodside's Assets in 2002 (from IRCE, 2003a–e)

Compound	**Concentration (mgL^{-1})**				
	NRA	GWA	CP	OL	NE
Benzene	7.3	1.2	1.3	2.3	0.7
Toluene	13.0	1.3	1.9	3.6	1.3
Ethyl Benzene	0.8	0.1	0.2	<0.2	0.3
Xylenes	8.3	0.7	1.1	3.3	1.5
Sum BTEX	**29.4**	**3.3**	**4.5**	**9.2**	**3.8**

Notes: Measured by PID/FID (USEPA 5030B, 8020A and 8260)

Polycyclic aromatic hydrocarbons

PAHs cover a broad range of compounds, which may be formed by a variety of mechanisms (Neff, 1979), such as:

- very rapid, high temperature (700°C) incomplete combustion or pyrolisis of organic materials (pyrogenic PAHs);
- very slow (millions of years) rearrangement and transformation of biogenic organic materials at moderate temperatures of 100-300°C to form fossil fuels (petrogenic PAHs);
- relatively rapid (days to years) transformation of certain classes of organic compounds in soils and sediments (diagenic PAHs); and
- direct biosynthesis by organisms (biogenic PAHs).

In environmental investigations it is common to measure the 16 PAH defined by the list of Priority Pollutants from the United States Environmental Pollution Authority (USEPA) (see Table 2.3). These 16 compounds are all full aromatic hydrocarbons without any substitutes. In crude oil, alkyl homologues usually are more abundant than the parent PAHs, however, this often is not so in PFW because of the decreasing aqueous solubility with increasing PAH alkylation, favouring retention in the oil phase.

Concentrations of total PAHs in PFW typically range from about 0.04mgL^{-1} to 3.0mgL^{-1} (Neff, 2002). Naphthalene and occasionally phenanthrene (three fused aromatic rings) and their alkyl homologues are the only PAHs that are present at higher than trace concentrations. These low molecular weight PAHs usually represent 95% of the total PAHs in PFW.

Four to six ring PAHs, some of which are phototoxic, mutagenic and carcinogenic, are rarely detected in PFWs that meet effluent standards for oil and grease. For example, the carcinogenic benzo(a)pyrene is rarely present in PFW at concentrations greater than about 0.1μgL^{-1}. The aqueous solubility of benzo(a)pyrene is so low and its affinity for the oil phase so high that it would not be expected to be present in PFW in dissolved form. Despite the low level measurements of PAHs in PFW, there is ongoing concern about the environmental effects of such components in the marine environment.

Table 2.3 The 16 USEPA priority PAHs

Compound	No. of rings
Naphthalene	2
Phenanthrene	3
Acenaphthylene	3
Acenaphthene	3
Fluorene	3
Anthracene	3
Fluoranthene	4
Pyrene	4
Benz(a)anthracene	4
Chrysene	5
Benzo(b)fluoranthene	5
Benzo(k)fluoranthene	5
Benzo(a)pyrene	5
Indeno(1,2,3-c,d)pyrene	5
Dibenz(a,h)anthracene	5
Benzo(g,h,i)anthracene	6

The concentration ranges of naphthalene, phenanthrene and dibenzothiophene (NPD) and other PAH compounds in PFW from oil and gas facilities in the North Sea are given in Table 2.4. Concentrations of NPD range from 0.001mgL^{-1} to10.4 mgL^{-1}. Concentrations of other PAHs range from 0. 0004mgL^{-1} to 4.125mgL^{-1}.

Table 2.4 Concentration range of NPD and other PAH compounds in PFW from oil and gas fields in the North Sea (1999 – 2001) (from OGP, 2002)

	NPD[1]		PAH[2]	
	Oil (mgL^{-1})	Gas (mgL^{-1})	Oil (mgL^{-1})	Gas (mgL^{-1})
Norway	0.8 – 10.4	0.24 – 0.8	0.001 – 0.13	0.003 – 0.05
UK	0.007 – 0.74	0.001 – 0.74	0.002 – 0.12	0.0004 – 0.23
Holland	N/A	N/A	0.0026 – 0.1545	0.002 – 4.125
Denmark	0.22 – 0.436	N/A	0.12 – 0.285	N/A

[1] including C1 – C3 alkyl homologues; [2] 16 USEPA PAH other than naphthalene and phenanthrene; N/A – not available

Studies of one specific field over a period of one week show that there is little variation in composition of aromatic hydrocarbons over that time span (OGP, 2002). Results from the Norwegian database also show that composition of PFW is relatively constant from one year to another at individual fields (OGP, 2002).

Table 2.5 presents the concentrations measured in the PFW from WEL's production facilities on the North West Shelf and Timor Sea in 2002. Values of NPD range from 0.67mgL^{-1} at NRA to 0.15mgL^{-1} at GWA. Of the other PAHs, only fluorene was detected in OL and NE PFW at 0.021mgL^{-1} and 0.018mgL^{-1}, respectively.

Table 2.5 PAH concentrations measured in PFW from Woodside's Assets in 2002 (from IRCE, 2003a–e)

Compound	Concentration (mgL^{-1})				
	NRA	GWA	CP	OL	NE
NPD[1]	0.670	0.150	0.304	0.568	0.537
Other PAHs[2]	ND	ND	ND	0.021[3]	0.018[3]

Notes: Measured by GC-MS in SIM mode (USEPA 3550B, 8270); [1] including C1 – C3 alkyl homologues; [2] 16 USEPA PAH other than naphthalene and phenanthrene; [3] fluorene; ND – Not Detected;

2.2.3 Phenols

Phenol is a hydroxy derivative of benzene with the formula C_6H_5OH. The five aromatic carbons not bonded to the hydroxyl group readily react with methyl carbons to form methyl phenol (alkyl phenols) and with halogens to form a wide variety of halogenated phenols. Phenol, alkyl phenols and to a lesser extent halogenated phenols are natural components of the environment. Many different phenols are synthesized by a wide variety of bacteria and fungi, plants and animals. Phenols can be formed from the oxidation of benzene. The most abundant phenols in many crude oils are the C2 through C9 alkyl phenols. However, phenol solubility decreases with increasing alkylation so PFW rarely contains detectable concentrations of the more highly alkylated phenols.

The most complete analysis to date of phenols in PFW are those from three production facilities in Indonesia (Neff and Foster, 1997) and five in the Norwegian sector of the North Sea (Roe Utvik, 1999). Phenols with up to five alkyl carbons were detected and total phenols ranged from 0.36mgL^{-1} to 16.83mgL^{-1} (Table 2.6).

Table 2.7 presents the concentrations measured in the PFW from WEL's production facilities on the North West Shelf and Timor Sea in 2002. Phenols with up to three alkyl carbons were detected. Both NRA and GWA had relatively high total concentrations at 15.4mgL^{-1} and 17.3mgL^{-1}, respectively. Concentrations at CP, OL and NE were much lower at less than 2.1mgL^{-1}.

Table 2.6 Concentration of phenol and different alkylphenol groups in PFW from three production facilites in Indonesia and five production facilities in the Norwegian Sector of the North Sea (from Neff, 2002)

Chemical	Indonesian PFW (mgL^{-1})	North Sea PFW (mgL^{-1})
Phenol	0.67 – 2.49	0.007 – 7.0
C_1-Phenols	0.77 – 1.69	0.011 – 6.78
C_2-Phenols	0.58 – 1.10	0.19 – 2.51
C_3-Phenols	0.30 – 0.59	0.064 – 0.60
C_4-Phenols	0.13 – 0.37	0.077 – 0.43
C_5-Phenols	0.04 – 0.09	0.007 – 0.02
C_6-Phenols	ND	ND
C_7-Phenols	ND	ND
C_8-Phenols	ND	ND
C_9-Phenols	ND	ND
Total Phenols	2.49 – 6.33	0.36 – 16.83

ND – Not Detected

Table 2.7 Concentration of phenol and different alkylphenol groups measured in PFW from Woodside's assets in 2002 (from IRCE, 2003a–e)

Chemical	NRA	GWA	CP	OL	NE
Phenol	4.00	2.90	0.73	0.03	0.25
C_1-Phenols	7.70	6.60	0.94	0.17	0.21
C_2-Phenols	3.33	6.34	0.36	0.17	0.06
C_3-Phenols	0.37	1.49	0.03	ND	ND
C_4-Phenols	ND	ND	ND	ND	ND
C_5-Phenols	ND	ND	ND	ND	ND
C_6-Phenols	ND	ND	ND	ND	ND
C_7-Phenols	ND	ND	ND	ND	ND
C_8-Phenols	ND	ND	ND	ND	ND
C_9-Phenols	ND	ND	ND	ND	ND
Total Phenols	**15.40**	**17.33**	**2.06**	**0.36**	**0.51**

Notes: Measured by GC-MS (USEPA 8270 modified); ND – Not Detected

2.2.4 Organic acids

Much of the total organic carbon (TOC) in PFW consists of organic acids. These are thought to have been produced by hydrous pyrolysis of kerogen and hydrocarbons in the source rocks and hydrocarbon-bearing formation (Neff, 2002). Most of the organic acids are short chain aliphatic monocarboxylic acids, such as acetic (C_2), propionic (C_3), butyric (C_4) and valeric (C_5) acids. Concentrations tend to decrease with molecular weight with the most abundant acid usually being acetic acid.

2.2.5 Metals

PFW may contain several metals in solution. The metals present and their concentrations are extremely variable, depending on the age and geology of the formation from which the oil and gas are produced. There is usually a poor correlation between concentrations of metals in crude oil and the water produced with it (Neff, 2002).

Metals are classified as alkali and alkaline earth metals (sodium, potassium, magnesium, calcium, strontium and barium) and heavy metals (arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver and zinc). The alkali and, to a lesser degree, the alkaline earth metals are very reactive. Hence they never occur in elemental form and are found combined with halide, sulphate, carbonate or silicate ions. In this form they are not considered toxic and water quality guideline values for these metals do not exist. The heavy metals are considered toxic and, with the exception of iron and silver, USEPA marine quality criteria and Australian and New Zealand Environment and Conservation Council (ANZECC) guideline trigger values exist.

Generally, heavy metal concentrations in PFW are very low (typically $<0.5mgL^{-1}$ – $1.0mgL^{-1}$ (UKOOA, 2002). The metals most frequently present in PFW at elevated concentrations include: barium, chromium, copper, iron, lead, nickel and zinc. Usually only a few of these metals are present at elevated concentrations in a particular PFW sample. Table 2.8 shows the concentration ranges of heavy metals from North Sea samples taken between 1999 and 2001 (UKOOA, 2002). These are average ranges and higher concentrations at individual facilities were detected.

Table 2.9 presents the concentrations measured in the PFW from WEL's production facilities on the North West Shelf and Timor Sea in 2002. In general heavy metal concentrations were low and not considered to be an environmental hazard.

Table 2.8 Concentration range of heavy metals in PFW from oil and gas fields in the North Sea (1999 – 2001) (from UKOOA, 2002)

	Heavy metal Concentrations	
	Oil (mgL^{-1})	Gas (mgL^{-1})[1]
Arsenic	0.679 – 1.300	0.030 – 0.414
Cadmium	0.145 – 0.313	0.033 – 0.097
Chromium	15.4 – 20.1	0.005 – 0.140
Copper	0.072 – 2.620	0.020 – 0.164
Lead	1.959 – 3.524	0.890 – 3.865
Mercury	0.045 – 0.157	0.008 – 2.630
Nickel	21.0 – 24.6	0.016 – 0.120
Zinc	16.0 – 26.0	11.002 – 14.640

[1] annual average concentrations from 35, 27 and 21 North Sea gas platforms in 1999, 2000 and 2001, respectively.

Table 2.9 Concentration range of heavy metals in PFW from WEL's Assets (IRCE, 2003a-e)

	Heavy metal Concentrations (mgL^{-1})				
	NRA	GWA	CP	OL	NE
Arsenic	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	0.0080	0.0200	0.0260	0.0270	0.0200
Copper	<0.005	<0.005	0.0060	0.0100	<0.005
Lead	<0.005	<0.005	<0.005	<0.005	<0.005
Mercury	<0.0001	0.0001	<0.0001	<0.0001	0.0002
Nickel	<0.005	0.0110	<0.005	<0.005	<0.005
Zinc	0.0230	0.0100	0.0110	0.0320	0.0270

Notes: Measured by Atomic Absorption Spectrometry.

2.2.6 Radioisotopes

Several naturally occurring radioactive materials (NORMs) occur in PFW. The most abundant, because of their relatively long half lives, are radium-226 and radium-228 (^{226}Ra and ^{228}Ra). Radium is derived from the radioactive decay of uranium and thorium associated with certain rocks and clays in the hydrocarbon reservoir. The half-lives for ^{226}Ra and ^{228}Ra are 1,620 and 5.76 years, respectively. They decay through several intermediates to stable ^{207}Pb and ^{208}Pb, respectively. Typical total radium concentrations in PFW range from $0BqL^{-1}$ to $190BqL^{-1}$ (Neff, 2002).

2.2.7 Process Chemicals

Large numbers of speciality additives are available for use in the production system of a well to aid in recovery and pumping of hydrocarbons, protect the production system from corrosion and facilitate separation of oil, gas and water. The number of additives used in a particular production system is usually low and depends on the particular production problems encountered in the well. They could include:

- biocides;
- corrosion inhibitors;
- scale inhibitors;
- oxygen scavengers;
- demulsifiers;
- emulsifiers;
- coagulent/deoiler;
- flocculant;
- antifoam agent;
- dispersants;
- thinners;
- viscosifiers;
- surfactants/detergents; and
- hydrate inhibitors.

Three process chemicals will be added to the Blacktip system. These are:

- Corrosion Inhibitor;
- Methanol/Mono Ethylene Glycol; and
- Demulsifier/coagulant.

2.3 Fate of PFW in the Marine Environment

2.3.1 General

An understanding of the processes involved in changing the nature and behaviour of the individual compounds in PW is essential to predict their fate and impact. This section describes some of the processes that PFW undergoes when discharged to the ocean and introduces the mechanisms by which marine organisms bioaccumulate contaminants.

2.3.2 Degradation processes

Upon discharge contaminants in the PFW undergo a number of degradation or weathering processes, 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, weathering is a complex process and difficult to predict with accuracy. It may produce new chemicals or result in speciation of chemicals in the mixture to forms that are more bioavailable and toxic than the original chemicals. Therefore, it is possible that PFW may not lose 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.

Plume behaviour is unique to each platform, however, Burns, *et al*. (1999) provide an estimated mass balance (within 900m) for petroleum hydrocarbons discharged daily from Harriet ‘A’, a shallow water platform in 22m of water on the North West Shelf of Australia. They estimate that 37% of hydrocarbons are dissolved and 36% become attached to suspended particles (11% of which settle and 25% remain suspended). Dispersion, photodegradation and biodegradation accounts for 24% and evaporation just 3%.

For Blacktip, dilution is likely to be the most effective process for reducing the inorganic and organic contaminants. Evaporation will also be important for removing volatile components. In experiments, Flynn *et al*. (1996) demonstrated that sparging had little effects on volatile fatty acids, however, it removed some of the phenols (<50%) and over 90% of BTEX and PAH compounds. Toxicity did not reduce significantly, suggesting, for that particular sample, volatile compounds were not necessarily the most important in determining the overall toxicity of the PFW. 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. As dilution and biodegradation are the most important processes for Blacktip they are described in more detail in the following two subsections.

2.3.3 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. Slicks may also be discoloured and give rise to odour problems. The presence of petroleum hydrocarbons in the effluent can enhance slick formation. Once a dense slick has formed, mixing is inhibited and advection can transport the poorly diluted effluent to environmentally sensitive areas where it can exert an undesirable effect.

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.

Studies have shown that slick formation can be prevented with an initial dilution of 100:1. Saline PFWs dilute rapidly upon discharge to well-mixed marine waters. Smith (1993), Terrens and Tait (1993), Stromgren *et al*. (1995) and Brandsma and Smith (1996) all predict a rapid initial dilution of discharges by 30- to 100-fold within the first few tens of metres of the outfall, followed by a slower rate of dilution at greater distances. Mixing is less rapid for positively buoyant or for high volume discharges (see for example Smith *et al*., 1996).

In most marine environments, current speeds and directions are not constant as they are driven by a variety of forces such as tide, wind and regional circulations. Under these conditions, the distribution and concentration of a PFW plume is observed to be highly variable over time and space (see Smith *et al*., 1996; Terrens and Tait, 1996; King and McAllister, 1998).

2.3.4 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).

Biodegradation experiments performed by Stromgren *et al*. (1995) and Roe Utvik (1996) with PFW from the North Sea have provided valuable information about the marine environmental fate of some organic components of PFW. They showed that whilst low molecular weight aliphatic and aromatic hydrocarbons tend to evaporate rapidly from the PFW mixtures, many of the medium molecular weight aromatic hydrocarbons and phenols are biodegraded by indigenous microbiota in seawater. Higher molecular weight organic components, as well as heterocyclic compounds may be resistant to biodegradation and persistent in the plume. In the field, these compounds are lost primarily by dilution and adsorption on to suspended particles, particularly living and dead organic matter (Neff, 2002). Due to the differential rate of biodegradation the relative concentrations of the different hydrocarbons remaining in seawater after discharge will vary over time.

Experiments by Flynn *et al*.(1996) showed that after eight days, over 99% of phenols and PAHs were degraded, and BTEX was reduced to below detection limits. Toxicity, as measured by Microtox®, was also reduced from 8.6% PFW to 100% PFW, suggesting that the components responsible for the initial toxicity are readily biodegradable. Biodegradation rates for individual components in PFW are given in Johnsen *et al*. (2000) (see Table 2.10).

Table 2.10 Biodegradation rates for PFW compound groups (from Johnsen *et al*., 2000)

Group	Main Group	Biodegradation rate 1/2 life (days)
1	BTEX	0.5
2	Naphthalenes	1.5
3	PAH 2-3 ring	17
4	PAH 4-ring +	350
5	Alkyl phenols C0 – C3	1.2
6	Alkyl phenols C4+	10
7	Aliphatic hydrocarbons	60
8	Metals	None
10	Organic acids	Not included
11-n	Process Chemicals	Specific data

2.3.5 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 <1.5mgL^{-1} from background levels, the resulting impact on dissolved oxygen levels will be <0.5mgL^{-1} (CSTT, 1993). A change of 0.5mgL^{-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. For the current project a BOD value below 1.5mgL^{-1} is taken as the threshold below which there should be no adverse impact on oxygen concentrations.

2.3.6 Bioaccumulation mechanisms

Bioavailability

A contaminant can have no effect on an organism unless it is bioavailable, ie, 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.

Bioaccumulation

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 to its concentration in all ambient environmental compartments in equilibrium with the organism.

Bio-concentration

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. The BCF can also be measured as the ratio of the uptake rate constant or uptake clearance (k_1) to the release rate constant (k_2).

$$BCF = C_t/C_w = k_1/k_2$$

Non-polar (un-ionisable) organic compounds such as aromatic hydrocarbons generally have a low aqueous solubility and a high lipid solubility. According to equilibrium partitioning theory, when an animal is exposed to a non-polar organic chemical dissolved in ambient water, the chemical partitions into tissue lipids until an equilibrium, approximated by the octanol/water partition coefficient (K_{ow}), for the chemical is reached. It is possible to predict the equilibrium BCF for a particular non-polar organic compound from its log K_{ow}, (if underlying assumptions are met) as follows:

$$\text{Log } BCF = a \log K_{ow} + b$$

EPA (1991) recommends using a = 0.79 and b = -0.4, from the experiments of Veith and Kosian (1983). This provides a conservative estimate of the potential for bio-concentration of non-polar organic chemicals. The BCF for polar (ionisable) compounds, such as phenols, is generally higher if ionised, however, their behaviour will be similar to un-ionisable organic chemicals if they remain un-ionised at the pH and salinity of seawater.

Bioaccumulation of metals by marine organisms is more complex than for organic chemicals. Concentrations of heavy metals in Blacktip PFW should be low and therefore bioaccumulation of this class of chemical is not considered to be an issue.

Trophic Transfer

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 (BF) can be defined as the ratio of the concentration of a contaminant in the tissues of the consumer to its concentration in the food.

2.4 Environmental Fate of Individual PFW components

2.4.1 General

This section described how the individual components described previously behave when discharged to the marine environment.

2.4.2 Oil compounds

Dissolved Oil

Dissolved oil in PFW (predominantly aliphatics, BTEX, low molecular weight PAHs and phenols) will dilute readily into the receiving water and be dispersed by the ambient currents. These compounds are bioavailable to marine organisms and will biodegrade rapidly. While they may bioaccumulate at lower trophic levels, vertebrates including fish have detoxification mechanisms that break hydrocarbon compounds down. They are also volatile and will evaporate if they reach the sea water surface and come into contact with the atmosphere. They do not adsorb strongly to suspended particles so are unlikely to be transported to the sea bed.

Dispersed Oil

Oil compounds associated with oil droplets will either follow the plume or be retained at certain depths in the water column depending upon their buoyancy and turbulence. Vertical turbulence generated by wind shear and wave action will mix oil droplets with diameters less than about 100µm into the water column. These smaller droplets tend to float back to the surface only very slowly where they are repeatedly forced back into the water column. In this case, they are considered to be permanently dispersed. Larger oil droplets remain at the sea surface where they will spread to form a thin micro-layer (sheen) that in calm water is typically less than 1µm thick. The micro layer is then splintered and dissipated through evaporation and surface turbulence. Surface turbulence breaks the micro-layer into smaller sized droplets which causes dispersal through the water column. Once hydrocarbons have been dispersed into the water column as fine droplets they may be removed through adsorption to particles followed by sedimentation and biodegradation, as described above.

Polycyclic Aromatic Hydrocarbons

Overview

PAHs are the petroleum hydrocarbon of greatest environmental concern in PFW because of their toxicity and persistence in the marine environment (Neff, 1987). The wide range of solubilities and partition coefficients exhibited by the different PAHs means that they exhibit a wide spectrum of behaviour (Neff, 2002). The most common PAHs (naphthalene, alkylnaphthalenes, fluorene and phenanthrene) are soluble and have relatively high Henry's law constants and tend to evaporate where possible from the water. Higher molecular weight PAHs are less soluble and are expected to be associated with particulates and the oil droplets in the PFW. These will partition primarily between the aqueous and solid (particulate) or colloidal phases according to their organic carbon/water partition coefficients (K_{oc}s), which are proportional to K_{ow}s. Biodegradation half lives range from readily to poorly biodegradable and vary from 1.5 days for naphthalene, 17 days for two to three ring PAHs and 350 days for more than four ring PAHs (Johnsen, *et al.*, 2000).

Bioaccumulation

The PAHs in PFW may bioaccumulate and cause adverse biological effects in marine organisms near offshore oil and gas production platforms (Neff, 2002). Ordinarily, the concentrations of PAHs in receiving waters in deep offshore areas are low enough due to the rapidly diluting PFW plume to prevent bioaccumulation. In contrast, discharges to shallow, poorly mixed coastal waters may not dilute rapidly enough and marine organisms may bioaccumulate PAHs to potentially harmful concentrations.

Burns and Codi (1999) measured PAH concentrations in the water column around a platform in 22m of water on the North West Shelf of Australia. Concentrations were highly variable reflecting the variability of PAH concentrations in the PFW and the complex nature of the current regime in the area.

Typical water concentrations of naphthalenes and PAHs at 10m depth and at different distances from an oil production platform are shown in Table 2.11 (from OGP, 2002). These were calculated from mussel residue and converted to water concentrations as described in Roe Utvik *et al*. (1999). The results confirm the high dilution rates, however, they are point measurements and do not provide a complete description of fate and behaviour. Comparisons of these results with predictions from the DREAM (Dose related Risk and Effect Assessment Model) model are generally favourable, supporting and justifying the application of models for regional evaluation of PFW (OGP, 2002). The DREAM model is a random walk, particle tracking model based on the same principle as that used in the present study and described in Section 4.3.3.

Table 2.11 Water column concentrations of naphthalenes and PAHs at different distances from an oil production platform in the Norwegian Sector of the North Sea

	Concentrations (μgL^{-1})			
	In PFW	**At 500 m**	**At 2,000 m**	**At 10,000 m**
Naphthalene	1200	0.04	0.013	0.007
PAHs	33	0.004	0.001	0.0004

2.4.3 Organic acids

Organic acids biodegrade rapidly in the ambient sea water and so are unlikely to be important contributors to toxicity of PFW in the ambient environment (Neff, 2002). However, many studies attribute the acute toxicity of PFW to organic acid concentrations (eg. DK, 2001). These studies use ecotoxicology results from freshwater species which have high toxicity values. These high values are likely to be due to a pH effect rather than the actual toxic effect of the compound. Natural seawater is a buffer solution and acidity will be quickly neutralised. Organic acids are therefore not considered to be toxic in the marine environment.

2.4.4 Heavy metals

The heavy metals associated with PFW are usually present as dissolved mineral salts. Reservoir water is anoxic and the metal ions are typically in low oxidation states. However, when brought to the surface and exposed to the atmosphere they oxidise. The metal oxides then combine with anions such as sulphides, carbonates and chlorides and form insoluble precipitates. Heavy metal concentrations are generally low in PFW. Dilution in the receiving environment reduces them to background levels and well below chronic toxic thresholds. When they form precipitates, there is the potential for build up in the sediments, however, the quantity will be so low and the spread across the sea bed so wide that the environmental impact will be insignificant.

2.4.5 Radioisotopes

Upon discharge of PFW to the ocean, radium is rapidly co-precipitated with barium sulphate. Radium concentrations in ambient water near PFW discharges are rarely higher than background levels. Toxic concentrations are well above the saturation concentrations of radium in sulphate-rich seawater. Marine animals are highly tolerant to low-level radiation as might occur in the traces of radium isotopes in the vicinity of PFW discharges. Radium, because of its low concentrations in solution in seawater, has a low bioavailability to marine organisms. There is also no evidence that radium accumulates in sediments or marine animals (molluscs, crabs and fish) living in the vicinity of offshore PFW discharges (Neff, 2002).

The Brookhaven National Laboratory performed a human health risk assessment for radium in PFW discharged to the northwestern Gulf of Mexico. It concluded that radium in PFW represents a minimal risk to even the most sensitive workers (platform crew and recreational fishermen) who consume fish from the vicinity of PFW discharges (Brookhaven National Laboratory (1992) in Neff (2002)).

2.4.6 Process Chemicals

General

The impact of process chemicals depends on the concentration at which they are discharged and the breakdown characteristics of the chemical. The initial dosage concentration range is specified by the chemical supplier and then fine-tuned by the operator to achieve optimum performance of the chemical in combination with other chemicals and the oil.

Many of these chemicals are more soluble in the oil than in PFW and remain in the oil phase. Others are water soluble and concentrate in the PFW and are disposed with it. The point in the production stream where the chemical is added influences the amount that may be discharged in the PFW. The fraction of chemical released into the water phase (*f*) can be estimated from the octanol/water partition coefficient (K_{ow}) as follows:

$$f = \frac{1}{(1 + K_{ow})\left(P_o / P_{PFW}\right)}$$

where, P_o is the total oil production and P_{PFW} is the total PFW production. The concentration of the process chemical in the PFW (C_w) can then be expressed as:

$$C_w = (C_d f) - (C_d r)$$

where, C_d is the dosage concentration and *r* is the fraction that reacts during the production process.

Due to the variability in the characteristics of the oil and the production process, the Oslo and Paris Commission (OSPAR) use a conservative formula for determining the concentration of a chemical discharged with the PFW. Reaction during the production process is ignored and a safety factor of 10% is applied so that the concentration in the discharge is now given by:

$$C_w = (C_d f) + (0.1 C_d)$$

For process chemicals not on the Pollution control Authority A list, OSPAR require ecotoxicity data on the whole product. Testing should be undertaken on marine organisms, including an alga and a crustacean.

As stated in Section 2.2.7, the process chemicals that will be added to Blacktip are:

- Corrosion Inhibitor;
- Methanol/Mono Ethylene Glycol; and
- Demulsifier/coagulant.

Corrosion Inhibitor

Corosion inhibitor will be added to the produced fluids in order to protect the production system from corrosion. Table 2.12 provides a list of corrosion inhibitors recommended from a detailed study aimed at selecting environmentally acceptable chemicals for Blacktip (de Reus, 2004).

Table 2.12 also includes their dose rate and hazard quotient (HQ) for each chemical. The hazard quotient, calculated using the CHARM model, provides an indication of the likelihood of adverse effects occurring due to the use and discharge of the chemical under a realistic worst-case scenario. An environmental effect can be expected if the HQ is greater than one. As can be seen from Table 2.12 the HQ ranges from 0.045 to 0.977. All four chemicals are therefore environmentally acceptable.

Table 2.12 Recommended Corrosion Inhibitor chemicals

Supplier	Inhibitor	Dose rate (L/day)	HQ (hazard quotient)
Baker Petrolite	CRW-85155	50	0.977
Champion-Servo	CK-981	25	0.239
Champion-Servo	CK-988	100	0.045
Nalco	EC-1440A	50	0.130

Methanol/Mono Ethylene Glycol;

Methanol will be injected upstream of the chokes on the offshore platform to prevent hydrate formation on cold start-ups. The injection rate will be around 20-40 Lhr^{-1} for a short duration (hours).

