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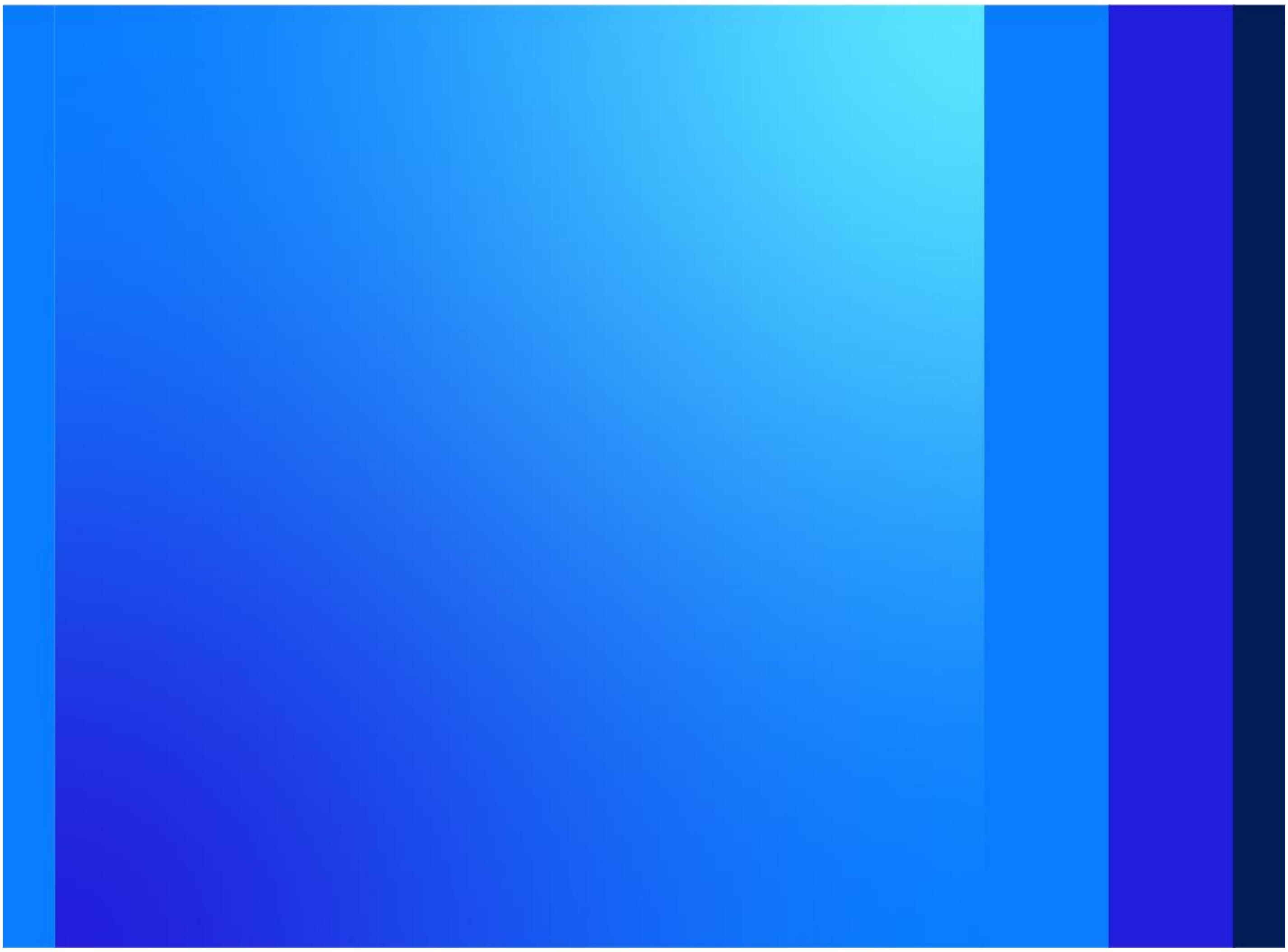
TIWI ISLAND HYDROGEN FACILITY

Desalination Plant Scoping Study

April 8th, 2022



TIWI ISLAND HYDROGEN FACILITY

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Abbreviations & Symbols	Definition
ASTM	American Society for Testing and Materials
CEB	Chemically Enhanced Backwash
CIP	Clean in Place
CORMIX	Cornell Mixing Zone Expert System
DO	Dissolved Oxygen
EC	Electrical Conductivity
EcOz	EcOz Environmental Consulting
EDI	Electro De-Ionisation
GEV	Global Energy Ventures
kWh	Kilowatt-Hour
mg/L	Milligrams per Litre
LAT	Landscape Analysis Tool
PFD	Process Flow Diagram
pH	pH Units
PPB	Parts Per Billion
PPM	Parts Per Million
PPT	Parts Per Trillion
PSU	Practical Salinity Unit
PVDF	Polyvinyl Difluoride
NTU	Nephelometric Turbidity Unit
RMSE	Root Square Mean Error
RO	Reverse Osmosis
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UF	Ultrafiltration
µS	Microsiemens

Executive Summary

Provaris Energy Ltd engaged Jacobs to undertake a desalination scoping study for a facility in the Tiwi Island. The objective of this study is to determine the typical desalination plant required to supply water for a hydrogen facility and inform on its likely inputs and outputs to enable better understanding of the potential environmental interactions.

The plant is intended to provide ultrapure water to feed electrolysis units to produce hydrogen for export. Development of the basis of study determined that the influent water quality would be broadly in line with standard seawater and that the product water quality would need to have a conductivity less than 1 µS/cm.

A process train for the desalination plant based on the requirements outlined in the basis of study. It was determined that a process train consisting of auto-strainers (4-off), ultrafiltration (UF, 3 trains), a two pass Reverse Osmosis system (RO, three trains) and Electro de-Ionisation trains (EDI, 4 trains) would reliably produce water at the specified quality and quantity. Owing to the remote location of the plant, a redundancy of N+1 was selected for each of the process units.

UF system adopted was such that the use of chemical coagulant is minimised to avoid the handling of backwash waste. Concentrate streams from the 2nd pass Reverse Osmosis and Electro de-Ionisation system are recycled within the plant to maximise overall system recovery. The specific energy of water production for the plant is estimated to be 4.5 kWh/m^3.

Scoping for the intake and outfall noted that the intake for the plant could be mounted on the jetty on the site or on a pontoon connected to the jetty, with each option having advantages and disadvantages. Depending detailed design factors, the intake could draw up to 50kW and have a discharge diameter of 450mm. Scoping of the outfall indicated that a jetty mounted discharge nozzle would provide sufficient local mixing and not impact the salinity around the intake.

Nearfield mixing was investigated using CORMIX modelling and suggest that the proposed outfall design shows good nearfield mixing.

The modelling undertaken showed that the proposed outfall site is subject to strong tidal currents which promote good mixing of the proposed brine discharge. Model results demonstrate that the impacts of the proposed brine discharges will be small and contained to an area in the immediately vicinity of the proposed outfall, with no salinity impacts of greater than 0.5 practical salinity units (PSU) predicted outside a zone of 100 m radius from the outfall.

1. Introduction

Provaris Energy Ltd (PV1) engaged Jacobs to develop a preliminary concept for a desalination plant located at Port Melville to supply water for hydrogen production via electrolysis. The objective of this study is to provide input into the environmental approvals process and will compose of the following tasks:

1. Present the typical infrastructure required to provide up to 4.2ML/d of water to the standard required for electrolysis.
2. Determine the expected key output streams from the desalination plant including product water, brine (concentrate) and any waste streams
3. Determine additional requirements (e.g., Energy demand and chemical requirements).
4. Determine indicative footprint.
5. Determine the extent of brine discharge influence during the operation of the desalination plant as well as conceptualising intake and brine disposal arrangements.
6. Recommend ways forward with further analysis relating to the desalination plant.

2. Basis of Study

2.1 Expected Influent Water Quality

Detailed site-specific water quality parameters in the locality of the planned facility are not available, therefore the anticipated influent water quality has been developed based on available information. Apart from total suspended solids (TSS), the physical parameters including dissolved solids (TDS), pH and water temperature have been based on measurements taken from the Darwin outer harbour zone[1]. The range of the mineral composition of influent seawater has been extrapolated from mineral composition[2] of seawater which is largely consistent globally applied to an estimated ranged of feed TDS. The adopted seawater quality is provided in Table 2-1.

Table 2-1 Adopted influent water quality.

Influent Properties[3]	Parameter	Unit	Typical Seawater	Minimum	Average	Maximum
Physical Properties	TDS	mg/L	34,483	35,000	37,820	39,000
	Temp	°C	17	25.9	26.5	29.0
	pH	-	8.1	7.90	8.25	8.30
	TSS	mg/L	-	5	10	100
Chemical Properties	Ammonia	mg/L NH4 as N	-	0.008	0.010	0.013
	Phosphorous	mg/L as PO4	-	0.00	0.00	0.00
	Barium	mg/L	0.05	0.05	0.05	0.06
	Bicarbonate	mg/L	140	143	153	158
	Borate	mg/L	4.5	4.57	4.94	5.09
	Bromide	mg/L	65	66	71	74
	Calcium	mg/L	400	406	439	452
	Chloride	mg/L	18,980	19,265	20,817	21,466
	Fluoride	mg/L	1.0	1.01	1.10	1.13
	Iodide	mg/L	0.05	0.05	0.05	0.06
	Iron	mg/L	0.002	0.00	0.00	0.00
	Magnesium	mg/L	1,262	1,281	1,384	1,427
	Potassium	mg/L	380	386	417	430
	Silica	mg/L as SiO2	0.016	0.02	0.02	0.02
	Sodium	mg/L	10,556	10,714	11,578	11,939
	Strontium	mg/L	13	13.19	14.26	14.70
	Sulphate	mg/L	2,649	2,689	2,905	2,996

Unlike TDS, TSS levels in seawater feedwater can be highly variable based on the location of seawater intake and are susceptible to more acute variation due to environmental conditions. The values for TSS have been estimated at 5, 10 and 100 mg/L for minimum, average and maximum feedwater qualities respectively. This is believed to represent a conservative approach, while assuming the required

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[1] https://depws.nt.gov.au/water/water-management/darwin-harbour/darwin-harbour-region-report-cards/darwin-harbour-report-card-2020/zone-6-outer-harbour

[2] https://web.stanford.edu/group/Urchin/mineral.html

[3] Minimum and Maximum water qualities have been taken as the extrapolated 10th and 90th percentile TDS data from Darwin respectively

flexibility in locating the seawater intake to avoid events resulting in TSS concentrations greater than 100 mg/L.

2.2 Required Electrolysis Feedwater Quality

Electrolysis requires extremely pure water to operate. The required operating feed operating parameters[4] and the feedwater water qualities, which are based on the American Society for Testing and Materials (ASTM) specifications[5] are provided in Table 2-2.

Table 2-2 Required Electrolysis Operating Conditions

Parameter	Unit	Minimum	Maximum
Pressure	bar	1	4.1
Temperature	°C	5	35
Standard		ASTM (Type I)	ASTM (Type II)
Requirement		Recommended	Required
Resistivity	MΩ/cm	> 18	> 1
Conductivity	µS/cm @ 25C	< 0.056	< 1
Total Organic Carbon	µg/kg	< 50	< 50
Sodium	µg/kg	1	5
Chloride	µg/kg	1	5
Silica	µg/kg	3	3

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[4] Operating conditions for NEL systems with Non-NEL feed equipment

[5] ASTM D1193 – 06 (2011)

3. Desalination Plant Process Requirements

3.1 Selected Plant Process Train

To develop the process train sizing and performance requirements, the required plant product water volume and qualities detailed in Section 2 were used as a basis and the process was developed from the product end of the plant to the seawater intake. The individual processes were selected based on the following criteria:

- The ability of the process unit to produce the required product water quality and quantity
- The operational simplicity and availability of the selected process unit
- The potential environmental impact of process unit waste products
- Experience from previous projects with regards to the applicability of the process units

The selected process train is provided in Figure 3-1 and the detailed Process Flow Diagram (PFD) with Mass Balance and preliminary plant layout is provided in Appendix A and Appendix B respectively.

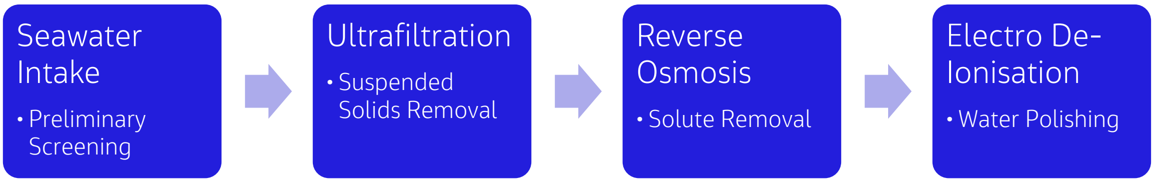

Figure 3-1 Selected Process Train

The process train consists of:

1. Seawater Intake and pre-screening to remove coarse solids to protect the downstream Ultrafiltration (UF) system from mechanical damage (caused by marine debris such as barnacles and shell material). This typically includes a coarse screen at the intake as well as finer screening prior to the UF system.
2. Ultrafiltration to remove suspended solids that would result in particulate fouling of the Reverse Osmosis (RO) system. The UF system will consist of multiple trains that utilise PVDF membranes with a nominal pore size less than 0.1 micron to filter out residual suspended solids.
3. A two-pass RO system using polyamide-based layered spiral wound membranes to remove dissolved solids from the seawater prior to Electro De-Ionisation (EDI) polishing. The first pass typically operates at a low recovery to minimise scaling risk and produces permeate salinity in the range of 300 mg/L. Permeate from the first pass is used to feed the second pass to remove additional TDS and produce water quality in the range of 5 mg/L.
4. The EDI unit operates as a single pass-through unit and uses resin packed beds, semi-porous membranes and anodic and cathodic electrodes to remove remaining charged dissolved solids from the water, producing a de-ionised product of the quality required for electrolysis.

Due to the preliminary nature of this work and the required process reliability, a conservative approach has been taken with regard to the design parameters, redundancy and capacity of the selected process to reduce the risk of single points of failure.

3.1.1 Seawater Intake, Outfall and Pre-Screening

The current sizing for the ocean intake and outfall, as well as pre-screening have been assumed and are subject to change based on subsequent coastal modelling work. As such the intake has been sized on the required feed flow necessary to provide the target product flow, and the outfall conditions have been determined based on the assumptions listed in subsequent sections and shown in Table 3-1. The specific intake and outfall design will be predicated on the modelling work.

Table 3-1 Intake and Outfall Parameters

Parameter	Unit	Intake	Outfall[6]
Flow	m^3/h	487	284
TDS	mg/L	39,000	64,000
TSS	mg/L	100	159
Risers	#	2	2

It has been assumed that water from the intake will flow via gravity into an intake wet well where it will be pumped to the UF Feed tank via auto-strainers in order to screen out any large objects, aquatic debris or additional coarse constituents from the UF system. If the seawater intake requires pumping, the pump will provide sufficient pressure to drive the strainer. The parameters for the pumps and auto-strainers are provided in Table 3-2.

Table 3-2 Intake Pumping and Screening Parameters

Parameter	Unit	Parameter
Design Intake Flow	m^3/h	487
Intake Flow Per-Pump	m^3/h	250
Design Pump Pressure	bar	3
No. of Duty Pumps/Strainers	#	2
No. of Standby Pumps/Strainers	#	1
Maximum Pump Flow	m^3/h	500
Strainer Recovery[7]	%	99.5
Nominal Strainer Aperture	µm	50

3.1.2 Ultrafiltration

While all UF is used to remove suspended solids from the seawater prior to treatment by the RO system, UF can be operated with or without coagulation, with the advantages and disadvantages of both approaches detailed in Table 3-3.

Table 3-3 Ultrafiltration System Coagulation Implications

Operating Condition	Advantages	Disadvantages
With Coagulation	▪ Higher operating recovery and smaller UF footprint ▪ Reduced impact of biofouling due to improved DOC control	▪ Additional chemical (coagulant) requirements ▪ Additional solids handling facilities required
Without Coagulation	▪ Ability to backwash directly into the outfall ▪ Removal of coagulant chemical requirement	▪ Potential increased risk of additional biofouling ▪ Lower operating recovery and higher footprint

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[6] Includes auto-strainer backwash, UF backwash, 1st pass RO concentrate and neutralized CIP waste

[7] Based on Amiad Omega series Auto-Strainers

Based on site area availability, simplicity of operation and ability to discharge backwash directly into the ocean outfall, we have opted to operate without coagulation at a low flux. Note that if on-site water sampling reveals a high level of total organic carbon (TOC), coagulation may be required, and the operational approach revisited. The key sizing parameters for the UF are provided in Table 3-3 and Operating Parameters are provided in Table 3-5.

Table 3-4 Ultrafiltration Sizing Parameters

Parameter	Unit	Value
Feed Tank Volume	m^3	250
No. of Feed Tanks	#	2
Design Net Product Flow	m^3/h	448
Product Flow Per Unit	m^3/h	232
No. of Duty Units	#	2
No. of Standby Units	#	1
Maximum Product Flow	m^3/h	464
Backwash Holding Tank Volume	m^3	40
Design Recovery	%	92.5

The UF system is sized to produce sufficient filtrate to allow for the required periodic backwashes which use UF filtrate whilst maintaining the required feed flow to the RO system. A backwash holding tank has been included to store up to three backwashes in order to allow for balancing the release of backwash waste into the outfall to prevent large instantaneous TSS increases associated with direct disposal from backwash to the outfall.

Table 3-5 Ultrafiltration Operating Parameters

Parameter	Unit	Value
Feed Water TSS	mg/L	100
Feed Pressure	bar	0.8
Nominal Pore Size[8]	µm	0.02
Product TSS	mg/L	0
Average Backwash TSS[9]	mg/L	159
Maximum Backwash TSS[10]	mg/L	1,333
Average Flux	LMH	16.5
Power Consumption	kWh/m3	0.28

Optimal performance of the operation of the UF system is maintained through both shorter Chemically Enhanced Backwashes (CEBs) and longer Cleans in Place (CIP). The frequency of each is dependent on manufacturer specification and preference but generally CEBs will happen at least daily, and CIPs based on monthly schedules or through performance metrics such as increasing differential pressure. The frequency and constituents of each clean are shown in Table 3-6.

Table 3-6 UF Cleans

Clean	Frequency (d)	Constituents
Hypochlorite CEB	0.5	Sodium Hypochlorite
Acid CEB	3	Hydrochloric Acid
Hypochlorite CIP	30	Sodium Hypochlorite Sodium Hydroxide

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[8] Based on the Inge Multibore UF series membranes

[9] Averaged over a 24 hour operation and assuming 100% TSS rejection.

[10] Anticipated TSS in the reject stream during backwashes

Clean	Frequency (d)	Constituents
Acid CIP	30	Hydrochloric Acid Citric Acid

Sodium Bilsulphite is added to the UF CIP tank in a 3:1 ratio after all Hypochlorite based cleans to quench any remaining free chlorine and prevent the release of chlorine gas which can occur if sodium hypochlorite is acidified.

3.1.3 Reverse Osmosis

Reverse Osmosis (RO) is used to remove the bulk of the dissolved constituents from the seawater prior to de-ionisation through the application of high pressure across spiral wound membranes, and is the most energy intensive process as it must overcome the osmotic pressure of seawater. Given the high salinity of seawater, a two-pass process is required to reduce the permeate quality to the range required for further polishing by EDI, shown in Figure 3-2.

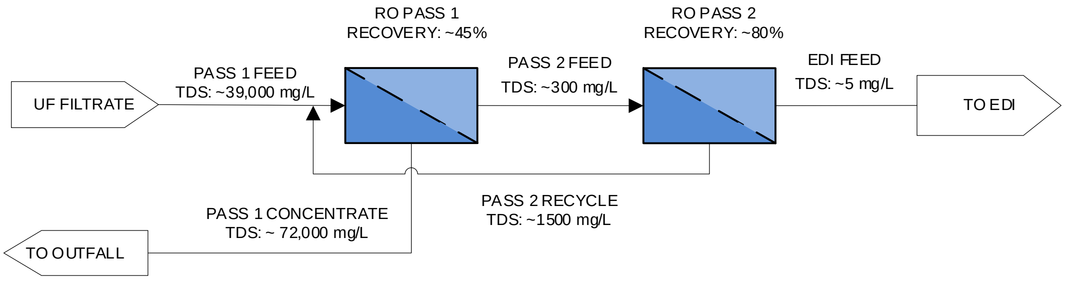

Figure 3-2 Reverse Osmosis System Arrangement

The RO process sizing and operating parameters are provided in Tables 3-7 and 3-8 respectively.

Table 3-7 Reverse Osmosis Sizing Parameters[11]

Parameter	Unit	Pass 1	Pass 2
Feed Tank Volume	m^3	225	125
No. of Feed Tanks	#	2	2
Design Product Flow	m^3/h	224	194
Product Flow Per Unit	m^3/h	125[12]	110[13]
No. of Duty Units	#	2	2
No. of Standby Units	#	1	1
Maximum Product Flow	m^3/h	250	220
Design Recovery	%	45	80

The RO system feed includes upstream antiscalant, pH control and cartridge filters to protect against scaling and particulate fouling respectively. Caustic and Acid CIPs will also take place periodically to remove any organic, colloidal, or inorganic scaling. Sulphuric acid is added prior to the first pass to drop the pH and decrease the risk of scaling whereas Sodium Hydroxide is added prior to the second pass to increase the pH and increase carbonate rejection and subsequent product TDS.

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[11] Pass 1 based on the Suez SeaTECH 252 series and Pass 2 based on the Suez PROflex-AP series. It should be noted that there are a number of vendors who could supply equipment for all process trains.

[12] Includes concentrate recycle from the Pass 2 Concentrate

[13] Includes concentrate recycle from the EDI Outlet

Table 3-8 Reverse Osmosis Operating Parameters

Parameter	Unit	Pass 1	Pass 2
Feed Water TDS	mg/L	38,256	214
Feed Pressure	bar	62.5	8.7
Feed pH	-	6.7	8.2
Product TDS	mg/L	223	2.1
Concentrate TDS	mg/L	69,456	2,187
Average Flux	LMH	16.5	25.9
Power Consumption	kWh/m3	2.26	0.33
Caustic CIP Frequency	d	30	180
Acid CIP Frequency	d	90	180

3.1.4 Electro De-Ionisation

Electro De-Ionisation (EDI) is used to polish RO permeate to reduce the remaining trace anions and cations, it operates through use of anionic and cationic selective membranes within resin packed beds to remove trace ions within the system. The means of ion removal are provided in Figure 3-3, noting that all concentrate streams will be recycled to the 2nd pass RO feed.

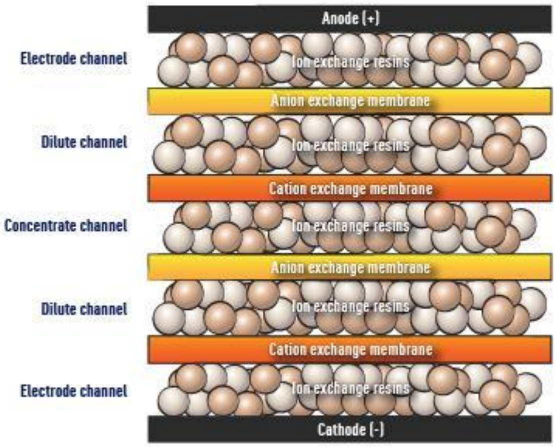

Figure 3-3 EDI means of operation

The EDI unit is capable of producing a discharge water quality as detailed in TM1. The design parameters for the EDI units are provided in Table 3-9 and operating ranges are provided in Table 3-10:

Table 3-9 EDI Sizing Parameters[14]

Operating Parameters	Unit	Value
Feed Tank Volume	m^3/h	100
No. of Feed Tanks	#	2
Design Product Flow	m^3/h	175
Product Flow Per Unit	m^3/h	60
No. of Duty Units	#	3
No. of Standby Units	#	1
Maximum Product Flow	m^3/h	180
Design Recovery	%	90%

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[14] Based on the Suez ECellX-12 product

Table 3-10 EDI Operating Ranges

Product Water Quality	Unit	Minimum	Maximum
Outlet Product Quality	Mohm-cm	16	
Outlet Conductivity	µS/cm		< 0.0625
Outlet Silica	ppb		< 5
Temperature	°C	4.4	40
Feed Pressure	bar	4.1	6.9
Pressure Drop	bar	1.4	2.8
Minimum Discharge Pressure	bar	1.3	5.5

3.1.5 Process Train Water Quality

The product water quality from each process train and the anticipated outfall water qualities are provided in Table 3-11 as a summary. If coagulation and solids capture is required as part of the pre-treatment (not allowed for in this study, subject to detailed water quality monitoring), the outfall TSS would be reduced to approximately 5 mg/L assuming a conservative 95% capture rate for the required solids handling system.