Methanol (or possibly Mono Ethylene Glycol) may also be injected at the onshore plant in the gas processing facility for hydrate control. This would likely be injected only occasionally upstream of the Low Temperature Separator (LTS) and so some will remain in the liquid leaving the LTS and end up in the condensate processing train, and therefore the water treatment process.

Methanol is miscible in water, non-carcinogenic and poses little long term risk to the environment. It is, however, a strong reducing agent and, in the short term, has the potential for depleting oxygen in the receiving waters. This will contribute to the BOD discussed in Section 2.3.5.

Demulsifie/coagulant.

Demulsifier/coagulant will be injected in the water treatment facility to aid in the operation of the gas flotation unit. Most, if not all, of this will be removed as skimmings from the unit and will therefore not enter the PFW.

Both the corrosion inhibitor and the methanol are water soluble so the majority of these additives will end up in the PFW discharge. On discharge to the marine environment, dilution will be the main factor reducing concentrations.

2.5 Assessing Environmental Effects and Risks

2.5.1 General

An effect on an organism is a measurable biological response which reduces its survival or reproductive capacity. A sustained widespread effect may alter the ability of a population or a community to persist. The ecological significance of an effect may be considered in terms of the magnitude and nature of the change induced at individual, population, community or higher trophic levels. The social and economic significance of effect can be considered in terms of impact on recreational or commercial fishing, tourism, conservation values and the benefit to the community of the petroleum industry (Cobby, 2002).

2.5.2 Toxicity

Toxicity depends on the chemical compounds present, the exposure duration (acute or chronic), the organisms impacted and the environmental compartment. Most hydrocarbons are considered non-specific narcotic toxins and their toxicity depends on attainment of a critical volume or concentration in the tissues of aquatic organisms (Neff, 2002). The toxicity of hydrocarbons in mixtures is additive, so the toxicities of a complex mixture depends on the total concentration of bioavailable hydrocarbons and degradation products in the water to which aquatic organisms are exposed.

Acutely toxic responses have a sudden onset after or during relatively high exposure, usually for short durations: within four days for fish and macroinvertebrates and shorter times (two days) for organisms with shorter life spans. The response may be lethal or sub-lethal. Examples of sublethal effects include: impairment of feeding mechanisms, growth rates, development rates, energetics, reproductive output, recruitment rates and increased susceptibility to disease and other histopathological disorders. Early development stages can be especially vulnerable to hydrocarbon exposure, and recruitment failure in chronically contaminated habitats may be related to direct toxic effects of hydrocarbon contaminated sediment.

In contrast, chronic responses involve endpoints that are realised over a relatively long period of time, often one-tenth of the life span of an organism or more. A chronic toxic response is usually characterised by slow toxic progress and long continuance and may be measured in terms of reduced growth, reproduction or fertilisation at different life stages, in addition to lethality.

Toxic concentrations are standardised as median lethal concentration (LC50s) for lethal responses or median effect concentration (EC50s) and median inhibition concentration (IC50s) for non-lethal response. Definitions for these terms are as follows:

LC50 The toxicant concentration killing 50% of exposed organisms at a specific time of observation.

EC50 The toxicant concentration estimated to cause a specified effect in 50% of exposed organisms at a specific time of observation.

IC50 The toxicant concentration estimated to cause a specified inhibition (eg. growth) in 50% of exposed organisms at a specific time of observation.

PFW from oil and gas wells vary widely in composition and toxicity to freshwater and marine organisms, confounding the development of generalisations about the causes of toxicity (Neff, 2002). This uniqueness makes it necessary to undertake site specific studies. In estimating the risk of PFW to marine organisms and ecosystems in the receiving water environment there are two different approaches:

- whole effluent toxicity (WET) testing; and
- individual component toxicity testing.

Whole Effluent Toxicity Testing

General

As its name suggests, WET testing involves undertaking ecotoxicological tests on the whole PFW sample. This method represents a toxicity value for the PFW prior to discharge to the ocean. It has the advantage that it is directly relevant to the effluent that is being discharged and it takes into consideration all chemicals in the PFW and any synergy or antagonism between them. The disadvantage is that degradation rates in the environment are unknown and are difficult to determine.

Worldwide toxicity data

Stephenson *et al*. (1994) have summarised marine and toxicity data for a large number of marine and freshwater organisms and PFW from throughout the world, particularly the North Sea (Table 2.13). Due to the extreme variability in chemical composition and toxicities of the PFW from different sources, no consistent trends between taxa and sensitivity to PFW emerge.

Table 2.13. Summary of the acute, sublethal and chronic toxicity of PFW from throughout the world to different taxa of marine and freshwater organisms (from Neff, 2002)

Taxon	Species	Test Endpoint	Test Duration (days)	EC50/LC50 (%PFW)
Algae	*Phaeodactylum tricornutum*	Growth	4	0.09 – 3.6
	Skeletonema costatum	Growth	2	4.5 – 67.6
			3	1.0 – 42.5
Coelenterates	*Campanularia flexuosa*	Growth	10	5.0
Bivalve Molluscs	*Crassostrea gigas* larvae	Mortality	2	5.0
	Mytilus californianus larvae	Shell formation	2	2.1
	Donax faba adults	Mortality	4	0.02 – 15.3
Polychaetes	*Neannthes arenaceodentata*	Mortality	4	18.1 – 28.6
Copepods	*Tisbe holothuriae*	Mortality	4	35.7 – 66.7
	Calanus finmarchicus	Mortality	1	10.0
	Arcatia tonsa	Mortality	2	2.0 – 18.0
		Reproduction	20	0.3 – 5.0
		Immobility	4	2.0
Amphipods	*Allorchestes compressa*	Mortality	4	29.4 - >100
	Chaetogammarus marinus	Mortality	4	0.2 – 3.2
Shrimp	*Penaeus aztecus* larvae	Mortality	2	0.8 – 1.2
	Penaeus aztecus juveniles	Mortality	4	6.0 – 18.3
	Penaeus aztecus adults	Mortality	4	7.8 – 17.8
	Penaeus setiferus adults	Mortality	4	7.0
	Crangon crangon adults	Mortality	1	2.0
Mysids	*Americamysis bahia*	Mortality	4	4.9 – 11.8
		Mortality	7	4.4 – 9.0
		Fecundity	7	0.7 – 7.0
Brine Shrimp	*Artemia salina*	Mortality	1	16.0 – 18.0
Barnacles	*Balanus tintinabulem*	Mortality	4	8.3
Echinoderms	*Strongylocentrotus Purpuratus gametes*	Fertilisation	1 hour	0.74 – 1.7
Fish	*Menidia beryllina* larvae	Mortality	4	>1.1 – 5.5
	Hypleurochilus germinatus	Mortality	4	15.8 – 40.8
	Cyprinodon variegaus	Mortality	4	7.2 – 60.0
		Mortality	7	3.7 - >28.0
	Poecilia reticulata	Mortality	4	0.75 – 42.3
	Oncorhynchus mykiss	Mortality	2	10.0

Acute and sublethal effect concentrations (as EC50 and LC50) of whole PFW ranges from 0.02% to more than 100%. Overall the most sensitive taxa appear to be marine algae, bivalve mollusc larvae, and various species of crustaceans, particularly larval forms. Among the crustaceans, mysids appear to be as or more sensitive than other crustacean species. Generally, fish are more tolerant to PFW than marine invertebrates.

North West Shelf and Timor Sea

Figure 2.1 summarises the ecotoxicology test results for NRA, GWA, CP, OL and NE (see IRCE, 2003a–e). Individual tests target toxicity of different components in the PFW, hence results, both between tests and facilities, are quite variable. For example, PFWs from NRA and CP are most toxic to the sea urchin fertilisation test whilst not so toxic to the acute prawn and chronic algae tests. In contrast, NE PFW is most toxic towards the prawn test and only moderately toxic to the sea urchin tests. GWA and OL show the most consistency across the suite of tests. In general, NRA PFW is consistently the most toxic. This is followed, in order of toxicity, by CP, OL, GWA and NE.

Both unfiltered and filtered samples from NRA and GWA were tested. The results showed little variation in toxicity. The filtered GWA sample was slightly less toxic for the sea urchin fertilisation, rock oyster larval development and algae growth inhibition tests, more toxic for the tiger prawn acute test and about the same for the sea urchin fertilisation test. These results are within experimental variability and it may be concluded that the dissolved component contributes most to the toxicity and that there would be only minor benefit in filtering the PFW prior to discharge.

Figure 2.2 summarises the Microtox® results. These tests exhibit significant sensitivity to the PFW and results correlate with the general trend shown by the more sophisticated tests, ie, NRA is the most toxic and Northern Endeavour being the least. Microtox® could therefore provide a useful and cost effective screening tool to monitor toxicity over time.

2.5.3 Risk Assessment

The ratio of the Predicted Environmental Concentration (PEC) to the Predicted No Effect Concentration (PNEC) (PEC/PNEC ratio) is an established technique to screen chemicals in offshore discharges (EC, 1996). It forms the basis of the OSPAR Harmonised Notification Scheme (OSPAR, 2000) and is used in the EIF tool (Johnsen *et al*., 2000). The PNEC is derived from ecotoxicity data and is the concentration below which it is believed there will be no detrimental effect on the environment. It 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, such as that used in the present study (see Section 4.3.3), provide spatially and temporally varying PECs for either the whole effluent or individual compounds. A PFW plume with a PEC/PNEC ratio of one will generally correspond to a probability of 5% that biota will be affected. In the EIF method, the combined risk of simultaneous exposure to a mixture of chemicals like PFW, is estimated by statistical summation of the risks for individual chemicals.

Figure 2.1 Ecotoxicology results for WEL's North West Shelf and Timor Sea Assets (from IRCE, 2003a-e)

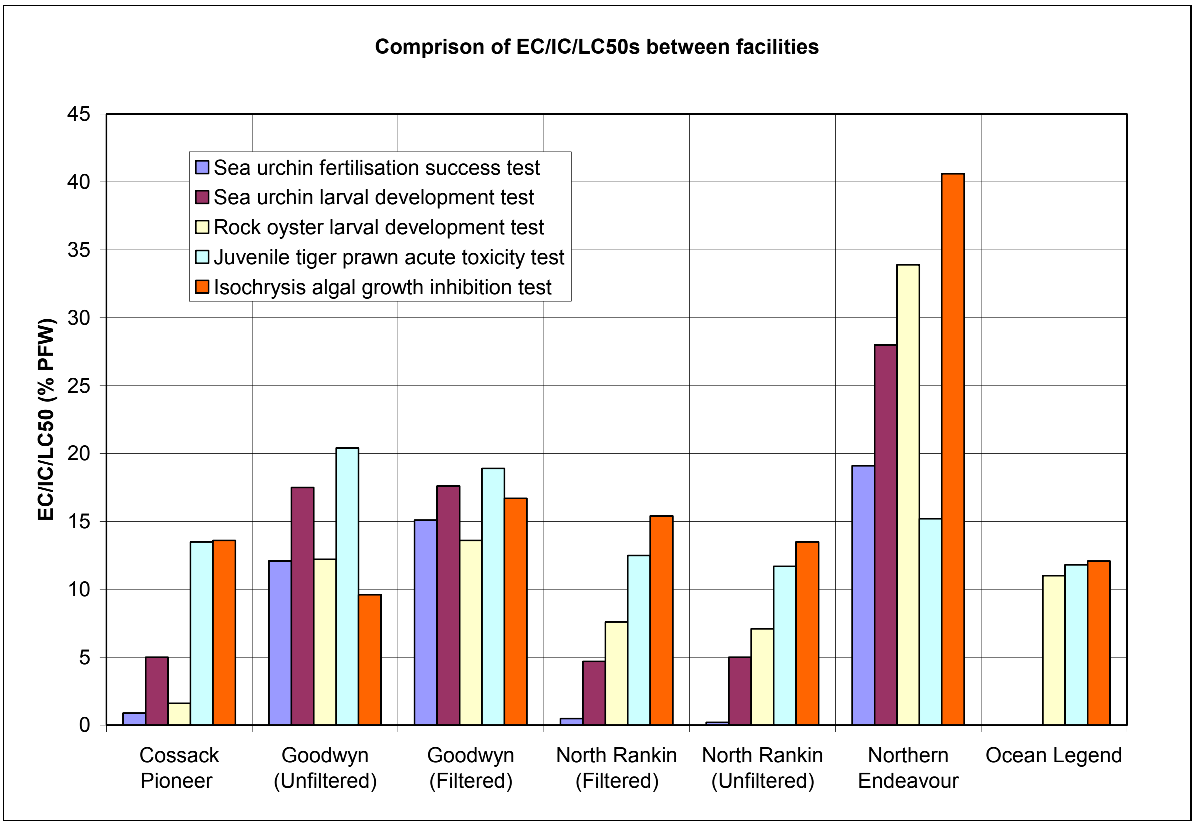
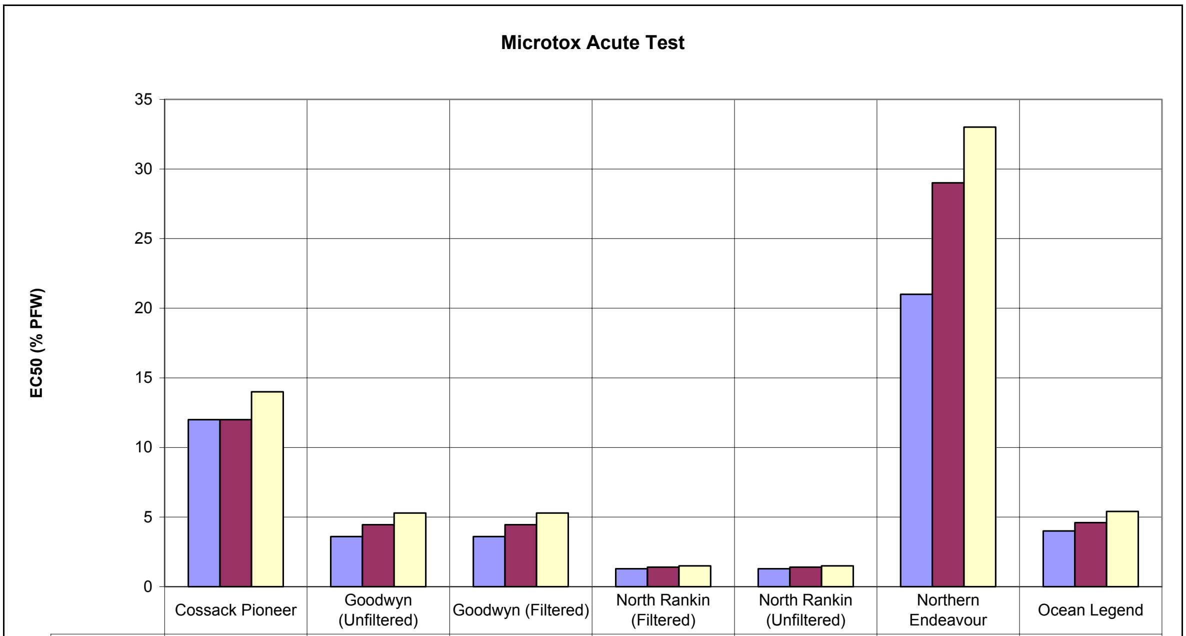


Figure 2.2 Comparison of Microtox® test results between facilities (from IRCE, 2003a-e)



	Cossack Pioneer	Goodwyn (Unfiltered)	Goodwyn (Filtered)	North Rankin (Filtered)	North Rankin (Unfiltered)	Northern Endeavour	Ocean Legend
EC50 5min	12	3.6	3.6	1.3	1.3	21	4
EC50 15min	12	4.5	4.5	1.4	1.4	29	4.6
EC50 30min	14	5.3	5.3	1.5	1.5	33	5.4

If spatial scale of the effect is limited to the immediate area around an offshore facility and the significance of the effect is considered to be low, then the risk is likely to be acceptable (Terrens and Tait, 1996). Conversely, if the spatial scale of the effect is widespread and the survival or reproductive capacity of marine organisms is significantly reduced then the risk is likely to be considered unacceptable. Where there are unacceptable risks, management actions to reduce risk to acceptable levels would be required.

2.6 Observations of Exposure and Effect

Bioaccumulation studies

Any assessment of PFW effects and risks should consider acute and chronic effects as a production facility may have an operating life of up to 25 years or more. Chronic effects are notoriously difficult to measure in the natural environment. The Offshore Operators Committee (1997) reported that there have been no field observations of bioaccumulation in marine organisms living naturally in the vicinity of offshore oil and gas facilities in the Gulf of Mexico. This lead to conclusions that exposure times to PFW concentrations above chronic toxicity levels is short.

In contrast, monitoring programmes in the Norwegian sector of the North Sea using caged mussels deliberately moored in the path of a PFW plume reveal elevated (compared to background) concentrations of PAHs in mussel tissue (Johnsen *et al*., 1998 and Roe Utvik *et al*., 1999). Burns and Codi (1999) also present results from caged oyster studies that show bioaccumulation. It is therefore possible for marine organisms to bioaccumulate particular chemical from PFW, however, it is uncommon in freely living organisms due to the intermittent nature of their exposure (see Section 4.3.8 for a further discussion).

Biochemical Marker Studies

An alternative to measuring bioaccumulation in marine organisms is to measure the biological response induced by contaminants using biochemical markers (biomarkers) (Cobby, 2002). As suggested in Section 2.3.6, an organism may be exposed to a contaminant but it will not necessarily be adversely affected. Table 2.14 provides a summary of biomarker tools, contaminant triggers, indicator type, mechanism and ecological relevance (see Cobby (2002) for further information). These biological responses or biomarkers are direct indicators of exposure or effect and provide environmental managers with an early warning system for identifying exposure and any adverse environmental effects.

Table 2.14 Summary of biomarker tools, contaminant triggers, indicator type, mechanism and ecological relevance (from Cobby, 2002)

Biomarkers	Triggers	Indicators	Mechanism	Ecological relevance
Mixed Function Oxygenase (MFO)	Petroleum hydrocarbons	Indicator of exposure	Initial step of detoxification process to eliminate contaminant out of the body.	Correlation with reduced reproductive success. Production of PAH metabolites is related to onset of cancer in fish.
Bile metabolites	Hydrocarbons (naphthalene, pyrene)	Indicator of exposure	Final steps of the elimination of hydrocarbons. After metabolites are made water soluble they are directed to the bile for elimination.	Production of PAH metabolites is related to onset of cancer in fish. PAH metabolites may be more biologically active than parent compounds and cause genetic damage.
DNA damage	Any biological active contaminant	Indicator of effect	Contaminant integrates itself into DNA molecule causing damage to the integrity of the DNA molecule. This causes incorrect synthesis of proteins, enzymes etc.	Damaged DNA can result in no viable eggs, malformed larvae, reduced reproductive success, biochemical imbalances in living organisms, cancers etc.
Sorbital dehydrogenase (SDH)	Hydrocarbons, Solvents, Hepatotoxic agents	Indicator of effect	SDH is normally present in the liver only. Its presence in the blood of an organism indicates liver damage.	Liver damage will affect vital functions including digestion, synthesis and regulation of production hormones, production of eggs by females, detoxification by MFO's.
Stress proteins	Any sustained or chronic mechanical or chemical stress	Indicator of effect	Stress causes higher levels of transcription errors during the synthesis of biomolecules. The role of stress protein is to repair transcription errors.	Any sustained stress (heat shock, acoustic disturbance, moulting, long term handling, exposure to chemicals) can induce stress proteins.

2.7 Regulatory Framework and International Best Practice for PFW Discharges

2.7.1 Australia

In Australia, the Petroleum (Submerged Land) Act (P(SL)A) Schedule of Specific Requirements for Offshore Petroleum Exploration and Production 1995 requires that PFW shall not be discharged into the sea unless approved by the Designated Authority (Clause 602 C and 616 (4)). Where approval is granted, the concentration of petroleum in any PFW:

- shall not exceed 50mgL^{-1} at any one time; and
- average less than 30mgL^{-1} during each 24 hour period.

The Schedule applies to both Commonwealth and State/Territory jurisdictions.

In addition, Regulation 13(3) of the Commonwealth Petroleum (Submerged Land)(Management of the Environment) Regulations 1999 (P(SL)(ME)R) states that operators are required to assess the environmental effects and risks associated with PFW discharge, as part of a petroleum activity.

As in most countries, the definition of "petroleum" is open to interpretation but is thought to refer to dispersed aliphatic hydrocarbons. Removal of polar compounds by filtering through Florisil (silica material) and nitrogen sparging is accepted practice. Measuring techniques vary but mostly in-line analysers are used (Sigrist, Horiba, Hach and Turner). Results are reported daily.

In Australia, guidelines for water quality are provided by the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000). These guidelines provide trigger values for various chemicals.

2.7.2 USA

The USEPA requires oil and grease concentrations in produced water to be monitored by EPA Method 413.1 or 1664A. Both methods are gravimetric. Non-polar and slightly polar organic matter in produced water is extracted with Freon (Method 413.1) or n-hexane (Method 1664A). In method 1664A, the analyst has the option to treat the hexane extract with silica gel to remove polar interfering compounds. The extract is dried and weighed to derive a concentration of total extractable organic matter (total oil and grease). It should be noted that in revision A of the method N-hexane extractable material is synonymous with "oil and grease", whilst applying silica gel (ie, Florisil) extracts the "non-polar material".

The discharge limits in the US varies depending on law in different States. In U.S. Federal waters and state waters of Upper Cook Inlet, Alaska, the current limit for total oil and grease (defined as dispersed and dissolved oil as measured by gravimetric or infrared analysis) in treated PFW is:

- 42mgL^{-1} daily maximum; and
- 29mgL^{-1} monthly average.

Discharge of PFW to estuarine and coastal waters is not permitted. Permits for the Gulf of Mexico prohibit discharge of more than 4,000m^3 per day of PFW from a single platform.

Since it is a generally realised fact that Infrared (IR) Absorption based methods are simpler, faster, cheaper and less labour intensive than gravimetric, the USEPA and American Society for Testing Materials (ASTM) have initiated a study with focus to develop a stand alone infrared absorption method replacing Freon as solvent.

2.7.3 OSPAR Signatory States

The OSPAR Convention is the basis for national laws governing the discharge of offshore wastes in the northeast Atlantic and covers the following countries: Belgium, Denmark, Faeroe Islands, Finland, France, Germany, Iceland, Ireland, the Netherlands, Norway, Portugal, Spain, Sweden and the United Kingdom of Great Britain and Northern Ireland. Under OSPAR, the regulatory limit for total oil and grease in PFW discharged to the waters of the northeast Atlantic is 40mgL^{-1} averaged over a month (Ray, 1996). The United Kingdom Offshore Operators Association (UKOOA) have adopted a voluntary standard of 30mgL^{-1}.

'Oil and grease' refers to the free (liquid phase) dispersed hydrocarbons. This is indicative of the origin of concerns of oil pollution at sea. This origin is from shipping-derived oil spills where the impact is from oil as a gross, smothering, 'physical' contaminant, responsible for damage to seabirds and other wildlife and contamination of beaches and coastal amenities. In contrast, the oil in PFW is a low concentration 'chemical' pollutant (soluble as a fine stable dispersion), which rarely appears as a visible contaminant. Effects, if any, are likely to be at tissue level and not at gross physical level as in the case of oil spills (Genesis, 2000).

In recognition of this, it is likely that in the future, changes will be made to regulations to account for:

- soluble and dispersed hydrocarbons;
- polycyclic aromatic hydrocarbons (PAHs);
- heavy metals;
- process chemical residues; and
- radioactivity.

2.7.4 Other Areas

The regulatory limit for total oil and grease in PFW discharged to most offshore waters of the Mediterranean, the Arabian Gulf and Asia is 40mgL^{-1}(Ray, 1996).

2.8 International Best Practice

It is common practice throughout the offshore industry to treat the PFW to below the regulatory limit and then to dispose to the ocean. Alternatives for PFW disposal include: piping to shore for onshore disposal; reinjection and down hole separation (Johnsen *et al*., 2000). There is also a move towards achieving zero environmentally harmful discharge. In Norway, for example, the government is requiring the oil industry operating in the Norwegian sector of the North Sea to develop a strategy for reaching this objective for PFW by 2005 (Frost *et al*. 2002). The Russian government also requires minimal discharges for the new Sakhalin Shelf oil and gas fields.

2.9 Treatment Technology

A detailed description of treatment technologies for PFW is beyond the scope of this review. The reader is referred to OGP (2002) for a useful introduction to technologies presently available. The summary of chemical removal capabilities for each technology is reproduced here in Table 2.15.

All of the technologies are capable of removing the dispersed oil fraction, with the actual performance being dependant on the fluid properties and process conditions. As a result of the removal of the dispersed oil droplets, an associated reduction in PAH concentrations is to be expected. Physical and enhanced separation techniques do not remove dissolved BTEX, NPD or PAHs, however, the new technologies are capable of removing at least some or all of these compounds. The advantages and disadvantages of each technique are given in OGP (2002).

2.10 Summary

PFWs are known to contain a number of chemical components that have potential to cause chronic effects in the marine environment. These include heavy metals, MAHs and PAHs. Although toxic effects have been demonstrated in the laboratory, no effects on species living naturally in the environment have been observed in the field. However, most studies recognise that the measurement of sub-lethal effects in the natural environment is difficult because of the nature of the species at risk and the presence of contaminants from other sources.

Each PFW is unique in its chemical composition confounding the development of generalities about the cause of toxicity. The high dilution received by PFW is believed to reduce PFW concentrations in the receiving environment to levels below toxic thresholds very quickly. PAHs are the petroleum hydrocarbon of greatest environmental concern in PFW because of their toxicity and persistence in the marine environment.

Although only small concentrations of contaminants are released, the continuous discharge of large volumes gives rise to environmental concern. Accordingly, most of the regulatory authorities from international to regional levels set limits on the concentration of petroleum hydrocarbons that can remain in PFW for ocean disposal. Oil is not a single substance but a very wide range of hydrocarbons substances, both in solution and dispersion. The component targeted by the regulation is dictated by the method used to measure the oil-in-water content, which up until recently has been the free (liquid phase) dispersed hydrocarbons. This is not the most toxic component, which is the dissolved phase. The regulations do not tend to consider the loading to the environment either. Operators in Australia are now required to assess the environmental effects and risks of PFW discharged to the ocean as well as to meet standard regulatory limits. There are moves in OSPAR signatory states to change regulation to legislate on the more relevant toxic components of PFW.

Table 2.15 Current PFW treatment technologies

Technology	**Removal Capability**			
	Dispersed oil	**BTEX**	**NPD**	**Other PAHs**
Physical separation				
Flotation	Yes	No	No	Some
Sparging	Yes	No	No	Some
Coalescence	Yes	No	No	Some
Enhanced separation				
Hydrocyclones	Yes	No	No	Some
Hydrocyclones + coalescence (Pect-F, Mare's Tail)	Yes	No	No	Some
Centrifuges	Yes	No	No	Some
Alternative (new) technology				
Absorption (polymers, MPPE, clays)	Yes	Yes	Yes	Yes
Adsorption (carbon, natural fibres)	Yes	Yes	?	?
Hydrocyclones + solvent extraction (C-Tour)	Yes	No	Yes	Yes
Membranes	Yes	Yes	Yes	Yes
Steam stripping	No	Yes	No	No
Biological (aerobic degradation)	Yes	Yes	?	?
Produced Water Reinjection	Yes	Yes	Yes	Yes

3 JOSEPH BONAPARTE GULF RECEIVING ENVIRONMENT

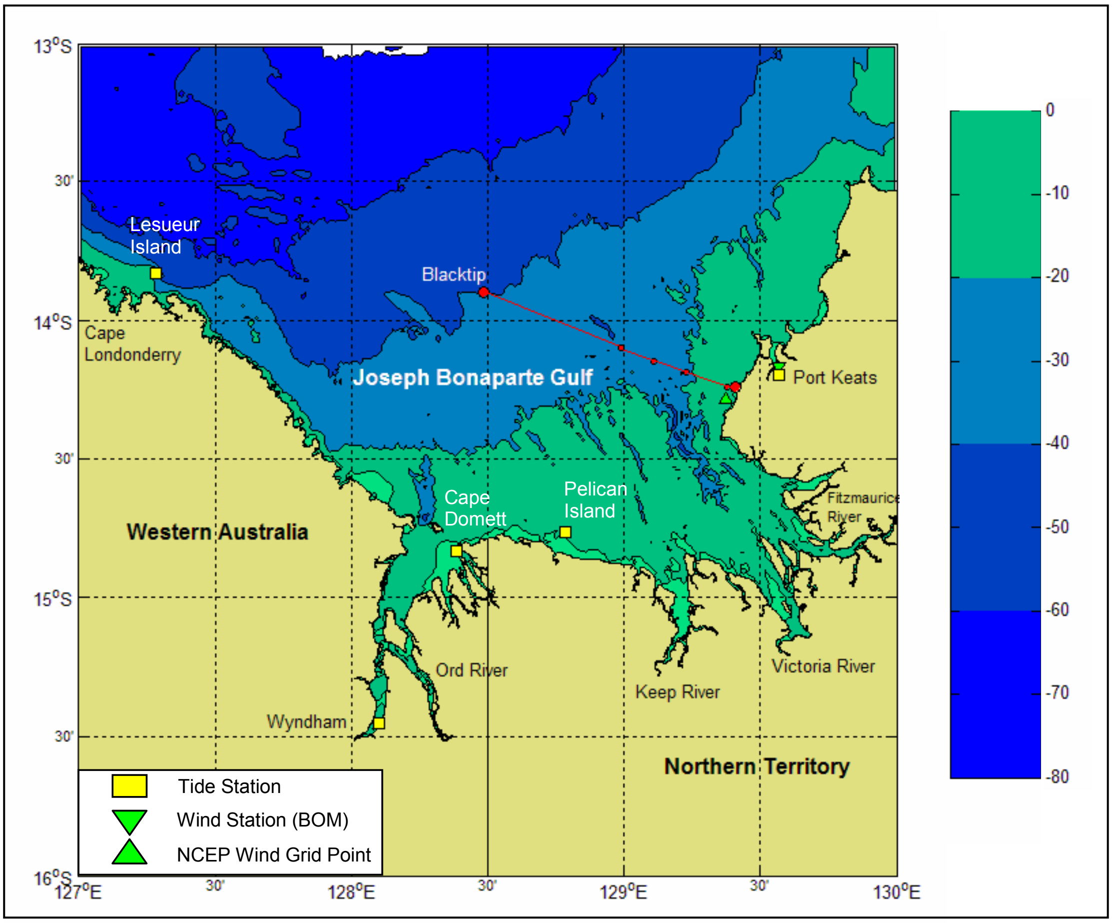
3.1 General

Joseph Bonaparte Gulf is a large embayment on the northwestern continental margin of Australia (Figure 3.1). It is approximately 300km east-west and 120km 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 560km. Several large rivers enter the gulf along its shoreline.

3.2 Bathymetry

The offshore facility is located on the Sahul Shelf in 50m of water (Figure 3.1). Depths along the pipeline route generally decrease shoreward. There are no reefs or emergent banks along the pipeline route although it does pass through a dune field in the nearshore region.

Figure 3.1 The Joseph Bonaparte Gulf



3.3 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 3.2(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 3.2(b) illustrates the typical atmospheric circulation for the dry season.

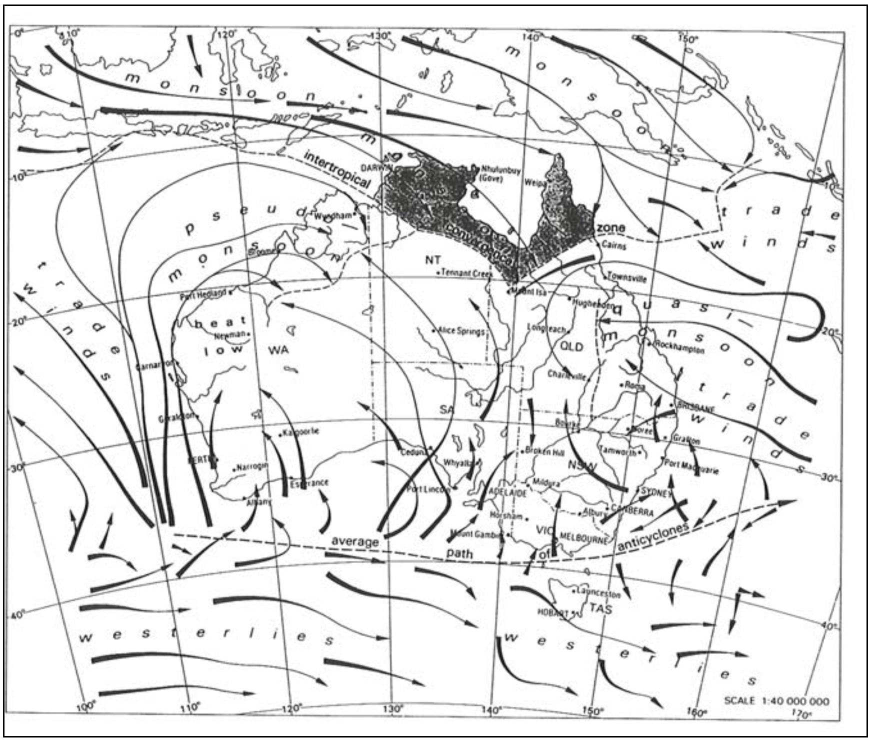
Mean daily maximum temperatures for Port Keats range from about 30 to 34°C, and minima from 14.5°C to 25°C. Annual rainfall is 750 to 900mm. Almost all rainfall occurs between November and April, the greatest falls being in January and February. The frequency and severity of the thunderstorms produce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

3.4 Winds

Monthly wind roses for Port Keats are shown in Figure 3.3. 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.

Figure 3.2 Generalised atmospheric circulation over Australia in Winter (July) and Summer (January) (from Swan *et al*., 1994)

(a) Summer



(b) Winter

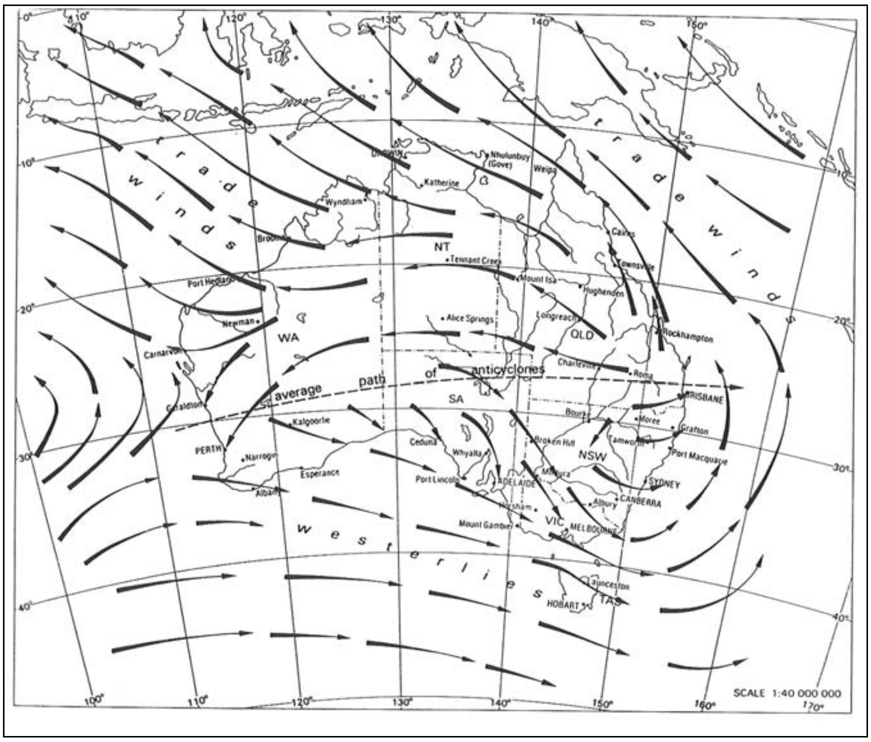


Figure 3.3 Monthly wind roses for Port Keats (2000 -2003)

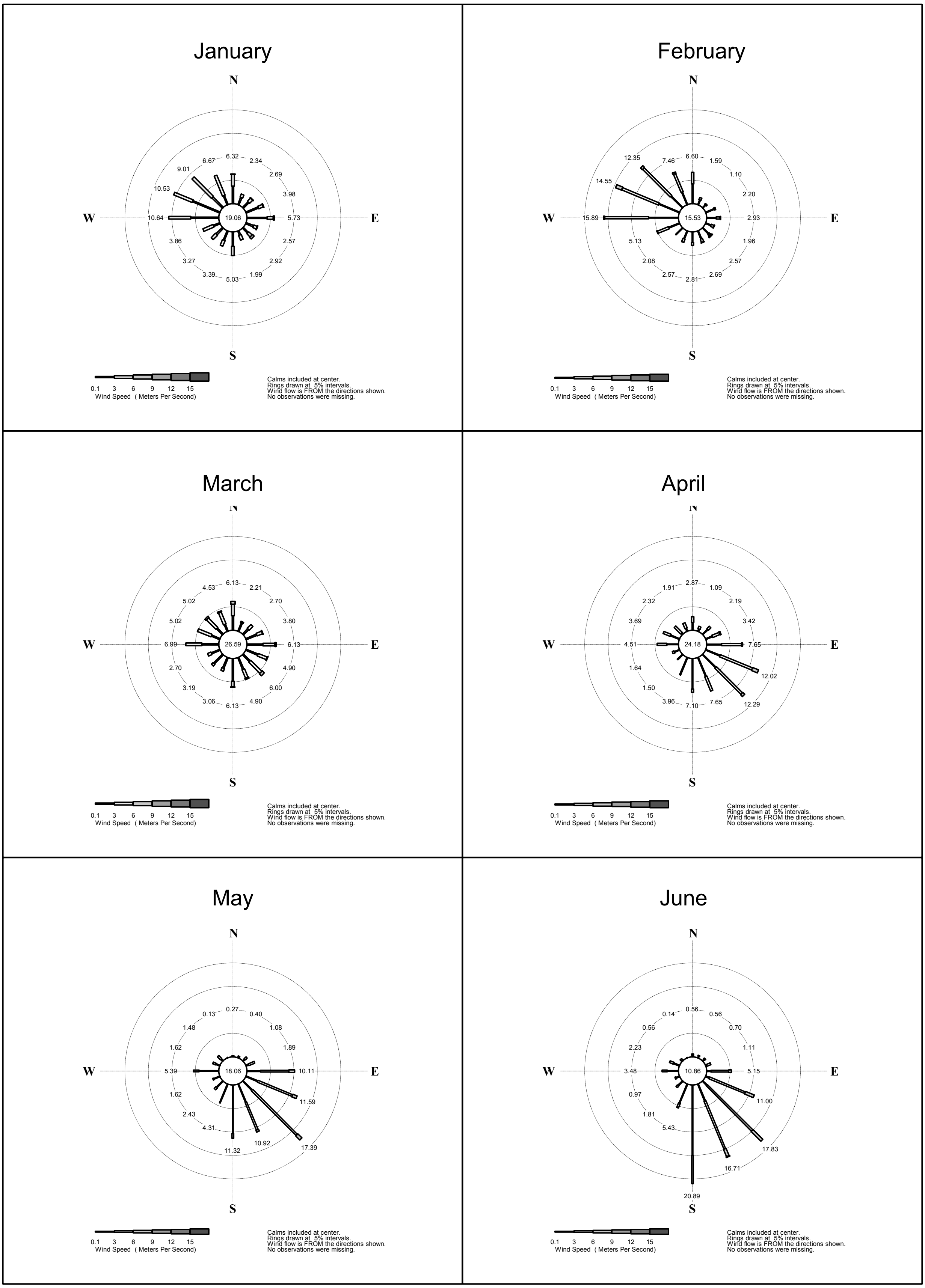


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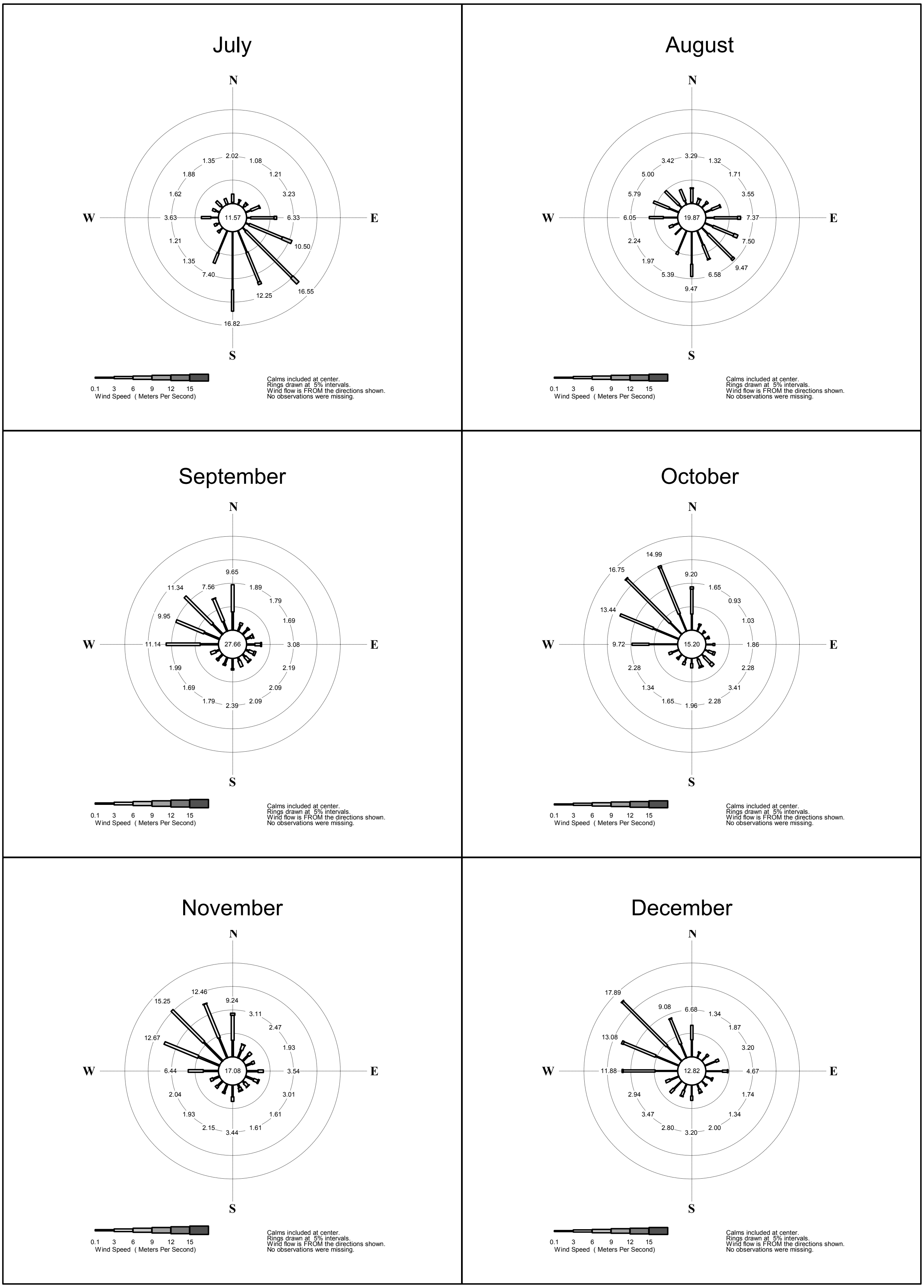
Figure 4.3 (cont.)



3.5 Oceanography

3.5.1 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 8m 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 3.4 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 3.1 provides the standard levels for Port Keats. Highest Astronomical Tide (HAT) exceeds 8m and the mean ranges for spring and neap tides are 5.6m and 1.9m, respectively. Tidal ranges will reduce offshore towards the Blacktip facility.

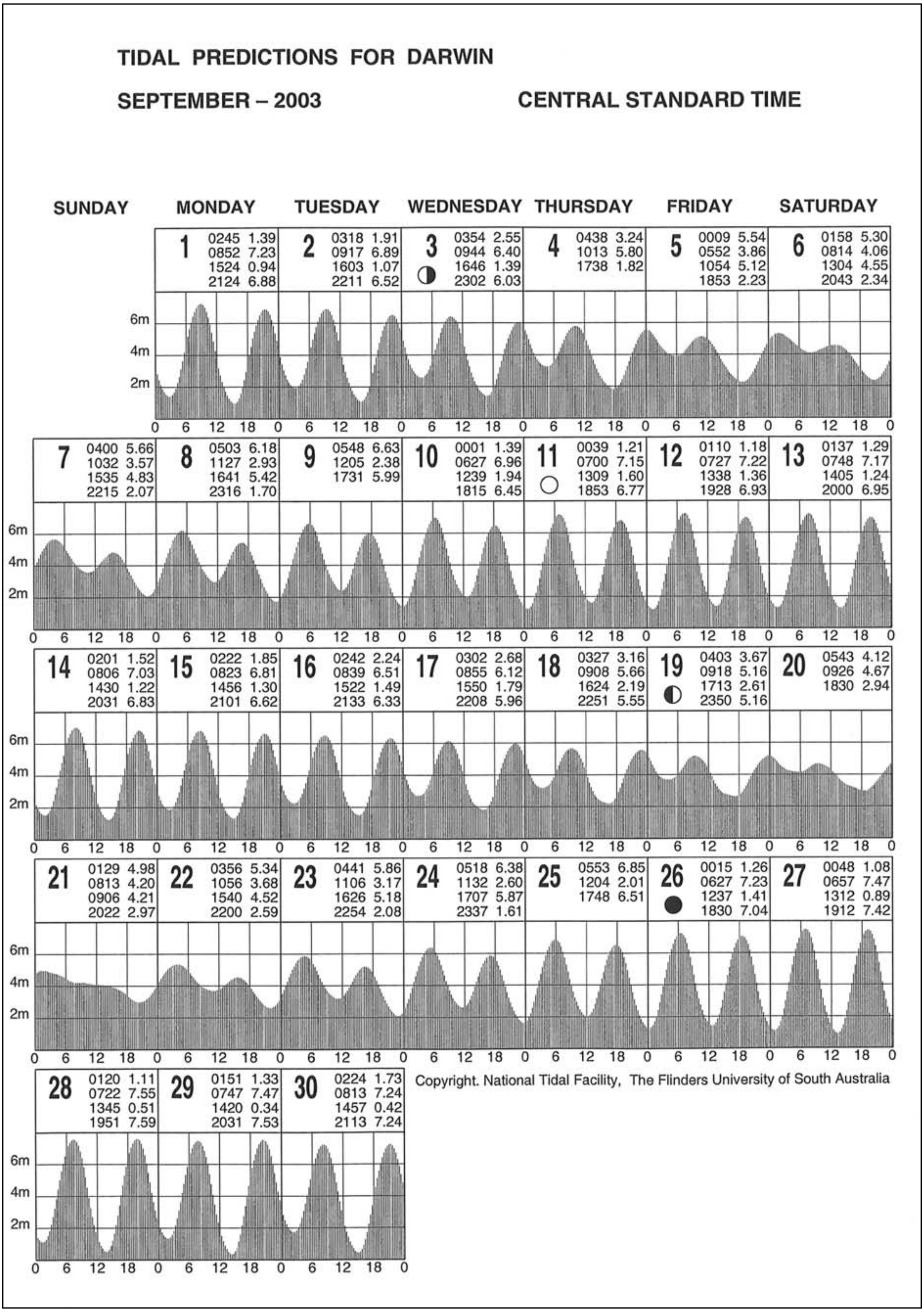
Table 3.1 Standard tide levels for Port Keats (Australian Hydrographic Services, 2003)

Port Keats	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

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.

Figure 3.4 Darwin tide curve for September 2003



3.5.2 Circulation

Tidal currents

Circulation in the Joseph Bonaparte Gulf is dominated by the large tidal currents. There are no site specific current measurements in the region of the Blacktip development, however, the hydrodynamic model developed for this study predicts current speeds at the offshore facility of up to 0.9ms^{-1} on spring tides and up to 0.2ms^{-1} on neaps. The currents rotate in a clockwise direction with the major flood and ebb directions towards the southeast and northwest, respectively. Further towards the shoreline, current speeds increase with tidal range and become directed more 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 (see Figure 4.6).

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 0.7ms^{-1} during extreme monsoonal or Trade Wind surges. More typically speeds would be in the range of 0.2ms^{-}1 to 0.4ms^{-1}.

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 0.2ms^{-1} 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.

3.5.3 Waves

Wave data were derived from a two degree global database constructed from a combination of remotely sensed satellite and modelled data (Young, 1999). The monthly mean significant wave heights (Hs), spectral periods (T_m) and directions for the nearest grid point (approximately 100km to the north northeast) are plotted in Figure 3.5. 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 southeasterly trade winds. Wave generation will be fetch limited and mean monthly significant wave heights are predicted to be fairly constant, ranging between 0.8m and 1.0m 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.

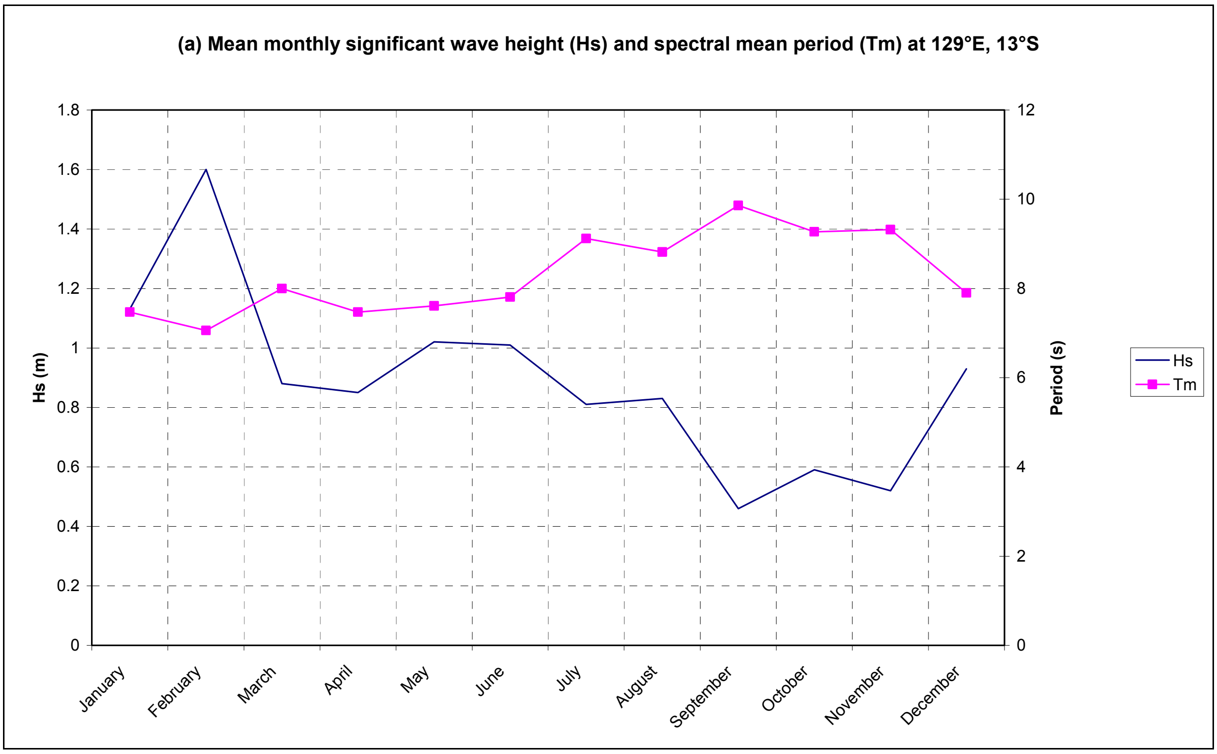
During the summer season, Blacktip is exposed to both sea and swell generated from the prevailing northwesterly monsoon winds blowing across the Timor Sea. As such the predominant swell direction at Blacktip is from the northwest with mean monthly periods of between seven and 10 seconds. Monthly mean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

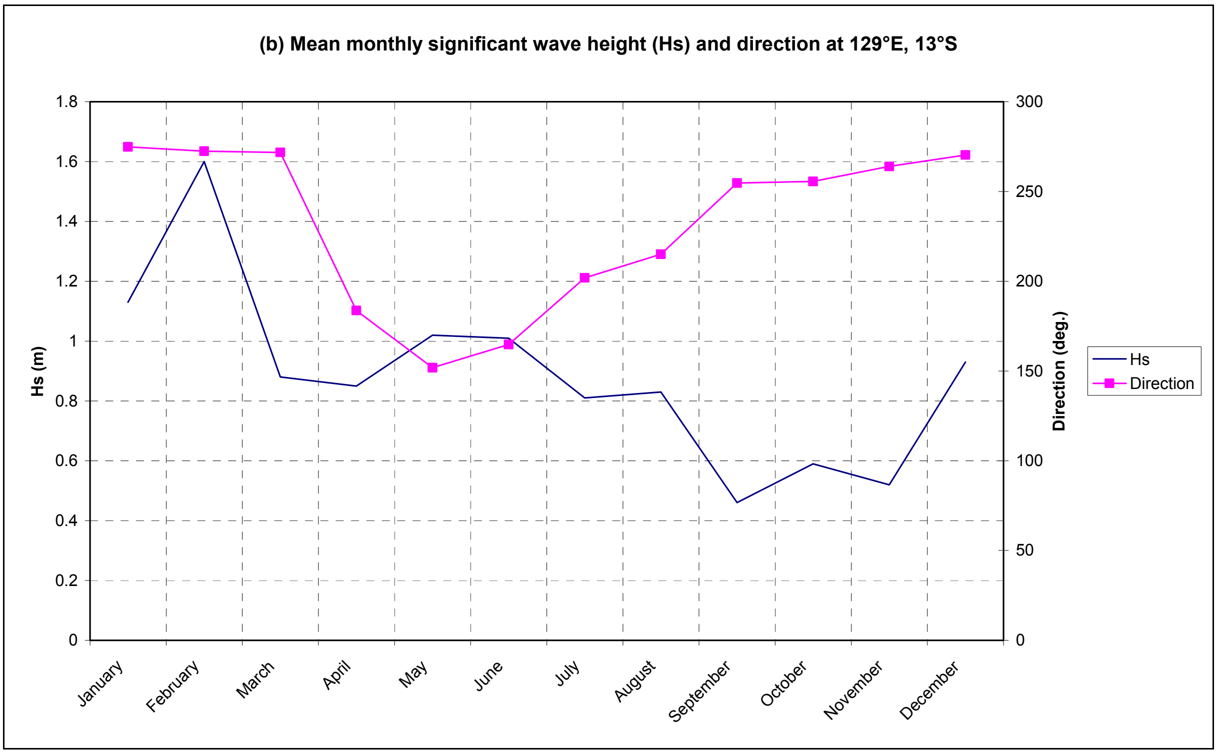
Extreme waves are generated by cyclones during the summer season. The 100 year return period wave will be of the order 5m.

3.5.4 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 (AODC, 2004). 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 3.5 Monthly mean wave parameters for grid location129°E, 13°S (approximately 100km NNE of Blacktip)





3.6 Biological Environment

3.6.1 Habitats

Coastal habitats in the Gulf include beaches, rocky coastlines and mangroves. The predominant coastline features in the vicinity of the proposed pipeline shore crossing are sand/mud beaches with occasional rocky headlands, small pockets of mangroves and occasional tidal creeks (Figure 1.2). The coasts to the north and south are predominantly sandy beaches with no mangroves. Approximately five kilometres to the south of the shore crossing lies the entrance to a small tidal creek lined with mangroves. Wadeye, approximately 17km to the north of the shore crossing, is the only large tidal inlet system nearby. The nearest significant mangrove conservation areas lie inside the Cambridge Gulf approximately 100km south-west of the project site. Joseph Bonaparte Gulf is not considered to be a significant mangrove area with only 20 known species and densities that are up to 20 times lower than at Gove or Darwin (LDM, 1994).

3.6.2 Flora and Fauna

General

Large terrigenous inputs and re-suspension by large tides are expected to limit the development of corals, seagrasses and other epibenthic organisms. A survey carried out by the WA Museum did not record any intertidal seagrasses in the Joseph Bonaparte Gulf, and no evidence of drift material was found at any of the sites surveyed (Walker *et al*., 1996), though LDM (1994) reported that discussions with local Aboriginal people indicated that seagrass and dugongs may occur along the coastline between Cape Hay to the north and Point Pearce to the south. The nearest large reefs or shoals that might support corals, Howland Shoals and the Emu Reefs, are located approximately 20 to 30km north of the proposed landfall.

Mammals

Whales and dugongs are not expected to be common inhabitants of the Joseph Bonaparte Gulf. The dugong (*Dugong dugon*) is a migratory species listed as vulnerable under the International Union for the Conservation of Nature and Natural Resources, Red Data Book of Threatened Species (IUCN). 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 (LDM 1994).

The two whale species recorded in the Northern Territory are unlikely to be found in the shallow waters of the project area as they are usually restricted to deep waters (sperm whale) or are very rare (blue whale). The northern migration of the humpback whale terminates in Campden Sound over 400km to the west of the proposed Blacktip Development and they are not expected to occur in the Joseph Bonaparte Gulf. A number of dolphins have wide distributions and are expected to occur within the Joseph Bonaparte Gulf including the Irrawaddy dolphin inhabits tropical, the spotted bottlenose dolphin, Risso's dolphin, Indo-Pacific humpback dolphin and pantropical spotted dolphin (Convention of Migratory Species 2004).

Reptiles

Reptiles in the Joseph Bonaparte Gulf include:

- turtles;
- saltwater crocodiles,
- the mangrove snake; and
- the mangrove monitor.

Turtles

Six species of marine turtle known to occur in Northern Australian waters, however data colected on turtle abundance and distribution in the Joseph Bonaparte Gulf is scarce and numbers are unknown. Examination of the turtle habitat database developed and supplied by Ray Chatto of the Parks and Wildlife Commission of the Northern Territory (PWCNT) indicates that suitable coastal saline flats habitat for sea turtles exist in the southeast of the Joseph Bonaparte Gulf at Turtle point at the mouth of the Victoria River and the Whale Flat area near the mouth of the Fitzmaurice River and to the north of the project area around Anson Bay.

Significant Flatback turtle breeding and nesting sites are documented on the north side of Cape Domett in the inner, western Joseph Bonaparte Gulf (Woodside, 2003) and anecdotal evidence suggests that they may historically have nest on sandy beaches to the north of the pipeline landfall. However, discussions with Wadeye Elders indicate that turtles have not nested in any number following a beach recession event about 15 years ago.