Table 3-11 Product Water Quality by Process Unit

	Parameter	Unit	Feed	UF Filtrate	RO Pass 1	RO Pass 2	EDI product	Outfall
Physical Properties	TDS	mg/L	39,000	39,000	271	3.3	-	63,523
	Conductivity	µS/cm	56,342	56,342	519	5.4	0.0625	91,770
	Temp	°C	26.5	26.5	26.5	26.5	26.5	26.5
	pH	-	8.3	8.3	8.2	6.5	6.5	7.0
Chemical Composition	TSS	mg/L	Up to 100	0	0	0	0	159
	Ammonia	mg/L NH4 as N	0	0	0	0	-	0
	Phosphorous	mg/L as PO4	0	0	0	0	-	0.002
	Barium	mg/L	0	0	0	0	-	0.1
	Bicarbonate	mg/L	158	158	36	0.75	-	256
	Borate	mg/L	5	5	0.83	0.58	-	8.5
	Bromide	mg/L	74	74	0.42	0.005	-	129
	Calcium	mg/L	452	452	0.73	0.006	-	787
	Chloride	mg/L	21,466	21,466	121.8	1.1	-	37,372
	Fluoride	mg/L	1.13	1.13	0	0	-	1.97
	Iodide	mg/L	0.06	0.06	0	0	-	0
	Iron	mg/L	0.02	0.02	0	0	-	0.035
	Magnesium	mg/L	1,427	1,427	2.307	0.005	-	2,484
	Potassium	mg/L	430	430	3.8	0.04	-	749
	Silica	mg/L as SiO2	0	0	2.00E-04	2.27E-06	2.27E-06	0.03
	Sodium	mg/L	11,939	11,939	88.3	0.81	-	20,858
	Strontium	mg/L	15	15	0.02	0.0002	-	26
	Sulphate	mg/L	2,996	2,996	5.5	0.02	-	5,277

3.2 Plant Energy and Chemical Requirements

3.2.1 Plant Chemical Requirements

Desalination plants require chemicals for two main functions in the process:

- Chemicals for the alteration of water chemistry to maintain continuous operation
- Chemicals used in periodic Cleans in Place (CIP) or Chemically Enhanced Backwashes (CEB) for the UF systems and CIP of the RO systems.

The chemical requirements for

3.2.2 Plant Chemical Application and Storage Requirements

As outlined in 3.1, a number of the plant processes will require chemicals to maintain consistent operation. The plant chemical, chemical properties and applications are detailed in Table 3-12.

Table 3-12 Chemical Properties and Applications

Chemical	Concentration (%)[15]	Bulk Density (kg/m^3)	Applications
Sodium Hypochlorite	12.5	1.20	UF CEBs/CIP
Sodium Bisulphite	50	1.35	UF CEBs/CIP
Hydrochloric Acid	30	1.20	UF CIP RO CIP Neutralisation
Citric Acid	50	1.25	UF CIP RO CIP
Sodium Hydroxide	50	1.50	RO Pass 1 Pre-Treat UF CIP RO CIP Neutralisation
Sulphuric Acid	98%	1.83	RO Pass 1 Pre-Treat
Antiscalant	100%	1.20	RO Pass 1 Pre-Treat

The amount of on-site storage depends on a number of factors including ease and security of supply, active chemical efficacy reduction under ambient conditions and safe storage. PV1 has indicated that the supply of the required chemicals to the site is unlikely to be problematic. A summary of the annual chemical consumption, proposed storage timeframes and means of storage are outlined in Table 3-13. A safety factor of 25% has been added to each of the storage volumes, which have been founded up to the nearest 100L. Space has been allowed for twice as many totes and drums to allow for a factor of safety.

Table 3-13 Chemical Storage Requirements and Methods

Chemical	Annual Consumption (L)	Delivery Frequency (d)	Storage Volume (L)	Storage Means
Sodium Hypochlorite	13,00	28	1,300	Totes
Sodium Bisulphite	8,700	28	900	Totes
Hydrochloric Acid	500	90	200	Drums
Citric Acid	2,000	90	2,000	Totes
Sodium Hydroxide	62,500	28	6,000	Tank
Sulphuric Acid	78,500	28	7,600	Tank
Antiscalant	4,400	90	1,400	Totes

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[15] As active chemical

3.2.3 CIP, Neutralisation and Flushing System

Both the UF and RO will have dedicated CIP systems consisting of Duty and Standby CIP pumps, chemical dosing recirculation loops and associated instrumentation, with both RO passes utilizing a common CIP system. UF CEBs will not use the CIP system but rather have chemicals dosed directly into the backwash line as part of the backwash sequence, the backwash from which will be directed to the outfall as per the proposed normal backwashing sequence.

UF and RO CIP make-up water will be provided from the RO flushing pumps from Pass 2 Permeate Tank, the capacity of which is well in excess of the calculated CIP volumes for the UF and RO CIPs as detailed in Table 3-14. The excess capacity within RO system allows for CIPs to be completed without any impact on the ultimate product water target flow. Sodium Bisulphite will be added to the UF CIP tank prior to the spent solution being transferred to the neutralisation tank.

The neutralisation tank has been sized for three times the volume of the largest CIP to allow for pH stabilisation prior to discharge through the outfall via gravity. The neutralisation system will have dedicated recirculation pumps and chemical dosing points along with required pH monitoring instrumentation. The neutralised CIP waste is unlikely to have a major impact in the overall outfall water quality due to the comparatively small volumes, being of lower TDS than the 1st pass RO concentrate and containing minimal suspended solids.

Table 3-14 CIP System Tank Sizing

System	Required CIP Volume (m^3)	Pipework Allowance (%)	CIP Tank Volume (m^3)
UF CIP	2.2	50	4
RO CIP	6	50	9
Neutralisation	18	50	27

Cleaning volumes are determined based on the number of membrane modules and volume of each individual module with a standard factor for 50% allowed for pipework volume, which is conservative, and on the assumption that only one train will be cleaned at any time.

3.2.4 Plant Energy Requirements

The plant energy requirements and their respective sources are outlined in Table 3-15.

Table 3-15: Anticipated plant power consumption

Process Unit	Unit	Specific Energy	Source
Seawater Intake	kWh/m3	0.10	Calculated with efficiency wire of 0.8
UF System	kWh/m3	0.28	Suez Wave Projection Software
RO System	kWh/m3	2.95	Toray RO Projection Software using an efficient 1st pass Energy Recovery Device (ERD)
EDI	kWh/m3	0.27	Calculated based on EDI datasheet and kVA efficiency of 0.9
Safety Factor	%	25%	Allowance for site services and amenities
Total Specific Energy	kWh/m3	4.49	
Daily Energy Use	kWh/d	19,000	

4. Intake and Outfall Design

Primary design objectives include:

- locating the intake for consistent seawater quality, to avoid intermittent stormwater discharge, propellor wash or wave-related turbidity, and
- locating the outfall in tidal current for dispersion and in non-pristine environment to limit the environmental risk.

Additional design objectives include:

- effective operation over the full tidal range,
- minimising marine growth on intake screens (material selection, e.g. CuNi)
- allowance for marine growth in intake pipelines (provide for pigging, dosing),
- convenient access for cleaning and maintenance.

A summary of preliminary sizing criteria is provided in Table 5-1. The design of intake and outfall pipelines is likely to result in velocities between 1.0 and 2.0 metres/sec and the resulting approximate pipeline diameters are indicated.

Table 4-1 Intake and outfall design criteria

	Design Flow Rates	Velocity (m/s) in a range of pipe diameters		
	Dia.	DN300	DN375	DN450
Intake	487 m3/hr = 135 l/s		1.22	0.85
Outfall	285 m3/hr = 79 l/s	1.12	0.72	

4.1 Intake Configuration

There are numerous intake configurations possible. A pier-mounted intake would need to cope with varying sea levels by utilising arrangements such as a fixed, full height coarse screen cage and submersible pumps. A pontoon mounted pumping system could be fabricated off-site and installed with minimal disturbance to the surroundings.

Johnson wedge wire screens would exclude objects greater than about 1.0mm in size and when fabricated in CuNi material would resist marine growth, limit fouling and reduce maintenance. Figure 5-1 illustrates one possible arrangement.

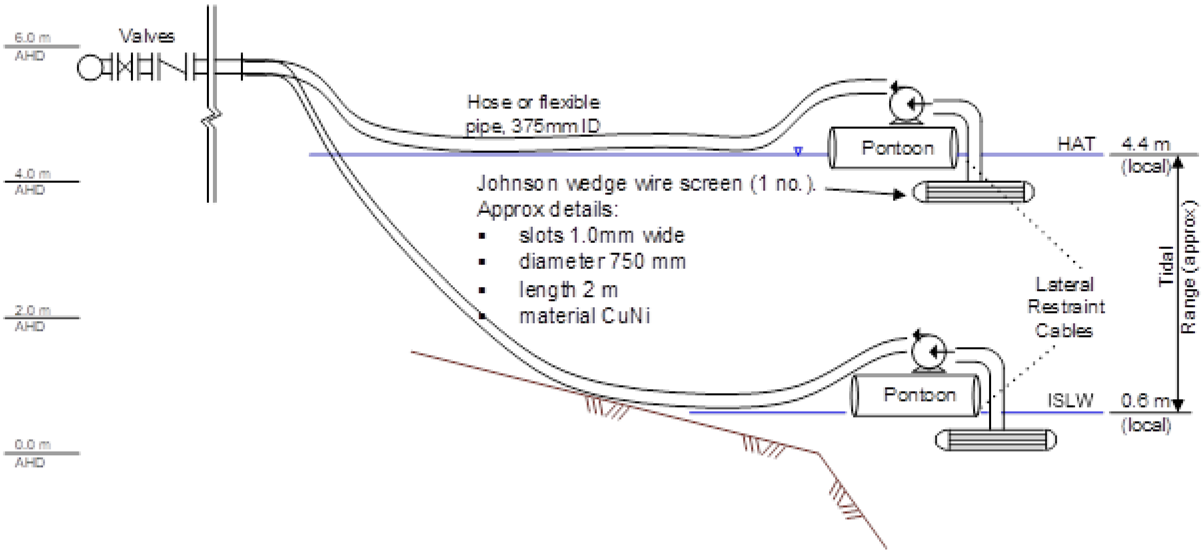

Figure 4-1 Intake arrangement schematic diagram

Power and water connections to shore would be required. The power demand would depend on the distance to the plant, the diameter of the pipeline and the elevation of the discharge point but is likely to be in the range 20 to 50 kW. Similarly (depending on the details) the intake pipeline or hose is likely to be in the range 300 to 450 mm diameter.

Likely requirements, assuming the intake pipeline and cables can be mounted on the existing floating jetty remote from mooring, are:

- Johnson wedge wire screens approximately 750mm in diameter and 2 m long. At least one meter below water and possibly another raised in a standby position.
- A pontoon attached to the existing floating jetty with 1 duty and 1 standby pump (the standby pump may also be in storage) and winching or lifting devices for periodic screen maintenance. Assume the intake pontoon is a self-contained unit, fabricated off-site and complete with any control or power cubicles, piping, manifold and valves (i.e. approx. house-boat in size). However, if the existing jetty has unused area, a pontoon may not be required.
- Short lengths of 300mm flexible hose connecting to 375mm diameter pipelines attached to the shore-facing side of the jetty and extending as a buried on-shore pipeline to the desalination plant site. Power and control cables in ducts on the jetty and buried (or overhead) to the power supply and desalination plant respectively.

4.1 Outfall Configuration

The anticipated discharge plume is shown in Figure 4-2, noting that a single 200mm nozzle should achieve background salinity +2ppt.

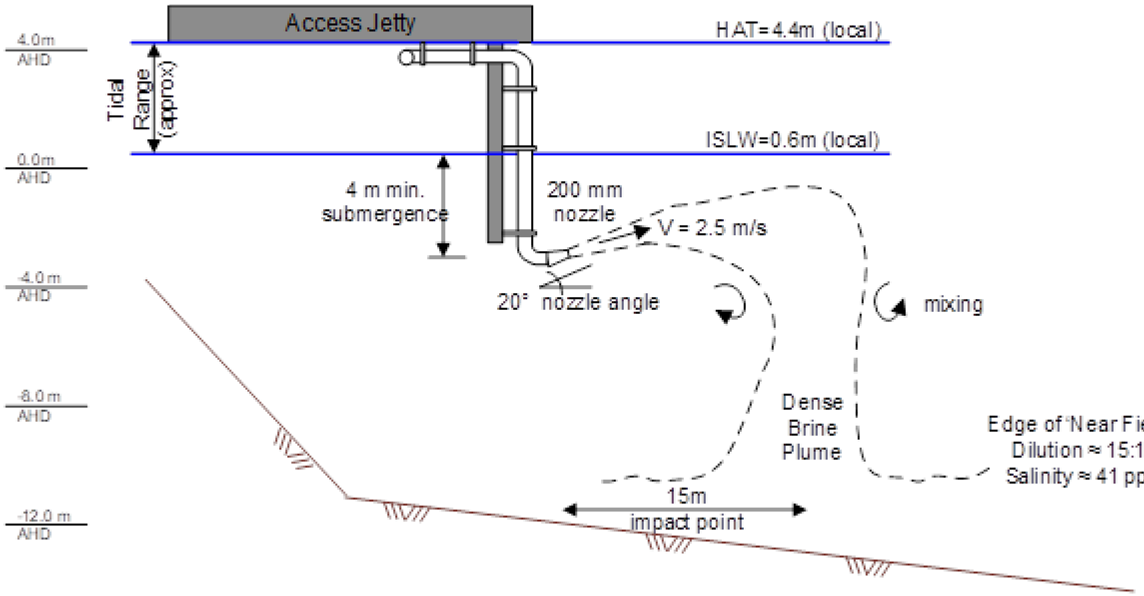

Figure 4-2 Outfall discharge plume

The work of Roberts and Abbesi (2014)[16] and Abbesi and Roberts (2015)[17] were used as the basis for this analysis , however there are numerous reference documents based on similar laboratory experiments that have been used on seawater desalination projects to the extent that the calculations undertaken represent current industry practice.

The dense plume behaviour is described by the dimensionless parameter dF/H where:

- d is the nozzle diameter,
- F the jet densiometric Froude number, and
- H the water depth.

Figures 83 to 86 in Roberts and Abbesi (2014)[16] give the parameters used in accordance with the Figure 5-3, the definition diagram.

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[16] Roberts, P.J.W. and Abessi, O (2014) *USBR, Optimization of Desalination Diffusers Using Three-Dimensional Laser-Induced Fluorescence - Report No. 167*

[17] Abessi, O and Roberts, P. (2015) Effect of Nozzle Orientation on Dense Jets in Stagnant Environments, *ASCE Journal of Hydraulic Engineering* **141**(8)

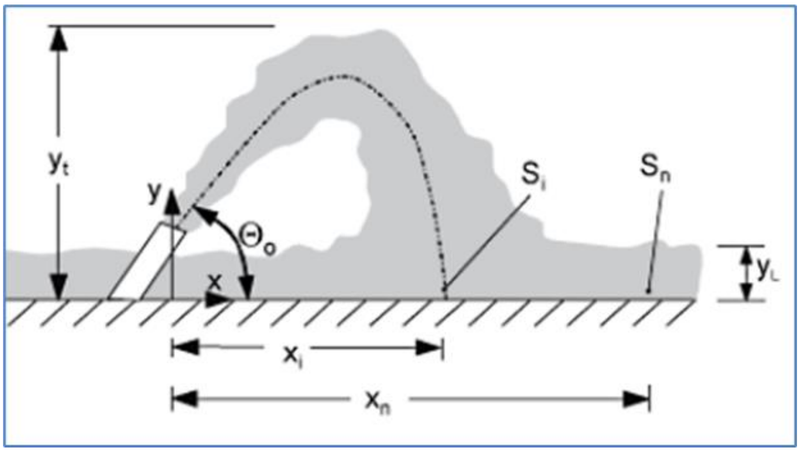


Figure 4-3 Outfall dispersion definition diagram

Inputs to diffusion calculations include:

- seawater salinity = 39 ppt.
- saline discharge of 79 l/s at 63.5 ppt
- a submerged nozzle, approx 200 mm dia at 30 degrees to the horizontal
- required salinity (Sn) < background +2ppt (i.e. <41ppt)
- near field distance (Xn) to be less than about 50 m (TBC).

Outputs from preliminary calculations include:

- nozzle velocity = 2.5 m/s approx
- plume impact distance (Xi) >15 m from nozzle
- impact point salinity (Si) = 40.5 ppt
- driving head above sea level = 5 m approx with a 0.3 m dia pipeline (depending on pipeline length etc.)

The advantages and disadvantages for this approach are summarised in table 5-2.

Table 4-2 Proposed approach advantages and disadvantages

Advantages	Disadvantages
Pipe/nozzle can be mounted on existing jetty.	Requires at least 4m water depth.
Conforms with accepted practice.	Not remote from the intake (but sufficiently distanced).
Tidal currents will augment mixing.	

Likely requirements include:

- a brine discharge header tank at the desalination plant to collect all discharge streams and allow for air release prior to the flow entering the outfall pipeline,
- a 300mm diameter HDPE gravity pipeline extending from the desalination plant to the opposite end of the existing jetty from the intake,
- a vertical HDPE drop pipe extending approximately 4m below sea level with a 200mm discharge nozzle suitable for the marine environment (possibly in CuNi or duplex stainless steel).

5. Preliminary Outfall Dispersion Modelling

Preliminary outfall dispersion modelling assessment was completed to evaluate the performance of the proposed outfall design and allow the impacts to nearby marine environment to be assessed.

The assessment consisted of the following two components:

- a nearfield investigation involving modelling using the mixing zone modelling tool CORMIX; and
- a farfield modelling assessment involving a three-dimensional hydrodynamic and advection-dispersion model of the Tiwi Islands region (MIKE3 FM).

For further details on the modelling assessment, reference should be made to Appendix C of this report.

The modelling assessment has indicated that the proposed outfall site is subject to strong tidal currents which promote good mixing of the proposed brine discharge.

Results from the nearfield modelling indicate that the proposed outfall design will achieve good nearfield mixing through positioning a 0.2 m diameter port 4 m below surface at the southern end of the wharf (approximate depth of 12 m at LAT based on available bathymetric charts) with predicted dilution ranging from ~20 for effluent discharged directly into stagnant water to up to about 300 during larger ambient flow conditions.

The result of the mixing zone modelling indicates that the modelled maximum salinity impact under typical ambient flow conditions is less than 1 PSU within 35 m from the outfall.

The results of the farfield modelling demonstrate that the impacts of the proposed brine discharges further outside the mixing zone will be small, with no salinity impacts of greater than 0.5 PSU predicted outside a zone of 100 m radius from the outfall. The maximum salinity impact at both intake locations under consideration will typically be less than 0.1 PSU above ambient salinity levels

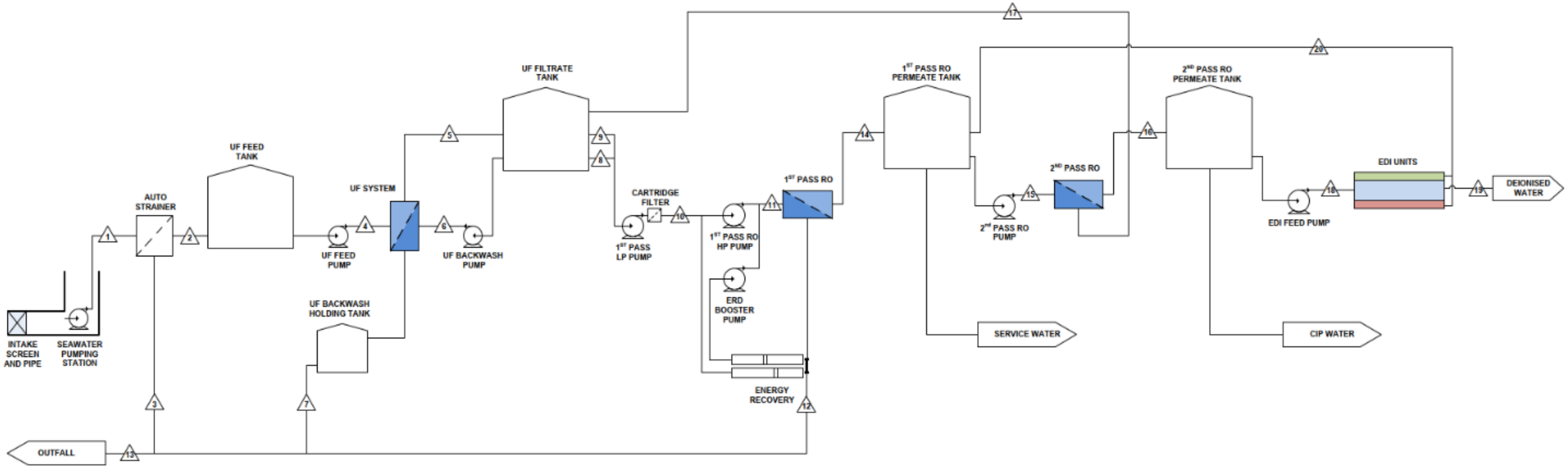
6. Conclusions

Typical desalination plant with 4.2 ML/d capacity has been scoped and sized to provide information potential interaction with adjacent environment. The plant will consist of intake and outfall, UF pretreatment and RO trains following by EDI to meet the product water quality requirement. The plant requires to draw approximately 490m^3/hr (approx. 12 ML/d) of raw seawater to produce the necessary output. The adopted pre-treatment train (UF) will not require chemical coagulation to minimise the need for managing the backwash and the solid waste. Whilst there are ranges of chemicals needed for cleaning of the membrane system, these will be neutralized prior to blending with the concentrate for disposal. The amount of neutralized chemical is anticipated to form a small fraction of the concentrate (typically less than 10m^3 per cleaning). The volume of concentrate is expected to be approximately 312 m^3/hr (approx. 8 ML/d) – largely concentrated seawater (approx. 64000 mg/L as TDS).

Both near and far field outfall modelling were carried out to determine the possible area of influence from the concentrate discharged and inform the location of the intake and outfall. The modelling shows that the proposed outfall site (south east end of existing jetty) is subject to strong tidal currents which promote good mixing of the proposed brine (concentrate discharge). The impacts of the proposed brine discharges will be small and contained to an area in the immediately vicinity of the proposed outfall, with no salinity impacts of greater than 0.5 PSU predicted outside a zone of 100 m radius from the outfall. This enables the intake to be located on the other side of the jetty without the risk of short circuiting.