Saltwater Crocodiles

The Northern Territory's saltwater crocodile population is the largest in Australia. The species is protected under Section 43 of the Territory Parks and Wildlife Conservation Act 2000, although it is not listed as threatened under the Commonwealth Environment Protection and Biodiversity Conservation (EPBC) 1999 Act. 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. The Ord River system has been gazetted as a nature reserve to protect crocodile breeding habitats in the area (LDM, 1994).

Sea Snakes

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 (Storr *et al*., 1986).

Fish

A number of fisheries can operate within waters of the Joseph Bonaparte Gulf, however, it appears that fishing effort is limited in all fisheries except for the Northern Prawn Fishery. Prawns are commercially caught in areas of the Joseph Bonaparte Gulf, mainly in the west of the gulf and, to the north, in Fog Bay. The juvenile prawns that migrate offshore to the fishery come from mangrove nursery habitats from the Victoria River in the east of the Gulf, to the Ord River and Cambridge Gulf in the west, forming a very extensive migration throughout the lower region of the Joseph Bonaparte Gulf. Although there is no data on the exact timing of the migration, it is likely to be from February to April and October to December (Neil Loneragan, Commonwealth Scientific and Industrial Research Organisation (CSIRO) Division of Marine Research, pers. comm., Febuary 2004).

4 DISPERSION MODELLING

4.1 General

Modelling of effluent dispersion from a pipeline is generally divided into two distinct zones:

- near field; and
- far field.

In the near field, transport is governed by the momentum of the discharge and the buoyancy resulting from the density difference between the effluent and the receiving waters. The dilution achieved as the wastewater rises to the surface is known as the initial dilution. Thereafter the plume is transported passively by advection and diffusion in the far field. The following sections describe the modelling work undertaken to simulate dispersion in these two zones for the Blacktip discharge.

4.2 Near field Dispersion

4.2.1 Objective

The objectives of the near field modelling are:

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

4.2.2 Model Overview

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 three-dimensional hydrodynamic equations governing the conservation of mass and momentum along the curved trajectory of a buoyant jet are solved yielding:

- the trajectory position; and
- centreline concentrations of pollutant mass, density deficit, temperature and salinity.

The computation ceases when the plume impinges on a boundary, after which time the physics change and the results are transferred to the far field model. Cross-sectional values are fixed as a Gaussian distribution. Theoretical details and the validation of CORJET are presented in Jirka *et al.* (1996).

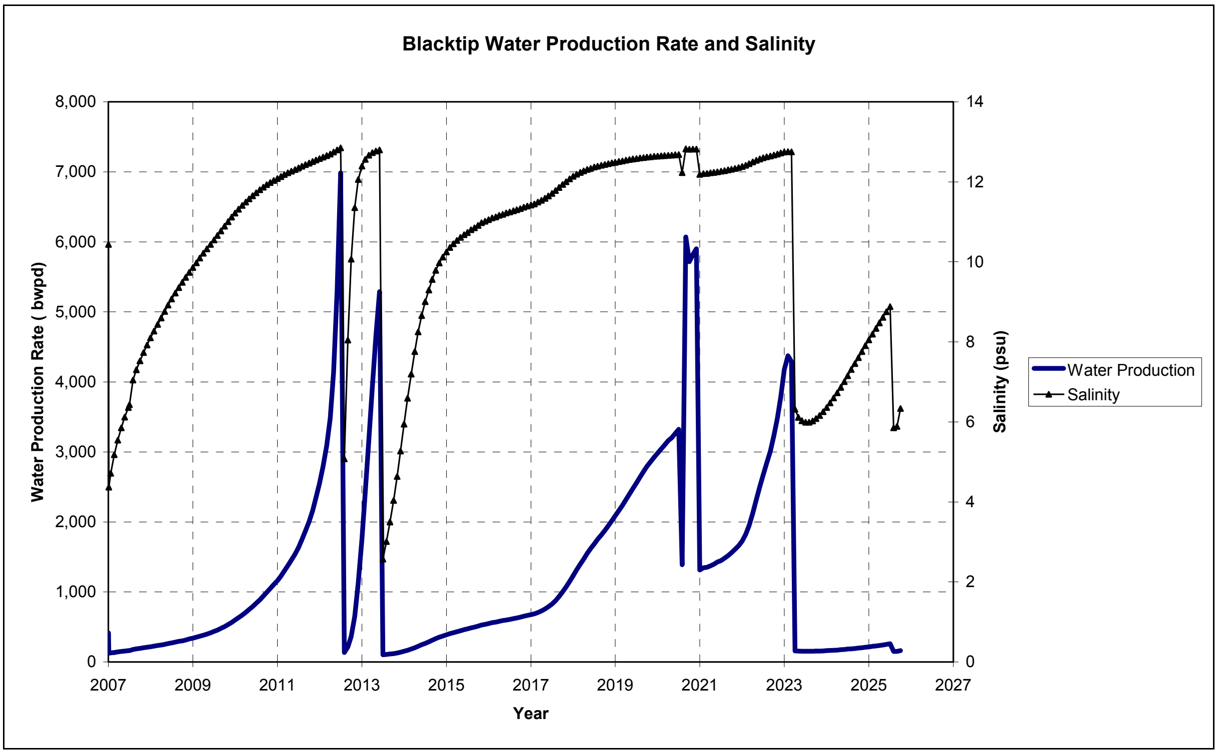
4.2.3 Model Setup

Discharge Flows

Figure 4.1 shows the projected PFW discharge rates over the life of the field. Flows increase from a minimum of 200bbl per day to a maximum of 7,000bbl per day. For the modelling three design flows were used:

- minimum – 200bbl per day;
- base – 2,000bbl per day; and
- maximum future – 7,000bbl per day.

Figure 4.1 Projected PFW flow rate and salinity for the life of the field (from WEL)



Preliminary Diffuser Design

Submarine outfalls consist of the pipe carrying the effluent to the discharge area and the end section or diffuser. For the Blacktip outfall, a six inch pipe has been proposed, however, the design of the diffuser is still yet to be decided. Best practice for diffuser design dictates that:

- the total cross sectional area of the ports must not exceed 65% of cross-sectional area of the pipe, to ensure that flow is distributed evenly through all the ports;
- port diameters should be between 20mm to 150mm to prevent blockage;
- discharge velocities range from $3ms^{-1}$ to $8ms^{-1}$ (higher velocities may require excessive pumping costs);
- the densimetric Froude number should exceed one to prevent saltwater intrusion; and

- port spacing should be in the range one-third to one-sixth of the water depth, so that the plumes from the individual ports just merge on reaching the surface.

Table 4.1 presents a preliminary diffuser configuration that complies with these design criteria

Table 4.1 Preliminary diffuser configuration

Parameter	Value
Diffuser diameter	60mm
No of diffusers	4
Length of diffuser	15m

The parameters used to set-up the model runs are summarised in Table 4.2. Diffuser alignment was set perpendicular to the ambient current direction. Ports were:

- single and unidirectional;
- discharge horizontally and point downstream (ie, co-flowing); and
- located 1m above the seabed.

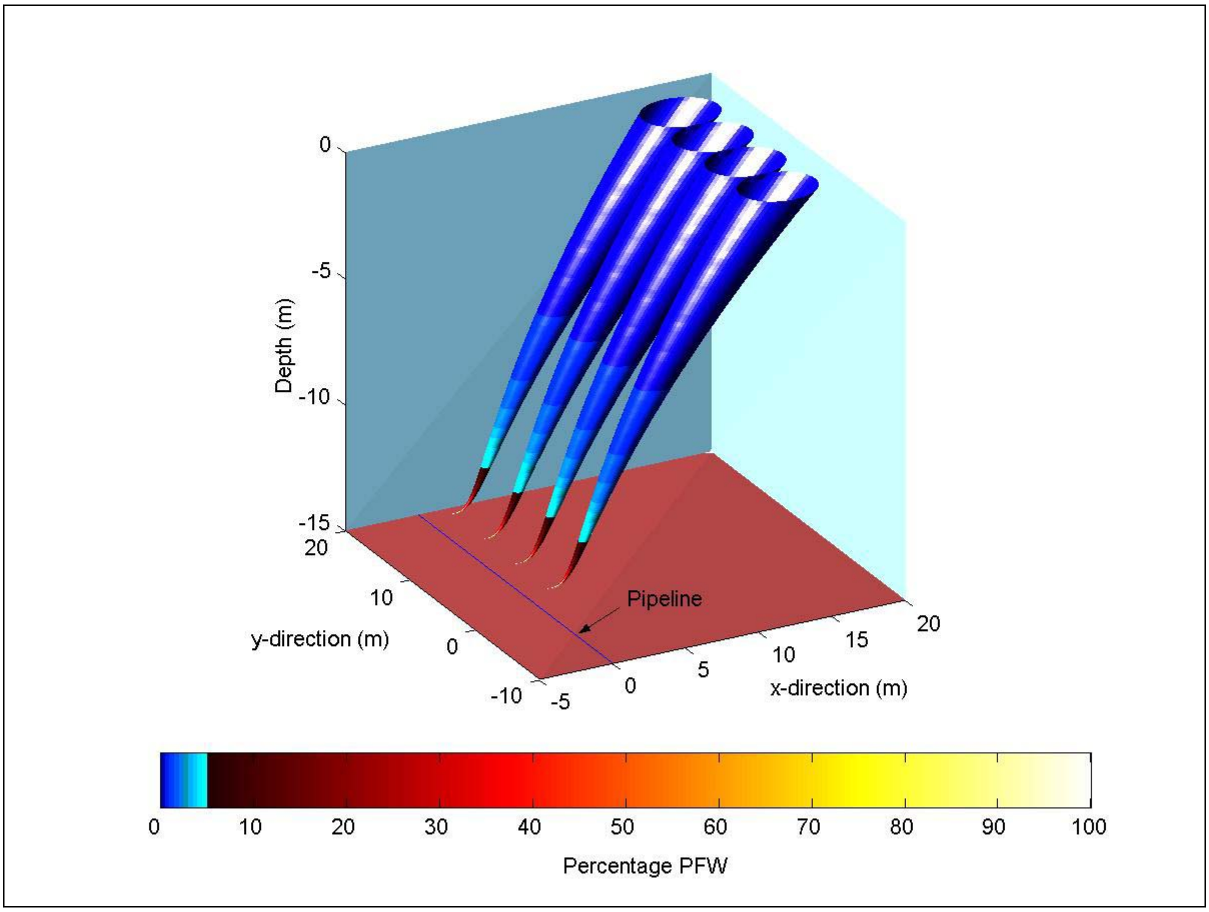
Table 4.2 Model set-up for initial dilution CORJET modelling

Parameter	Value
Ambient conditions	
Average depth	15m
Depth at discharge	15m below LAT
Ambient velocity (CORJET)	$0.05ms^{-1}$
Stratified condition	Unstratified
Ambient temperature	28°C
Ambient salinity	34psu
Discharge parameters	
Discharge orientation	Horizontal (co-flowing)
Port diameter	60mm
Discharge flowrate	7000bbl per day
Temperature	28°C
Salinity	10psu
Concentration	100%
Coefficient of decay	$0s^{-1}$

4.2.4 Model Results

Figure 4.2 shows the predicted horizontal and vertical trajectories of the jet plume in the near field region. The PFW emits from the discharge pipe 14m below the sea surface and rises under the influence of its own buoyancy towards the surface. Due to the relatively low flows, initial dilution is high. Within the first 5m, 100 dilutions are achieved and by the time the plume hits the surface, it has received 700 dilutions. On reaching the surface it spreads horizontally whilst mixing vertically downwards. At this point, dispersion becomes controlled by far field processes (ambient current and passive diffusion).

Figure 4.2 Initial dilution for preliminary diffuser design (worst-case future discharge rate)



4.3 Far Field Dispersion Modelling

4.3.1 Objective

The objectives of the far field modelling 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 is made up of two modules:

- a hydrodynamic module that provides the necessary velocity fields to advect the PFW; and
- a dispersion model that simulates the fate and behaviour of the PFW.

These modules are described in more detail in the following subsections.

4.3.2 Hydrodynamic Model

Overview

The hydrodynamics applied in the present study were 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.

Model Details

Figure 4.3 shows the grid for the Joseph Bonaparte Gulf. Elevations and currents were computed at 11,621 points (nodes) in the model domain. Using the significant flexibility provided by the FE method, grid resolution was increased considerably towards the coast and in particular towards the landfall for the Blacktip pipeline (Figure 4.4). The fine nearshore grid spacing was necessary to resolve the complex coastline geometry whilst coarse offshore resolution aids in computational efficiency.

Node resolution varies from approximately 50km offshore to 50m inshore. Model bathymetry is shown in Figure 4.5. This was interpolated from the Australian Geological Survey Office (AGSO) database. The model was forced from the open boundary by tidal elevations calculated from the M2, S2, N2, O1 and K1 tidal constituents. The amplitudes and phases for these were taken from the FES-95.2 global ocean model (Le Provost *et al*., 1998).

The model was validated against tidal stations around the coastline. Examples of vector fields for a spring tide at mid ebb and flood are shown in Figure 4.6 (a) and (b), respectively.

4.3.3 PFW Dispersion Module

Model Overview

The PFW dispersion module is based on the classic random walk particle tracking method (Sherwin, 1992) and assumes that the mass of the discharge can be idealised as a large number of particles that move independently under the action of tide and wind. The particle tracking is integrally linked with the FE model and uses a highly accurate fourth order Runge-Kutta method to interpolate velocities between nodes (Blanton, 1995).

The motion of the particles is the sum of two effects:

- advection by the tidal currents, and
- dispersion due to turbulence and current shear effects.

Advection is calculated by stepping through the variations in the current field in time and space. Dispersion is included by subjecting each particle to a random displacement at each time step. The dispersive displacement (random step) of each particle at each time step (dt) is scaled by the square root of the increment in the variance of the effluent plume which is given by the product:

(increment in variance) = 2Kdt

where K is the horizontal (K_{xy}) or vertical (K_z) diffusion coefficient. The actual step length taken by each particle is also determined by a random number selected from a normal distribution with zero mean and unit variance which is scaled by the product (2Kdt). Steps in the x, y and z co-ordinate directions are made independently. Steps in the vertical plane allow for reflection of the particle from the seabed and surface. The current velocity applied to each particle is corrected according to its level in the water column using a Van Veen profile.

Model grid

The model was set up over a 16km x 16km rectilinear grid, with a resolution of 100m. The time step for particle tracking was set at 180 seconds.

Figure 4.3 Hydrodynamic model grid

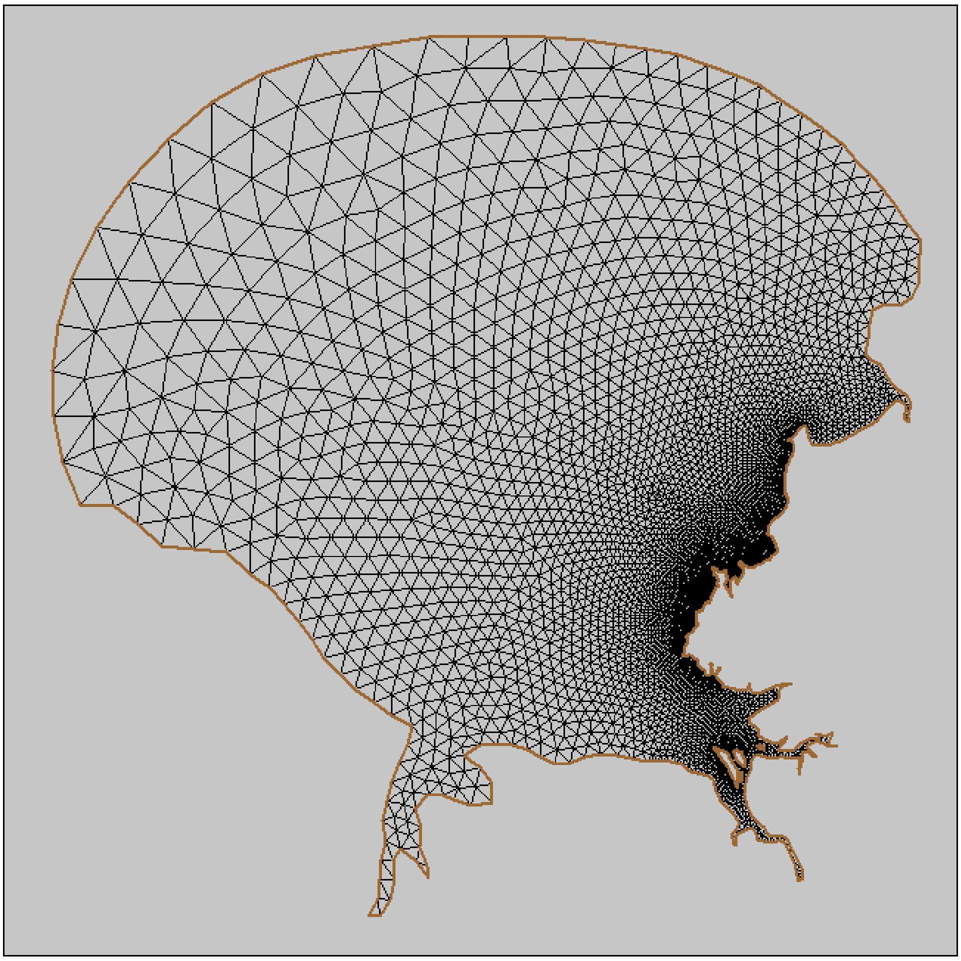


Figure 4.4 Details of model grid in the vicinity of the outfall

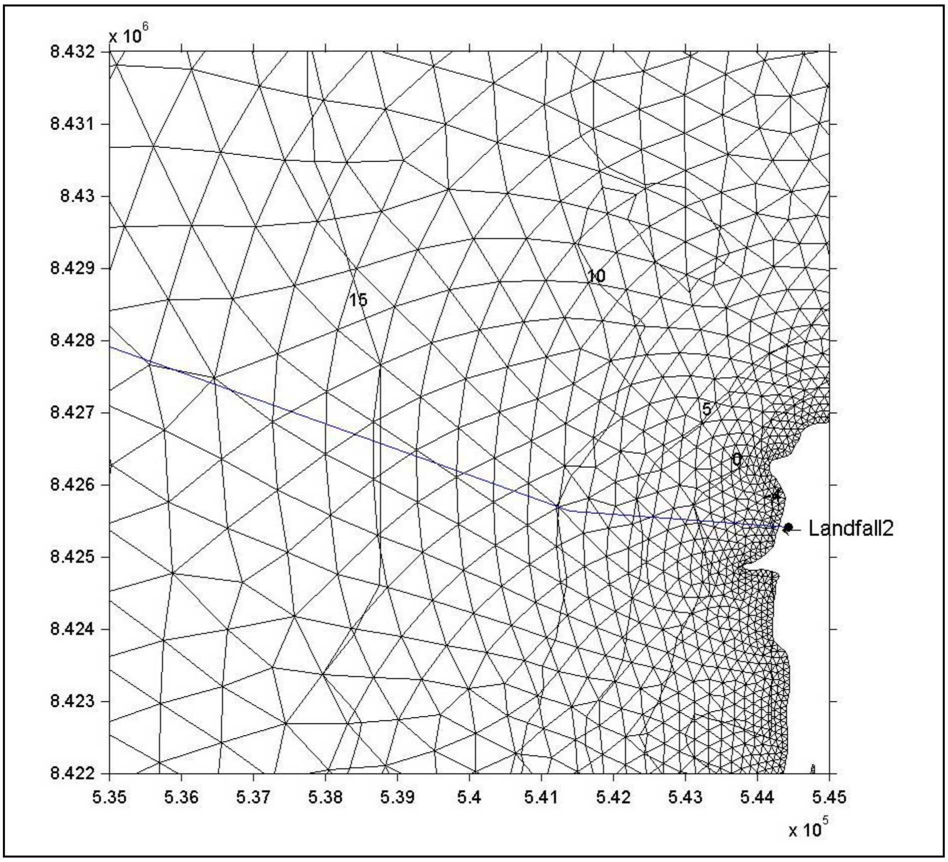


Figure 4.5 Model bathymetry in metres

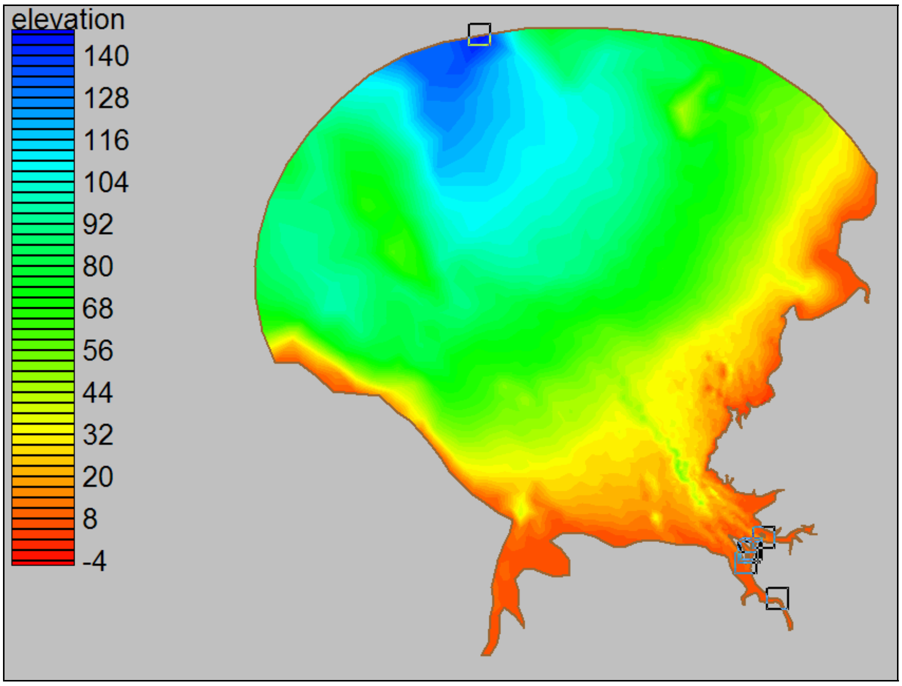
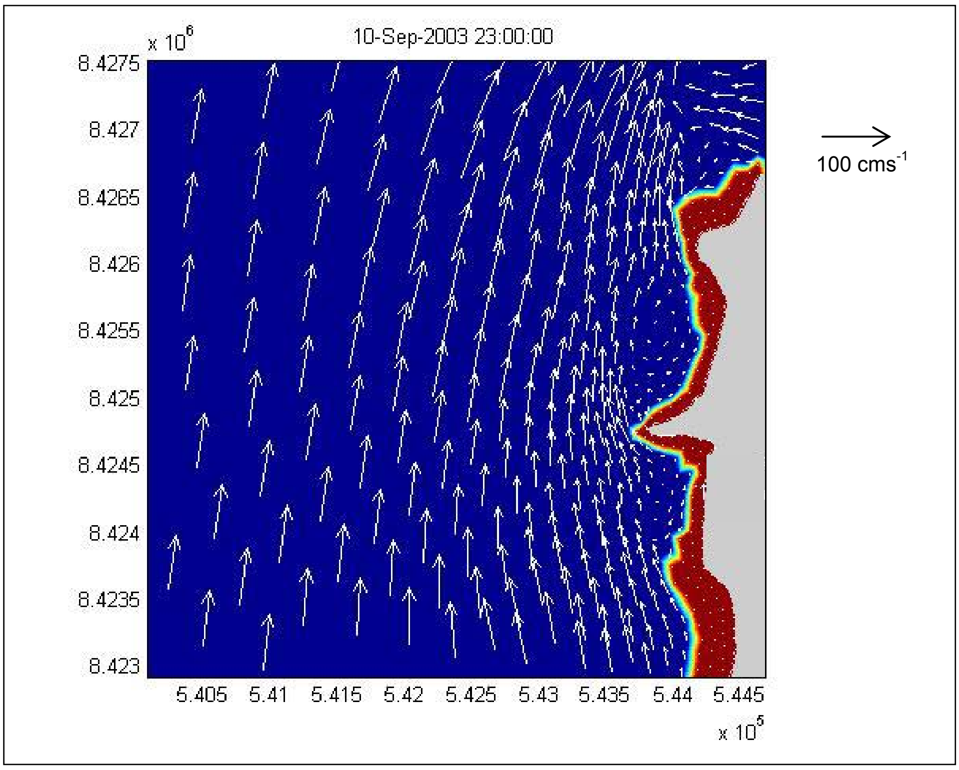
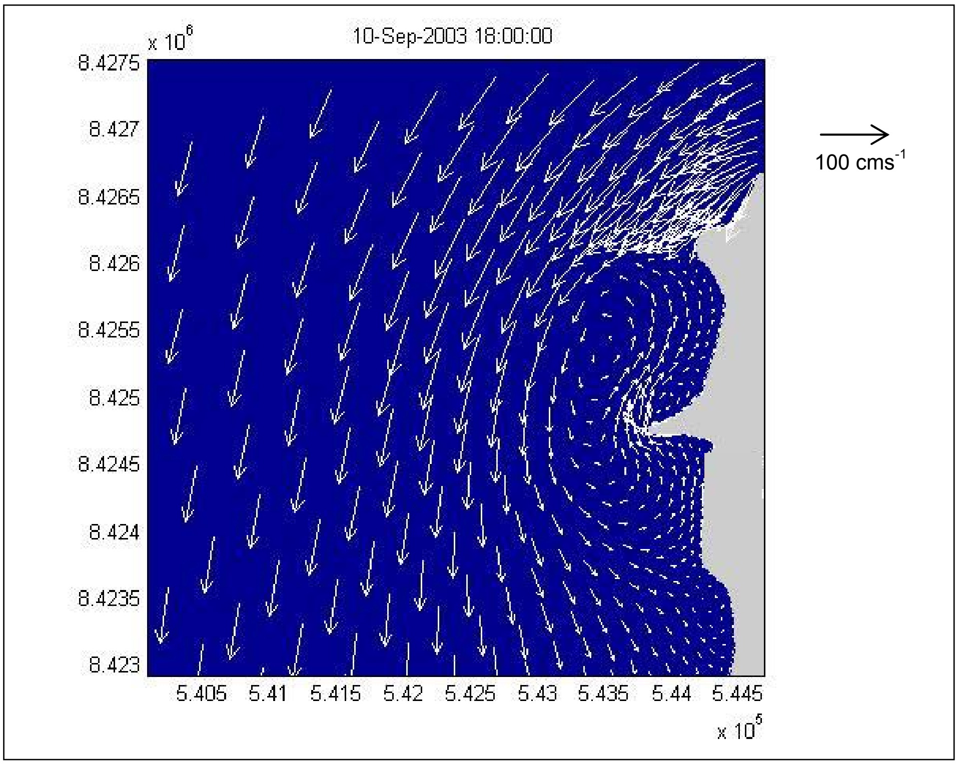


Figure 4.6 Predicted spring tide vector fields in the vicinity of the landfall for the Blacktip pipeline

(a) Ebb Tide



(b) Flood Tide



4.3.4 Model scenarios

Table 4.3 summarises the model scenarios undertaken. These used seven different discharge locations, (Figure 4.7), three discharge flows, spring and neap tides and onshore “worst-case” wet season wind conditions.

Worst-case periods were targeted as it is reasonable to assume that if the risk is acceptable under such conditions then it will be acceptable for all other times when conditions are more favourable for dilution and mixing. These simulations do not take into consideration biodegradation as this is unknown for the whole PFW.

Figure 4.7 Positions of discharge locations tested

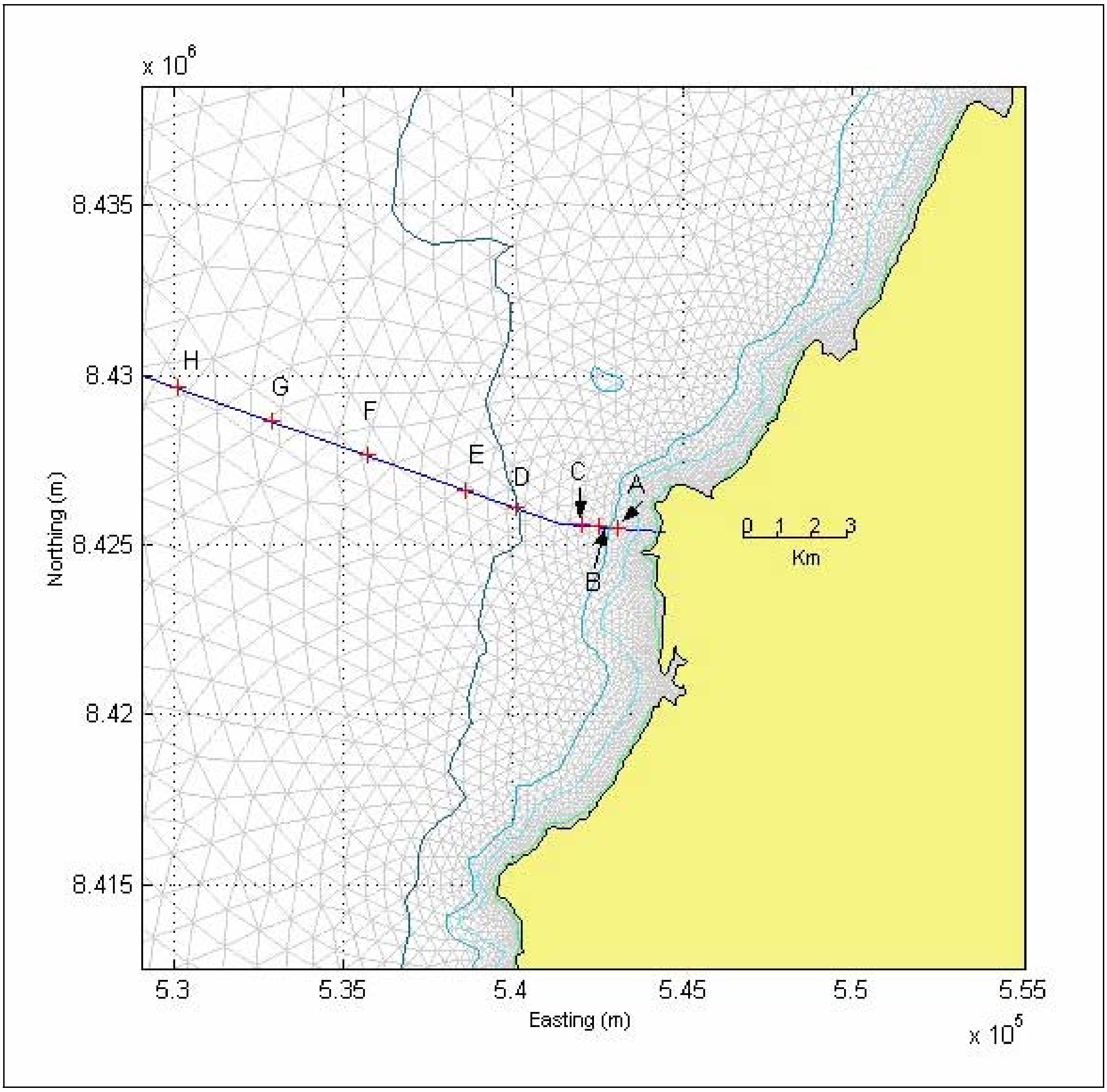


Table 4.3 Summary of model runs

Scenario No.	Discharge Location	Discharge flow (bbl/day)[1]	Tide	Wind
1	A	6,000	Neap	2ms^{-1} NW
2			Spring	
3	B		Neap	
4			Spring	
5	C		Neap	
6			Spring	
7		200	Neap	
8			Spring	
9		15,000	Neap	
10			Spring	
11		6,000	Neap	Typical wind profile for wet season
12			Spring	
13	C	6,000bbl/hr	Neap	
14	D	6,000		
15	E (6km)			
16	F (9km)			
17	G (12km)			
18	H (15km)			

[1] unless otherwise specified

4.3.5 Brief Description of Results

The following presents a brief description of the outcomes from the simulation. This is followed by a more in-depth discussion of the results from the preferred discharge location. Animations and plots for all simulations are presented digitally on CD.

Continuous discharge from locations A to C

Scenarios 1 to 12 examined the impact for continuous discharges from locations A to C (Figure 4.7). These were undertaken for the three design flow rates on spring and neap tides and under typical wind conditions for the “wet season”.

For location A, the plume was entrained into the nearshore gyre and coastline impact occured during the first tidal cycle (Figure 4.8). Due to the high dilution and large tidal currents, levels and duration of impact were low with predicted nearshore peak concentrations of 0.01% PFW (10,000 dilutions) occurring for just one to two hours at any single location per tidal cycle.

Locations B and C were outside the influence of the nearshore gyre and the plume generally remained further offshore. The wind gradually forced the plume shoreward and after about two tidal cycles there was a low concentration coastline impact at about 0.005% PFW (Figure 4.9). Again due to strong tidal currents, this impact was very sporadic with concentration peaks occurring for about one hour per tidal cycle.

Batch discharge

Simulation 13 was undertaken to assess the impact of a batch discharge from Location C. For this 7000 bbls of PFW were released over one hour on the ebb tide (Figure 4.10). As the discharge rate had increased, plume concentrations were higher than the continuous discharge (typically 0.15% PFW (600 dilutions) at 100m from the discharge location). Coastline impact occurred after four tidal cycles at 0.02% PFW (5000 dilutions).

Locations D to H

Simulations 14 to 18 examined the effect of moving the discharge progressively offshore, from 4km (Location D) to 15km (Location H). These were undertaken for maximum future discharge flows, neap tides and typical winds for the "wet season". All locations demonstrated high rates of dilution and minimal coastline impact.

There are a number of logistical advantages with discharging from the Swamp Mooring and this location is the preferred option at the present time. A full set of results and impact assessment are presented in the following section.

Figure 4.8 Predicted PFW concentration from discharge Location A

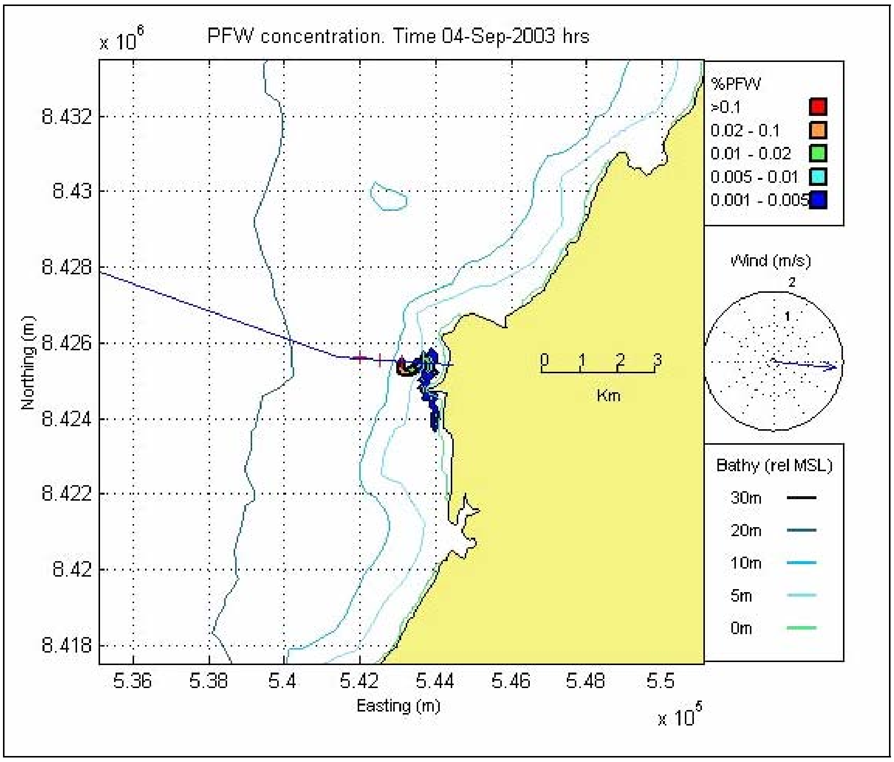


Figure 4.9 Predicted PFW concentration from discharge Location C

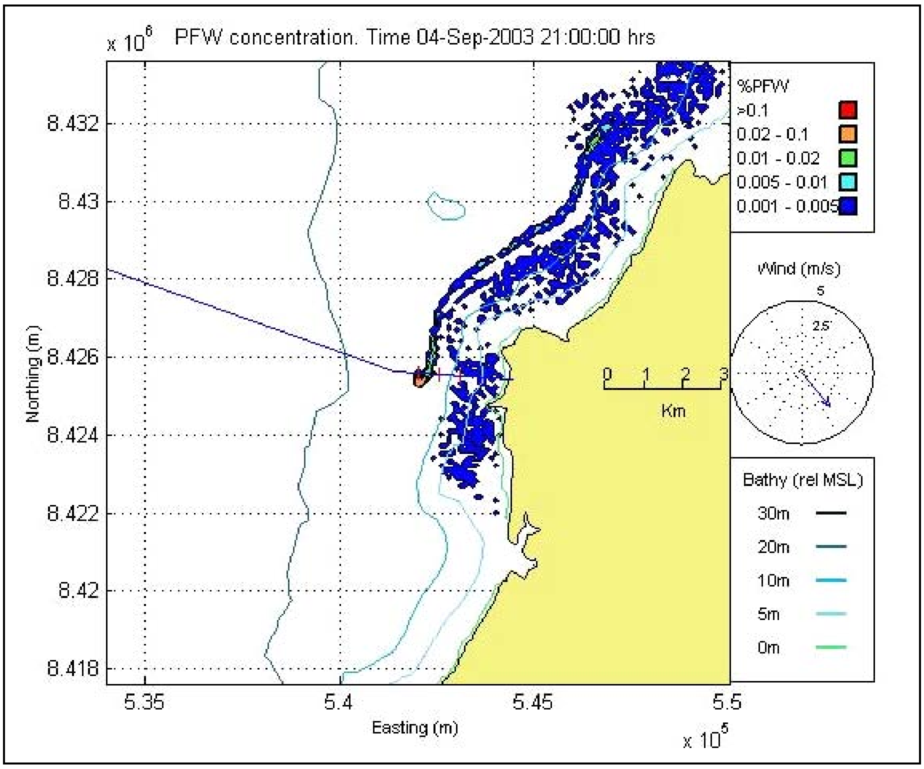
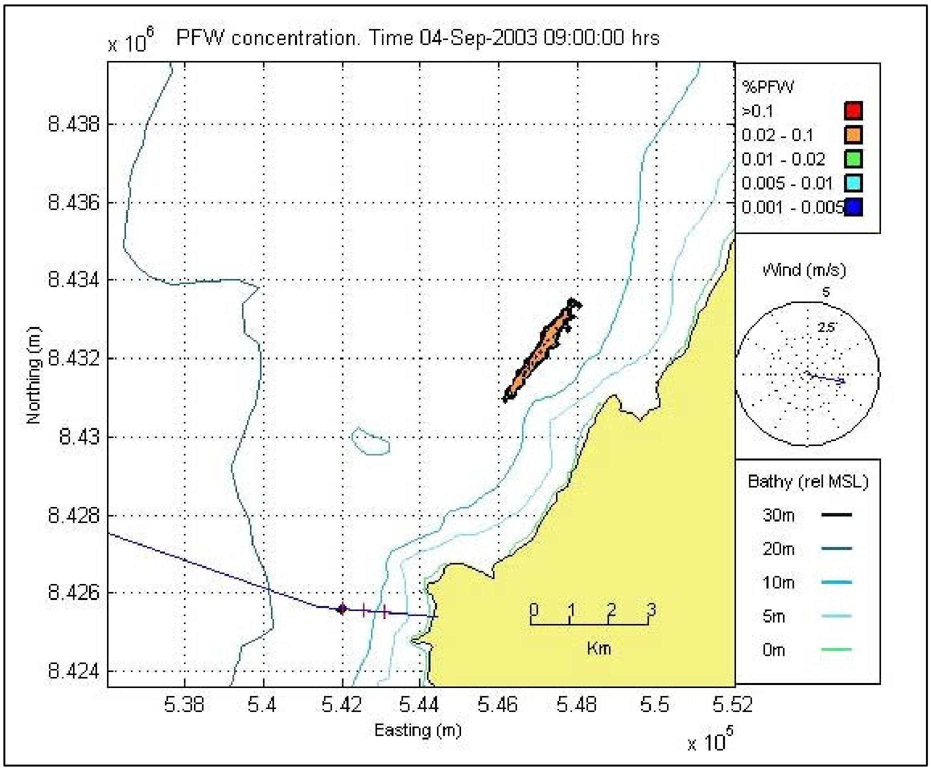


Figure 4.10 Predicted PFW concentration for batch discharge from discharge Location C



4.3.6 Preferred Discharge Location

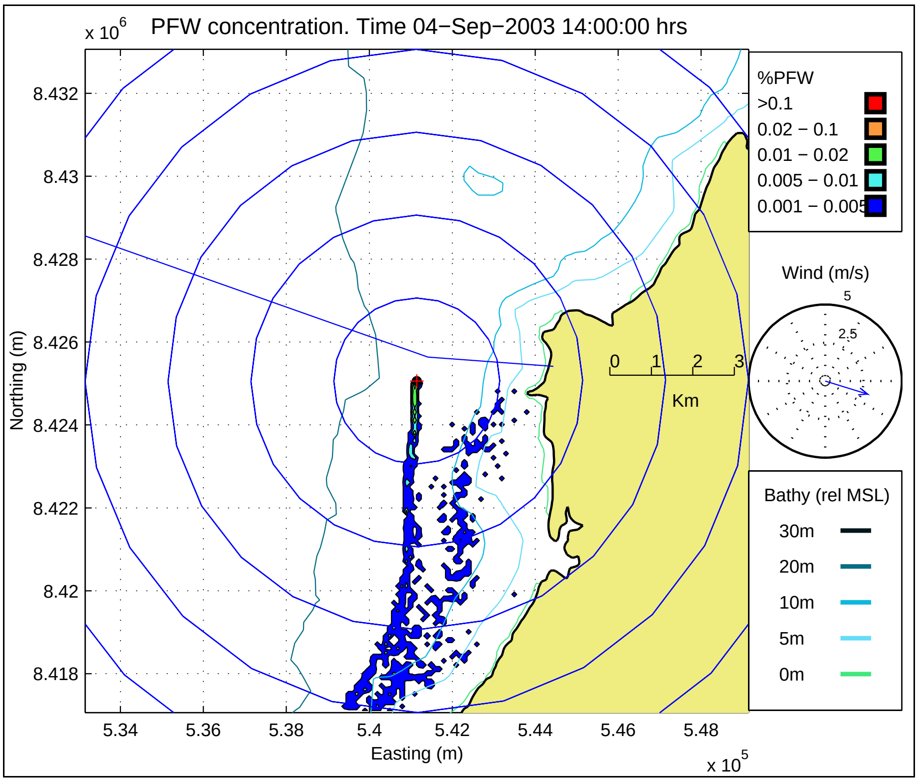
The optimal balance in terms of minimal environmental impact and acceptable cost to the project is to position the discharge in the vicinity of the Swamp Mooring. Figure 4.11 (a) – (i) present a series of plots showing the predicted concentration of PFW at three hour intervals for maximum future flows under "worst-case" ambient conditions (neap tide and typical "wet season" winds).

At high water (Figure 4.11(a)), PFW pools at slack water and concentrations increase to a maximum of 0.05% PFW. On the ebb tide, the plume is advected parallel to the bathymetry for a distance of approximately seven kilometres towards the north. With the increasing ambient flow, there is additional dilution and concentrations reduce to 0.01% PFW. At low water the discharge pools and once again concentrations build up to a maximum of 0.05%. The flood tide advects the plume about six kilometres towards the south.

Approximately six hours after discharge, the plume starts to break up and fragment. This fragmented plume continues to move up and down the coastline with the tide. Superimposed on the ebb and flood of the tide is a persistent onshore surface drift driven by wind and waves. After three tidal cycles the plume impacts the coastline with a very low concentration of between 0.001% and 0.005% PFW (100,000 to 20,000 dilutions).

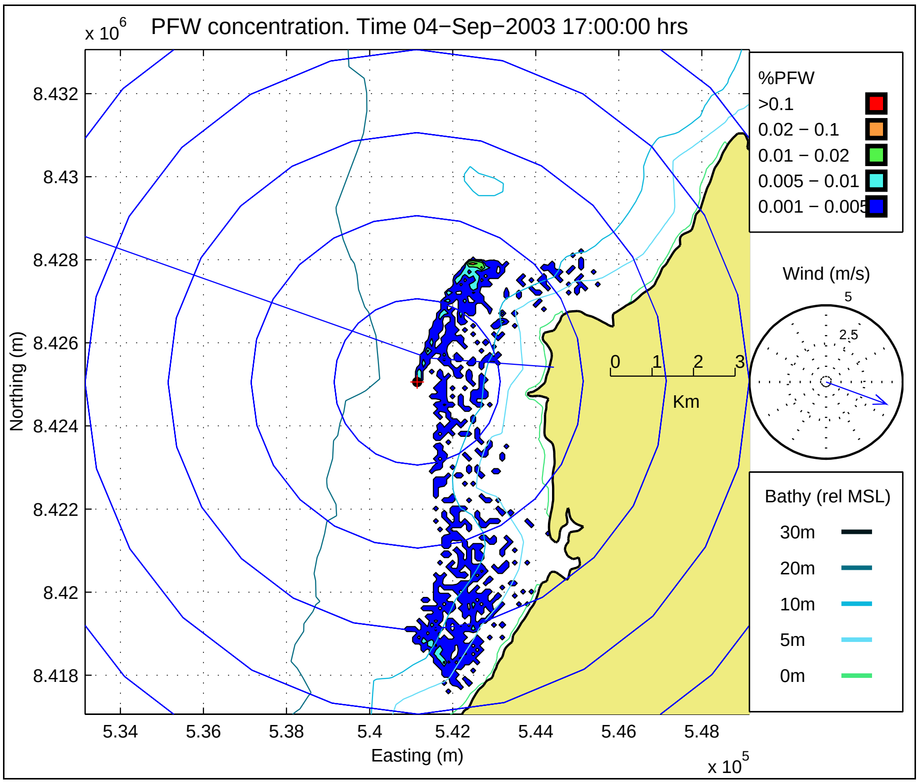
Figure 4.11. Predicted PFW concentration on a neap tide

(a) High Water

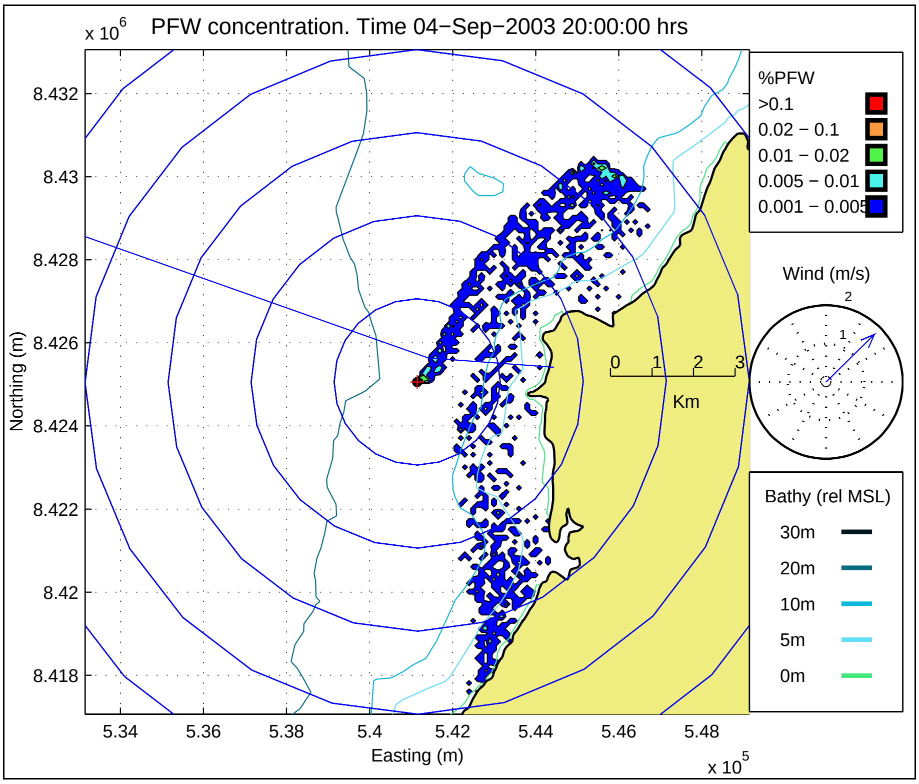


Note: Range rings are drawn at 2km intervals centred on the discharge point

(b) Mid ebb

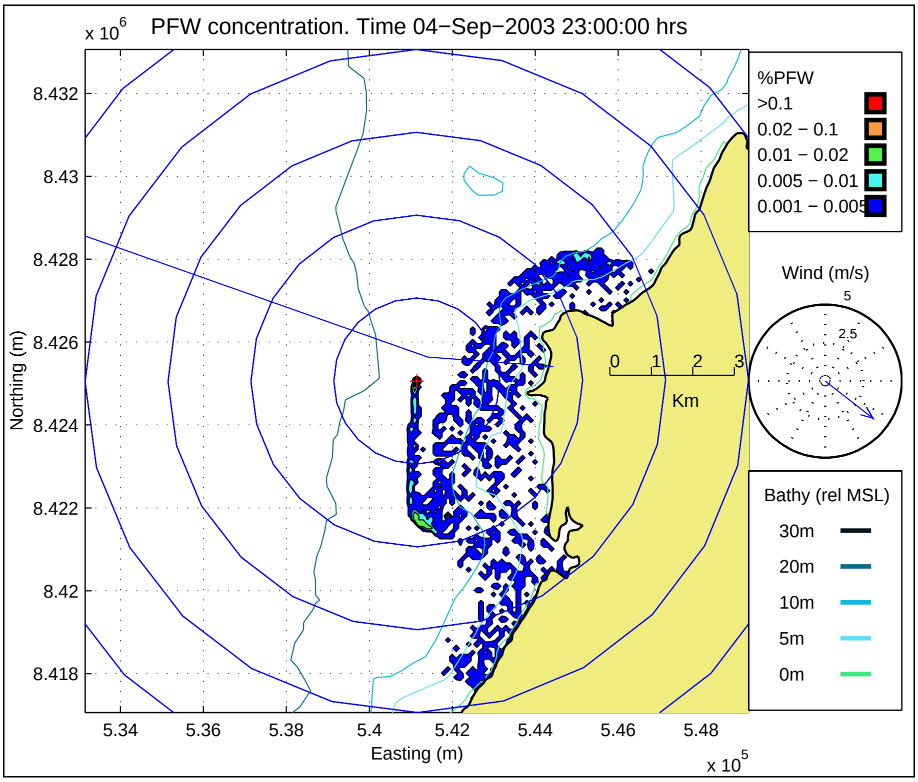


(c) Low water

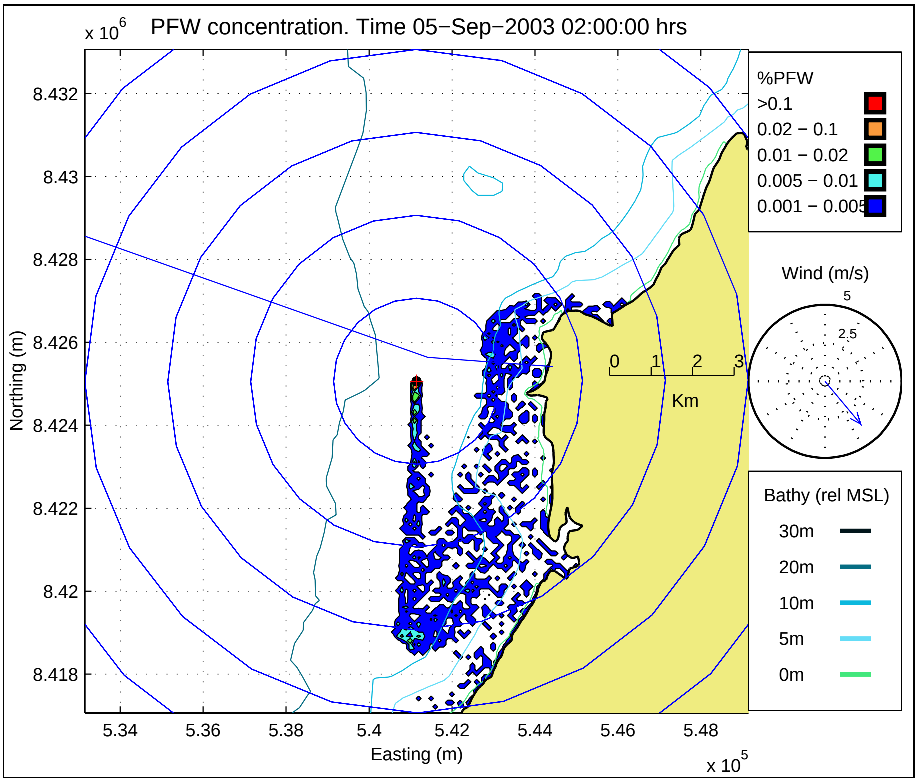


Note: Range rings are drawn at 2km intervals centred on the discharge point

(d) Mid flood

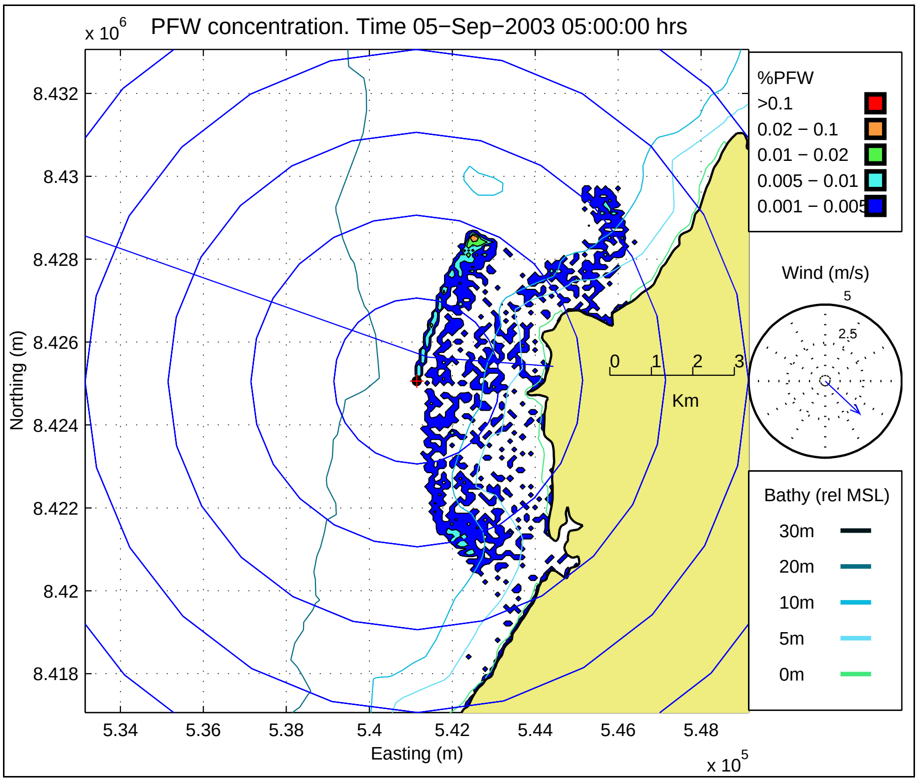


(e) High water

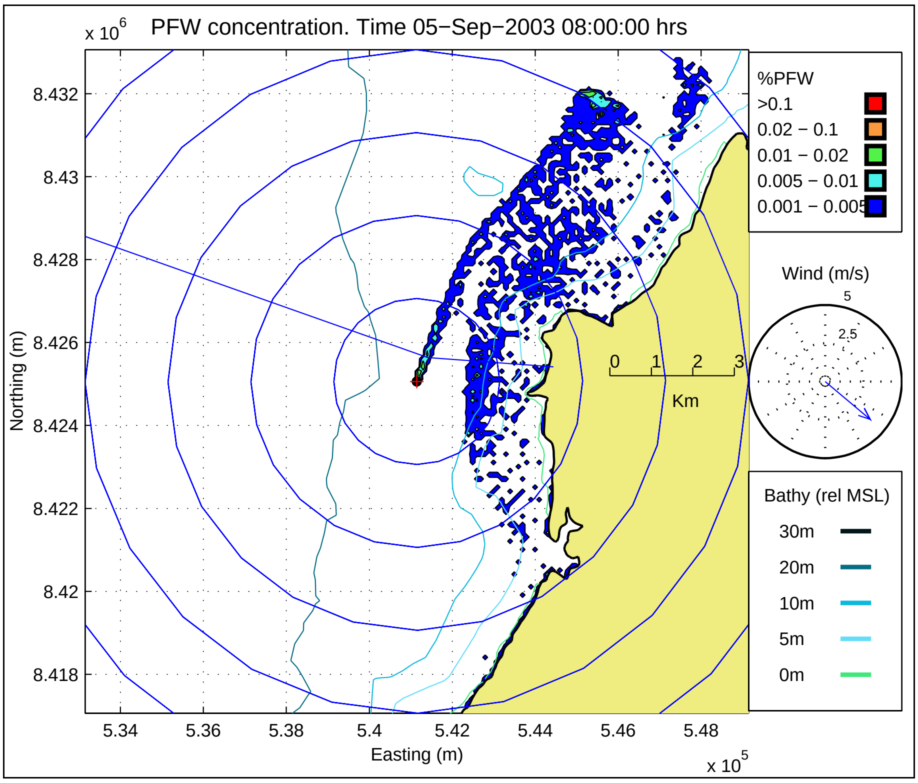


Note: Range rings are drawn at 2km intervals centred on the discharge point

(f) Mid ebb

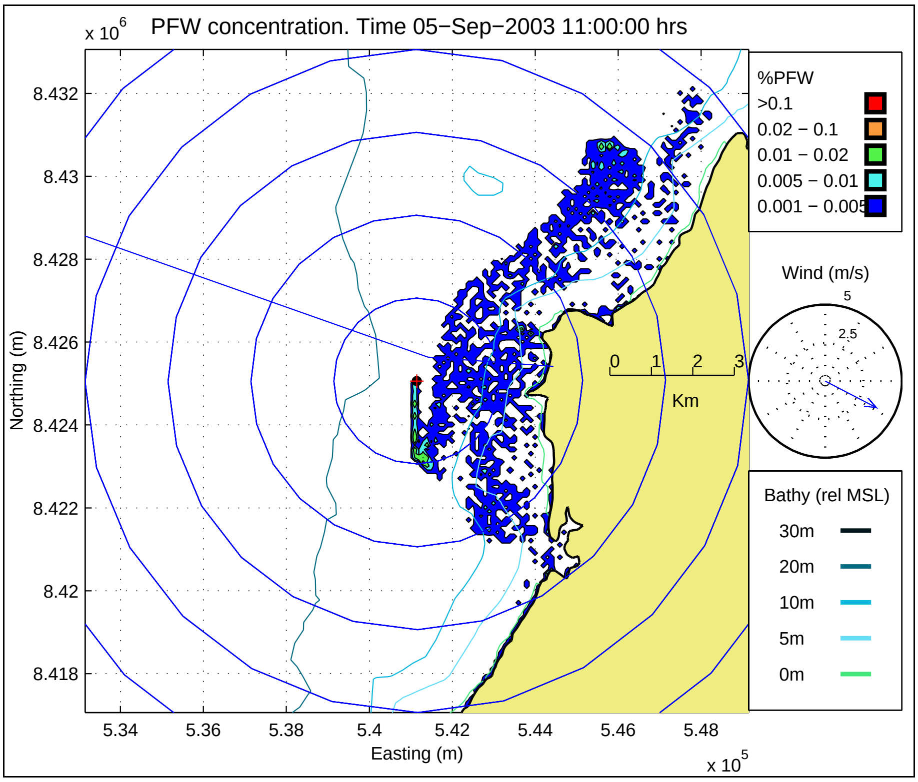


(g) Low water

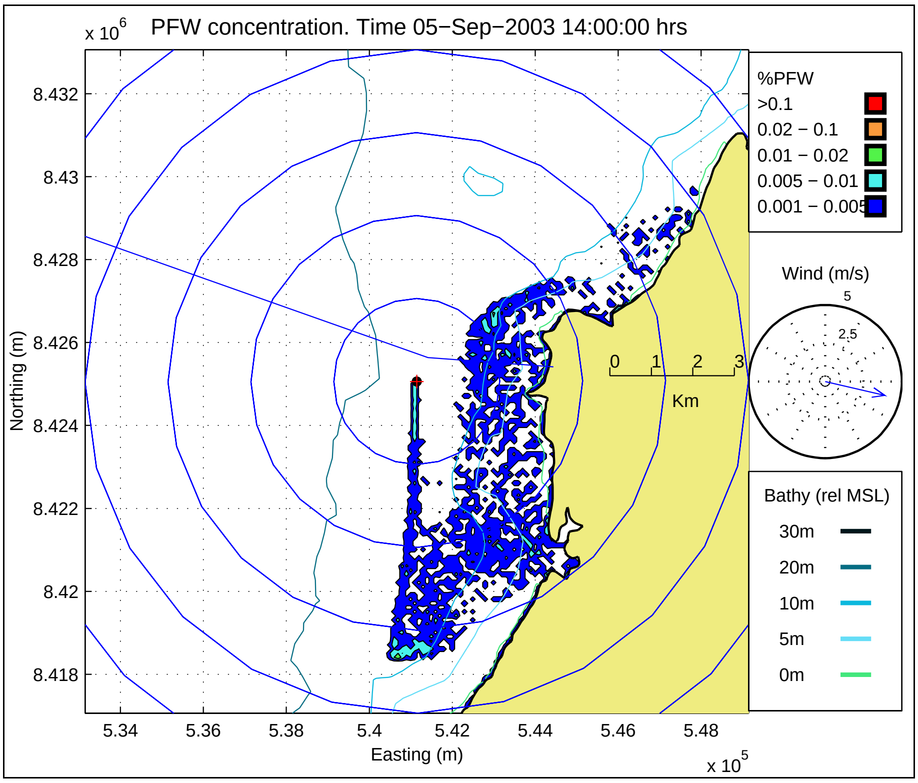


Note: Range rings are drawn at 2km intervals centred on the discharge point

(h) Mid flood.