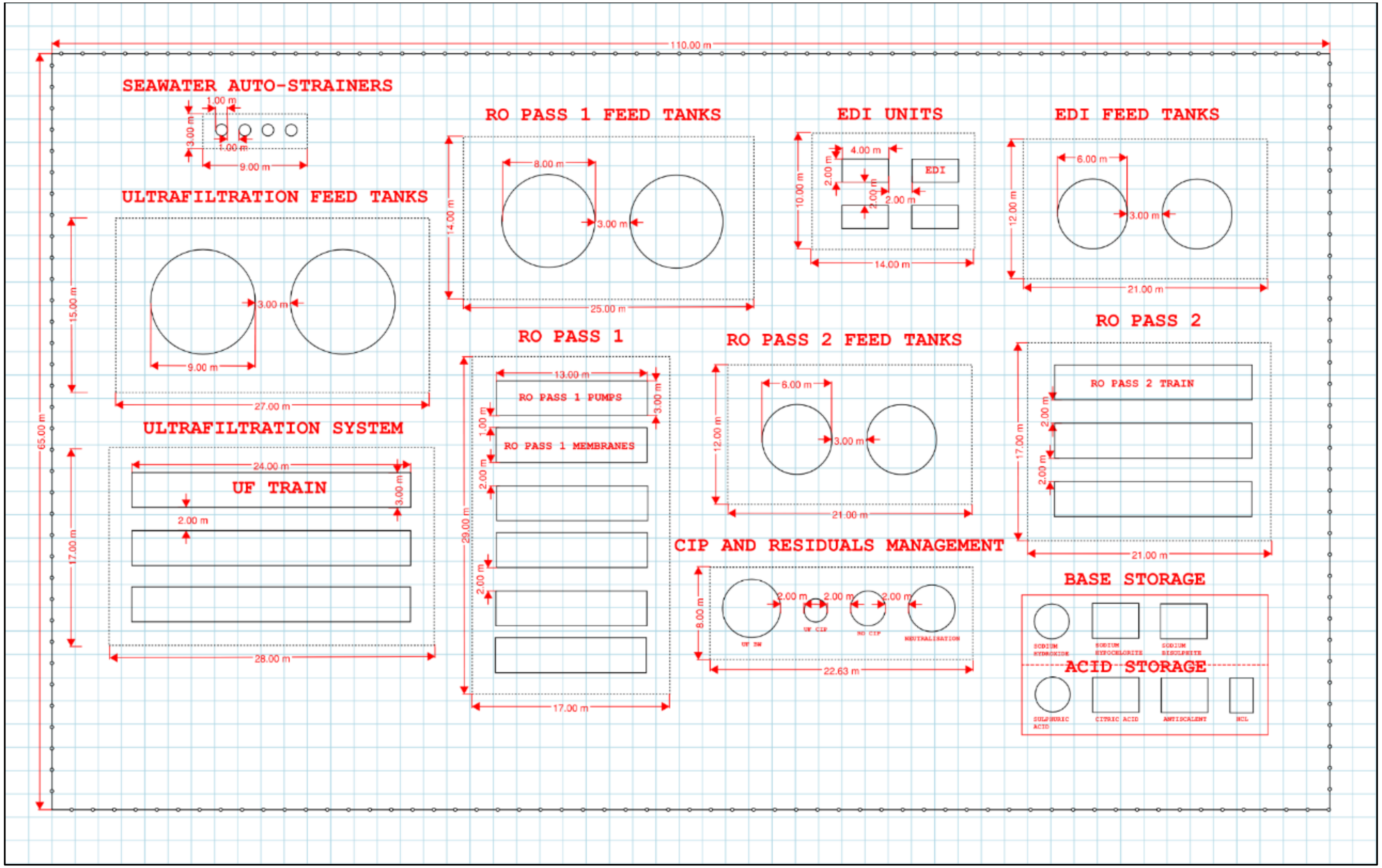
This study mainly relied limited water quality measurement nearby the site and typical seawater make-up. In the future stage, targeted water quality monitoring will be required to confirm the validity of the desalination process adopted in this study. It is understood that there may be other contaminants of concern both with the environmental interaction and/or treatment process. The water quality monitoring will aid defining their potential environmental impact and need for any further processing need for the desalination plant.

Appendix A. Process Flow Diagram



Stream No.	-	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Stream ID	-	Seawater Intake	Strained Seawater	Strainer Backwash	UF Feed	UF Filtrate	UF Backwash Inlet	UF Backwash Outlet	Net UF Filtrate	2nd Pass RO Conc. To 1st Pass Feed	1st Pass RO LP Feed	1st Pass RO HP Feed	1st Pass RO Concentrate	Ocean Outfall	1st Pass RO Permeate	2nd Pass RO Feed	2nd Pass RO Permeate	2nd Pass RO Conc. Recycle	EDI Feed	EDI Product	EDI Recycle
Flow	m3/h	487	485	2	485	485	36	36	448	49	497	497	273	312	224	243	194	49	194	175	19
	MLD	11.7	11.6	0.1	11.6	11.6	0.9	0.9	10.8	1	11.9	11.9	6.6	7.5	5.4	5.8	4.7	1.2	4.7	4.2	0.5
TDS	mg/L	39,000	39,000	39,000	39,000	39,000	39,000	39,000	39,000	2,776	38,000	38,000	68,000	64,000	223	223	3	2,776	3.3	0.063	33.0
TSS	mg/L	100	100	100	100	0	0	1333	0	0	0	0	0	159	0	0	0	0	0	0	0
Pressure	bar	3	2.5	0	0.8	0.5	0.4	0	0.6	6.9	4	62.5	0	0	0.5	8.6	0.5	6.9	4.1	1.3	1.3
pH	pH units	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.4	6.70	6.70	7.00	7.00	4.98	8.20	6.53	8.42	6.53	-	-

Appendix B. Preliminary Site Layout



Appendix C. Preliminary Outfall Modeling

Desalination Plant for Tiwi Island Hydrogen Facility – Preliminary Outfall Dispersion Modelling

Date:	31 March 2022
Project name:	Desalination Plant for Tiwi Island Hydrogen Facility
Project no:	IA410666
Attention:	Garry Triglaycanin
Company:	Provaris Energy Ltd
Prepared by:	Jiangtao Xu and Jess Ryan-Slinger
Reviewed by:	Joris Jorissen
Revision no:	1
Copies to:	Dennis Cho, Bradley Allpike, Doug Franklin, Dom Peters

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1. Introduction

1.1 Background

Provaris Energy Ltd (PV1) is considering a green hydrogen export project on Tiwi Islands, Northern Territory. The project includes the development of a hydrogen production facility, which requires up to 4.2 ML/day of demineralised water. The demineralised water will be produced by a desalination plant which is proposed to be constructed at the Port Melville industrial estate. PV1 is proposing that the seawater inlet and brine outlet pipework would be located in the Apsley Strait (out from the Port Melville berth) near the existing Port Melville facilities.

Jacobs have been engaged to assist PV1 in developing a preliminary concept for the desalination plant to support the environmental approvals application process for the project. Key tasks associated with Jacobs' scope include the following:

1. Establishment of Basis of Design;
2. Determination of the process requirement and footprint of the desalination plant;
3. Preliminary outfall dispersion modelling to assess the dispersion of the brine from the proposed desalination plant; and
4. Development of a preliminary concept for the intake/outfall system.

This technical memorandum summarises the preliminary outfall dispersion modelling undertaken to inform the project.

1.2 Scope

The scope of work associated with the preliminary outfall dispersion modelling includes the following:

- Desktop review of existing information to assess the metocean and coastal physical processes at the site;
- Confirmation of intake and outfall design parameters;

- Preliminary hydrodynamic modelling (MIKE3-HD/AD) to establish the hydrodynamics and dispersion characteristics around the site;
- Development of a nearfield model using CORMIX to investigate nearfield mixing processes around the outfall; and
- Preliminary farfield dispersion modelling to assess the farfield mixing behaviour of the proposed effluent discharge.

1.3 Dispersion Assessment Approach

The outfall dispersion modelling approach has developed on the basis of the primary project objective, i.e., to evaluate the impact of the brine plume dispersion. The modelling framework applied includes evaluation of near and farfield mixing using the following industry standard modelling systems:

- Cornell Mixing Zone Expert System (CORMIX) for nearfield dispersion analysis and optimisation of diffuser design
- MIKE3 FM HD/AD for farfield dispersion analysis and identification of the farfield environmental impact area

1.3.1 Nearfield Modelling

The nearfield analysis (refer to Section 5) has been undertaken based on the following strategy:

- CORMIX near field modelling using the identified characteristics/properties of receiving water and brine effluent. A range of simulations have been undertaken to bound the impact as well as to evaluate the sensitivity for near field mixing to different design factors. This includes simulation of a typical, worst- and best-case simulation, as well as sensitivity tests for ambient flow speed, effluent and ambient density, as well as variable port heights and alignment options.
- Model results will be used to verify the farfield model assumptions and guide the configuration of farfield model.

1.3.2 Farfield Modelling

Nearfield modelling does not simulate the further farfield dilution of the effluent into the surrounding marine environment by ocean currents. This requires additional investigation through farfield modelling over a broader time and length scale (covering at least a full month tidal cycle, over area 100’s of meters to a few kilometres).

Farfield mixing is investigated via a three-dimensional hydrodynamic and advection-dispersion model of the Tiwi Islands, using the MIKE3 FM hydrodynamic model detailed in section 4. The model considers the baroclinic forcing, i.e. the impact of density gradient/stratification to flow circulation. The dispersion of effluent plume is thereby simulated by a full 3D baroclinic model considering the density forcing, advection and dispersion processes.

Review of metocean climate shows the project site can be characterised as strong tidal energy and weak wave energy environment (refer to section 2). It is envisaged that wave impact will be secondary in the process of brine plume mixing. The impact of waves is thereby not considered in this study.

1.3.3 Assessment Criteria

Results from the nearfield and farfield dispersion assessment will be provided to EcOz Environmental Consulting (EcOz) for interpretation and input into the environmental approvals process for the project. Based on discussions with EcOz, it is understood that there are no specific mixing zone assessment criteria for the Northern Territory, with projects in this region assessed on a case-by-case basis.

2. Physical Setting

2.1 Project Site

The proposed desalination plant is located at the Port Melville, a multi-user facility supporting the Northern Territory oil and gas industry, marine transport, and the local Tiwi community. The Port is located at the northern end of the Apsley Strait on Tiwi Islands, Northern Territory (refer to Figure 2-1). Around the site, the Aspley Strait is approximately 2 km in width and has a maximum water depth of ~50 m. The proposed intake/outfall will be positioned in the immediate vicinity of the Wharf at Port Melville as discussed in Section 3.

Figure 2-1 Project Site and Proposed Intake and Outfall

2.2 Climate

The Tiwi Islands are characterised by its tropical monsoonal climate, experiencing three differing seasons, namely:

- **Kumunupunari –** (March to August) is the dry season with predominantly south-easterly winds and temperatures typically ranging between ~19 and 30°C.

- **Jamutakari –** (December to February) is the wet season when most of the rain falls consistently every day and the swamps, creeks and rivers are full. A consistent north-west wind blows (Wunijaka) during this season.
- **Tiyari –** (September to November) is the season of hot weather and high humidity, but modest rain. It is a transitional season when the local wind gradually transfers from south-easterly to north-westerly.

Figure 2-2 to Figure 2-4 present wind roses for each of the three seasons, based on measurements at Pirlangimpi station, located approximately 2 km north of Port Melville, during the period from Jan 1980 to Jan 2022.

These figures show that, overall, the wind in the region is relatively weak with over 90% of wind records having a wind speed of less than 6 m/s. A review of gridded global wind data from NASA's MERRA-2 global reanalysis model (refer to extraction location in Figure 2-6) shows the similar seasonal/diurnal pattern offshore, except that these winds are stronger than the sheltered strait with wind speeds typically up to 1.5-2 times higher.

The area is exposed to high risk of tropical cyclones, primarily occurring during months of wet season. For instance, a category 5 tropical cyclone (TC Thelma) was recorded in the vicinity of Tiwi Island region in Dec 1998, causing significant impact to local communities.

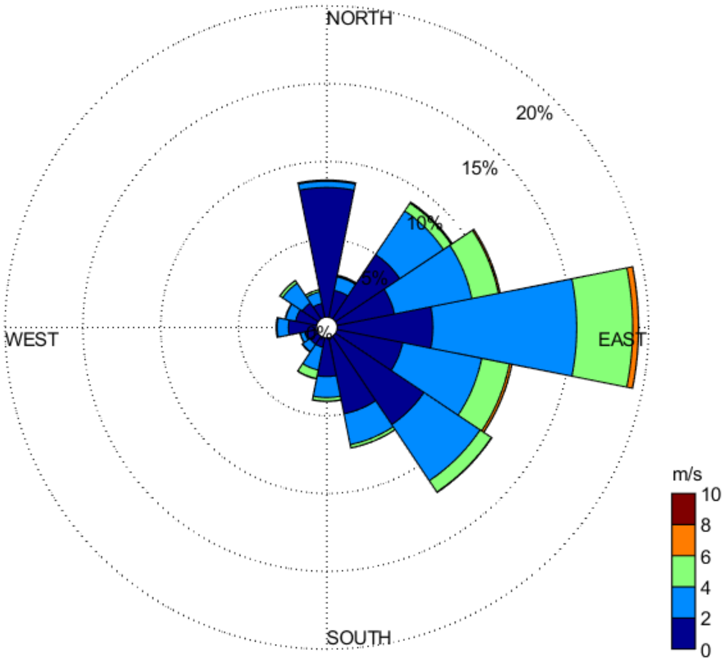


Figure 2-2 Kumunupunari (Mar- Aug) wind rose based on wind data at Pirlangimpi station (Data source: https://www.ncei.noaa.gov)

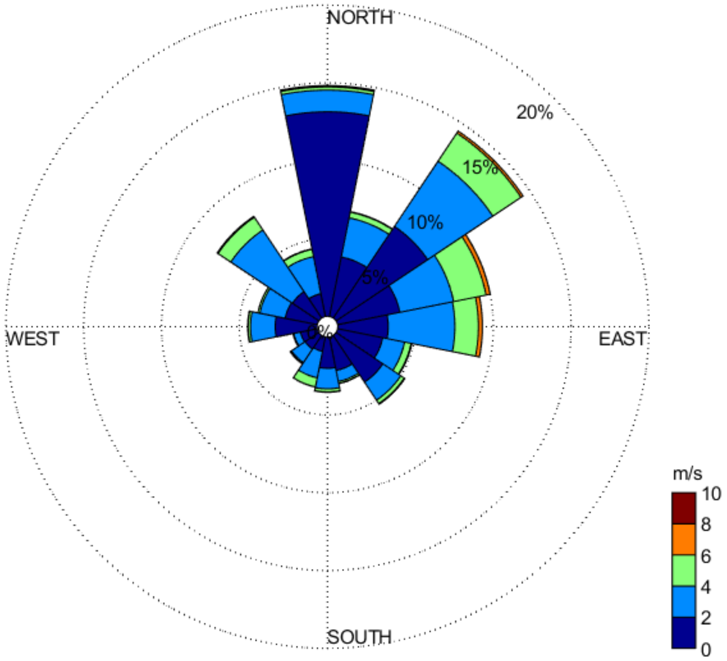


Figure 2-3 Tiyari (Sep-Nov) wind rose based on wind data at Pirlangimpi station (Data source: https://www.ncei.noaa.gov)

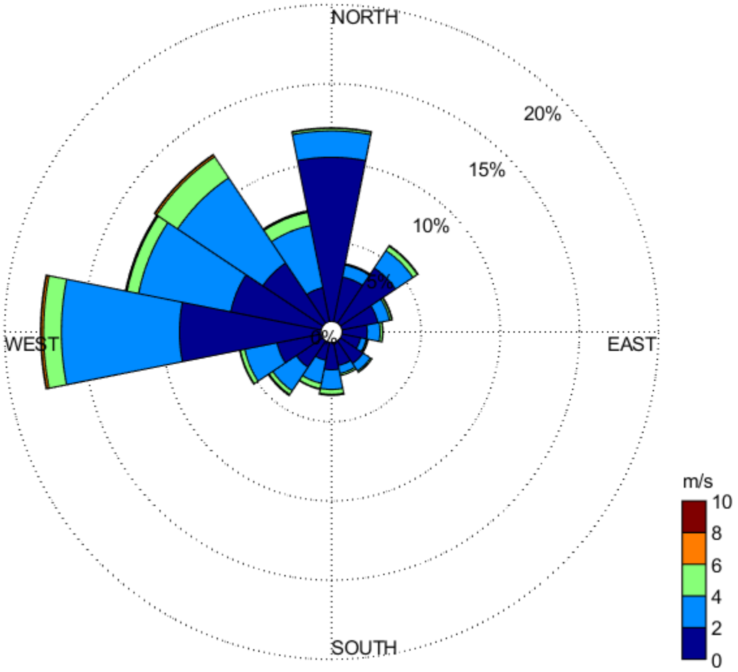


Figure 2-4 Jamutakari (Dec-Feb) wind rose based on wind data at Pirlangimpi station (Data source: https://www.ncei.noaa.gov)

2.2.1 Wave Climate

The regional wave climate around Tiwi Islands is dictated by the seasonal wind climate. The wave climate around the Islands is characterised by moderate wave heights.

CSIRO (2013) indicates that the seasonal averaged significant wave height off the coast of the Tiwi Islands may range from ~1.5 m in dry season (**Kumunupunari**) to ~1 m in wet season (**Jamutakari**) based on results from the CAWCR wave hindcast model from 1979-2009. Tropical cyclones may generate wave heights that are substantially higher. Waves are north-westerly in wet season and easterly/south-easterly in dry season, in line with the seasonal wind. Wave conditions during the transitional season (**Tiyari**) were not reported by CSIRO's study.

Waves inside the Aspley Strait are generally of low wave heights with wave heights at Port Melville estimated to be below approximately 0.3 m during typical operational conditions and up to approximately 0.7 m during cyclonic events (NT Port and Marine, 2017a).

2.3 Tides

2.3.1 Tidal Levels

Tidal levels at the project site are summarised in Table 2-1, which were extracted from the Australian Hydrographic Office's AusTide Software (2022) at Barlow Point South (Port num 63325) located immediately north of the project site. A semi-diurnal tide with diurnal inequalities is present at the site, resulting in two high tides and two low tides per day.

Table 2-1 Tidal Plane at Barlow Point South as per the Australian Hydrographic Office (2022)

Tidal Plane	Barlow Point South (m LAT)
HAT (Highest Astronomical Tide)	4.4
MHWS (Mean High Water Spring)	4.2
MHWN (Mean High Water Neap)	3.2
MSL (Mean Sea Level)	2.7
MLWN (Mean Low Water Neap)	2.2
MLWS (Mean Low Water Spring)	1.2
LAT (Lowest Astronomical Tide)	0.0

2.3.2 Tidal Current

The large tidal range within the Aspley Strait generates strong tidal currents at the site. During flood tide, the currents flow from north to south and during the ebbing tide from south to north.

Available information on tidal currents at the project site is limited, with some existing reports indicating that maximum tidal flows in the vicinity of the Port may be greater than 1 m/s (refer to section 2.3.2). Hydrodynamic modelling has been undertaken to predict the tidal currents at the site (refer to Section 4).

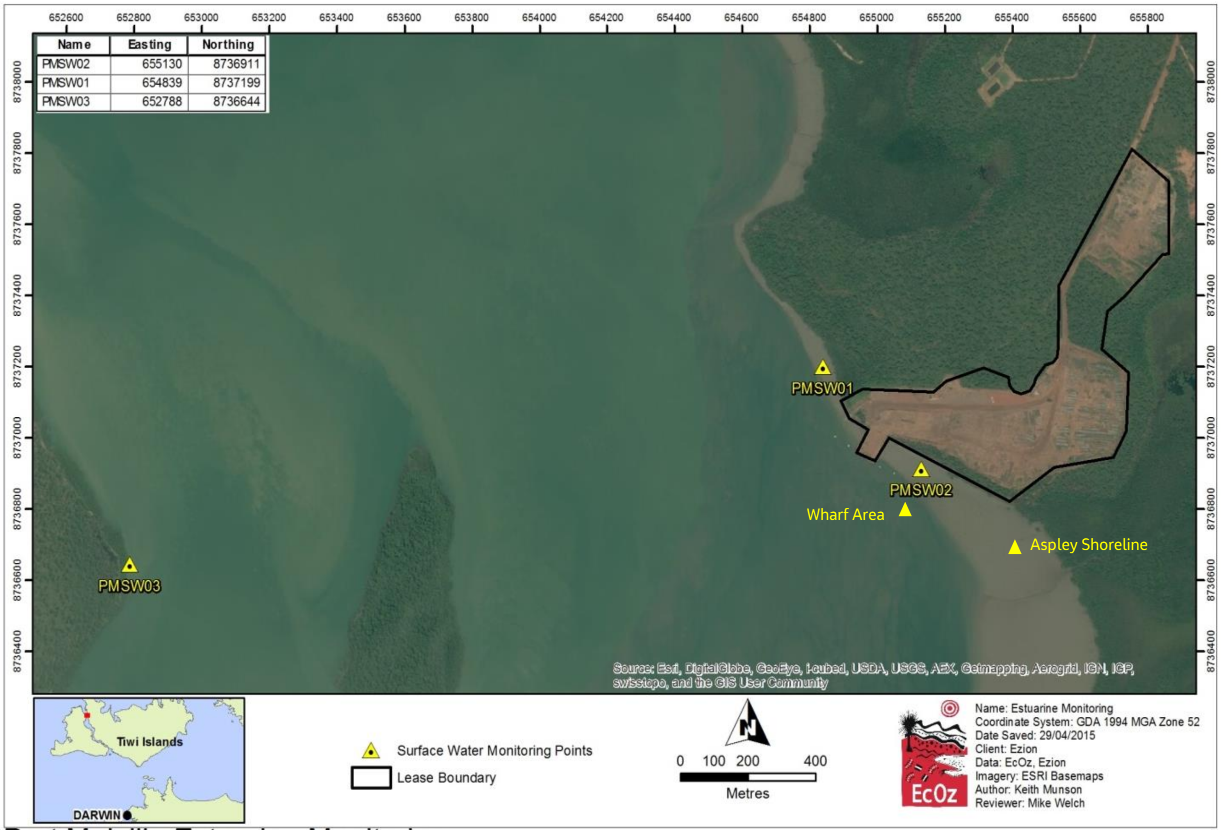
2.4 Receiving Water

2.4.1 Monitoring data

Water quality monitoring data from Port Melville's monthly water quality program was analysed to characterise the ambient water quality around the site.

The monitoring data monitoring data contains physical parameters such as PH, Dissolved Oxygen (DO), Electrical Conductivity (EC), Total Dissolved Solid (TDS), Total Suspended Solid (TSS), Salinity, Temperature and Turbidity, as well as chemical parameters such as Dissolved Major Anions, Cations and Metals, Nutrients, Petroleum etc (refer to Appendix A). Analysis of water quality monitoring data for samples taken in the vicinity of the site over the period during Sep 2015 and Dec 2021 (refer to Figure 2-5 for sampling locations) indicates the following:

- The nearshore water temperature ranges from ~18°C to 34°C. The median temperature for all sampling data is 28.5°C which is similar to the annual mean temperature from IBL global model (refer to section 2.4.1). The lowest temperature was observed at the end of summer in 2017. For the same month in 2016, water temperature was over 30°C. This indicates significant variabilities (interannual/diurnal/storms) superimposed over the typical seasonal pattern. Both local weather conditions and freshwater discharge contributed to the variation of nearshore water temperature.
- Salinity levels range from ~12 ppt to ~37 ppt. In June 2016, a significant gradient in the salinity levels was observed near the site with a measure salinity level of ~32 ppt at sampling location "Wharf Area" and a salinity level of ~15 ppt at sampling location "Apsley shoreline" (only ~300 m apart), indicating that significant spatial variability in salinity levels could occasionally be experienced near the site. This variability is likely caused by freshwater inflows from nearby creek systems.
- Turbidity is generally the largest (maximal value of 438 NTU) at the sampling locations "Wharf Area" and "Aspley shoreline" and the smallest (<10) at "PMSW3" on other side of the Strait. There are however periods of low turbidity data near the wharf and the shoreline. Project site turbidity is likely determined by weather conditions, vessel movements, tidal phases as well as discharge of high turbidity water into the strait.
- A reasonable correlation was found between Total Suspended Solids (TSS) concentration and Turbidity.



Name	Easting	Northing
PMSW02	655130	8736911
PMSW01	654839	8737199
PMSW03	652788	8736644

Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

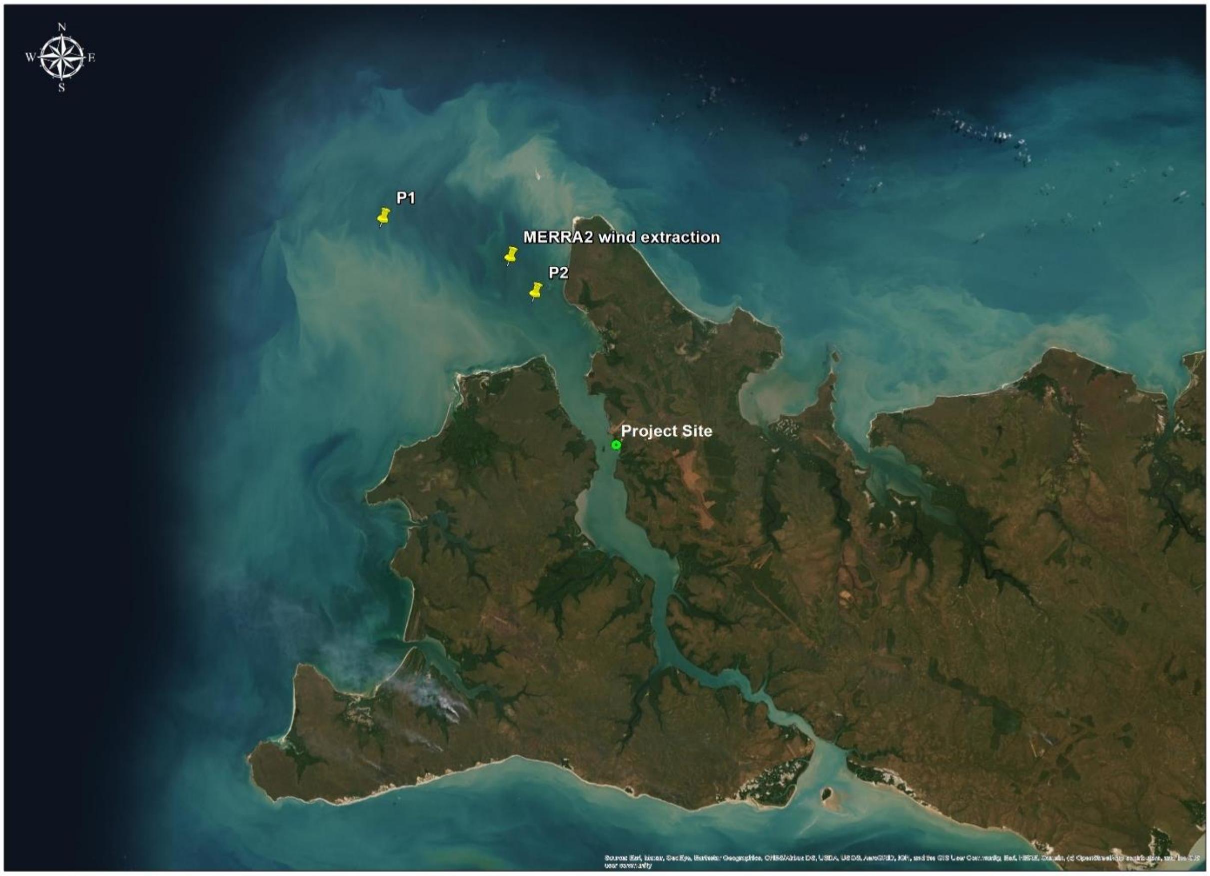
Name: Estuarine Monitoring
Coordinate System: GDA 1994 MGA Zone 52
Date Saved: 29/04/2015
Client: Ezion
Data: EcOz, Ezion
Imagery: ESRI Basemaps
Author: Keith Munson
Reviewer: Mike Welch

Figure 2-5 Port Melville Water Monitoring Points (from EcOz Estuary Monitoring Database)

2.4.2 Hindcast Ambient Temperature and Salinity

Daily average ambient water temperature and salinity at an offshore site (P1) and in the Strait (P2) (see Figure 2-6) were extracted from CMEMS's IBI-Reanalysis Ocean model over a 30-year duration (1993-2020). Time sequences are shown in Figure 2-7 and indicate that:

- The water temperature has a clear seasonal patten, showing monthly average temperature ranging from about 26°C in July (winter) to over 31°C in Dec (summer). The 10th percentile, 50th percentile,90th percentile temperature is a about 26°C, 29.4°C and 31.2°C respectively. Within 10 m contour line, water is well-mixed vertically, showing only weak stratification at sampling points (within 0.2°C salinity difference between surface and bottom). Given the data has been averaged daily (capturing no diurnal variations), stronger stratification may occur during daytime from solar heating.
- There are both seasonal and interannual variations in salinity. Water salinity fluctuates at a small range typically between ~34 ppt in April to 34.7 ppt in Nov (monthly averaged), and may be lower during some particular years, e.g. less than 34 PSU during the 2011 La Niña event. Water is well-mixed within 10 m contour, so little differences in salinity are evident throughout the water column.



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community, Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

Figure 2-6 **Location of Data Extraction.**

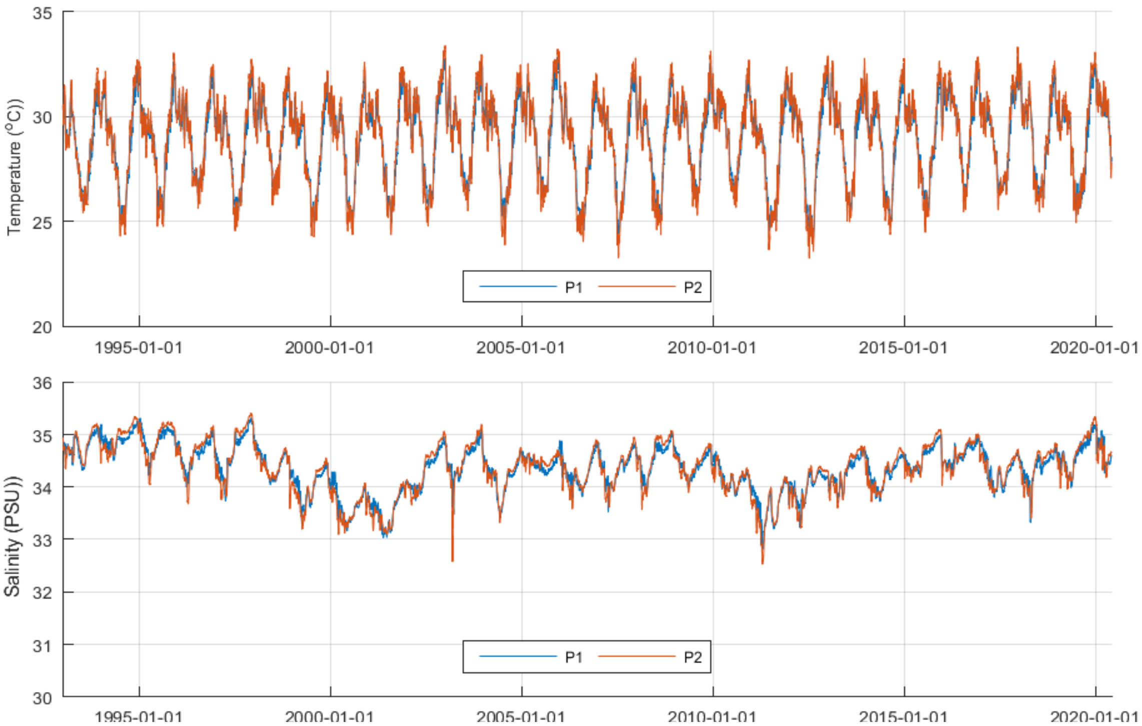


Figure 2-7 **Ambient water temperature results from Copernicus IBA-Reanalysis dataset**

Comparison of the local water quality measurement data to offshore hindcast data indicates that the temperature and salinity has a greater range of variation near the project site when compared to the values for the offshore waters. The differences are expected to be related to impacts from solar heating, evaporation on the shallower water in the Strait as well as catchment inflows.

The effects of the substantial fluctuations in temperature and salinity, as observed in the monthly monitoring data, on the nearfield mixing performance of the proposed outfall has been assessed as part of the near field modelling assessment (refer to Section 5).

3. Intake and outfall configuration

3.1 Effluent characteristics

Key characteristics of the proposed effluent discharge, as adopted for the preliminary outfall dispersion modelling assessment, are summarised in Table 3-1.

Table 3-1 **Effluent water quality characteristics**

Parameter	Intake	Outfall
Flow Discharge (m^3/s)	-0.135	0.079
Temperature (°C)	Ambient (~29.4 typical)	Ambient (~29.4 typical)
Salinity (PSU)	Ambient (~34.5 typical)	Intake Salinity/0.58 (~59.5 typical; ~63.5 max)
Density (kg/m^3)	1021.2 typical	1040 typical; 1044 max

3.2 Intake and outfall concept

Figure 3-1 presents the intake and outfall concepts considered in the outfall dispersion assessment. Two options for the intake location have been investigated in this assessment, namely:

- **Option 1**: Intake to be located approximately 500 m north of the wharf to locate the intake away from water quality variations (e.g. stormwater discharges and propellor wash).
- **Option 2**: Intake to be located on northern end of the wharf to maximise the use of existing infrastructure and minimise the construction footprint.

It is envisaged that for both options the intake would be mounted on a floating pontoon system with mounted pumps. Sea water for the intake would be extracted close to the surface.

The outfall is proposed to be located on the southern end of the existing wharf. Available bathymetric charts of the region indicate that water depths at the southern end of the wharf are greater than those at the northern end, and hence better mixing is likely to be achieved by located the outfall at the southern end.

It is proposed that the outfall comprises of a single nozzle (0.2 m diameter) which will be positioned at approximately 4 m below the deck of the floating access jetty. The nozzle will have a vertical angle of 20^0 and typically release the effluent with a jet speed of ~2.5 m/s.

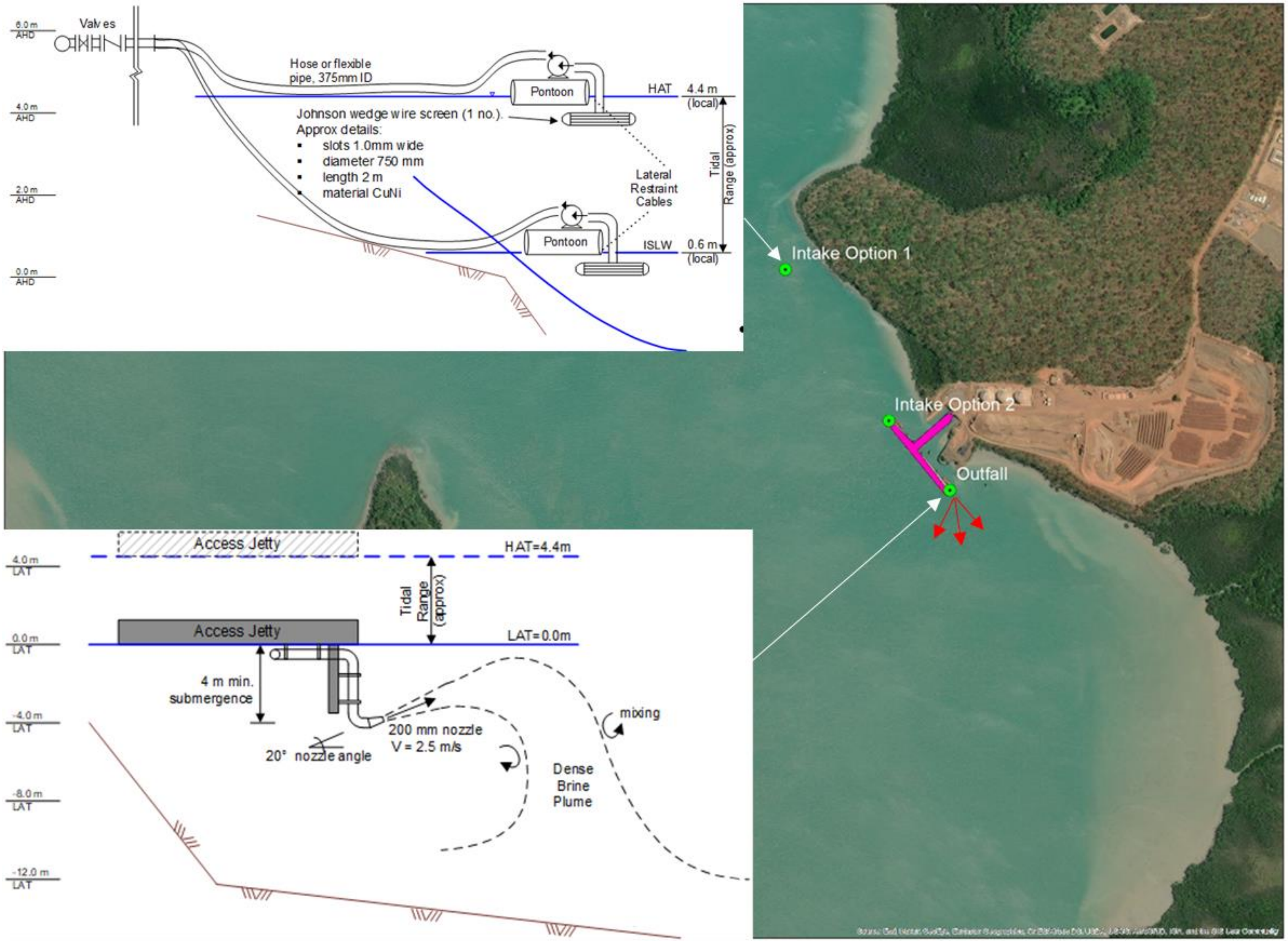


Figure 3-1 **Intake & Outfall Concept Design. Red arrows denote port alignment options.**

4. Baseline Hydrodynamic Modelling

4.1 Introduction

Hydrodynamic modelling has undertaken to establish the hydrodynamic regime around Port Melville assess the farfield mixing behaviour of the proposed effluent discharge. A MIKE 3D FM/AD model of the Aspley Strait region was developed for this purpose.

MIKE 3D FM is a commonly used hydrodynamic modelling tool to simulate water level variation and flows, including density driven flows, in oceanic and coastal environments. MIKE 3 FM solves the 3D Non-Linear-Shallow-Water-Equations (NLSWE) on a flexible mesh using a finite-volume numerical scheme (DHI, 2022).

4.2 Model Setup

4.2.1 Mesh and Bathymetry

A layered flexible mesh approach was adopted to resolve the model in the vertical and horizontal domain. In the horizontal domain, the model mesh is comprised of triangle and quadrilateral elements. This approach enables a variation of the mesh resolution within the model area and tailoring of finer mesh in selected sub-areas, e.g. Port Melville and the outfall location. Mesh size ranges from over 20 km offshore to approximately 20 m in cross-streamwise direction and 50-70 m in streamwise direction at this site.

The model bathymetry was derived from the following sources:

- Jeppesen Norway’s C-MAP digital bathymetric database. CMAP data has good accuracy and coverage in nearshore and offshore water, while it lacks sampling points upstream of the strait and in the intertidal zone.
- Geoscience Australia 30 m resolution DEM data from Elvis. This dataset is developed based on a combination of shallow and deep water multibeam surveys as well as satellite derived elevations to fill data gaps (the latter of which is likely the case for the significant proportions of the Aspley Strait).

The model mesh and bathymetry are presented in Figure 4-1 and Figure 4-2.

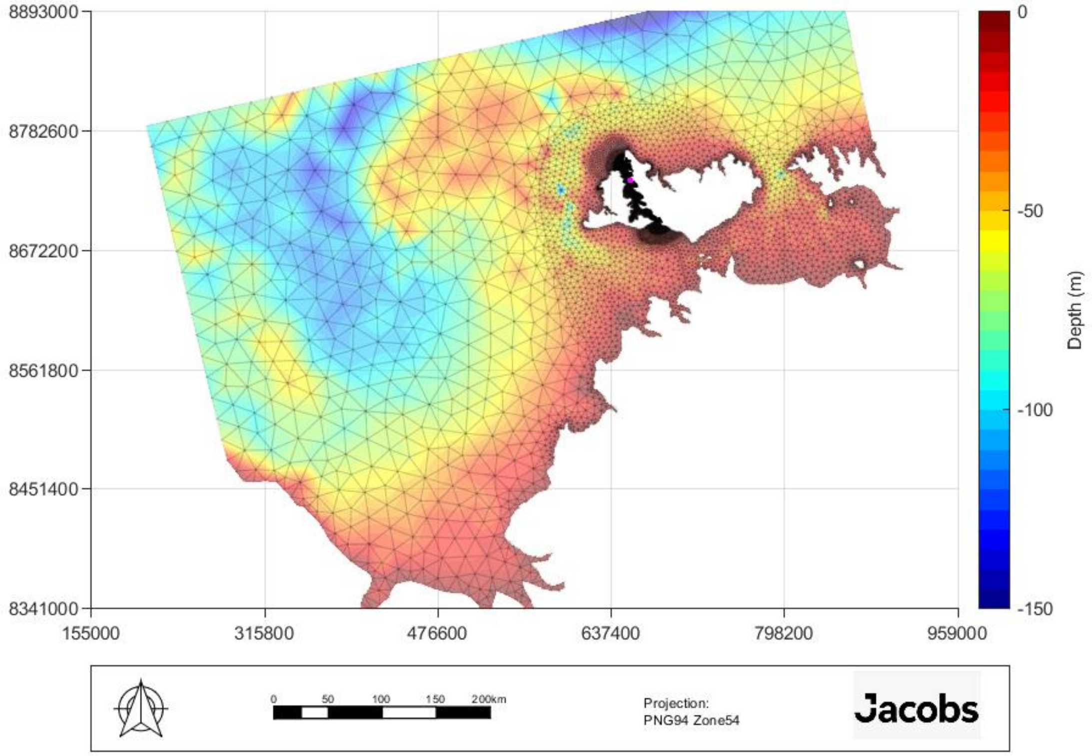


Figure 4-1 Model Mesh & Bathymetry (MSL m), Model Domain

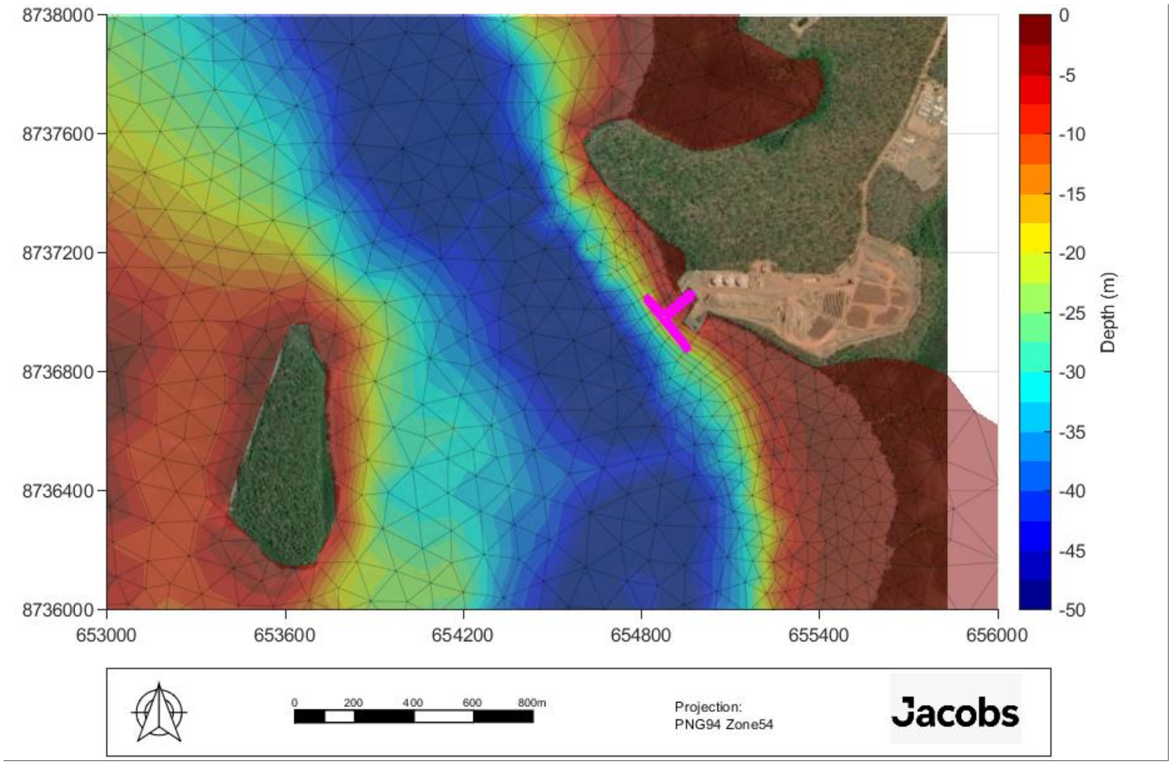


Figure 4-2 Model Mesh & Bathymetry (MSL m), Project Site

4.2.2 Boundary Conditions

The model extent includes a number of open boundaries requiring the definition of boundary conditions. These boundary conditions define the forcing functions to drive flow in and out of the modelled area. Flow within the model area is dominated by tidal conditions.

4.2.2.1 Tide Boundary

Tidal levels are extracted from Global Tide Model developed by DTU Space. The model is available on a 0.125° x 0.125° resolution grid for the major 10 constituents in the tidal spectra. The model utilises the latest 17 years' multi-mission measurements from TOPEX/Poseidon, Jason-1 and Jason-2 satellite altimetry for sea level residual analysis. The constituents consider the semidiurnal M2, S2, K2, N2 the diurnal S1, K1, O1, P1, Q1 and the shallow water constituents M4.

A comparison between DTU tide prediction and local tide prediction by AusTide constitutes (Goodrich Bank Station 63192) is provided in Figure 4-3. It shows a good consistency (observed differences in order of centimeters) between DTU predictions and regenerated AusTide predictions, indicating reliable offshore tidal boundary inputs from DTU space in this region.

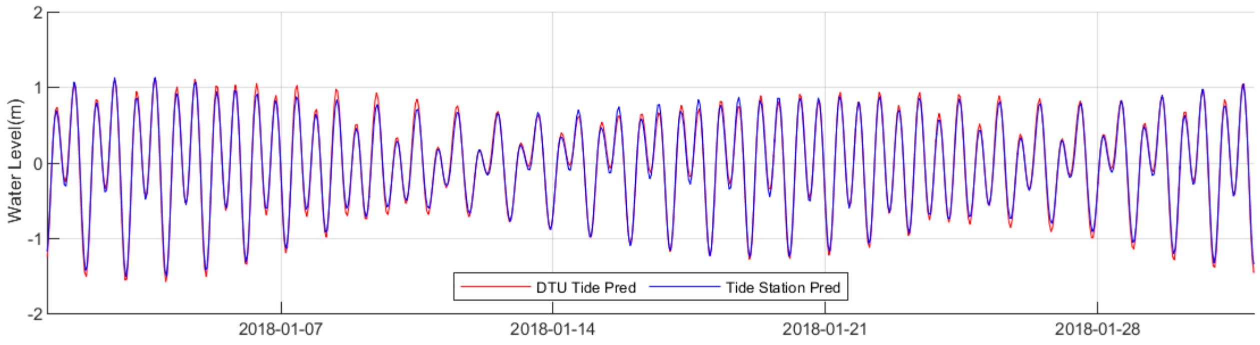


Figure 4-3 Comparison of DTU Tide prediction with AusTide prediction (Goodrich Bank Station 63192)

4.2.2.2 Thermal Boundary

Daily averaged salinity and temperature hindcast data from CMEMS global ocean eddy-resolving reanalysis model results have been used to drive the model boundary conditions and initialise the model in the absence of adequate spatially variable temperature and salinity measurement. Internal heating and cooling processes have not been modelled explicitly.

4.2.3 Hydraulic Roughness

Hydraulic bed friction was applied as bottom roughness based on logarithm boundary layer algorithm. It is a standard way to implement friction impact to a 3D hydrodynamic model. A constant bottom roughness of 0.05 m was applied to the model domain. Roughness near the model boundary was manually increased to limit boundary instability. This adapted roughness value was established as part of the model calibration/validation process, detailed in Section 4.3.