(i) High water.



Note: Range rings are drawn at 2km intervals centred on the discharge point

4.3.7 Risk Assessment

The traditional PEC/PNEC approach was used to assess the risk. As described in Section 2.5.3, this approach demonstrates the zone of potential affect by calculating and presenting contours of the PEC/PNEC ratio. Any value over one then indicates a potential zone of impact. In the absence of any ecotoxicology data for the PFW, the PNEC was set at 0.1% PFW, the lowest no observed effect concentration (NOEC) measured from all WEL's assets on the North West Shelf (IRCE, 2003a).

Figure 4.12 – Figure 4.15 show (a) the maximum predicted PFW concentration that occurred over the three tidal cycle simulation and (b) the corresponding PEC/PNEC ratio contours, for model layers one to 4, respectively. Highest concentrations occur in the surface waters around the discharge location. These peak at just over 0.1% PFW within the surface waters, up to 400m from the discharge point. The highest concentrations would occur for short periods of time as the tides turn at slack waters. PEC/PNEC ratios therefore exceed one for only a short duration.

4.3.8 Evaluation of Environmental Effects

General

The PEC/PNEC approach is highly conservative as it assumes an ecological response immediately on contact with PFW exceeding the PNEC. In contrast, the PNECs are derived from ecotoxicology studies in which organisms are exposed to the PFW for durations that are unlikely to be experienced in the field. The objective of this section is to present a more intuitive assessment of the risk posed to biological communities from the PFW being discharged from the Blacktip outfall. These communities include:

- benthos;
- plankton;
- sessile Invertebrates (communities attached to the platform);
- fish;
- marine mammals; and
- sea birds.

Benthos

Benthos communities are found in or around the seabed. They are unlikely to be affected because the plume disperses rapidly in the water column and does not impact directly on the seabed. Furthermore adsorption onto suspended sediment particles will be low, limiting the extent of sedimentation to the seabed.

Plankton

Planktonic organisms live freely in the water column and drift with the water currents. Plankton may also include the early stages (eg. egg, larva and spores) of non-planktonic species (fish, benthic invertebrates and algae). Figure 4.16 illustrates the typical exposure period for passive floating organisms. Once discharged to the receiving environment, dilution reduces the concentration of toxic chemicals in the PFW. Under the present discharge rate and configuration, initial dilutions are high. For a worst-case scenario, a freely floating organism passing directly over the discharge pipe may be exposed to PFW concentrations above the PNEC value in the mixing zone for a short duration. There is therefore the potential for impact, however, the exposure concentration will be continually diluting and only organisms residing directly in the plume would be impacted, which constitutes a small proportion of the community.

Sessile marine invertebrates

Sessile marine invertebrates are those that are attached to the substrata and infrastructure surrounding the discharge. These do not have the opportunity to move to avoid toxic affects and potentially are the most exposed communities to the plume. Even though these organisms cannot move, the plume would be continually moving around them depending on the direction and speed of ambient currents. Sessile invertebrates may therefore be impacted sporadically by high concentrations of PFW, however, when they encounter clean seawater, they would have the opportunity to release accumulated hydrocarbons.

Fish

Figure 4.16 shows the typical exposure periods for motile organisms such as fish. These 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 the organism. Moreover, the volume of water exposed to concentrations above PNEC values is relatively small both under present and projected discharge rates.

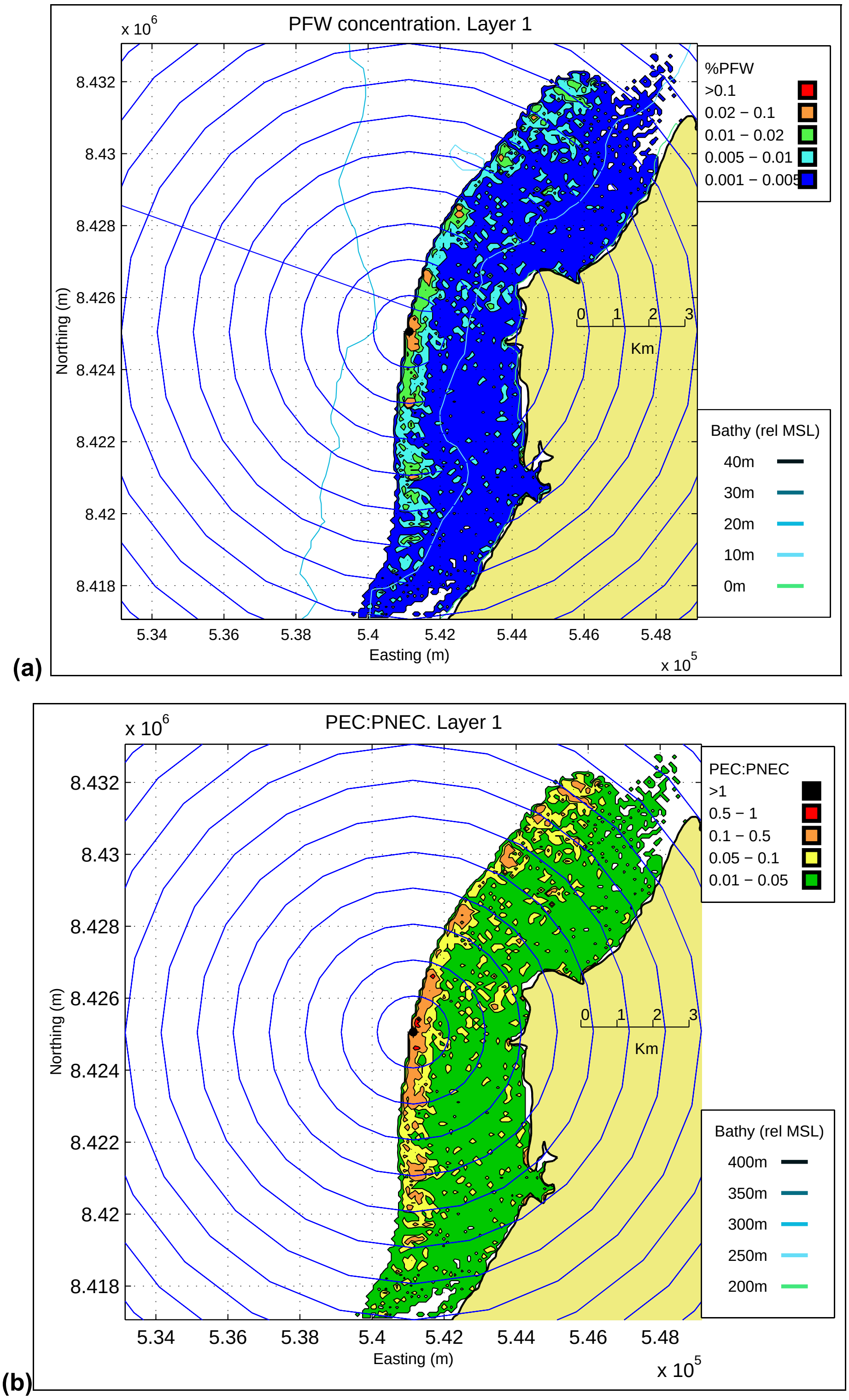
Marine mammals

As marine mammals feed on fish and/or plankton, they are most likely to be affected by trophic transfer (ie, 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. They are also generally migratory so individuals are not likely to be affected by any localised contamination that may occur.

Seabirds

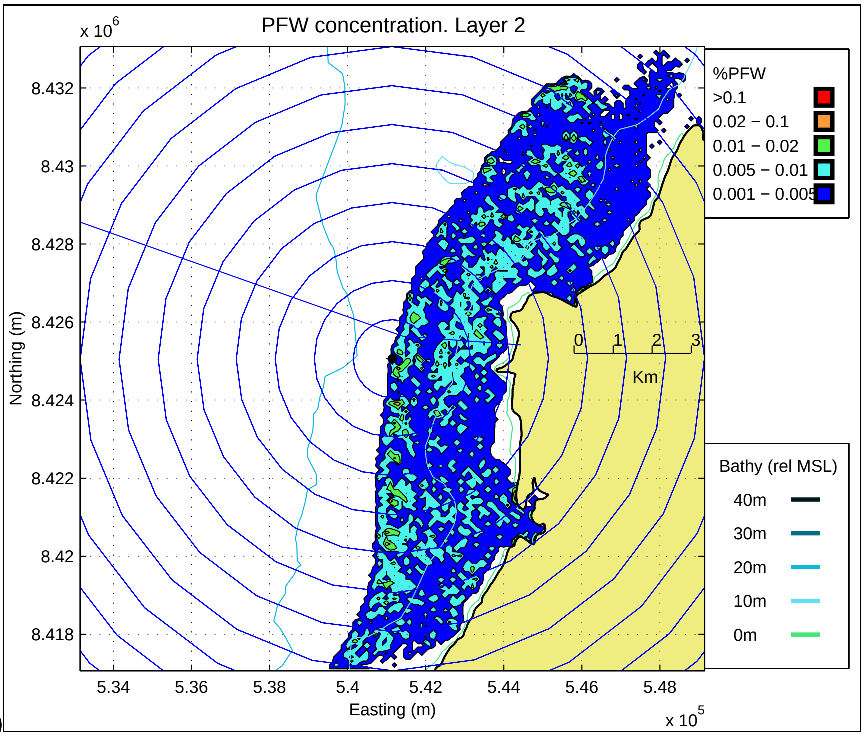
Seabirds are harmed mainly by the physical properties of floating oil and not the toxicity. (Furness and Camphuysen, 1997). As with the marine mammals, there is the potential for trophic transfer and indirect effects such as changes in the availability of food sources. As the food source is not likely to be impacted, the risk to sea birds is low.

Figure 4.12. Scenario 14: (a) maximum PFW concentrations and (b) PEC/PNEC ratios over three tidal cycles for layer one (0-2 m) on a neap tide

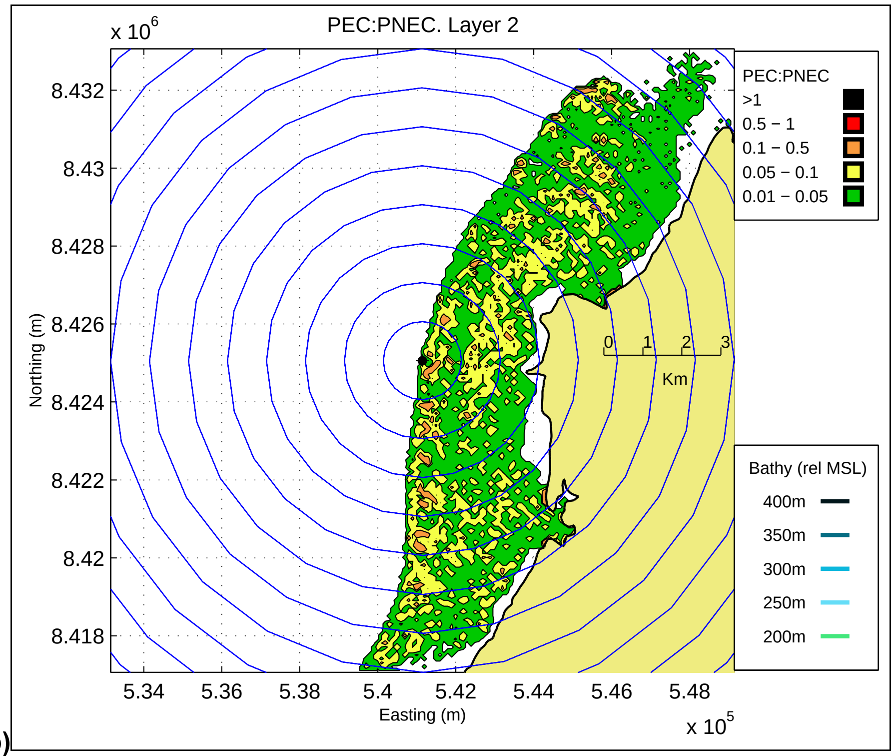


Note: Range rings are drawn at 1km intervals centred on the discharge point

Figure 4.13. Scenario 14: (a) maximum PFW concentrations and (b) PEC/PNEC ratios over three tidal cycles for layer two (2-4 m) on a neap tide



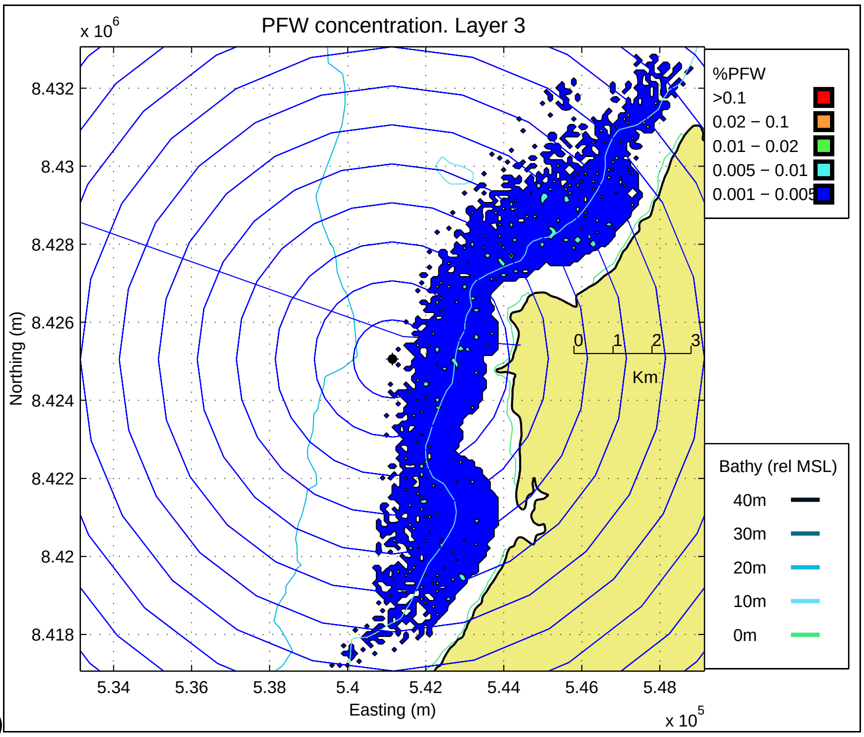
(a)



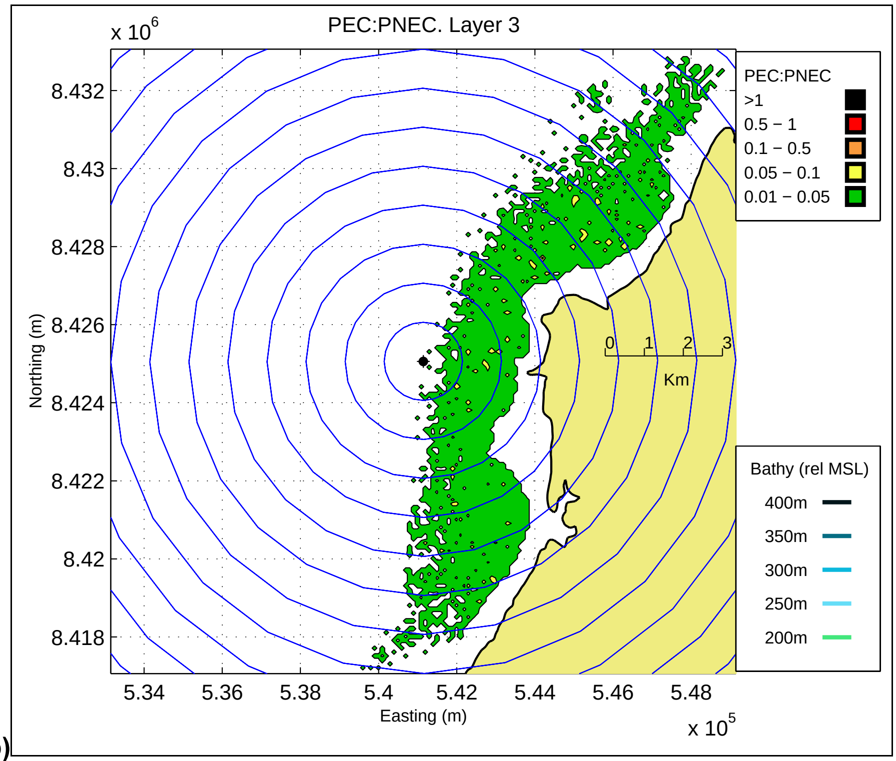
(b)

Note: Range rings are drawn at 2km intervals centred on the discharge point

Figure 4.14. Scenario 14: (a) maximum PFW concentrations and (b) PEC/PNEC ratios over three tidal cycles for layer three (4-6 m) on a neap tide



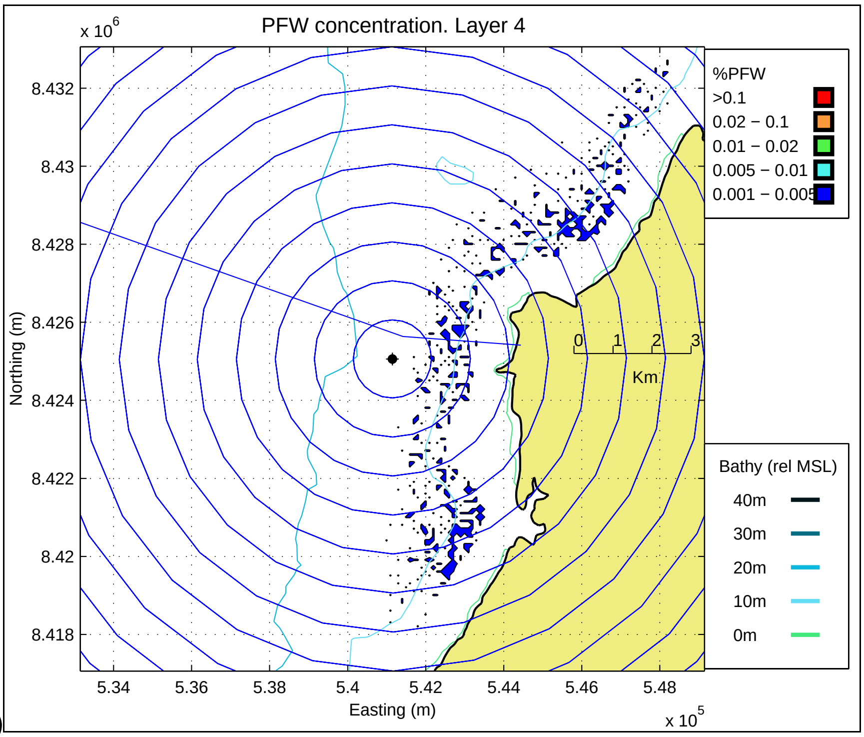
(a)



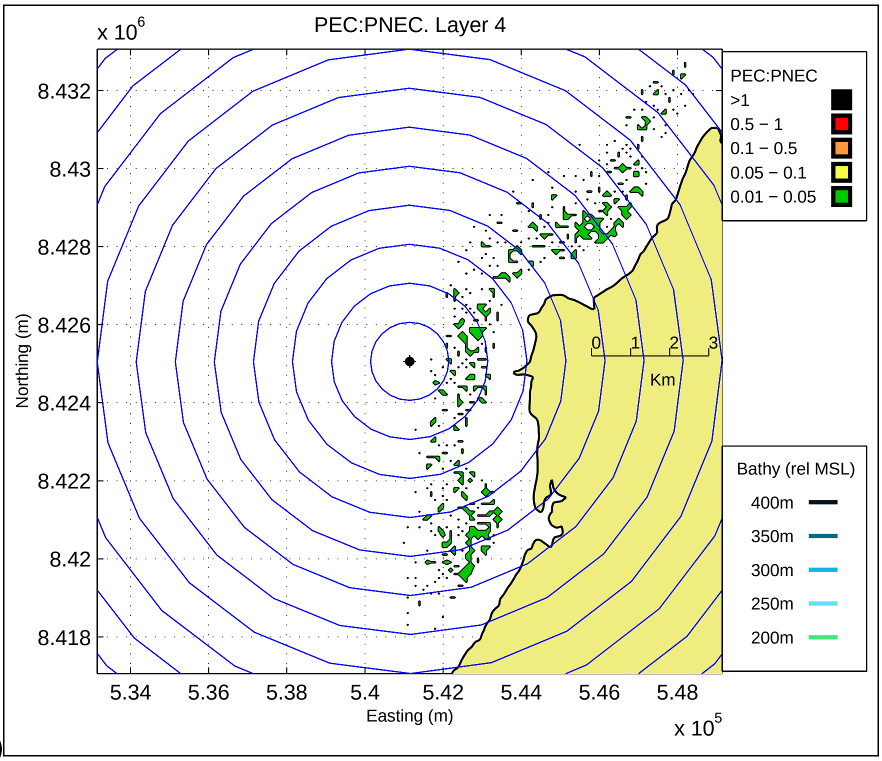
(b)

Note: Range rings are drawn at 2km intervals centred on the discharge point

Figure 4.15. Scenario 14: (a) maximum PFW concentrations and (b) PEC/PNEC ratios over three tidal cycles for layer four (6 - 10 m) on a neap tide



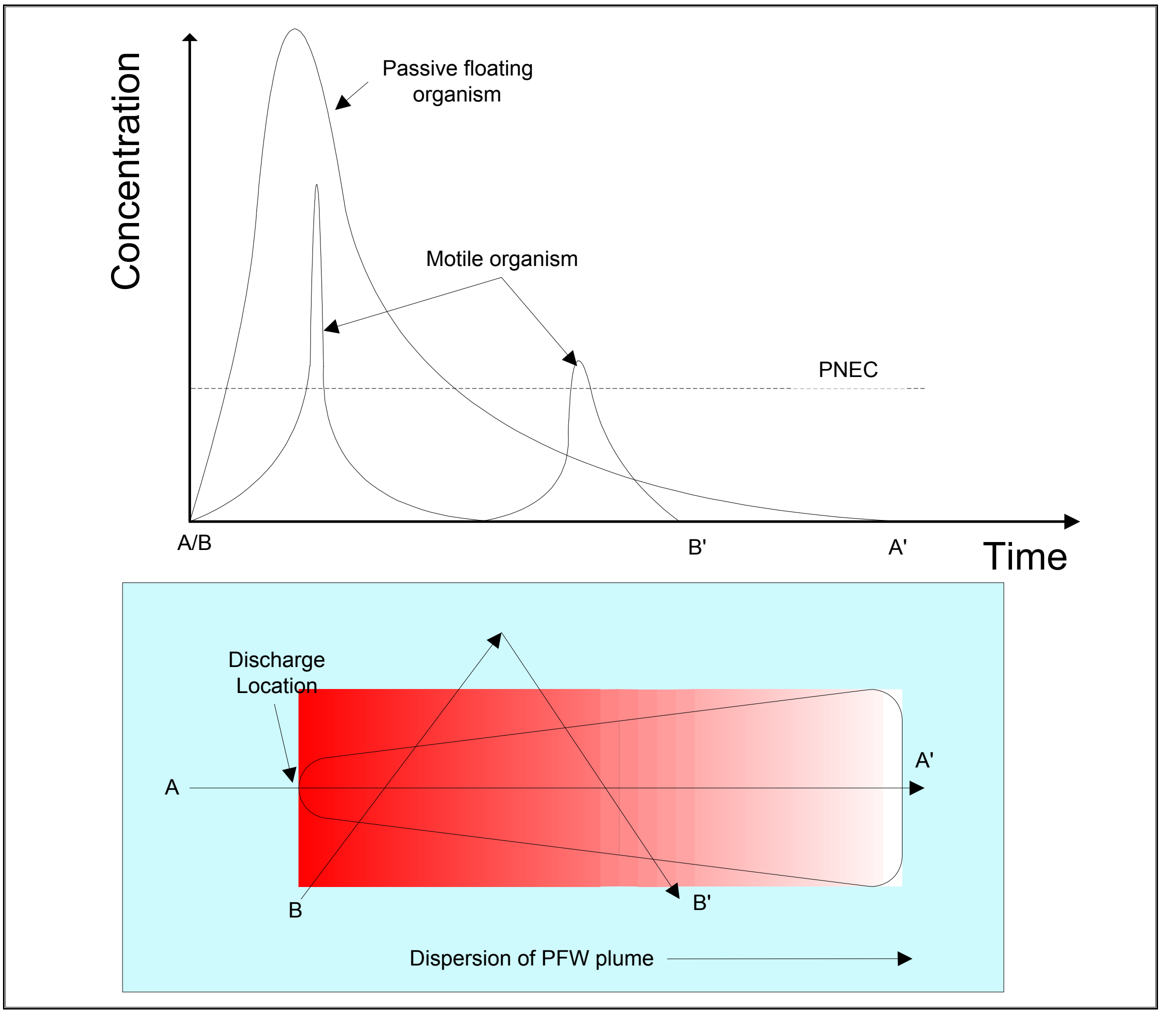
(a)



(b)

Note: Range rings are drawn at 2km intervals centred on the discharge point

Figure 4.16 Conceptual model for PFW exposure times for passive and motile organisms



4.4 Dissolved Oxygen

4.4.1 General

Prior to discharge PFW is likely to have little or no DO. This should not be a problem as even under worst-case conditions the discharged plume should receive 700 initial dilutions (see Section 2.3.5), which mean that by the time the plume reaches the sea surface DO concentrations should be virtually back to ambient levels. However, the PFW discharge will contain a range of organic compounds and chemicals that will start to decompose and utilise oxygen immediately on discharge. The rate at which oxygen is utilised is measured by the Biochemical Oxygen Demand (BOD) of the effluent.

This section presents an assessment on the likely impact of this oxygen utilisation on DO levels in the receiving waters. From this analysis, maximum BOD concentrations are given that will most likely maintain oxygen levels above 90% saturation limits as required by the ANZECC guidelines.