4.2.4 Eddy viscosity and dispersion

A scaled eddy viscosity formulation was used to simulate dispersion processes in the model. The Smagorinsky model has been used to represent horizontal eddy-viscosity and the Log Law formulation to represent vertical eddy-viscosity. In lieu of suitable site-specific monitoring data to inform further model calibration, a horizontal eddy viscosity coefficient of 0.28 has been adopted, as well as a horizontal scaling factor of 1.0 and a vertical scaling factor of 0.0001 based on recommendations by DHI (DHI, 2022).

For the purposes of the far field dispersion modelling (refer to section 6), model sensitivity tests were undertaken for the horizontal and vertical scaling factors to investigate their impact on the plume extent as discussed in Appendix B. Based on the results of the analysis, the adopted scaling parameters are considered appropriate.

4.3 Model Verification

Model verification was undertaken to ensure that the model appropriately simulates the key hydrodynamic processes. The model verification process involved assessment of the model's capability to simulate tidal water level fluctuations and flow current magnitudes at the site.

4.3.1 Water Level

No water level measurements could be made available for model calibration/validation purposes. Instead, the performance of the model was verified by comparing modelled water levels against water level predictions at Barlow Point South provided by AusTide. Figure 4-4 presents the comparison over one month of period during January 2018 (covering a full spring-neap tide cycle), demonstrating that both the tidal range and phase are simulated at good accuracy. The observed RMSE (Root Mean Square Error) is less than 0.2 m (about 5% tidal range), indicating satisfying model performance in reproducing tide levels around Tiwi Island (a macro tide environment).

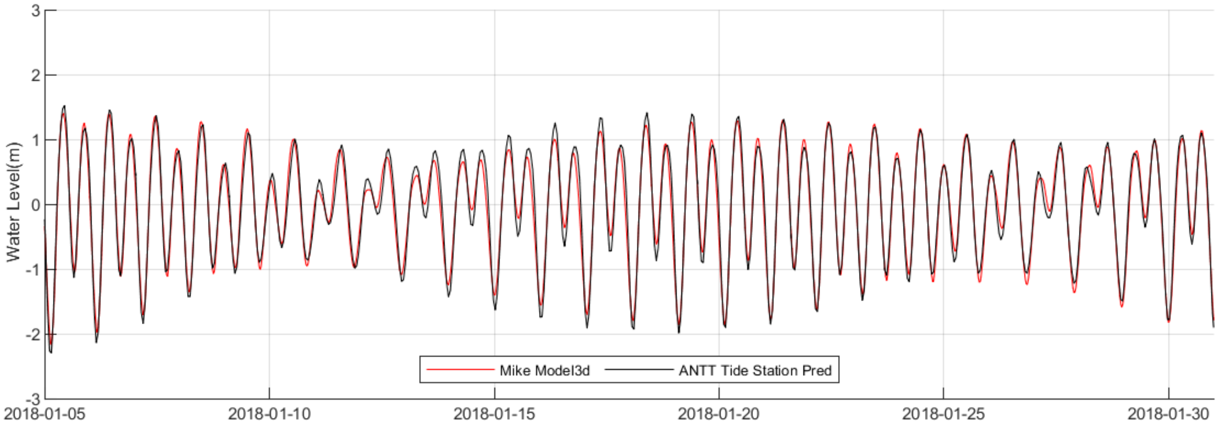


Figure 4-4 **Modelled water levels vs AusTide tidal predictions at Barlow Point South**

4.3.2 Tidal Flow

As per section 2.3.2, available information on tidal currents at the project is limited. Some existing reports suggest the following:

- The Operations Environmental Management Plan for Port Melville (EcOz, 2016) indicates that maximum tidal flows measured in nearshore region may exceed 1.3 m/s from time to time, based on site measurements by Maritime Engineers Pty Ltd.
- Port Melville information handbook (NT Port and Marine, 2017b) suggests maximum current speeds of ~0.8 m/s during flood tides, and maximum ebb currents greater than ~1.5 m/s in the nearshore area.
- The Tidal Energy in Australia (2020) report suggests maximum tidal flow may range from 1.25 m/s during flood tide to over 2.5 m/s during ebb tides at Port Melville.

Except above information, there was no in-situ velocity measurement to verify the model.

Results from Jacobs hydrodynamic model suggest that the maximum nearshore current speeds in the vicinity of the Port exceed 1 m/s as shown below in Figure 4-5 and Figure 4-6. The model results indicate that the maximum ebb tide current speeds are higher than maximum flood tide current speeds, consistent with the reported observations.

Furthermore, the results from Jacobs hydrodynamic model indicate that strong local flows may be present around the Wharf, suggesting that reported field measurements in the area are sensitive to the location of measurement. The modelled spatial variation in flow speed indicates presence of local flows around structures, which could result in vortex shedding, and flow separation in the vicinity of the Wharf. Jacobs hydrodynamic model does not explicitly simulate these secondary processes.

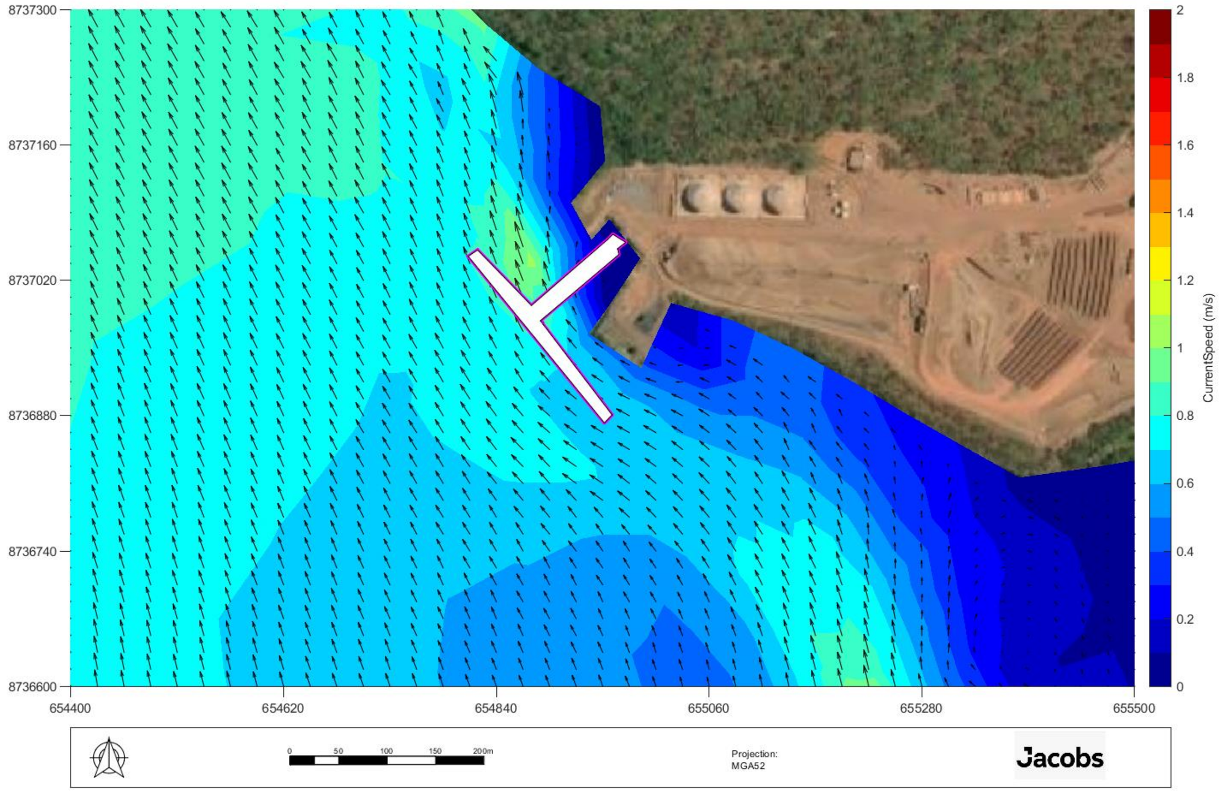


Figure 4-5 Surface Tidal Flow at Ebb Phase During Spring Tide (21-Jan-2018 06:00:00)

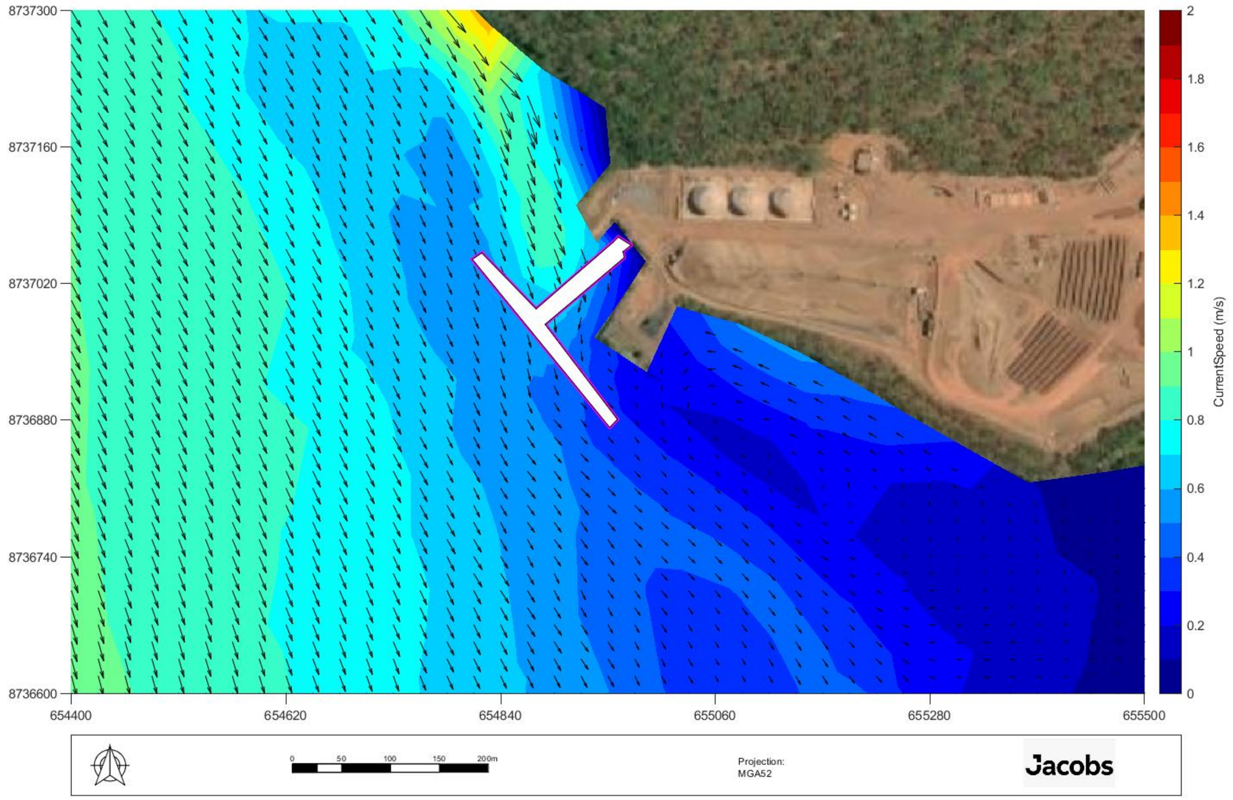


Figure 4-6 Surface Tidal Flow at Flood Phase During Spring Tide (20-Jan-2018 06:30:00)

4.4 Results of Tidal Simulations

Following the model verification process, the MIKE3 FM model was used to determine typical current speeds in the vicinity of the project site. This involved simulation of a 40-day period from 1 January 2018 to 10 February 2018. A warmup period of 10 days was applied to ensure that any erroneous signals generated from the specified initial conditions were absent from the results.

Tidal currents were extracted at three sampling locations (intake option 1, intake option 2 and the outfall, see Figure 4-7) to determine typical current speeds in the vicinity of the project site.

The maximum modelled tidal current is in the range of ~1.3 m/s near the intake option 1, about 1 m/s near the intake option 2 and ~0.8 m/s near the outfall during a spring tide (Figure 4-7).

Current roses of the data are presented in Figure 4-8. It shows relatively stronger ebb tidal flows for at both intake option 2 and the outfall locations. At the outfall, in particular, the flood flow is significantly weakened due to the shoreline formation and presence of port facilities.

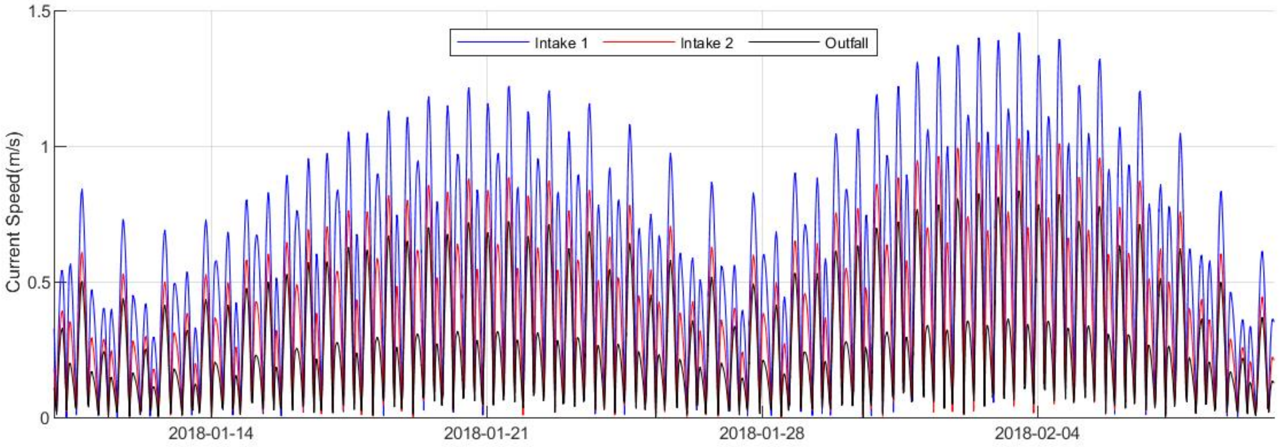


Figure 4-7 Modelled current speed at the proposed intake and outfall locations

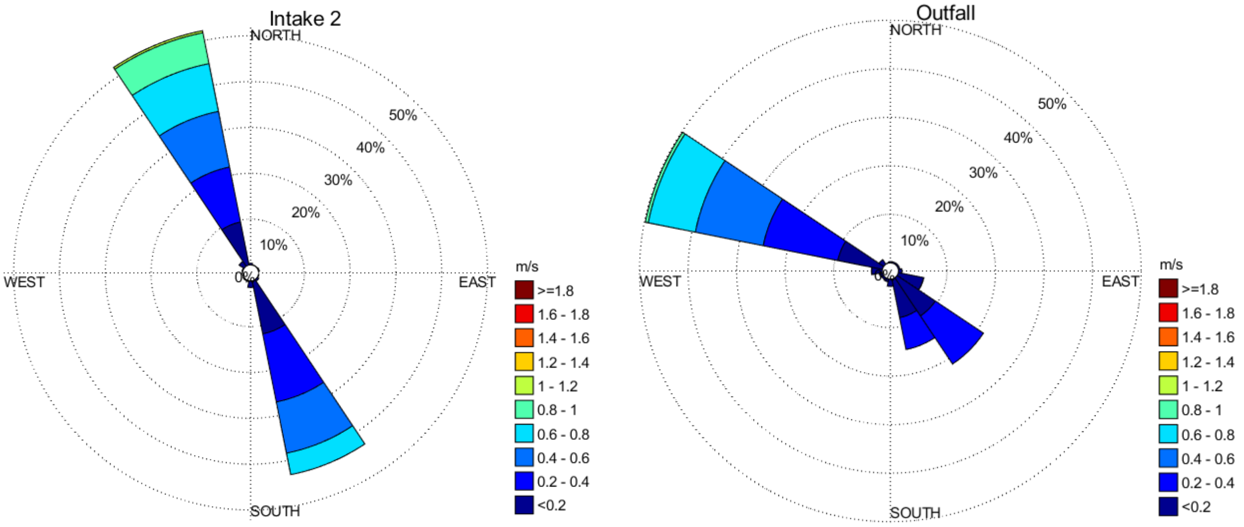


Figure 4-8 Current Rose extracted from no wind, existing scenario simulation. Left side) at Intake 2; Right side) at outfall location. Convention of Direction - clockwise from north where the current is going.

5. Near Field Modelling

5.1 Introduction

Nearfield dilution begins immediately on discharge from the outfall pipe. The principal mechanism associated with initial dilution is the mixing that occurs as the stream of effluent exiting the discharge port entrains surrounding seawater due to turbulence generated by its initial momentum and buoyancy effects. In this study, the behaviour of this negatively buoyant brine jet is affected by factors such as the vertical angle of discharge, the height, angle and diameter of the port opening, the density of brine and receiving water, the jet speed and the speed of ambient flow etc (see Figure 5-1 for the diagram of a typical negatively buoyant jet).

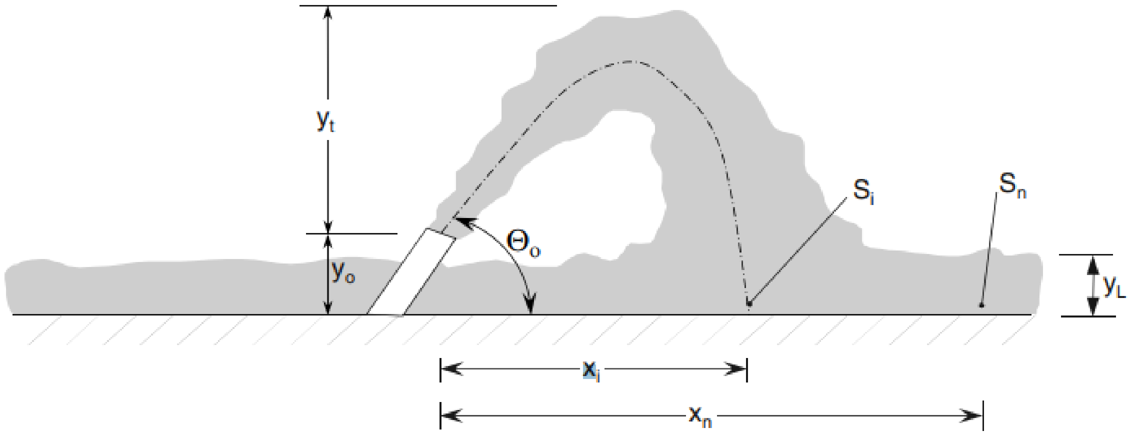


Figure 5-1 Concept Diagram of Nearfield Mixing process (from Roberts et al 1997) for single port diffuser. y_t is the terminal rise height, y_0 is the port height, Θ is vertical discharge angle, S_i is the distance from port to impact point, S_n is the distance from port to end of nearfield mixing, y_r is thickness at the end of near field.

The process of nearfield mixing is modelled using Cornell Mixing Zone Export System (CORMIX). It is an industry standard modelling tool that has been widely used to investigate the nearfield mixing processes of various types of effluents and diffuser designs.

5.2 Model Inputs and Scenarios

Model inputs are obtained through a review of the outfall concept design (refer to Section 3) as well as results from the baseline hydrodynamic modelling (refer to Section 4). Key input parameters are as follows (also refer to Table 5-1):

- Outfall configuration is in line with the concept design drawings shown in Figure 3-1. For the standard case (base case), the nozzle of the outfall is assumed to be oriented perpendicular to the shoreline alignment in order to maximise the trajectory of the plume across the ambient flow. The 20° vertical angle was chosen to increase to horizontal momentum as the port is already located high above the seabed. Sensitivity tests were also undertaken to investigate alternative orientations, including orientating the nozzle parallel to the shoreline.
- The density of effluent has been calculated based on an estimated temperature of 29.5°C and maximum Total Dissolve Solid of 63,523 mg/L as the standard case. Sensitivity tests of effluent and ambient water density have also been investigated to identify their impacts to near field mixing.
- According to available water quality monitoring data, both temperature and salinity may fluctuate significantly in the nearshore. To bound the impact of this on the nearfield mixing behaviour of the outfall, a number of scenarios (base-, best- and worst-case) have been considered to evaluate the behavior of effluent mixing in different ambient environment.
- Based on the results of the baseline hydrodynamic modelling and available literature, various steady flow scenarios have been considered to investigate the nearfield mixing during various stages of the tide. Given the different time scale of near field mixing (seconds) and tidal excursion (hours), it is reasonable to separate these processes. The potential impact of unsteady flow to plume dilution is more suitable to be investigated by farfield model.

- Overall, three extreme ambient water scenarios have been considered for the proposed outfall configuration. These scenarios have enveloped the most extreme ambient environment for near field mixing. Additional model scenarios are considered for the purpose of sensitivity tests and investigations.

Table 5-1 Model inputs for CORMIX Modelling (standard scenarios, excluding sensitivity tests)

Parameter	Model Input		
	Base Case	Worst Case	Best Case
Receiving environment			
Ambient seawater temperature (ºC)	29.4	34	18
Ambient Salinity (PSU)	34.5	12	34.5
Ambient seawater density (kg/m3)	1021.2	1002.9	1024.9
Water Depth (m)	12	12	12
Ambient current velocity (m/s)	0.5 (typical spring current speed at the outfall)	0 (conservative minimum current speed)	2 (conservative maximum current speed)
Outfall Configuration			
Flow Speed (m/s)	2.5	2.5	2.5
Effluent density(kg/m3)	1044.1	1044.1	1044.1
No of Port	1	1	1
Effective port diameter (m)	0.2	0.2	0.2
Port Vertical Angle (o)	20	20	20
Port horizontal angle (o relative to shoreline)	90	90	90
Port Height (m Above Seabed, Low Tide Condition)	8	8	8

5.3 Results

5.3.1 CORMIX Nearfield Model Results

Table 5-2 summarises the results of the nearfield modelling. Corresponding mixing plots for the standard model scenarios (i.e. Case 1 to 3) are shown in Table 5-3. These results are based on the achieved water quality at the edge of the theoretical nearfield mixing zone based on CORMIX. The nearfield impact zone based on a 1 PSU and 2 PSU increase are discussed in Section 5.3.2.

Key findings based on Table 5-2 are as follows:

- The representative case (Case 1) shows a near field mixing trajectory of less than 4 m in cross-streamwise direction which is determined by the buoyancy of the effluent as well as the initial momentum of the jet. At the end of nearfield, the jet has been diluted for over 250 times by the ocean water (excess salinity <0.1 PSU). The ambient flow plays a key role in near field mixing as the trajectory of the plume along the stream (~50 m) is order of magnitude longer than the cross-streamwise direction.
- For the worse case condition (Case 2), a stagnant water at slack tide under fresher receiving water (e.g. after a rainfall event) has been assumed. The model results show a significant reduction in nearfield mixing. The modelled dilution at the end of near field is approximately 20.7 (excess salinity of ~1.2

PSU) which envelops the worst-case dilution for effluent discharged into stagnant fresh water. The trajectory of near field mixing across the stream is less than 10 m at the time when the plume impacts the seabed.

- The best-case condition (Case 3) assumes an ambient flow speed of 2 m/s. Under such circumstance, the effluent will be diluted by over 770 times (excess salinity <0.1 PSU) at the end of nearfield process. The nearfield plume does not go far in cross streamwise direction, while it travels for over 300 meter in streamwise direction.
- For all modelled cases, the plume does not travel far in cross streamwise direction. It will likely form a narrow stream of plume that travels alongside the tidal flow. For all-modelled scenarios, the near field mixing shows less than 1.2 PSU salinity increase.
- Sensitivity tests (Case 4-Case 11) show that ambient flow plays a major role in nearfield mixing where the dilution factor increases from 20.7 in stagnant water (flat tide) to over 400 at flood tide or over 700 for more extreme flow conditions. The effect of density of ambient/effluent water is relatively small showing only marginal impact to the dilution rate at the end of near field mixing process (<5% for ±4kg/m^3 density variation). Water depth has notable impact to near field dilution as it elongates the jet trajectory before impacting the seabed, increasing the nearfield mixing.
- Port horizontal orientation has limited impact to the near field mixing process. The estimated impact is less than 5% for typical flow regime (within 1 m/s) for all considered alignment options. However, the overall shape and formation of plume may change under different port orientations. For instance, the plume would be narrower and more stretched if port opening is parallel to the tidal flow.