4.4.2 Receiving Waters

The concentration of DO is highly dependent on temperature, salinity, biological activity (microbial primary production) and rate of transfer from the atmosphere. Based on water temperatures (26 to 30°C) and salinity (34psu) of the receiving waters in the vicinity of the Blacktip PFW discharge, DO saturation levels will vary from 6.22mgL^{-1} to 6.64mgL^{-1}. The 2000 ANZECC guidelines for fresh and marine water quality recommend that DO in tropical Australia should not normally permitted to fall below 90% saturation, determined over at least one tidal cycle. For Blacktip, this equates to 5.6mgL^{-1}.

4.4.3 Biochemical Oxygen Demand

The BOD provides a measure of the rate at which oxygen is consumed by bacterial activity and is thus an indirect measure of the organic content of wastewater. Experiments have shown that BOD decays exponentially with time, t, according to the equation:

$$BOD_c = BOD_0 e^{-K_{BOD} t}$$

where:

BOD_c is the concentration at time t;

BOD_0 is the original concentration; and

K_{BOD} is the BOD decay rate.

K_{BOD} is temperature dependant and can be calculated from:

$$K_{BOD}^{T_1} = K_{BOD}^{T_2}\theta^{(T_1 - T_2)}$$

where:

$K_{BOD}^{T_1}$ is the decay coefficient at temperature T_1;

$K_{BOD}^{T_2}$ is the decay coefficient at 20°C (typically between 0.2 and 0.3); and

θ is the temperature coefficient for reaction rates (typically 1.056 for T>20°C).

For temperatures of 28°C and $K_{BOD}^{T_2}$ of 0.26 this yields a value of 0.4 day^{-1}.

4.4.4 Oxygen Utilisation

Oxygen utilisation (D_{O2}) in a bounded stream can be predicted using a modified version of the classic Streeter-Phelps oxygen sag equation (Metcalf and Eddy, 1991), given by:

$$D_{O2} = \frac{K_{BOD}BOD_0}{K_{O_2} - K_{BOD}}\left(e^{-K_{BOD}t} - e^{-K_{O_2}t}\right)$$

where:

K_{O2} is the reaeration coefficient.

The graphical representation of the Streeter-Phelps oxygen sag equation is given in Figure 4.17, using the values specified in Table 4.4. For illustration purposes, the initial BOD concentration was set at 5000mgL^{-1}. After 700 initial dilutions this decreases to 7.14mgL^{-1}. As can be seen from the DO curve, oxygen utilisation commences immediately after discharge. It will continue to fall until a critical point is reached when the rate of oxygen utilised by waste decomposition equals the rate of atmospheric reaeration. Thereafter DO concentrations increase as the rate of reaeration exceeds the rate of utilisation.

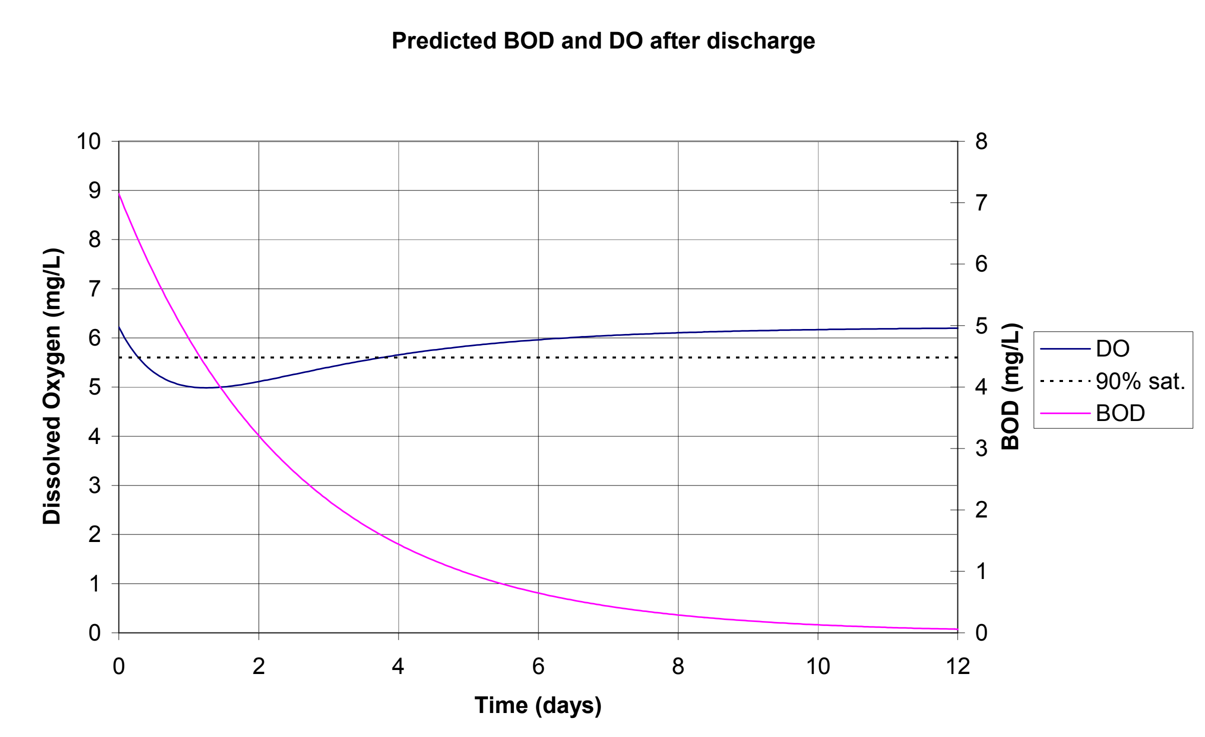
Table 4.4 Summary of values used in Streeter Phelps equation

Parameter	Value
$O_{2\ sat.}$	6.22 mgL^{-1}
BOD_0	7.14 mgL^{-1} (5,000 mgL^{-1} prior to initial dilution of 700)
K_{BOD}	0.4 day^{-1}
K_{O2}	1.4 day^{-1}

The principle is the same for the open ocean, however, in addition to the decay process, BOD concentrations reduce through dispersion of the plume in the receiving waters. This may be countered in regions of slow moving currents by build up due to poor flushing and recirculation of the plume over itself.

In studies undertaken for the European Urban Wastewater Treatment Directive it was estimated that where BOD levels deviate by less than 1.5mgL^{-1} from background levels, the resulting impact on DO will be less than 0.5 mg/l. (CSTT; 1993). This can also be seen from the oxygen sag and BOD concentration curve in Figure 4.17. In the dispersion modelling presented next, 1.5mgL^{-1} was used as the threshold value below which there should be no adverse effect in the environment from reduced oxygen levels.

Figure 4.17 Concentrations of BOD and DO predicted by the Streeter-Phelps equation.



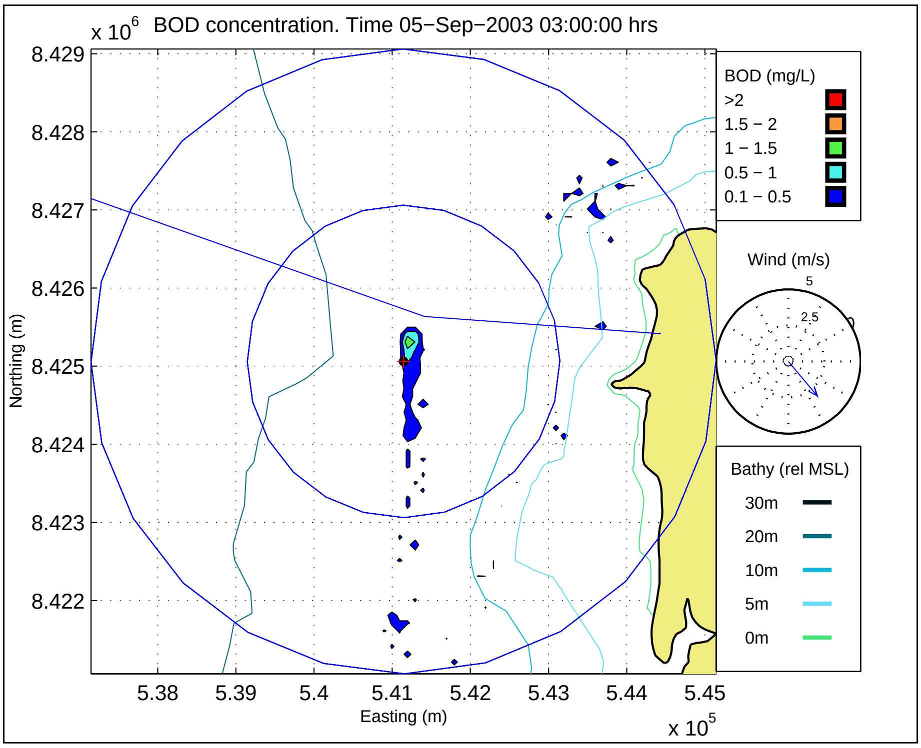
4.4.5 Dispersion Modelling

BOD was simulated using the PFW dispersion model with the objective of deriving a maximum value for the effluent discharge. The scenario undertaken was identical to that described in Section 4.3.6, with the exception that BOD was modelled instead of a conservative tracer. The initial BOD concentration was set at 1,200mgL^{-1} and the decay coefficient at 0.4 day^{-1}.

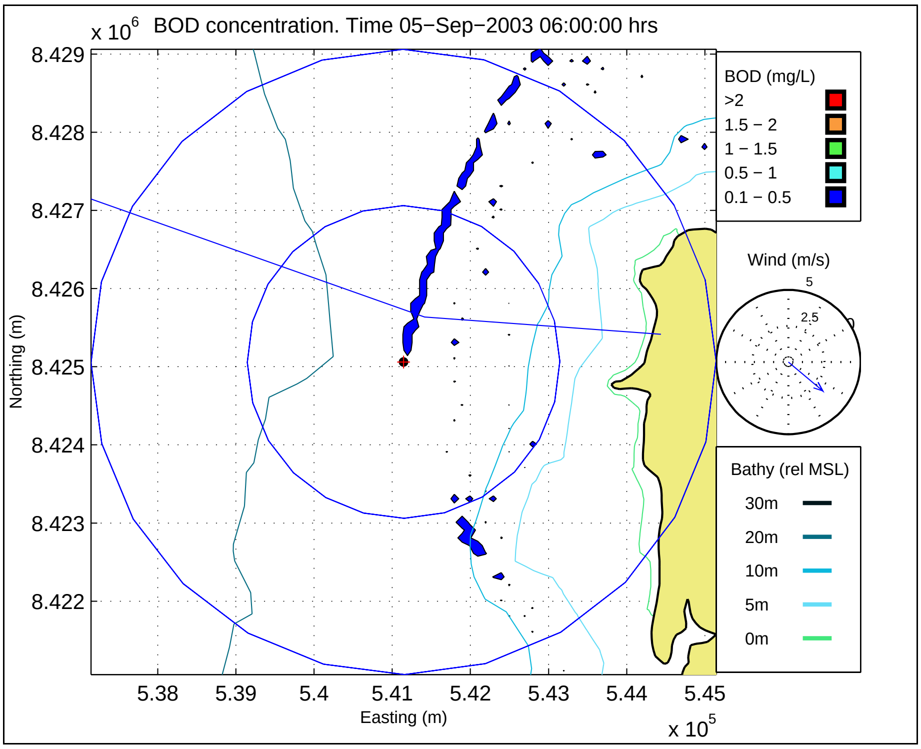
Figure 4.18 (a) – (d) present a series of plots showing the predicted concentration of BOD at three hourly intervals for maximum future flows under “worst-case” ambient conditions (neap tide and typical “wet season” winds). At high water (Figure 4.11(a)), the plume pools at slack water and BOD concentrations increase to a maximum of 1.5mgL^{-1}. On the ebb tide, the plume is advected parallel to the bathymetry contours for a distance of approximately 12km towards the north. With the increasing ambient flow, there is additional dilution and concentrations reduce to less than 0.5mgL^{-1}. At low water the discharge pools and once again concentrations peak at 1.5mgL^{-1}. The flood tide advects the plume about 10km towards the south.

Figure 4.18. Predicted BOD concentration on a neap tide

(a) High Water

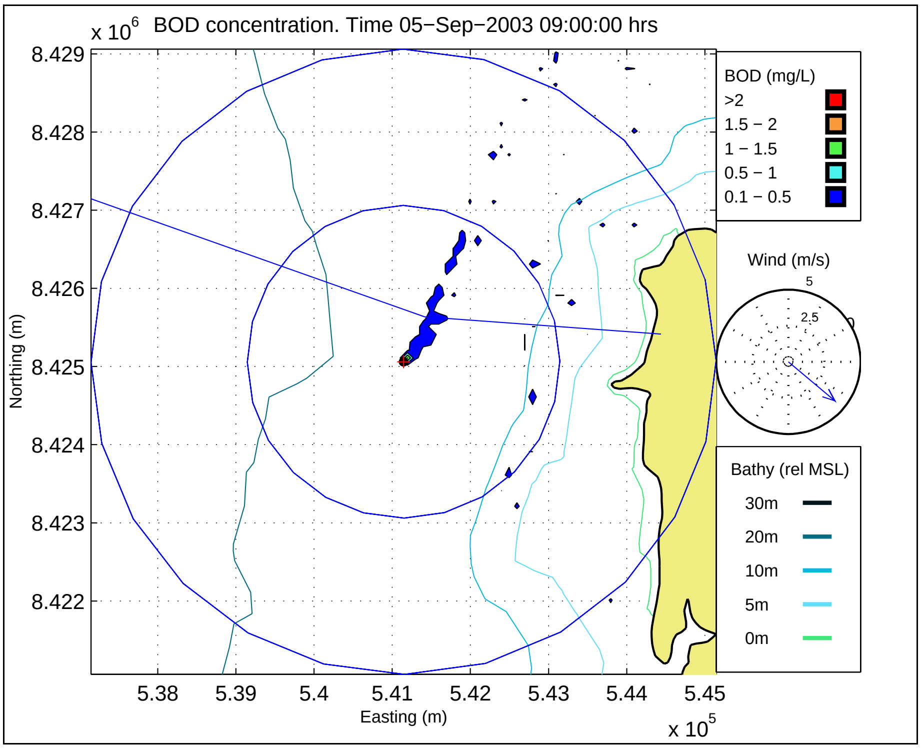


(b) Mid ebb

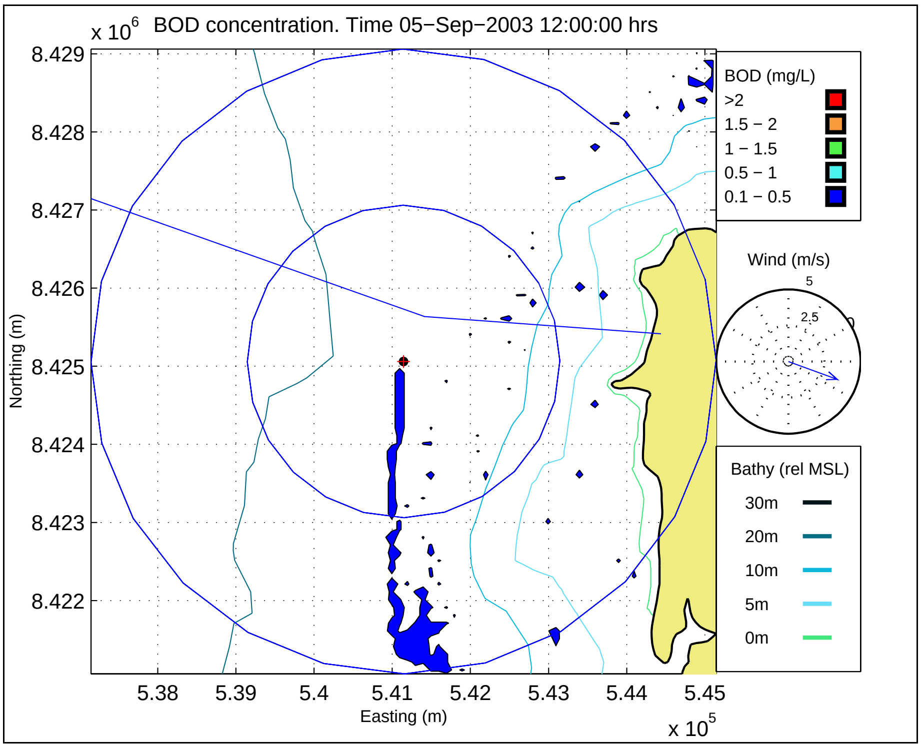


Note: Range rings are drawn at 1km intervals centred on the discharge point

(c) Low water



(d) Mid flood



Note: Range rings are drawn at 1km intervals centred on the discharge point

4.4.6 Risk Assessment

The traditional PEC/PNEC approach was used to assess the risk. As described in Section 2.5.3, this approach demonstrates the zone of potential affect by calculating and presenting contours of the PEC/PNEC ratio. Any value over one then indicates a potential zone of impact. The PNEC was set at 1.5 mg/L BOD. As stated above, this is the concentration at which the change in DO levels will be less than $0.5mgL^{-1}$.

Figure 4.19 and Figure 4.20 show (a) the maximum predicted BOD concentration that occurred over the three tidal cycle simulation and (b) the corresponding PEC/PNEC ratio contours, for the top two layers in the model, respectively. Highest concentrations occur in the surface waters around the discharge location. These peak at about $1.5mgL^{-1}$ BOD within 100m from the discharge point. The PEC/PNEC ratios peak at about one suggesting that the change in DO levels will be less that $0.5mgL^{-1}$ at all times.

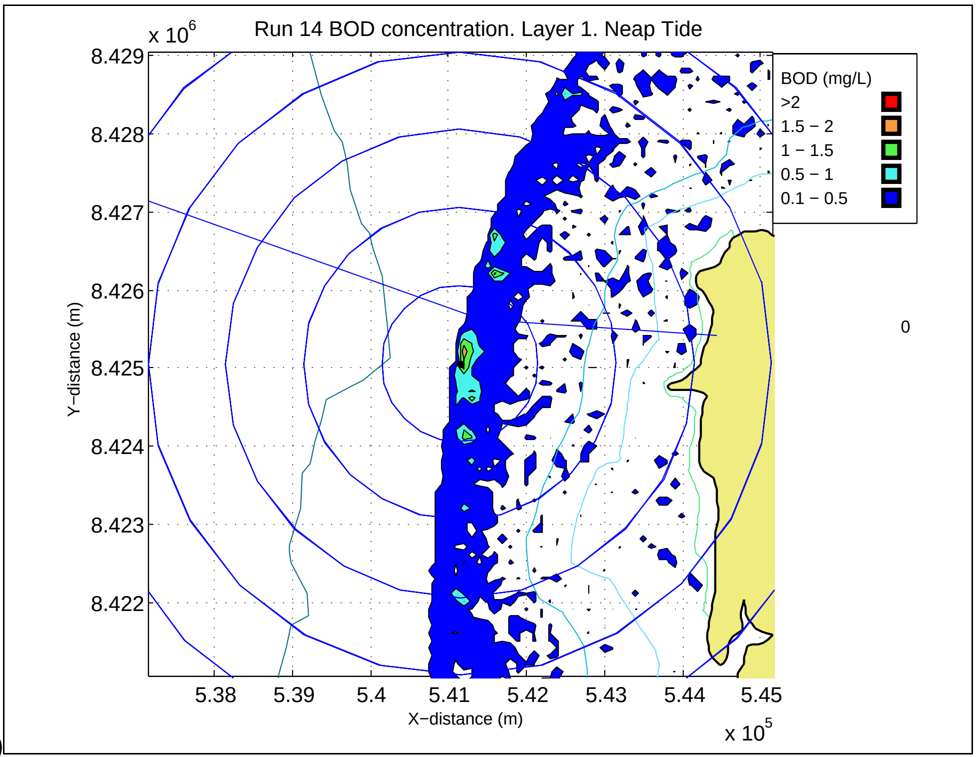
4.4.7 Recommended maximum BOD Concentrations

A BOD concentration of $1,200mgL^{-1}$ was found to be the limit for the design rate of 6000 bbl day^{-1} to maintain BOD levels in the receiving environment below the critical value of $1.5mgL^{-1}$. This value was used to scale BOD concentrations for the other design flow rates. Results are presented in Table 4.5.

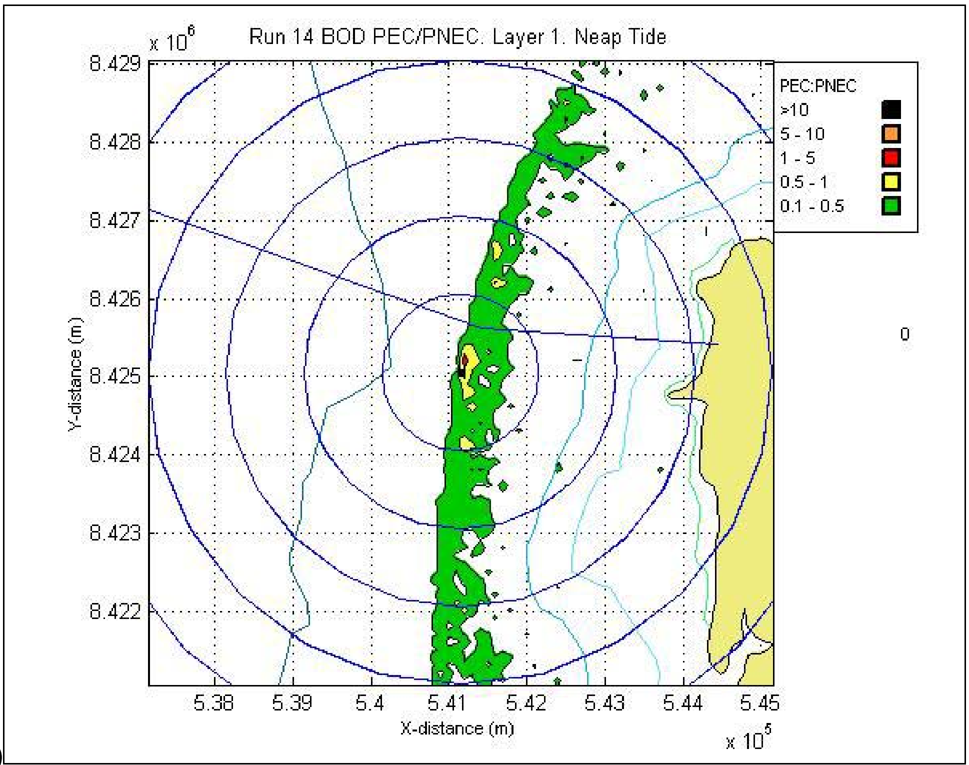
Table 4.5 Recommended maximum BOD concentrations for each design flow rate.

Design flow rate (bbl day^{-1})	Maximum BOD conc. (mgL^{-1})
6000	2,500
2000	7,500
200	75,000

Figure 4.19. Scenario 14: (a) maximum BOD concentrations and (b) PEC/PNEC ratios over three tidal cycles for layer one (0-2 m) on a neap tide



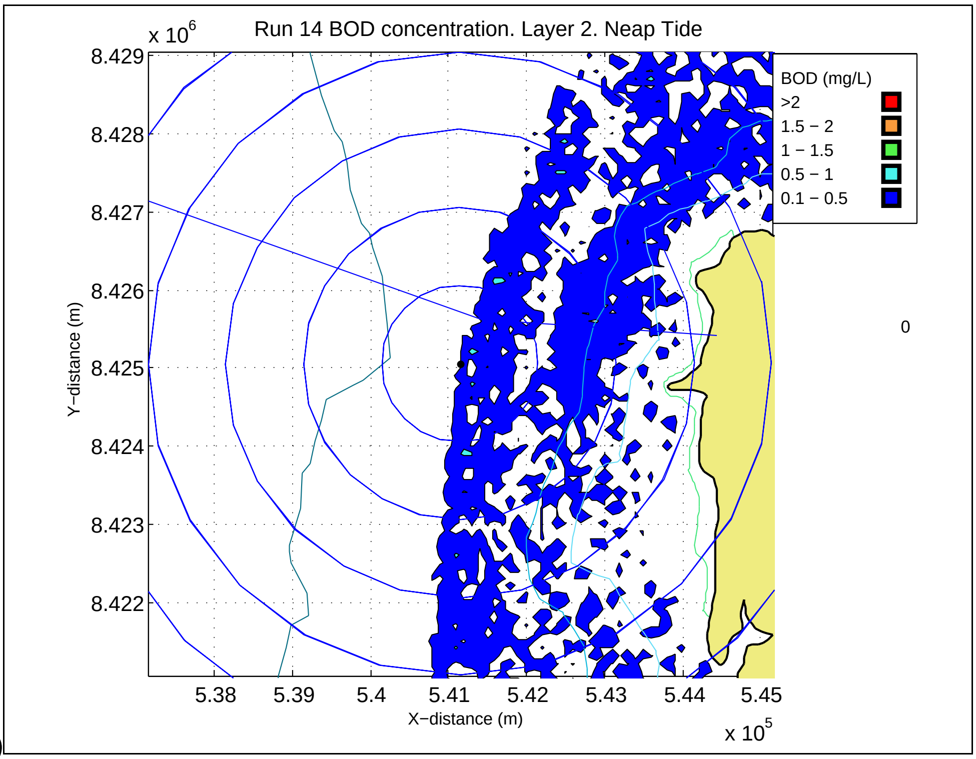
(a)



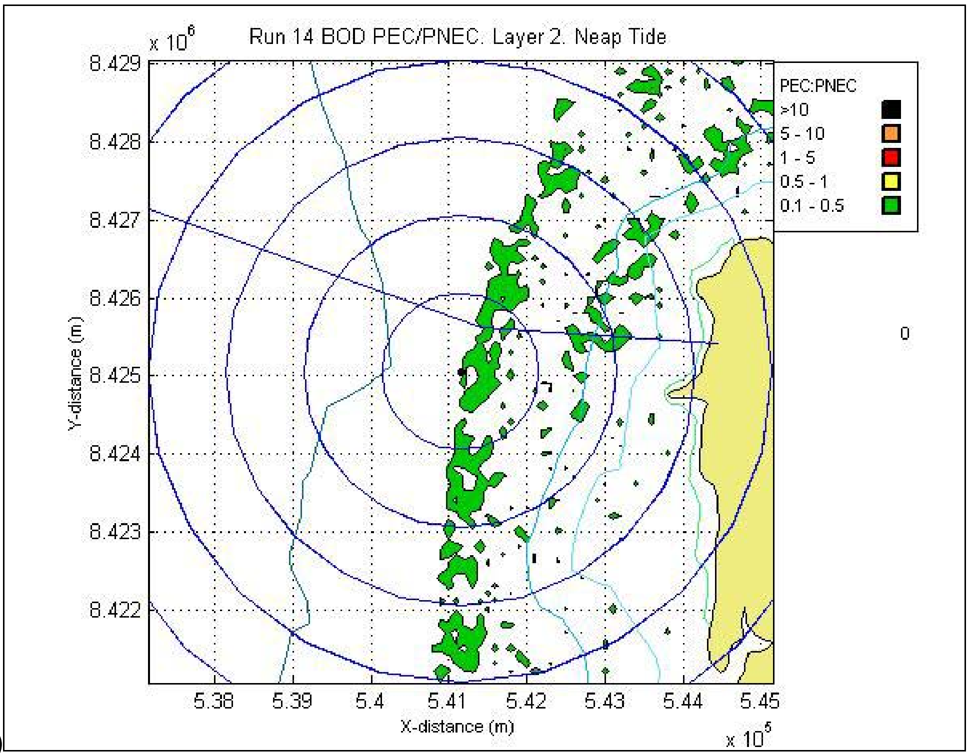
(b)

Notes:

Figure 4.20. Scenario 14: (a) maximum BOD concentrations and (b) PEC/PNEC ratios over three tidal cycles for layer two (2-4 m) on a neap tide



(a)



(b)

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

It is common practice in the petroleum industry to remove as many hydrocarbons as possible from PFW by physical or enhanced separation techniques and then discharging directly to the ocean. It is recognised that the separation process is not 100% effective and trace concentrations of chemical contaminants can remain in the discharge. Hydrocarbons and process chemicals are the contaminants of most concern in PFW.

Ecotoxicology experiments under laboratory conditions have demonstrated that undiluted PFW can be toxic to marine organisms. In contrast, detecting a measurable impact on marine ecosystems in the vicinity of PFW discharges has proved difficult. The reason for this is that dilution and biodegradation in the receiving environment reduces contaminant concentrations to levels below which they can have an impact on marine organisms. Where concentrations do exceed thresholds, exposure times for free-moving organisms are generally short.

The preferred disposal option for Blacktip PFW is onshore treatment followed by discharge through a long sea outfall. The discharge location will be near the Swamp Mooring, which lies in 15m of water. Corrosion inhibitors, hydrate inhibitor and demulsifiers will be added to the process stream. These will be selected based on their low toxicity and enhanced environmental performance. Onshore treatment allows more scope for treatment as there is not the space restriction of offshore facilities and contaminant concentration will be reduced to as low as practicable prior to discharge.

Numerical modelling has been undertaken to assess the environmental impact and to derive an effective discharge strategy for the Blacktip PFW. The assimilative capacity of the receiving water is high with strong tidal currents of up to $0.9ms^{-1}$ on a spring tides and $0.2ms^{-1}$ on neaps. Tides are semidiurnal and currents slacken four times a day.

Using a four port diffuser configuration, near field dispersion modelling showed that at least 700 initial dilutions would be achieved for the maximum future discharge rate. This would reduce PFW concentrations to 0.14%.