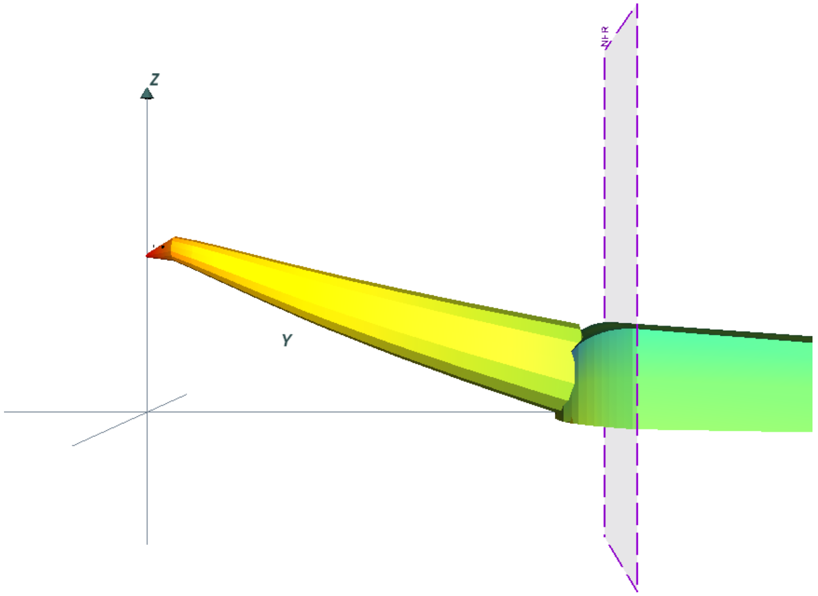
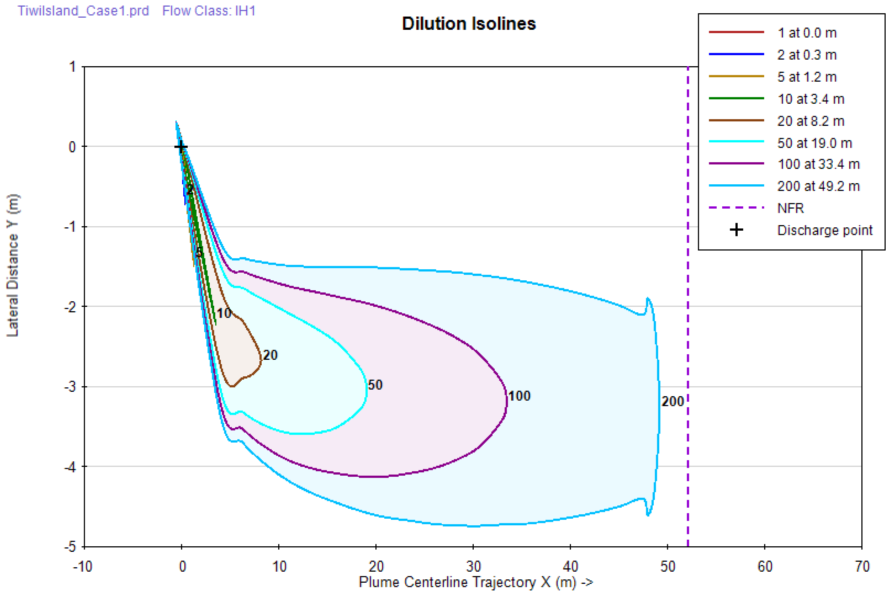
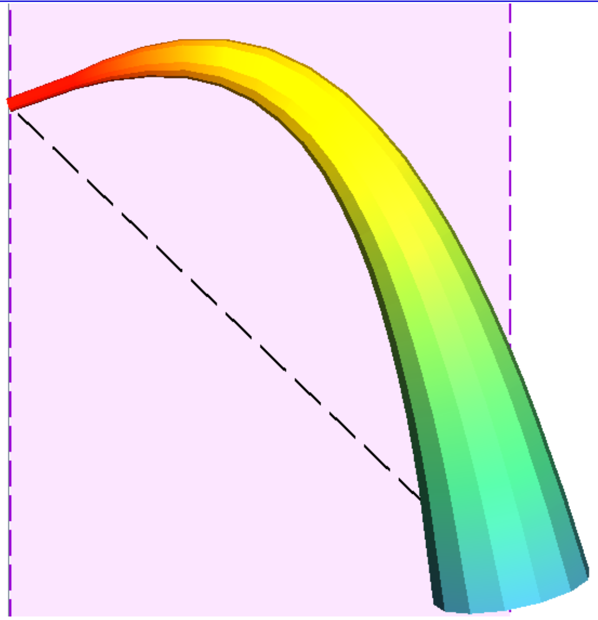
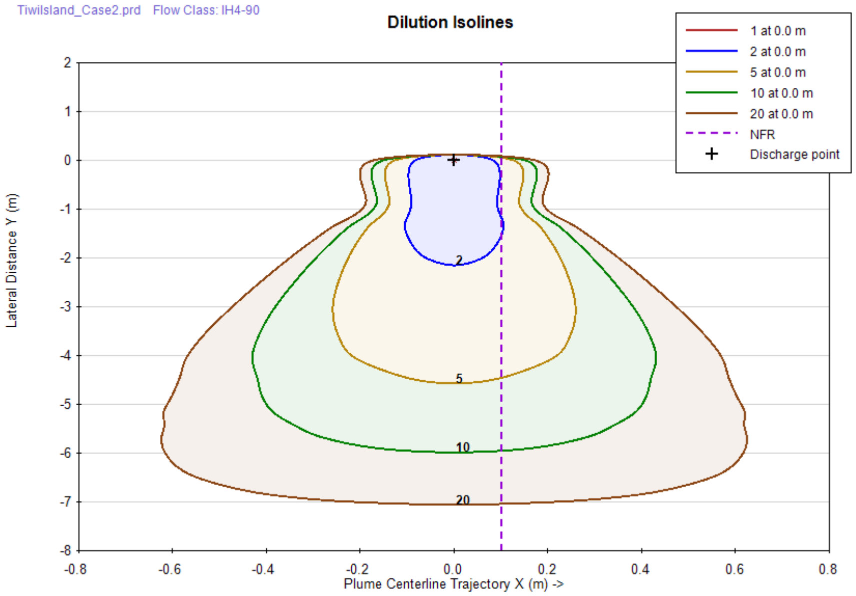
The following conclusions can be made based on the nearfield modelling results:

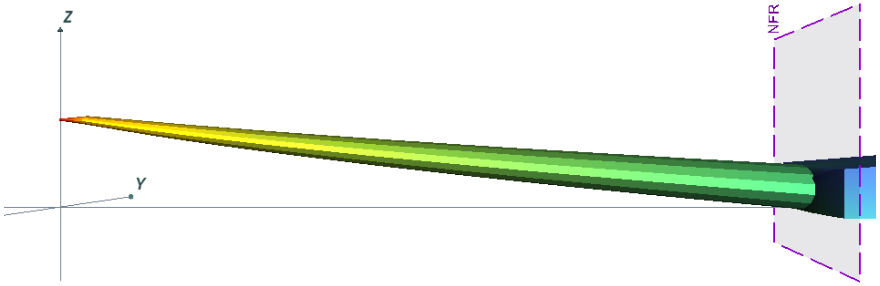
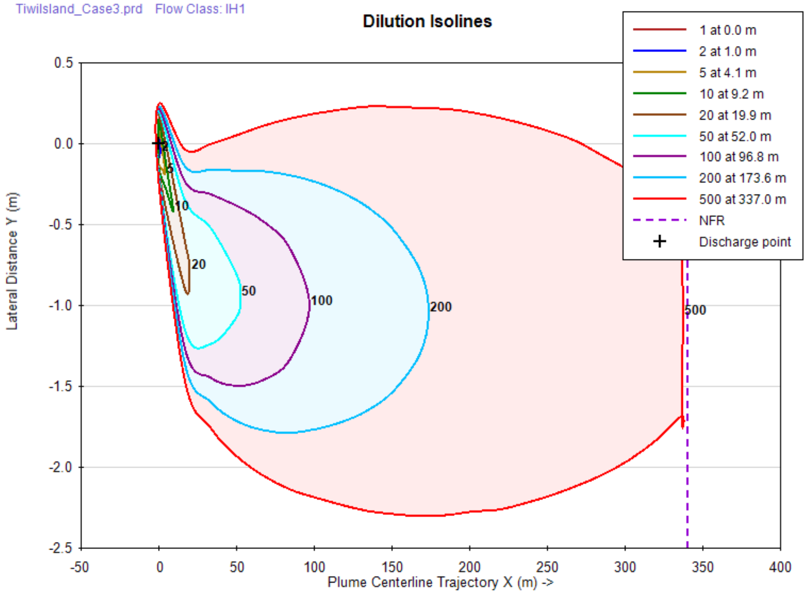
- The overall impact of brine discharge after near-field mixing is very small. For all modelled scenarios, the predicted salinity at the end of the mixing zone is less than 1.2 PSU above the salinity of the ambient water. This level of salinity increase is within the range of ambient salinity fluctuations.
- Tidal current has significant contribution to nearfield mixing as it significantly elongates the mixing process in streamwise direction.
- The brine plume is likely to be narrow (a few meters in width) cross the strait while elongated (order of a few hundred meters) along the tidal flow.
- Near field mixing is sensitivity to ambient flow speed, height of the port relative to seabed, while not very sensitive to small changes in density of effluent and receiving water. The orientation of the port (horizontal direction) has also limited impacts to near field mixing.

Table 5-2 Summary of Near Field Mixing for Proposed Outfall Diffuser Design.

Case	Group	Receiving environment Density (kg/m3)	Receiving environment Density (kg/m3)	Horizontal Discharge Angle (°)	Port Height (m above seabed)	Effluent Density (kg/m3)	Dilution (end of Nearfield)	Excess salinity (PSU)	Lateral Distance (m end of Nearfield)	Longitudinal Distance (m end of Nearfield)
Case 1 (Typical)	Standard Runs	1021.2	0.5	90	8	1044.1	265.5	<0.1	3	52
Case 2 (Worst)		1002.9	0	90	8	1044.1	20.7	1.2	7	0
Case 3 (Best)		1024.9	2	90	8	1044.1	770.2	<0.1	1	340
Case 4	Sensitivity Tests for Ambient Flow	1021.2	0	90	8	1044.1	20.5	1.2	9	0
Case 5		1021.2	0.05	90	8	1044.1	40.4	1.8	9	2
Case 6		1021.2	0.1	90	8	1044.1	52.9	0.5	8	13
Case 7		1021.2	0.15	90	8	1044.1	86.5	0.3	7	14
Case 8		1021.2	0.25	90	8	1044.1	156.6	0.2	5	24
Case 9		1021.2	0.75	90	8	1044.1	339.3	<0.1	2	83
Case 10		1021.2	1	90	8	1044.1	403.1	<0.1	2	118
Case 11	Sensitivity Tests for Effluent and ambient density	1018	0.5	90	8	1044.1	260.9	<0.1	3	49
Case 12		1024	0.5	90	8	1044.1	270.2	<0.1	3	56
Case 13		1021.2	0.5	90	8	1040.35	271.8	<0.1	3	58
Case 14	Sensitivity Tests for port heights	1021.2	0.5	90	10	1044.1	371.5	<0.1	3	67
Case 15		1021.2	0.5	90	12.5	1044.1	528.2	<0.1	3	88
Case 16	Sensitivity Tests for port horizontal alignment	1021.2	0.5	0	8	1044.1	267.8	<0.1	0	55
Case 17		1021.2	0.5	30	8	1044.1	274.1	<0.1	2	55
Case 18		1021.2	0.5	60	8	1044.1	272.5	<0.1	3	54
Case 19		1021.2	1	0	8	1044.1	432.1	<0.1	0	123.8
Case 20		1021.2	2	0	8	1044.1	652.8	<0.1	0	289

Table 5-3 Near Field Mixing Plots

Case	Jet Shape	Dilution Contour
Case 1		
Case 2		

Case	Jet Shape	Dilution Contour
Case 3		

5.3.2 Nearfield Impact Zone Identification

The nearfield impact zone for assumed dilution criteria (based on salinity) has been investigated. Based on discussions with EcOz, it is understood that there are no specific mixing zone assessment criteria for the Northern Territory. Hence, for the purposes of this study, a 1 in 1000 parts (1 PSU) and a 2 in 1000 parts (2 PSU) excess salinity have been adopted as indicative criteria to identify the area of impact for nearfield process (entrainment and mixing of effluent jet).

Table 5-4 summarises typical and extreme cases that envelop the footprint of potential impact zone adjacent to the diffuser port. The results indicate that:

- 1 PSU salinity criteria (1 in 1000 parts) requires a nearfield dilution rate of approximately 24, corresponding to a plume with a maximum width of ~8 m in cross-streamwise direction and a maximum length of ~35 m in streamwise direction.
- 2 PSU salinity criteria (2 in 1000 parts) requires a nearfield dilution rate of approximately 11.5, correspond to a plume with a maximum width of ~7 m in cross-streamwise direction and a maximum length of ~18 m in streamwise direction.
- In stagnant water, the plume forms a roundish shape when settles to the seabed. The footprint of this plume can be stretched by tidal flow, showing larger impact area downstream while smaller impact area cross-shore.
- The extent of impact may increase in streamwise direction if the effluent is discharged parallel to the tidal flow (i.e. horizontal discharge angle of 0°).
- As a reference, Western Australia sets out a 200 m width Low Ecological Protection (LEP) zone immediately adjacent to the outfall location (EPA, 2016). The predicted mixing zone size is much smaller than the referred mixing zone size.

Table 5-4 Nearfield Mixing Zone Identification

Parameter	Design Parameters		Criteria 1				Criteria 2			
	Horizontal discharge angle (°)	Ambient current (m/s)	Delta Salinity (PSU)	Required Dilution	Cross shore distance from port (m)	Downstream length from port (m)	Delta Salinity (PSU)	Required Dilution	Cross shore distance from port (m)	Downstream length from port (m)
Case 1	90	0.5	1	24	4	11	2	11.5	3	5
Case 2	90	0	1	24	8	2	2	11.5	7	1
Case 3	90	2	1	24	2	20	2	11.5	2	15
Case 10	90	1	1	24	2	17	2	11.5	2	10
Case 16	0	0.5	1	24	2	16	2	11.5	2	10
Case 20	0	2	1	24	2	35	2	11.5	2	18
Maximum			1	24	8	35	2	11.5	7	18

6. Far Field Scenario Modelling

6.1 Model Inputs

The MIKE3 FM hydrodynamic model was used to simulate the dispersion of the brine. Model inputs are detailed in section 4.

For the farfield model, effluent has been implemented as a simple source located at the bottom layer. This assumption is in line with near field model results that effluent plume will settle to seabed at the end of the near field. The effluent parameters are taken from Table 3-1. Temperature of effluent is configured to be the same as ambient water. Salinity of effluent is 59.5 PSU (constant), which is calculated from about 42% freshwater production rate from intake seawater (34.5 PSU). The adopted settings represent the most typical condition of effluent when the intake is not affected by freshwater inputs.

The intake has been implemented as negative source point in the surface layer, allowing only inflow of ambient water. Both salinity and temperature are considered to be the same as ambient water. Modelling was undertaken for both intake locations (option 1 and option 2) to investigate any impact of the intake source on the plume dispersion.

Each model run included 10 days spin up period and 30 days production run period to cover a full month spring and neap tide cycle (overall 40 days).

6.2 Scenarios

Both tide and wind play a role in driving the flow through the strait. In this study, three different climate scenarios are considered:

- typical spring and neap tide cycle, no wind;
- typical spring and neap tide cycle, 6 m/s north-westerly wind (i.e. upper ambient wind speed, **Jamutakari** scenario)
- typical spring and neap tide cycle, 6 m/s south-easterly wind (i.e. upper ambient wind speed, **Kumunupunari** scenario)

For each climate scenario, the model simulates both the existing and development cases in order to derive the residual impact from the proposed intake/outfall options.

The region is subject to cyclones, however such impacts are prone to intensify effluent dilution and therefore have not been investigated.

6.3 Model Results

6.3.1 Farfield dispersion maps

For far field modelling, both salinity increase (Development minus Existing Scenario) and dilution rate have been used to identify the area of far-field impact (i.e., dispersion/advection of the plume in tidal flow). Spatial maps of these results are summarised in Appendix C.

Results from the farfield scenario modelling show negligible impact of the intake locations (refer to Figure 6-1 for Intake Option 1 and Figure 6-2 for Intake Option 2). The intake rate (~0.13 m^3/s) is too small to induce notable impacts to the ambient flow field (with strong tidal currents) that would affect the dispersion of effluent from the outfall. For this reason, the impacts of only one set of model results (Option 2) are presented in Table C-1.

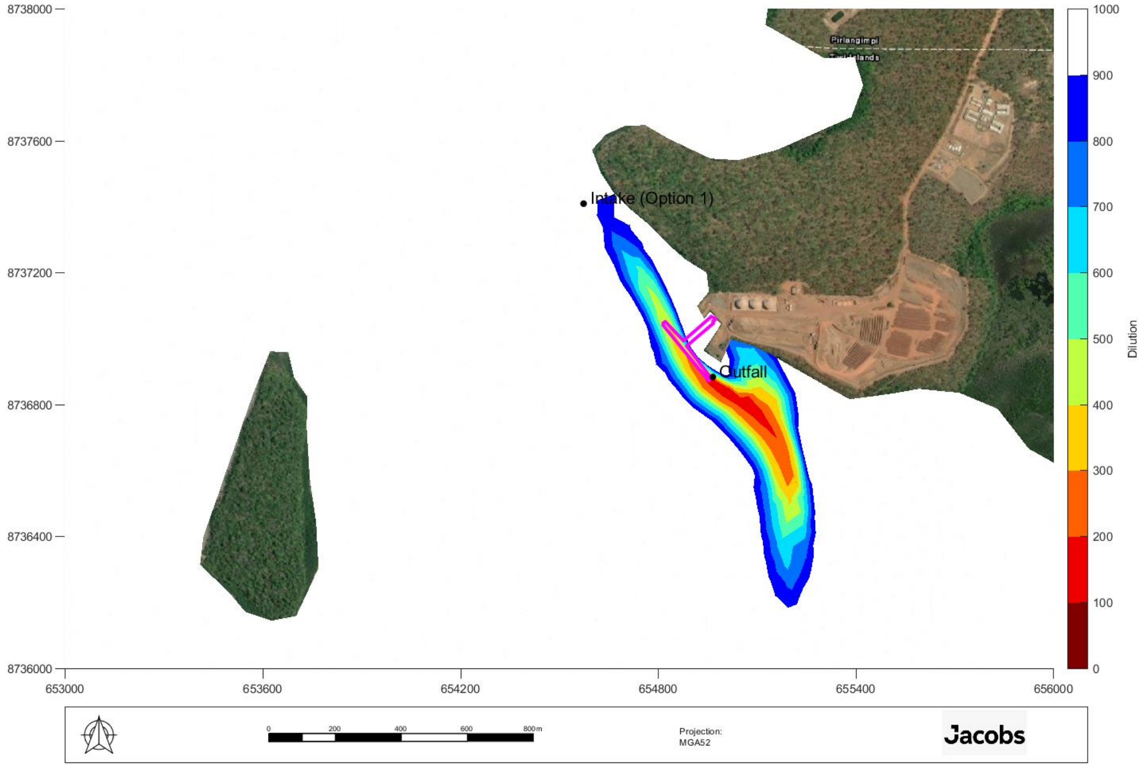


Figure 6-1 **Modelled 90th percentile near bed dilution rate – Model scenario: "Intake Option 1 - no wind"**

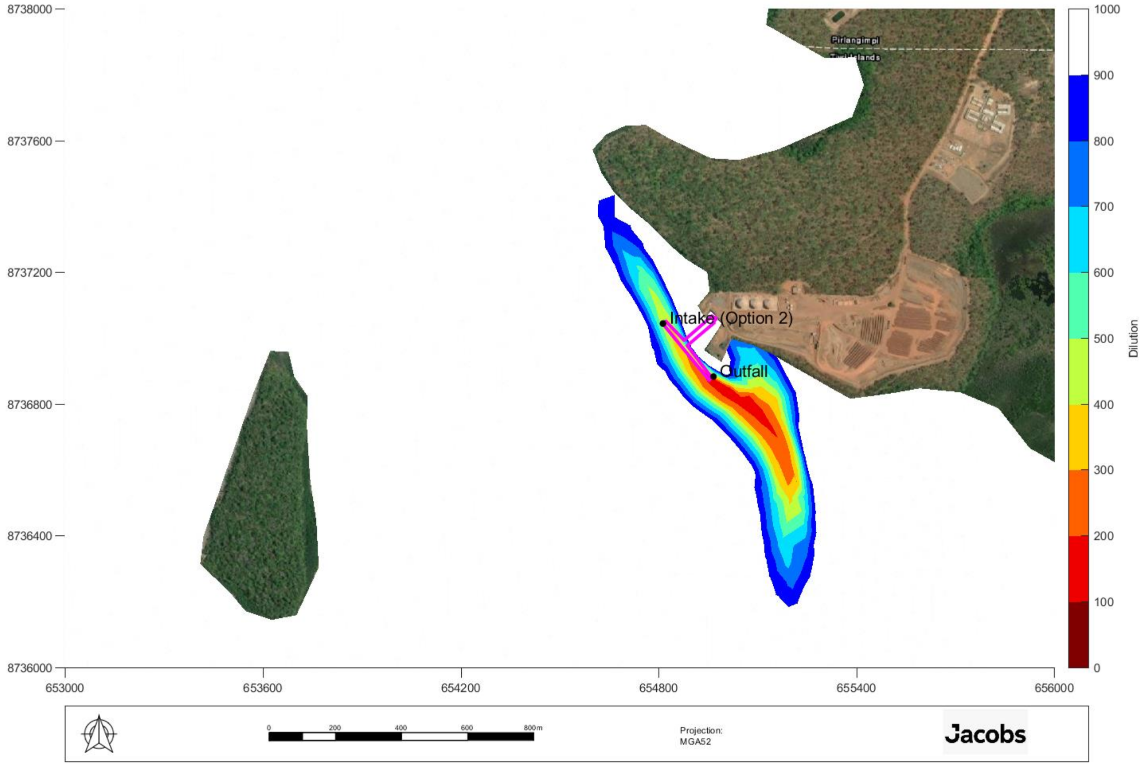


Figure 6-2 **Modelled 90th percentile near bed dilution rate – Model scenario: "Intake Option 2 - no wind"**

Modelled salinity levels have been extracted for both the surface and bottom layers, the latter of which corresponds to the maximum salinity levels (and lowest dilution levels) throughout the water column. Results are shown of the 70th and 90th percentile excess salinity and dilution respectively. The 70th percentile results depict the levels that are predicted to be exceeded 30% of the time, and the 90th percentile results depict the levels that are predicted to be exceeded 10% of the time.

Key findings are summarised as followings:

- The largest salinity impacts occur near the seabed.
- The impacts in the surface layer are very small; less than 0.1 PSU for all modelled scenarios (the minimum dilution rate within the surface layer is larger than 1000).
- Comparing the results of the three ambient wind cases modelled (No wind, SE wind and NW wind) indicates that wind does not play a significant role in the farfield mixing of the discharge with all cases yielding a very similar area of impact.
- Excess salinity concentrations in the farfield domain are modest (refer to example model results for the no wind scenario in Figure 6-3). Based on the 90th percentile results, no salinity impacts of greater than 0.5 PSU are predicted outside a zone of 100 m radius from the outfall.

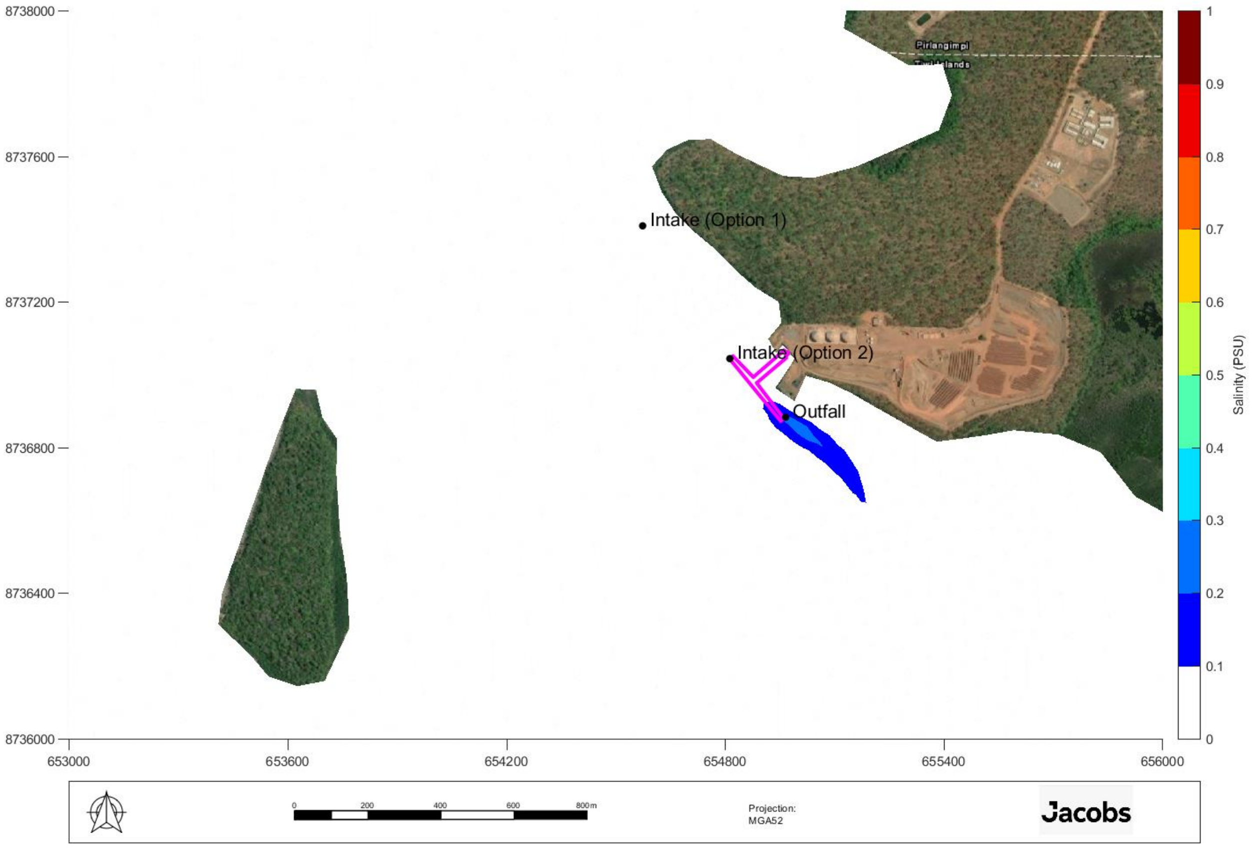


Figure 6-3 Modelled Salinity Increase – Intake Option 2, 90th percentile, bottom layer, no wind

6.3.2 Impact to Nearby Locations

Model results were extracted at a number of locations surrounding the Site to determine the temporal variations of the salinity impacts at these locations. The location of these data extraction points are shown in Figure 6-4. Data was extracted from both the surface and the bottom layer.

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 6-4 **Data extraction points**

Model results are presented in Figure 6-5 and Figure 6-6. These figures indicate that for both intake options the salinity levels of the intake water are not expected to be impacted by the outfall discharge with no material impact predicted at both intake locations (refer to plots of intake option 1 and 2, surface layer).

Furthermore, the plots illustrate that there will be no significant salinity impact on the extraction locations that are located more than 500 m from the proposed outfall with modelled impacts at “Harris Island”, “Creek Outlet 1”, “Creek Outlet 2” and “Barlow Point” all being less than 0.05 PSU.

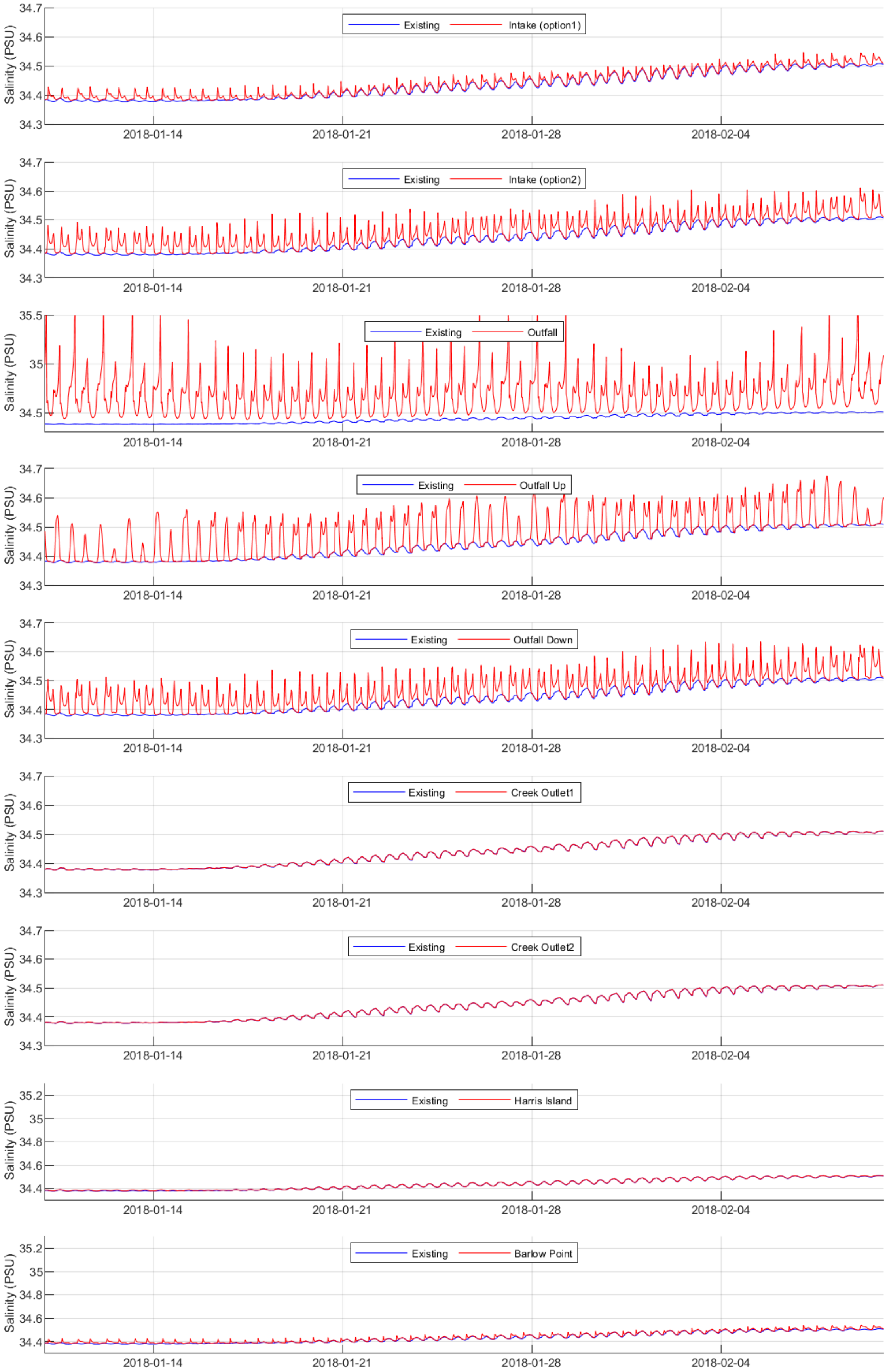


Figure 6-5 Comparison of Bottom Salinity Time Sequences (Existing versus Development, no wind scenario)

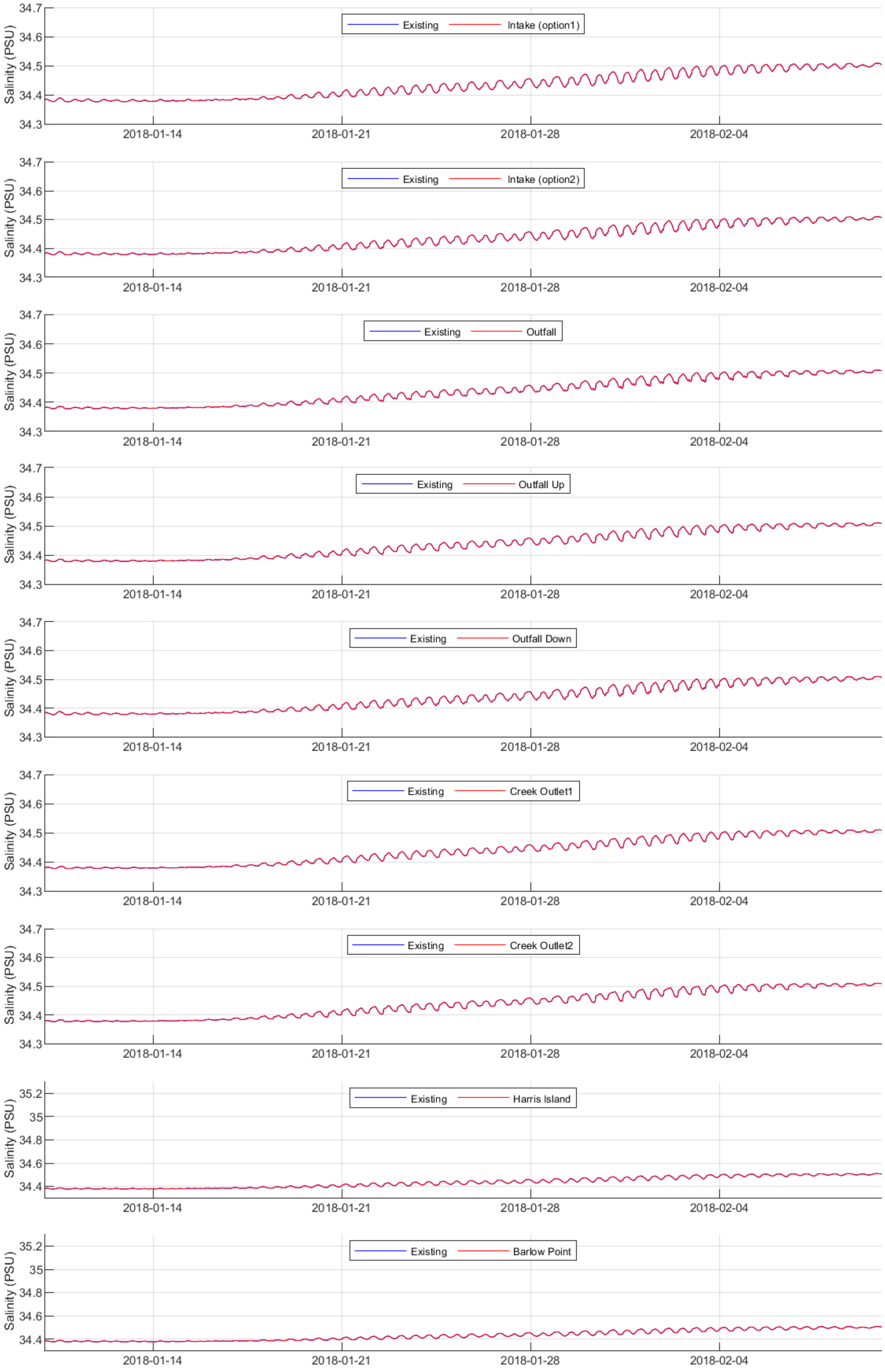


Figure 6-6 Comparison of Surface Salinity Time Sequences (Existing versus Development, no wind scenario)

7. Summary

Preliminary dispersion modelling has been undertaken to evaluate the performance of the proposed outfall design as well as to examine the potential environmental impact to nearby water environment to assist environmental approval.

Nearfield mixing has been investigated using CORMIX. Model results suggest the key factors that determine nearfield mixing are 1) port height above seabed, and 2) ambient flow. The proposed outfall design shows good nearfield mixing through positioning a 0.2 m diameter port 4 m below surface at the southern end of the wharf (approximate depth of 12 m at LAT based on available bathymetric charts). From the perspective of nearfield mixing, there is no requirement for further design optimisation. The predicted dilution ranges from ~20 for effluent discharged directly into stagnant water to over 300 for more extreme flow scenarios. The predicted impact zone for typical ambient flow is within 35 m from the outfall to achieve mixing within 1 PSU excess salinity.

Farfield mixing is investigated via a three-dimensional hydrodynamic and advection-dispersion model of the Tiwi Islands (MIKE3 FM). The accuracy of far-field model is to a large extent determined by model configuration. The following settings have been considered for the modelling:

- Grid size optimization to simulate the formation of stretched plume under strong tidal flow. The adapted resolution is about 20 m in cross-streamwise direction and about 50-70 m in streamwise direction. The grid size is in line with the size of nearfield mixing zone.
- Effluent was discharged at the bottom layer based on the results of the nearfield study which shows that the effluent plume eventually settles to bottom layer over a short distance from the outfall.

The modelling undertaken shows that the proposed outfall site is subject to strong tidal currents which promote good mixing of the proposed brine discharge. Model results demonstrate that the impacts of the proposed brine discharges will be small and contained to an area in the immediately vicinity of the proposed outfall, with no salinity impacts of greater than 0.5 PSU predicted outside a zone of 100 m radius from the outfall.

The modelling further demonstrates that salinity levels at both intake location option 1 and 2 will typically be less than 0.1 PSU above ambient salinity levels, and the intake water will not be affected by the outfall discharge.

This small impact of the outfall provides some flexibility to the positioning of the intake, as long as it will be located at least 100 m from the point of discharge of the outfall.

8. References

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Appendix A – Port Melville Water Quality Monitoring Data

Table A-1 Port Melville Water Quality Measurements. DO is dissolved oxygen, EC is electrical conductivity, TSS is total suspended solid, TDS is total dissolved solid, BOD is Biological Oxygen Demand.

Site	time	PH	DO (%)	EC (uS/cm)	TDS (g/L)	Salinity (ppt)	Temp (°C)	Turbidity (NTU)	TSS (mg/L)	BOD (mg/L)
PMSW01	16/09/2015	7.03	87	51600	33.5	33.8	28.4	23.1	12	-
PMSW02	16/09/2015	6.17	62	51300	33.4	33.6	28.7	21	14	-
PMSW03	16/09/2015	6.67	94	51600	33.5	33.8	29.2	20.3	7.6	-
PMSW01	17/12/2015	7.74	83	52800	34.3	34.6	32	13.3	15	-
PMSW02	17/12/2015	7.85	85	52800	34.3	34.6	31.9	11.5	12	-
PMSW03	17/12/2015	7.75	83	59100	34.0	34.4	31.7	15.7	19	-
Apsley shoreline*	2/02/2016	8.10	-	50000	-	-	-	-	51	-
PMSW01	22/03/2016	7.76	50	48900	31.7	31.7	32.4	20.7	11	-
PMSW02	22/03/2016	7.74	52	48200	31.4	31.3	32.4	8.84	10	-
PMSW03	22/03/2016	7.74	58	49500	32.1	32.1	32.2	22	18	-
Apsley shoreline*	7/03/2016	7.80	-	50000	-	-	-	-	100	<5
Wharf Area	7/03/2016	8.10	-	51000	-	-	-	-	40	<5
Apsley shoreline*	22/03/2016	7.63	48	48800	31.7	31.6	34.1	Over	150	<5
Wharf Area	22/03/2016	7.80	-	45000	-	-	-	35	24	<5
Apsley shoreline*	19/04/2016	7.71	-	34000	-	-	32.3	104	140	<5
Wharf Area	25/05/2016	7.20	104	50100	32.58	32.6	-	32.9	79	<5
Apsley shoreline*	25/05/2016	7.28	-	55500	49.50	32.4	-	438	45	<5
Wharf Area	22/06/2016	6.70	-	53110	32.16	32.2	29.1	23.2	15	<5
Apsley shoreline*	27/07/2016	-	-	-	-	-	-	-	-	-
Wharf Area	27/07/2016	7.95	-	48120	31.32	31.4	-	32.8	54	<5
Apsley shoreline	24/08/2016	8.09	-	55600	36.10	36.9	-	12.5	8.2	<5
Wharf Area	24/08/2016	8.23	-	57000	37.00	37.8	-	15.7	11	<5
Apsley shoreline	15/09/2016	8.29	-	55060	35.83	36.4	-	14.5	18	-
Wharf Area	15/09/2016	7.86	-	49870	32.43	32.7	-	17.8	10	-
PMSW01	21/10/2016	8.00	-	54000	-	-	-	49	70	-
PMSW02	21/10/2016	8.10	-	54000	-	-	-	23	22	-
PMSW03	21/10/2016	8.10	-	54000	-	-	-	35	39	-
Wharf Area	23/11/2016	7.14	-	-	-	-	-	14.9	9.2	<5
Apsley shoreline	23/11/2016	7.50	-	-	-	-	-	8.5	6	<5
Wharf Area	18/01/2017	7.27	-	48810	31.73	31.9	25.4	82.8	83	<5
Apsley shoreline	18/01/2017	7.04	-	48600	-	-	26.0	79.9	90	<5
Wharf Area	13/02/2017	6.53	-	52942	34.45	35.03	20.0	18.5	49	<5
Apsley shoreline	13/02/2017	7.17	-	53235	34.60	35.18	20.0	38.3	91	<5
PMSW01	13/02/2017	7.33	-	52659	34.29	34.86	20.4	46.8	78	-
PMSW02	13/02/2017	7.40	-	52980	34.45	35.03	19.6	43.4	73	-
PMSW03	13/02/2017	7.52	-	54649	35.52	36.25	19.1	46.4	64	-
Wharf Area	8/03/2017	7.75	-	45575	29.66	29.64	18.1	56.7	34	<5
Wharf Area	17/04/2017	7.99	-	46615	30.27	30.16	-	5.22	6.6	<5
Apsley shoreline	17/04/2017	8.10	-	46774	30.413	30.42	-	6.54	14	<5
Wharf Area	18/06/2017	6.33	-	48400	31.57	31.57	-	6.5	3.9	<5

Apsley shoreline	18/06/2017	7.01	-	48290	31.38	-	-	7	19	<5
PMSW01	18/06/2017	7.36	-	48858	31.63	31.68	-	11.8	20	-
PMSW02	18/06/2017	7.57	-	50130	32.57	32.67	-	25.2	18	-
PMSW03	18/06/2017	7.69	-	48772	31.71	31.76	-	16.8	11	-
Wharf Area	11/07/2017	7.86	-	49225	32.00	32.21	-	5.83	11	<5
Apsley Shoreline	11/07/2017	8.07	-	49405	32.032	32.21	-	5.87	12	<5
Wharf Area	20/08/2017	7.93	-	48618	31.577	31.64	-	7.78	17	<5
Apsley Shoreline	20/08/2017	7.12	-	48828	31.7265	31.84	-	6.2	21	<5
Wharf Area	11/09/2017	6.74	98	50446	32.79	33.10	-	19.1	12	<5
Apsley Shoreline	11/09/2017	6.65	94.1	49114	31.96	32.21	-	16.9	44	<5
Wharf Area	17/10/2017	7.83	97.4	52813	34.33	34.72	-	10.3	8.6	<5
Apsley shoreline	17/10/2017	7.86	97.7	54036	35.12	35.60	-	13.4	7	<5
PMSW01	17/10/2017	7.89	95.4	54089	35.16	35.71	-	9.2	8.4	-
PMSW02	17/10/2017	7.9	94.9	54163	35.21	35.79	-	10	12	-
PMSW03	17/10/2017	7.89	94.9	54393	35.35	35.98	-	8.7	7	-
Wharf Area	27/11/2017	7.88	90.8	52200	33.92	34.30	-	20	17	<2
Apsley shoreline	27/11/2017	6.97	86.1	52420	34.01	34.42	-	20	13	<2
PMSW02	18/12/2017	7.34	-	51900	-	-	-	8.66	5	-
Apsley shoreline	15/01/2018	7.13	87.5	48788	17.23	31.90	-	6.7	13	<2
Wharf Area	5/02/2018	6.45	94	46993	-	30.65	25.9	38.1	64	<2
Apsley shoreline	5/02/2018	7.14	93.8	46429	-	30.28	25.8	18.5	36	<2
Wharf Area	28/03/2018	7.99	-	-	-	-	-	114	188	<2
Apsley shoreline	28/03/2018	7.99	-	-	-	-	-	162	200	<2
PMSW01	28/03/2018	7.94	-	-	-	-	-	4.3	6	-
PMSW02	28/03/2018	8.02	-	-	-	-	-	4.5	7	-
PMSW03	28/03/2018	7.93	-	-	-	-	-	3.8	5	-
Wharf Area	28/05/2018	7.60	-	46600	30.349	30.4	-	20.1	72	<2
Apsley shoreline	28/05/2018	7.70	-	46500	30.30	30.3	-	8.97	27	<2
Wharf Area	27/06/2018	8.22	-	51361	33.345	33.72	-	-	18	<2
Apsley shoreline	27/06/2018	8.29	-	51688	33.605	33.97	-	-	27	<2
PMSW01	4/07/2018	7.96	-	-	-	-	-	21.5	34	-
PMSW02	4/07/2018	8.02	-	-	-	-	-	18.1	30	-
PMSW03	4/07/2018	8.03	-	-	-	-	-	16.6	32	-
Wharf Area	18/07/2018	-	-	48230	31.349	31.5	-	-	35	<2
Apsley shoreline	18/07/2018	-	-	48820	31.758	31.9	-	-	48	<2
Wharf Area	21/08/2018	-	-	53200	-	-	-	5.8	8	<2
Apsley shoreline	21/08/2018	-	-	53100	-	-	-	4.2	9	<2
Wharf Area	25/09/2018	7.88	-	56083	36.45	37.31	-	1.3	9	<2
Apsley shoreline	25/09/2018	7.76	-	55320	35.97	36.77	-	4.2	17	<2
Wharf Area	17/10/2018	8.19	-	-	-	-	-	5.8	11	<2
Apsley shoreline	17/10/2018	8.17	-	-	-	-	-	5.3	11	<2
PMSW01	17/10/2018	8.20	-	-	-	-	-	2.2	10	-
PMSW02	17/10/2018	8.21	-	-	-	-	-	2.7	8	-
PMSW03	17/10/2018	8.23	-	-	-	-	-	6.8	13	-
Wharf Area	13/11/2018	7.97	-	-	-	-	-	7.8	16	<2