Far field modelling predicted that during slack waters PFW would build up and concentrations would reduce to a maximum of 0.1%PFW within 400m from the discharge. Based on ecotoxicology work previously undertaken by WEL on offshore facilities, this is below the predicted concentration at which there could be harm to marine organisms.

These exotoxicity values are believed to be conservative as the tests included sublethal endpoints and were undertaken on organisms in their most sensitive stages of life (eg larval development or fertilisation). Moreover, exposure times were greater than those likely to be experienced in the natural environment. Assuming that the treated Blacktip PFW is no more toxic than PFW from other Woodside Assets, there should be minimal environmental impact from discharging it to the 15 m depth contour in the Joseph Bonaparte Gulf.

5.2 Recommendations

Once PFW becomes available, ecotoxicology tests should be undertaken and the toxicity of process chemicals should be reviewed. Ecotoxicity should include tests on juvenile prawns as this species constitutes an important fishery in the Joseph Bonaparte Gulf.

As well as reducing the concentration of dispersed oil, treatment should focus on removing PAHs and reducing the toxicity of process chemicals, the compounds of most concern in PFW. Model results should take into consideration any further benefits provided by the proposed treatment.

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IRCE, 2003c. Cossack Pioneer Produced Formation Water Assessment. Doc. No. ENV-REP-02-078-CP REV 1.

IRCE, 2003d. Ocean Legend Produced Formation Water Assessment. Doc. No. ENV-REP-02-078-OL REV 0.

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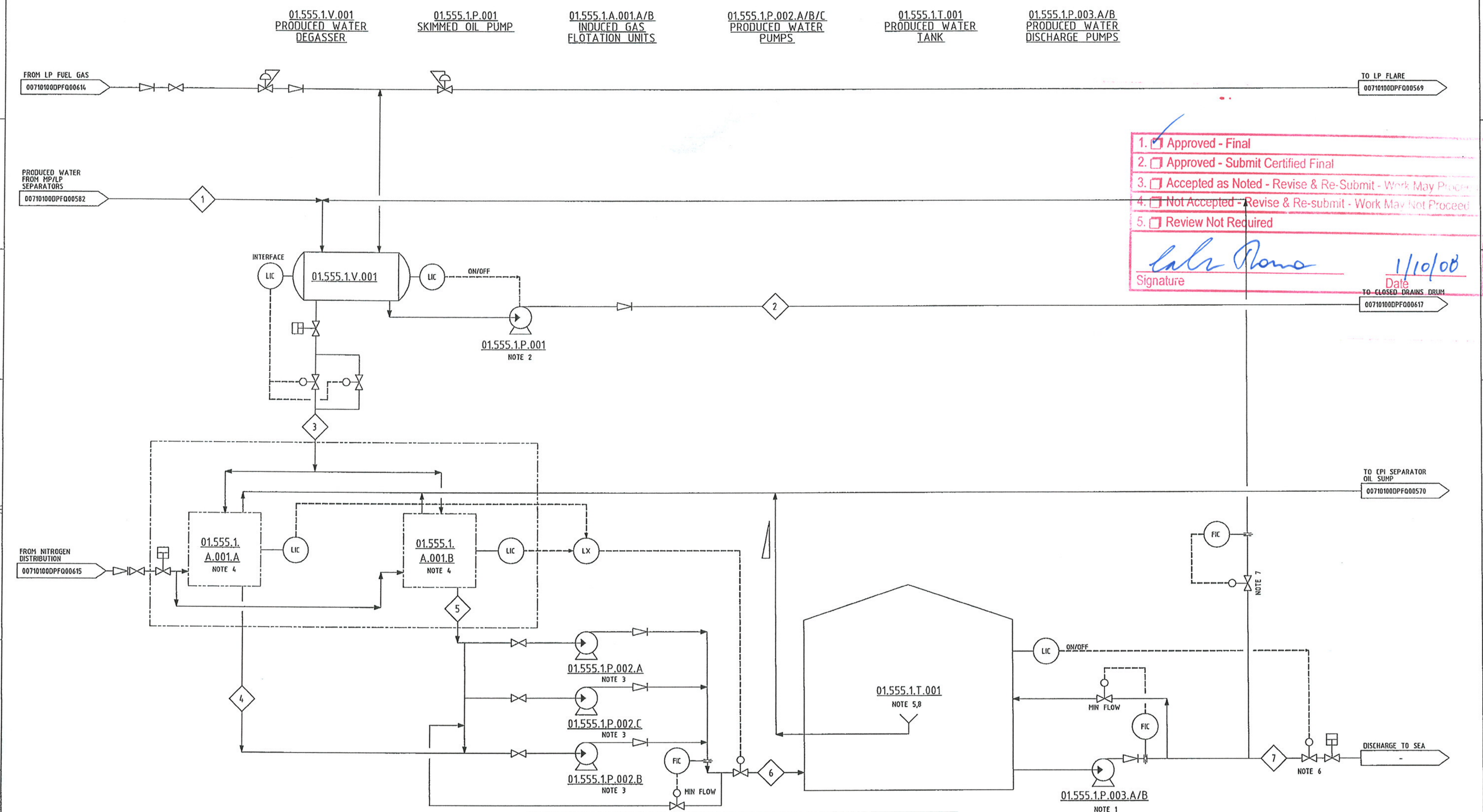
APPENDIX D PROCESS UTILITY FLOW DIAGRAMS



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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

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.

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

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
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5. Review Not Required

Signature .... Date 1/10/08

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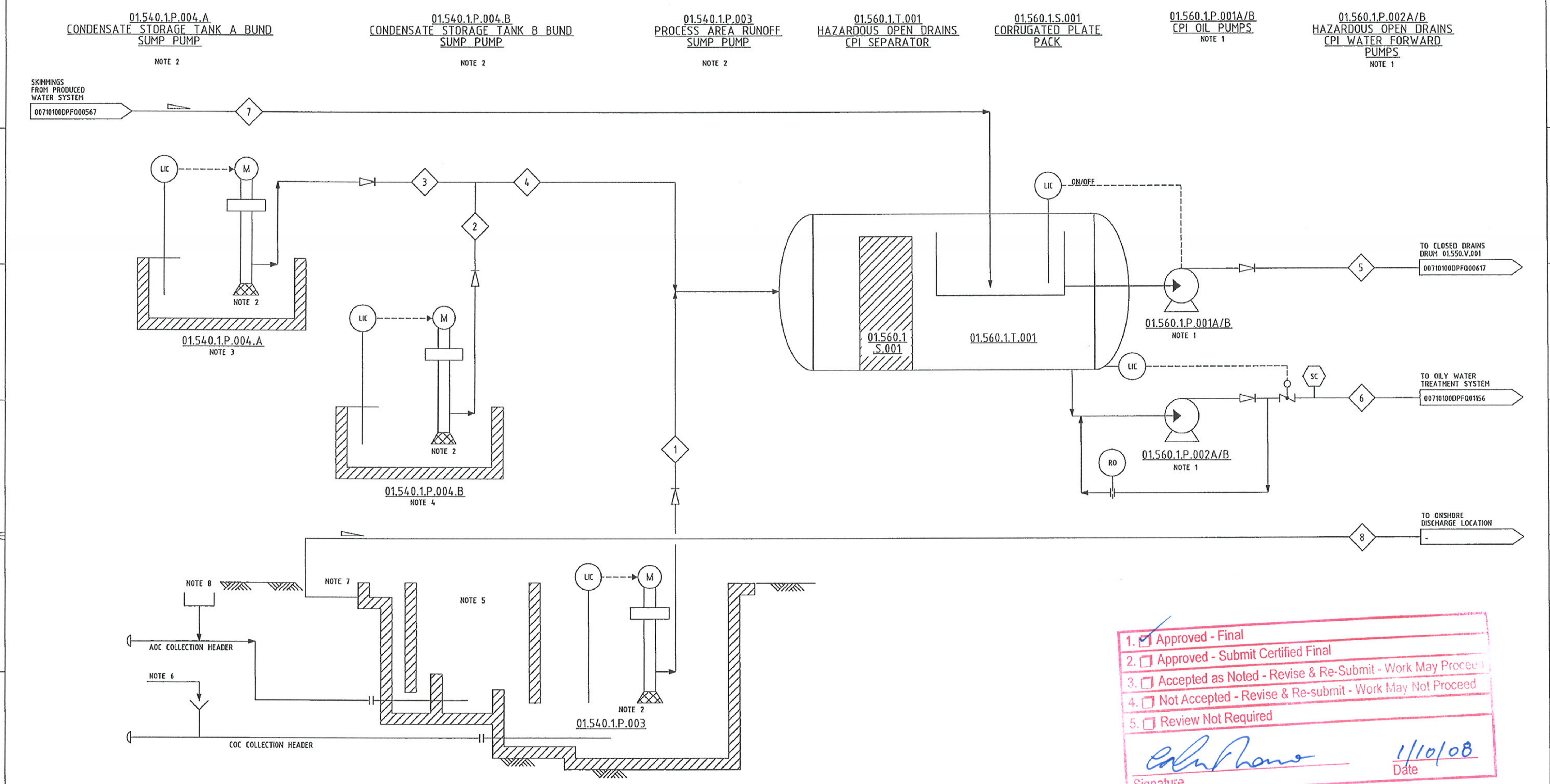
GENESIS

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



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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

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).

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

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.

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

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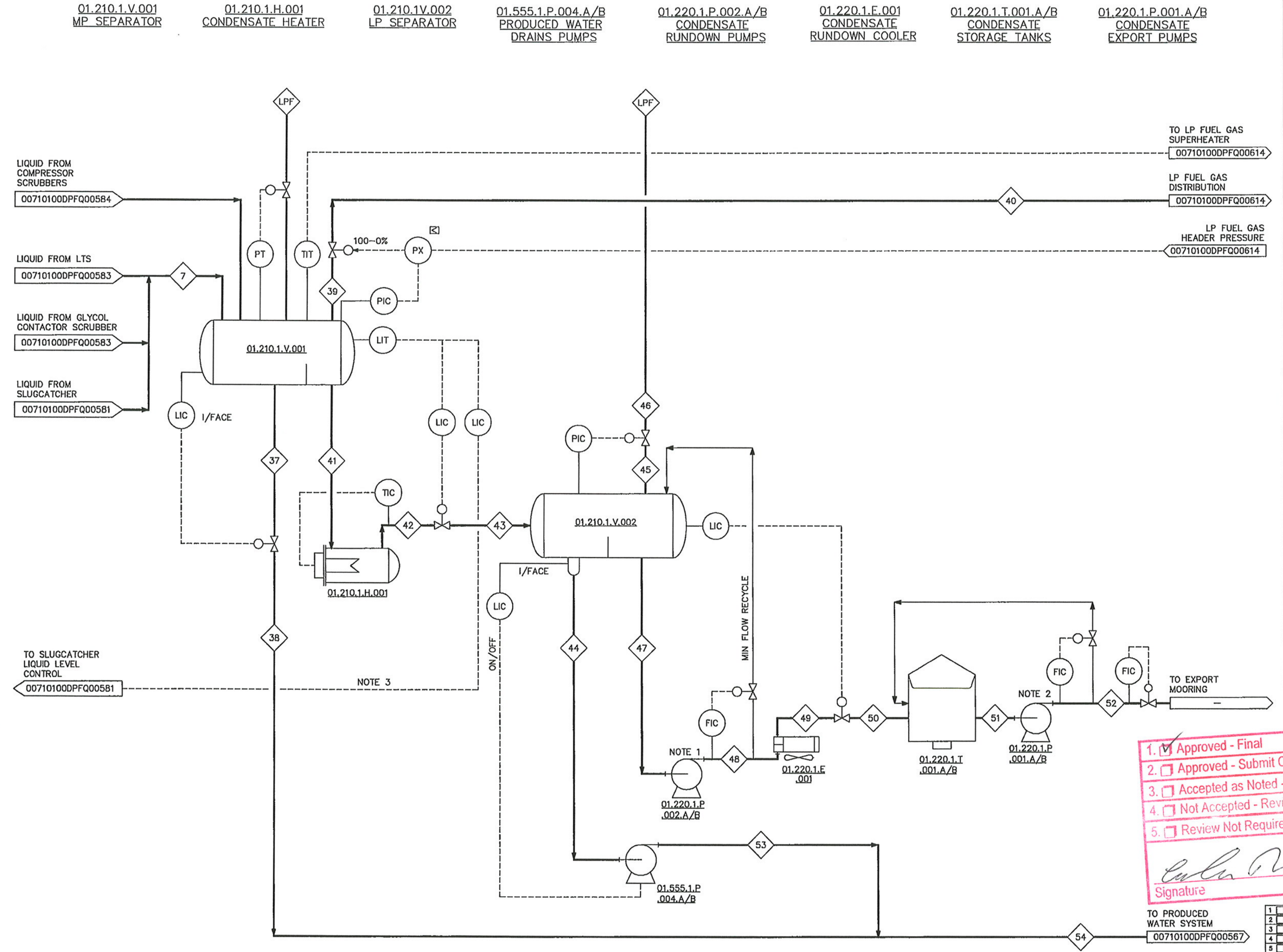

NOTES:

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:
1111111111111111111111111111111111111111111111111111111111111111111
111111111111
                      CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX1:
Subsystem version:
 Submerged Single Port Discharges           CORMIX_v.3.20
_____September_1996
-------------------------------------------------------------------
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-------------------------------------------------------------------
------------
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
-----------------------------------------------------------------
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-----------------------------------------------------------------
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BEGIN MOD101: DISCHARGE MODULE

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

END OF MOD101: DISCHARGE MODULE
-----------------------------------------------------------------
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-----------------------------------------------------------------
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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
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** End of NEAR-FIELD REGION (NFR) **
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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
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CORMIX1: Submerged Single Port Discharges              End of
Prediction File
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APPENDIX F MANAGEMENT OF CHANGE FORM #00658 – TRIAL OF PRODUCED WATER CLEAN UP EQUIPMENT

MANAGEMENT OF CHANGE FORM

SECTION A: INITIATION (To be completed by the change originator and entered in the Change Register)

Title of Change: Trial of Produced Water Clean Up Equipment **MOC No.** 00658

Location: YGP **Date of Request:** 16/04/2024 **Originator:** A. Elshab

Priority Classification	Type of Change	Timing
☐ Safety Critical	☐ Permanent	☒ Priority 1 - immediate action
☒ Non Safety Critical	☒ Temporary – Expiry 20/10/2024	☐ Priority 2 - action within 5 days
☐ Regulatory		☐ Priority 3 - next available resource

Nature of Change

☐ Case to Operate	☐ Procedural	☐ Software
☒ Equipment	☐ Drawings	☐ Design
☐ Process	☐ Organisation / People	☐ Activity

Description of Change: (Attach additional sheets, marked up P&ID's, other drawings, cost estimates, schedules.)

Installation and trial of temporary equipment to the Produced Water system. The temporary equipment to be installed will be as follows:

1. Inclined Plate Lamella (IPL) (solids removal)
2. Oily Water Separator (OWS) and Structure
3. Produced Water Surge Tank
4. 2 x Chemical Dosing Skids
5. Produced Water Transfer Pump
6. Scouring Pump
7. Generator Set (Diesel)
8. Associated hoses to connect the equipment (mixture of flanged and cam-locked)

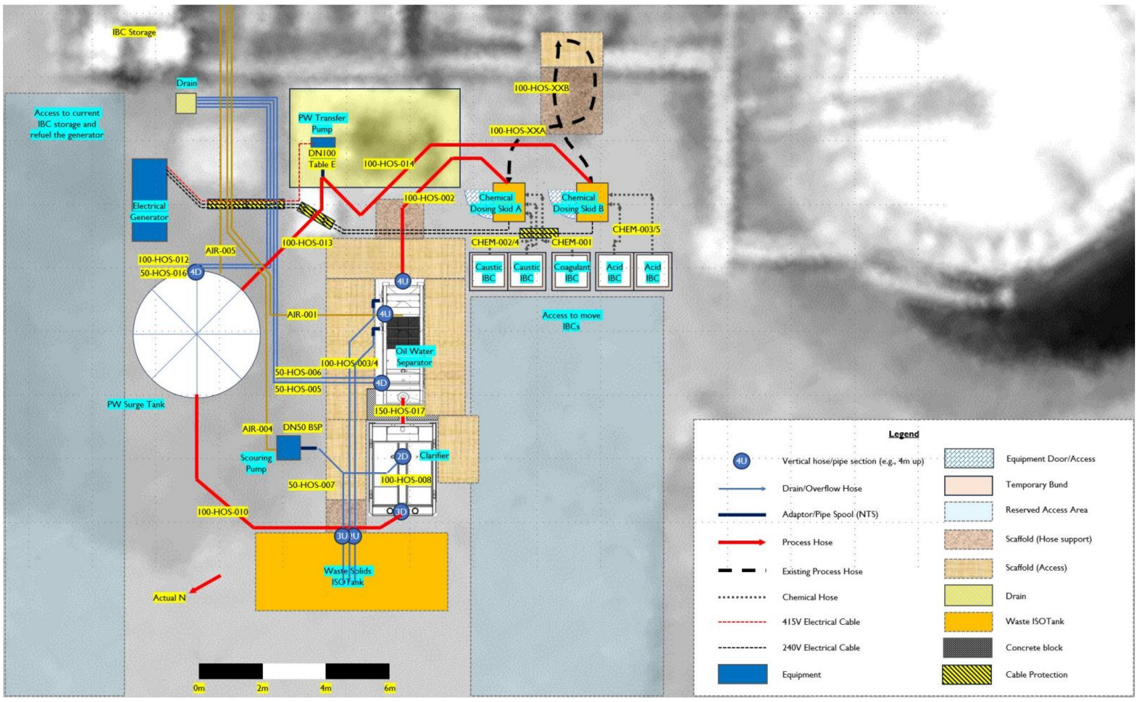

Figure 1 – Proposed Trial Equipment Layout

Reason for Change:

MANAGEMENT OF CHANGE FORM

An investigation identified that all other domestic gas plants located around Australia have the ability to utilise large evaporation ponds for the Produced Water received into the plant once it is separated from the condensate. This allows for all potential contaminants to either evaporate or remain within the pond for later removal as required. Due to the location of the YGP processing facilities (tropical region), an evaporation pond does not physically work for approximately six months of the year (wet season) due to the humidity preventing evaporation and the volume of rain that would increase the level of the pond with a risk of overflow to grade.

In accordance with the facilities Basis of Design document (2006), at the time of writing the project was not given any guidance on the limits for discharging Produced Water to sea. Then project decided to introduce the offshore specification at the time which was free oil in water at less than 30 mg/L. The YGP Produced Water system was therefore designed to this requirement only.

Since the initial Environmental Protection Licence (EPL) was issued, the NTEPA have been imposing additional limits on specific parameters at each EPL renewal (every 5 years). This has been based on monitoring of agreed parameters and limits applied in line with the sampling requirements of the licence.

The sample results are presented in the annual reports to the NTEPA – with any increasing parameter being added to the licence renewal or beforehand if deemed necessary.

In the 2015 Benzene was added to the licence with an imposed limit. This has not been exceeded with the formation water received over the period of time.

In the 2020 EPL renewal, Toluene, Ethylbenzene and m+p xylene (BTEX) and metals (Copper, Manganese and Zinc) were added to the licence with limits applied from the ANZG 2018 guidelines.

The BTEX and metals limits imposed have since been difficult to achieve with the installed facilities that were only ever designed for free oil removal. A CETCO package was procured in 2012 to assist with removing the oil, carbon filters have been trialled in an attempt to remove the BTEX however due to it being entrained in the water there was no success. The CETCO filters have provided a better result with free oil and solids.

Nitrogen sparging was introduced at the pump return line to the PW Tank with an initial reduction of BTEX observed with the monthly samples. Over 12 months of monitoring this has plateaued, with the ability to ensure Benzene remains below limits, Ethylbenzene achieving below limits and Toluene and m+p xylene reducing in level however remaining above limits.

Equipment Installation Trial

Engineering Consultants (Process Engineering Consultants) were contracted to advise on potential solutions to reduce the solids, BTEX and metal components of the water. The consultants selected deal with older facilities located in Gipplsland, Victoria and offshore in Bass Strait and therefore had experience with this type of discharge requirements. A concept was developed for off-the-shelf equipment trial including two main components for oil in water, solids removal, BTEX and metals coupled with controlled chemical injection packages. This concept was then further refined, materials selected to suit the trial and a bill of materials supplied for procurement.

The equipment does not have any remote control and is purely manual with exception of the chemical dosing cabinets that monitor water pH and adjust dosing to suit the required neutral pH of the water.

The equipment to be utilised as detailed above is temporary, and to be facilitated as a trial only to determine the effectiveness of removing the BTEX and metals components of the water. If successful, this will be developed into an engineering project for permanent equipment complete with remote operation, monitoring and trip (process safety) functionality to ensure the system is safe to operate.

Known Implications of change: (History, previous non-conformance, previous failures, previous change.)

1. Tie-in to installed Produced Water Treatment System (through existing CETCO package hoses)
2. Oily Water Separator and Inclined Plate Lamella are both open top vessels
3. Overflow protection for the OWS, IPL and Surge tank are required to run into the AOC header drain and therefore into the HOD pit
4. There is no process monitoring (pressure, temperature, flow, level) instrumentation installed on the system – it is

MANAGEMENT OF CHANGE FORM

purely manual and therefore requires personnel in the field whilst operating

5. Chemical injection will occur at the start of the process (caustic for emulsion breakout and coagulant for solids and metals) and acid at the Surge Tank to decrease the pH to discharge level before discharging to the PW tank
6. Nitrogen sparging will occur at the OWS to attempt to remove the BTEX components across the column of the water passing through. This will result in BTEX odour being present in the vicinity – BTEX monitoring will be required to ensure appropriate boundaries can be established as required

SECTION B: EVALUATION (To be completed by Technical Approver of nominated change)

Accountable for MOC	**Name:**	**B. Gillespie**	
Identification of Stakeholders	**Stakeholder List**	**Impact**	**Notification Required**
	Eng/Main/AI Manager	Eng/Main/AI	☒ Yes ☐ No
	POS	Operations	☒ Yes ☐ No
	HSE Manager	Safety/Environemnt	☒ Yes ☐ No
Has a TDRQ been completed?		☐ Yes ☒ N/A	**Ref:**
Identification of Affected Systems:		☐ Environment Plan ☐ Safety Case ☐ Procedure	☐ Management System ☐ ☐
Required Regulatory Permits obtained		☐ Attached	☒ Not Required
Identification of applicable Codes and Standards		☐ Attached	☒ Not Required
Contingency planning in place?		☐ Attached	☒ Not Required
Additional technical support or expertise sourced? Process Engineering Consultants used to design the process, select the equipment, develop the construction plan and develop the commissioning and operating procedures.		☒ Attached	☐ Not Required
Documentation required to manage change process (list):		☒ Attached	☐ Not Required
Drawing / Documents Delivery / Acceptance Details:			

Technical Approver Evaluation: ____________ (Print name) ____________ (Signature) ____________ (Date)

SECTION C: RISK ASSESSMENT

Technical Approver to assess risk associated with the change in accordance with ENI-HSE-PR-001 Risk Management and Hazard Identification.

	Safety	Environment	Reputation	Assets	Other
Consequence	3 3	2 2	2 2		
Frequency	B A	C B	C B		
Risk Ranking	Pre - Medium Post - Low	Pre - Medium Post - Low	Pre - Medium Post - Low		

Comments

Risk Assessment conducted based on the following Consequences:

Safety – chemicals being utilised for PW treatment and personnel exposure to Produced Water. BTEX components in the air due to open top vessels

Environment – Produced Water spill to grade

MANAGEMENT OF CHANGE FORM

1. **Both the Oily Water Separator (OWS) and Inclined Plate Lamella (IPL) are open vessels. To eliminate the risk of an overflow to grade, both vessels will have a hose connected at the top of the vessel that will run off to the AOC header drain located at the PW skid**
2. **The surge tank overflow is also directed to the drain and will be contained to the HOD pit in the event of the tank being over filled**
3. **The adjusted design has the OWS located fully within the concrete bund adjacent to the PW Treatment skid (original Cetco package location). This will contain any overflows to the HOD pit directly**
4. **The IPL will be located half inside the concrete bund. Any overflows will be contained to the hose directed to the drain to the HOD pit.**
5. **HOD pit will be tested and pumped down to 50% to allow quarantining of any PW that overflows from the OWS or Inclined Plate Lamella**
6. **The design incorporates two cabinets at each end for chemical dosing of Sodium hydroxide 30% (caustic) and citric acid currently in use for water treatment (breaking of emulsion and reducing pH). Both cabinets contain online pH monitoring for automatic dosing to achieve the required levels. Dosing occurs inside the cabinets.**
7. **A coagulant will be incorporated to assist with metals and particulate removal. MSDS is contained in Appendix and has been reviewed by Logistics to ensure it is safe for transport to site.**
8. **The system will be connected through the existing Cetco package flexible hoses. This removes the requirement for process break-ins at pipe spools**
9. **The equipment is connected between the IGF's and the PW tank. This will allow either storage of the water in PW tank if a single pass successfully cleans the water to within specification or can be passed through the PW treatment facilities again to further polish the water**
10. **Noting both vessels (OWS and IPL) are both open to atmosphere, there is a potential for BTEX to be present in the atmosphere surrounding the OWS and IPL. Once water is admitted to the system, a portable BTEX meter shall be used to monitor the concentration and determine if a personnel boundary needs to be installed around the treatment equipment**
11. **PPE will be made available for use for personnel to use working in the area.**
12. **Noting the system is a trial to determine if it will provide the required results (BTEX, solids and metals removal), the system is all manual in operation with exception of the chemical dosing system. Therefore personnel will remain in the Produced Water area during operation to ensure an overflow event does not occur.**
13. **Commissioning and Operating procedures have been developed by the Process Engineering consultants who have designed the system. The procedures shall be reviewed by the Production team to ensure alignment with site operating procedures**
14. **The Pre-Start Up Safety Review (PSSR) shall be utilised prior to commissioning (Attached to this MOC)**
15. **Scaffold will be established around the OWS and IPL to monitor levels of water and access valves around the base of the OWS. Access to be restricted to personnel operating the system only.**
16. **Personnel have the ability to locate to a safe area immediately in the event the BTEX indications exceed short term or long term exposure limits.**
17. **Barricading of the area to be established whilst water treatment is in progress. All site personnel shall be advised during morning pre-starts to remain clear of the area**

Conditions & mitigation measures (what must be done)

No	Action to be Taken	Action Party	Target Completion Date	Date Action Completed	Entered into Sharepoint
	System to constructed in accordance with design as supplied by engineering consultants	Engineering	04/05/2024		
	System to be commissioned in accordance with commissioning procedure by Engineering Consultants with site staff in attendance	Engineering	06/05/2024		
	Site staff to be trained in the operation of the process by Engineering Consultants	Engineering/Production	08/05/2024		

MANAGEMENT OF CHANGE FORM

RISK MATRIX

Consequence					Likelihood or Annual Frequency					
					0	A	B	C	D	E
Severity	Company Reputation	People (Health & Safety)	Environment	Assets / Project	0 - Non credible / Could happen in E&P industry (Freq <10-6 /y)	A - Rare / Reported for E&P industry (Freq 10-6 to 10-4 /y)	B - Unlikely / Has occurred at least once in Company (Freq 10-4 to 10-3 /y)	C - Credible / Has occurred several times in Company (Freq 10-3 to 10-1 /y)	D - Probable / Happens several times per year in Company (Freq 10-1 to 1 /y)	E - Frequent / Several times per year at one location (Freq >1 /y)
1	**1**-Slight impact	**1**-Slight health effect / injury	**1**-Slight effect	**1**-Slight damage	Low	Low	Low	Low	Low	Low
2	**2**-Minor impact	**2**-Minor health effect / injury	**2**-Minor effect	**2**-Minor damage	Low	Low	Low	Medium	Medium	Medium
3	**3**-Local impact	**3**-Major health effect / injury	**3**-Local effect	**3**-Local damage	Low	Low	Medium	Medium - High	High	High
4	**4**-National impact	**4**-PTD or single fatality	**4**-Major effect	**4**-Major damage	Low	Medium	Medium - High	High	High	High
5	**5**-International impact	**5**-Multiple fatalities	**5**-Extensive effect	**5**-Extensive damage	Medium	Medium - High	High	High	High	High

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MANAGEMENT OF CHANGE FORM

SECTION D: APPROVAL

Approval level to be determined as per Management of Change Procedure.
If formal risk assessment was carried out, the HSE Manager signature indicates they have been consulted about the change.

Technical Approval: Brett Gillespie
(Print name) (Signature) (Date)

Functional Approval: Dave McCubben
(Print name) (Signature) (Date)

HSE Manager Consulted: Joe Covic
(Print name) (Signature) (Date)

Change communicated to:

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

Training packages complete?

☐ Yes (please list) ☐ No ☐ Not Applicable

SECTION E: COMPLETION & CLOSE-OUT

Change undertaken as described: Yes ☐ No ☐
Deviations:

Critical Information Updated: Yes ☐ No ☐
(Updated drawings/procedures available, communication/training complete, necessary inspections performed)

Regulatory Permits Filed: Yes ☐ No ☐
Comments:

Code Compliance	Code No.	Details of Compliance / Non-compliance

Functional Close-out:
(Print name) (Signature) (Date)

HSE Manager Close-out:
As required
(Print name) (Signature) (Date)

Date closed out on Register: **Name:**

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