Apsley shoreline	13/11/2018	8.01	-	-	-	-	-	7.8	14	<2
Wharf Area	13/12/2018	-	-	-	-	-	-	-	10	<2
Apsley shoreline	13/12/2018	-	-	-	-	-	-	-	8	<2
Wharf Area	30/01/2019	7.91	-	-	-	-	-	221	176	<2
Apsley shoreline	30/01/2019	8.02	-	-	-	-	-	308	424	<2
Wharf Area	7/03/2019	-	-	-	-	-	-	-	30	<2
Apsley shoreline	7/03/2019	-	-	-	-	-	-	-	28	<2
Wharf Area	4/04/2019	-	-	-	-	-	-	-	124	<2
Apsley shoreline	4/04/2019	-	-	-	-	-	-	-	87	<2
Wharf Area	30/04/2019	-	-	-	-	-	-	-	16	<2
Apsley shoreline	30/04/2019	-	-	-	-	-	-	-	52	<2
Wharf Area	27/05/2019	-	-	-	-	-	-	-	11	<2
Apsley shoreline	27/05/2019	-	-	-	-	-	-	-	20	<2
PMSW01	19/06/2019	-	-	-	-	-	-	-	17	-
PMSW02	19/06/2019	-	-	-	-	-	-	-	21	-
PMSW03	19/06/2019	-	-	-	-	-	-	-	12	-
Wharf Area	3/07/2019	-	-	-	-	-	-	-	7	2
Apsley shoreline	3/07/2019	-	-	-	-	-	-	-	5	<2
Wharf Area	31/07/2019	-	-	-	-	-	-	-	3	2
Apsley shoreline	31/07/2019	-	-	-	-	-	-	-	6	3
Wharf Area	28/08/2019	-	-	-	-	-	-	-	27	<2
Apsley shoreline	28/08/2019	-	-	-	-	-	-	-	14	<2
Wharf Area	9/10/2019	-	-	-	-	-	-	-	7	<2
Apsley shoreline	9/10/2019	-	-	-	-	-	-	-	7	<2
PMSW01	4/11/2019	-	-	-	-	-	-	-	8	-
PMSW02	4/11/2019	-	-	-	-	-	-	-	4	-
PMSW03	4/11/2019	-	-	-	-	-	-	-	7	-
Wharf Area	20/11/2019	-	-	-	-	-	-	-	8	<2
Apsley shoreline	20/11/2019	-	-	-	-	-	-	-	9	<2
Wharf Area	18/12/2019	-	-	-	-	-	-	-	6	<2
Apsley shoreline	18/12/2019	-	-	-	-	-	-	-	6	<2
Wharf Area	15/01/2020	-	-	-	-	-	-	-	31	<2
Apsley shoreline	15/01/2020	-	-	-	-	-	-	-	20	<2
PMSW01	28/01/2020	-	-	-	-	-	-	-	13	-
PMSW02	28/01/2020	-	-	-	-	-	-	-	13	-
PMSW03	28/01/2020	-	-	-	-	-	-	-	22	-
Wharf Area	26/02/2020	-	-	-	-	-	-	-	25	<2
Apsley shoreline	26/02/2020	-	-	-	-	-	-	-	31	<2
Wharf Area	25/03/2020	-	-	-	-	-	-	-	58	<2
Apsley shoreline	25/03/2020	-	-	-	-	-	-	-	85	<2
Wharf Area	27/04/2020	-	-	-	-	-	-	-	3	45
Apsley shoreline	27/04/2020	-	-	-	-	-	-	-	5	3
Wharf Area	22/06/2020	-	-	-	-	-	-	-	23	<2
Apsley shoreline	22/06/2020	-	-	-	-	-	-	-	8	<2
Wharf Area	20/07/2020	-	-	-	-	-	-	-	9	3

Apsley shoreline	20/07/2020	-	-	-	-	-	-	-	6	3
Wharf Area	31/08/2020	-	-	-	-	-	-	-	6	<2
Apsley shoreline	31/08/2020	-	-	-	-	-	-	-	<1	<2
Wharf Area	28/09/2020	-	-	-	-	-	-	-	6	<2
Apsley shoreline	28/09/2020	-	-	-	-	-	-	-	18	<2
PMSW01	27/09/2020	-	-	-	-	-	-	-	17	-
PMSW02	27/09/2020	-	-	-	-	-	-	-	19	-
PMSW03	27/09/2020	-	-	-	-	-	-	-	5	-
Wharf Area	26/10/2020	-	-	-	-	-	-	-	4	<10
Apsley shoreline	26/10/2020	-	-	-	-	-	-	-	9	<10
Wharf Area	30/11/2020	-	-	-	-	-	-	-	17	3
Apsley shoreline	30/11/2020	-	-	-	-	-	-	-	9	<2
Wharf Area	11/01/2021	-	-	-	-	-	-	-	<3	<2
Apsley shoreline	18/01/2021	-	-	-	-	-	-	-	8	<2
Wharf Area	2/03/2021	-	-	-	-	-	-	-	50	<2
Apsley shoreline	2/03/2021	-	-	-	-	-	-	-	321	<2
Wharf Area	30/03/2021	-	-	-	-	-	-	-	48	<2
Apsley shoreline	31/03/2021	-	-	-	-	-	-	-	64	<2
Wharf Area	27/04/2021	-	-	-	-	-	-	-	8	<2
Apsley shoreline	27/04/2021	-	-	-	-	-	-	-	15	2
Wharf Area	25/05/2021	-	-	-	-	-	-	-	13	<2
Apsley shoreline	25/05/2021	-	-	-	-	-	-	-	26	<2
Wharf Area	22/06/2021	-	-	-	-	-	-	-	13	<2
Apsley shoreline	22/06/2021	-	-	-	-	-	-	-	14	<2
PMSW01	18/07/2021	-	-	-	-	-	-	-	11	-
PMSW02	18/07/2021	-	-	-	-	-	-	-	12	-
PMSW03	18/07/2021	-	-	-	-	-	-	-	9	-
Wharf Area	3/08/2021	-	-	-	-	-	-	-	11	<2
Apsley shoreline	4/08/2021	-	-	-	-	-	-	-	11	<2
Wharf Area	1/09/2021	-	-	-	-	-	-	-	<2	<2
Apsley shoreline	1/09/2021	-	-	-	-	-	-	-	<2	<2
Wharf Area	13/10/2021	-	-	-	-	-	-	-	17	<2
Apsley shoreline	13/10/2021	-	-	-	-	-	-	-	9	<2
Wharf Area	10/11/2021	-	-	-	-	-	-	-	34	<2
Apsley shoreline	10/11/2021	-	-	-	-	-	-	-	10	<2
Wharf Area	8/12/2021	-	-	-	-	-	-	-	34	2
Apsley shoreline	8/12/2021	-	-	-	-	-	-	-	15	2
Median		7.75	91.55	49315	31.859	31.9	28.5	17.05	15	3
Max		8.29	125	59100	49.5	37.8	34.1	438	424	45
Min		6.17	48	19885	14.73	12.02	18.1	1.3	3	2

Appendix B – Sensitivity analysis of eddy viscosity and diffusivity scaling factors

A scaled eddy viscosity formulation was used to simulate dispersion processes in the MIKE3 FM hydrodynamic model as outlined in section 2.4.2. In lieu of site-specific monitoring data to inform detailed model calibration, a sensitivity analysis was undertaken to investigate the impact of the horizontal and vertical scaling factors on the far field brine dispersion.

Sensitivity model runs were undertaken for a 14-day period to cover a neap and spring tidal cycle, and were based on the 'no wind' far field model scenario (as defined in section 6.2). Additional details of this sensitivity analysis for the horizontal and vertical scaling factors are outline below.

Horizontal scaling factor

In the horizontal plane, both eddy viscosity and diffusivity rely on the Smagorinsky eddy viscosity model to simulate sub-grid dispersion processes that are not resolved explicitly by the model.

A horizontal scaling factor of around 1.0 is recommended in the MIKE3 FM User Guide (DHI, 2022) when using more sophisticated eddy viscosity models, such as the adopted Smagorinsky model. Hence a horizontal scaling factor of 1 has been adopted in the Farfield Model.

Sensitivity testing was undertaken to examine the sensitivity of the model results to variations in the horizontal scaling factor. The sensitivity testing involved varying the horizontal scaling factor by +/- 20%.

Results from these sensitivity tests indicate only a small change in the model results (refer to Figure B-1 to Figure B-3), and hence a scaling factor of 1.0 is deemed appropriate as this assumes the entrainment/advection of mass is the same as tracers, e.g. temperature and salinity.

It is worthwhile to note that, at the length scale of ocean processes (10s of meter of greater), mixing of mass and tracer are driven by the same advection process. In theory, there should not be any differences between eddy viscosity and eddy diffusivity in horizontal plane.

Vertical scaling factor

Vertical eddy viscosity was simulated by the Log Law formulation to represent the increased eddy viscosity away from the vertical boundary. The vertical scaling factor is a calibration parameter to suppress vertical numerical mixing that may not be physically sound.

In lieu of site-specific monitoring data to inform detailed model calibration of this parameter, a vertical scaling factor of 0.0001 was adopted for this study in line with values recommended in the MIKE3 FM User Guide (DHI, 2022).

Sensitivity testing was undertaken to investigate the plume impact associated with scaling factors from 0 (no vertical dispersion) to 1. Results from these sensitivity tests indicate:

- The bottom layer corresponds to the lowest dilution levels (i.e. maximum salinity levels) throughout the water column for all sensitivity runs.
- Negligible difference for model runs with a scaling factor of 0 (Figure B-4) and 0.0001 (Figure B-2).
- The modelled bottom dilution rate using vertical scaling factor of 1 is an order of magnitude smaller than the other two cases, i.e. scaling factor of 0.0001 and 0 (refer to Figure B-5).
- The impacts in the surface layer are very small for all sensitivity tests; less than 0.1 PSU for all modelled scenarios (the minimum dilution rate within the surface layer is larger than 1000).

The adopted vertical scaling parameter of 0.0001 is reasonably conservative in terms of predicting the maximum salinity concentrations in the bottom layer and is considered as appropriate for this study.

<u>Summary</u>

Sensitivity tests suggest that the adopted eddy viscosity and diffusivity settings are appropriate for the purpose of the study in the absence of suitable site-specific monitoring data for model calibration. It is not envisaged that any further refinement of the eddy viscosity and diffusivity parameters (through model calibration) would materially change the overall conclusion of this study.

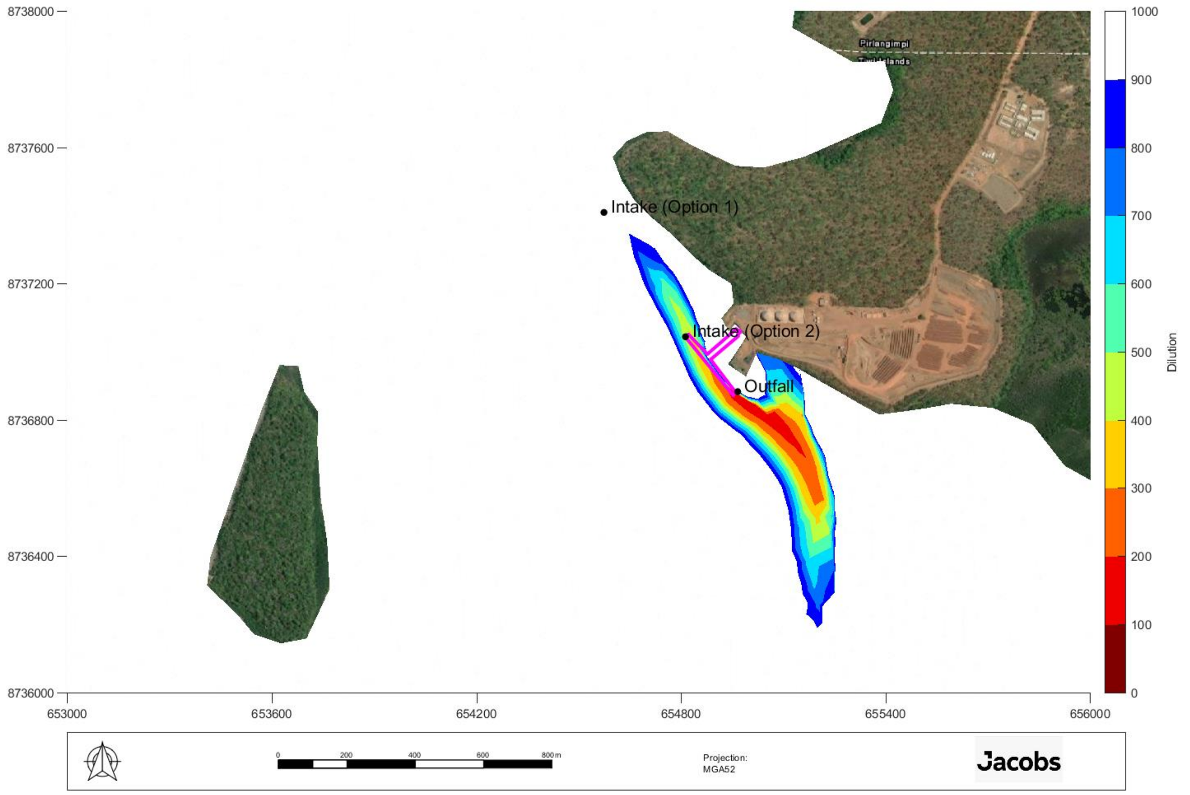


Figure B-1 Modelled 90th percentile near bed dilution rate – Model scenario: Intake Option 2, no wind, vertical scaling factor = 0.0001. Horizontal scaling factor = 0.8.

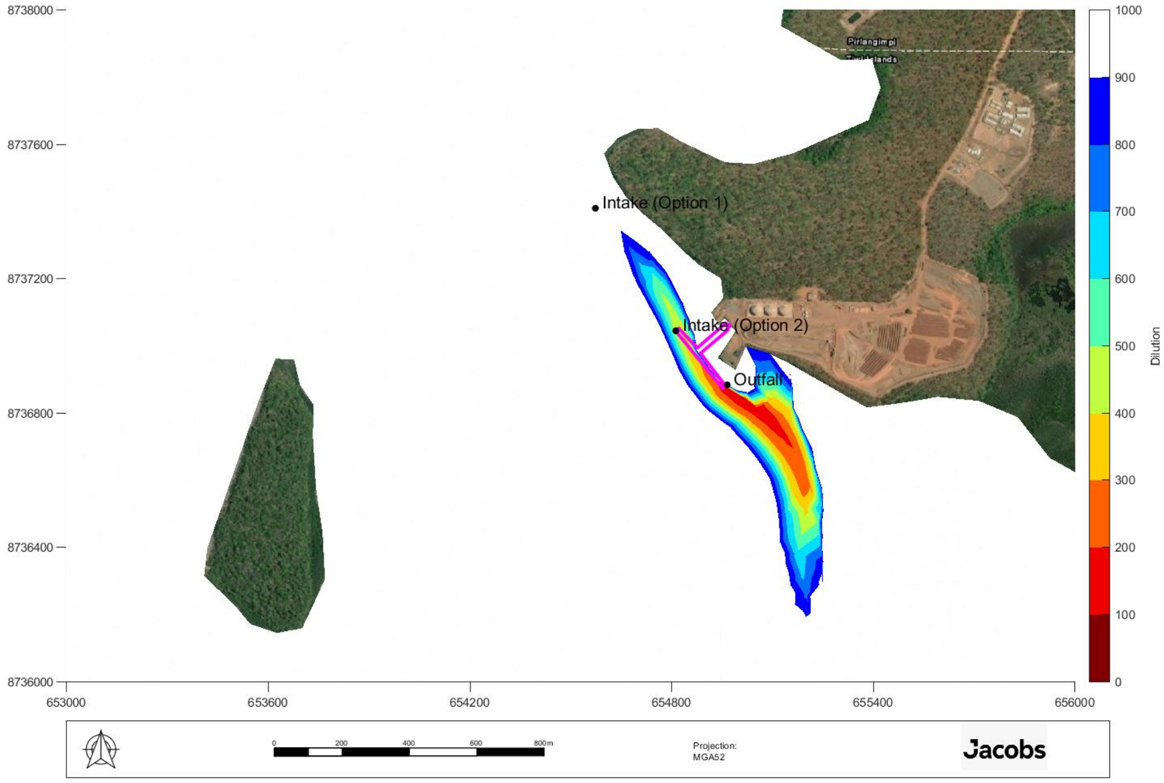


Figure B-2 Modelled 90th percentile near bed dilution rate – Model scenario: Intake Option 2, no wind, vertical scaling factor = 0.0001. Horizontal scaling factor = 1.

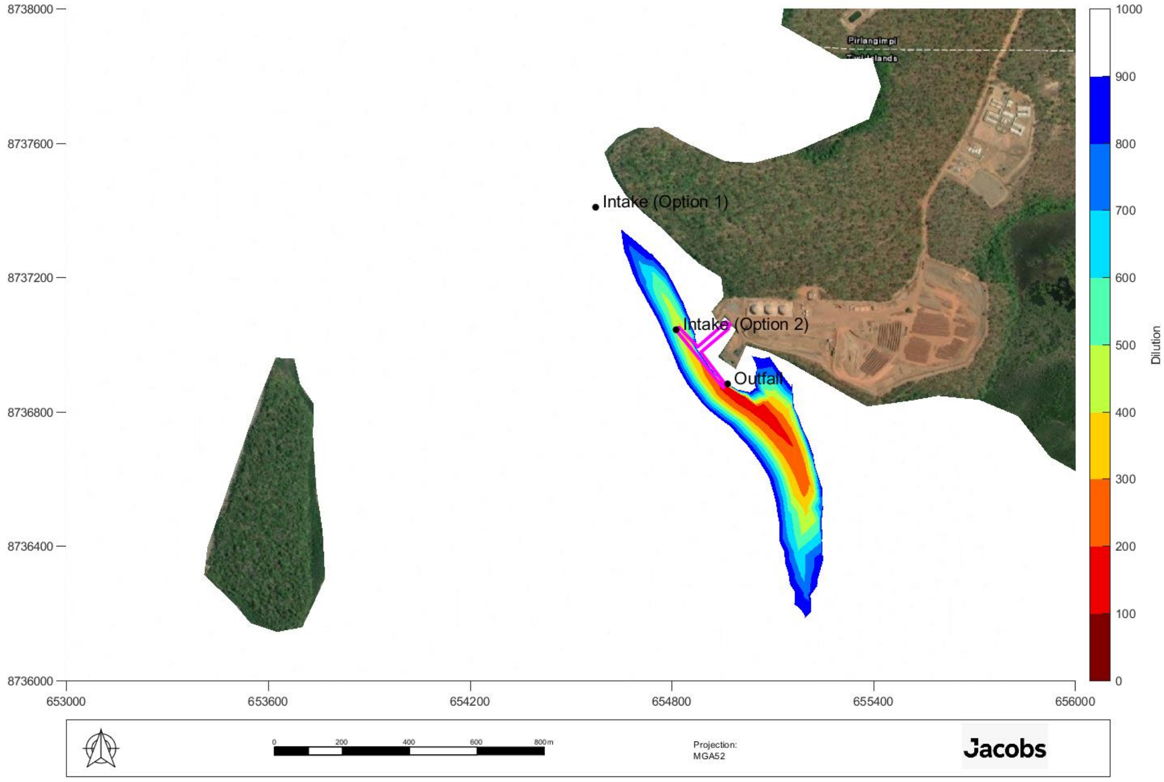


Figure B-3 Modelled 90th percentile near bed dilution rate – Model scenario: Intake Option 2, no wind, vertical scaling factor = 0.0001. Horizontal scaling factor = 1.2.

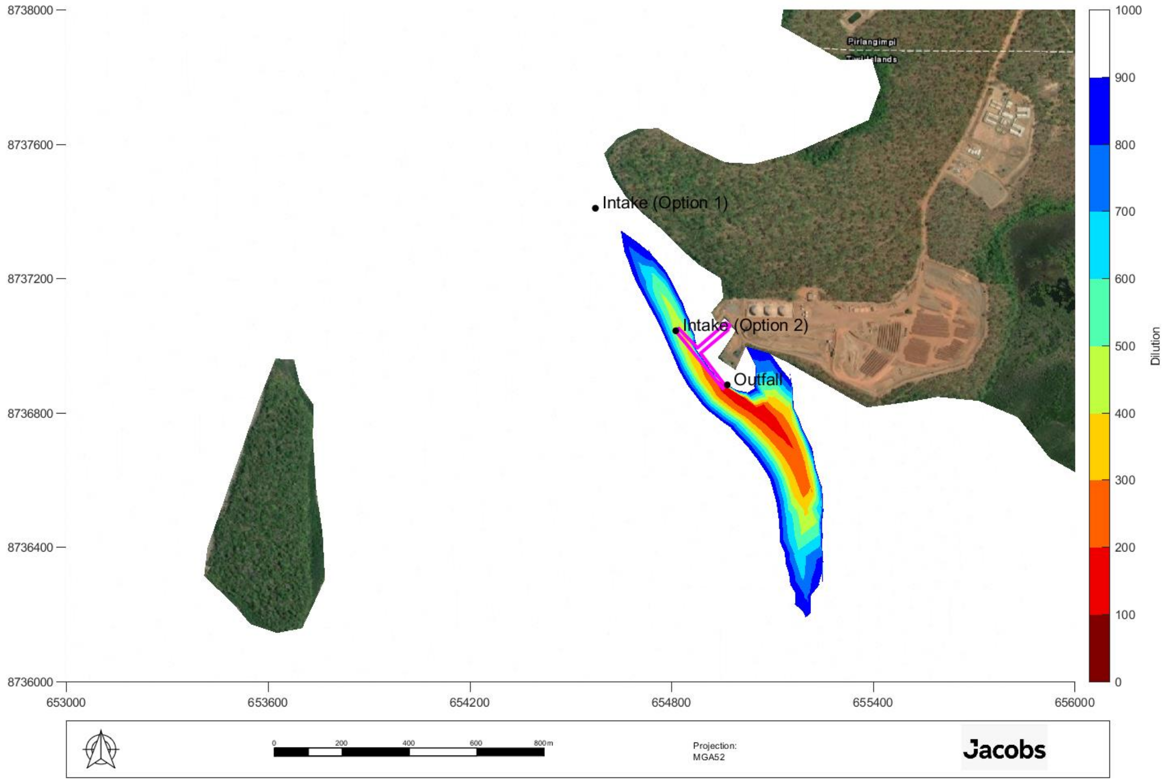
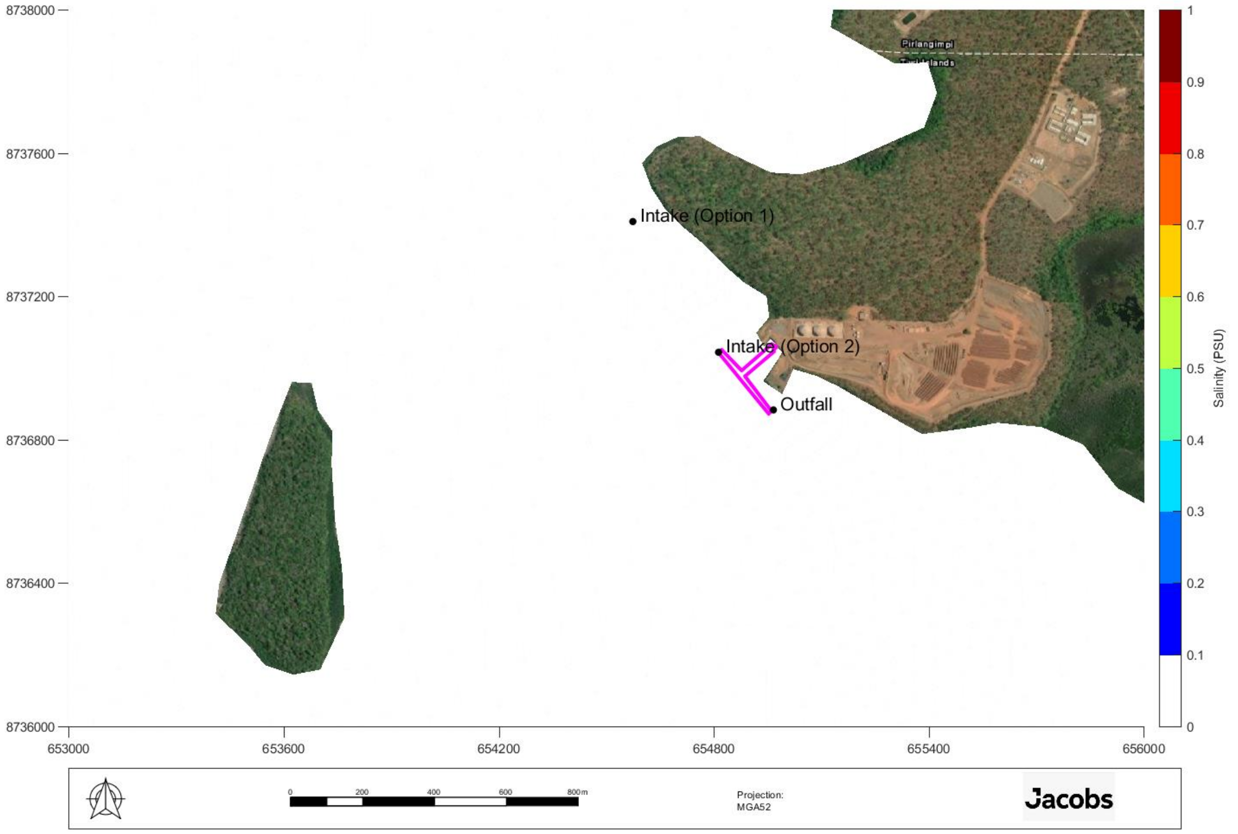
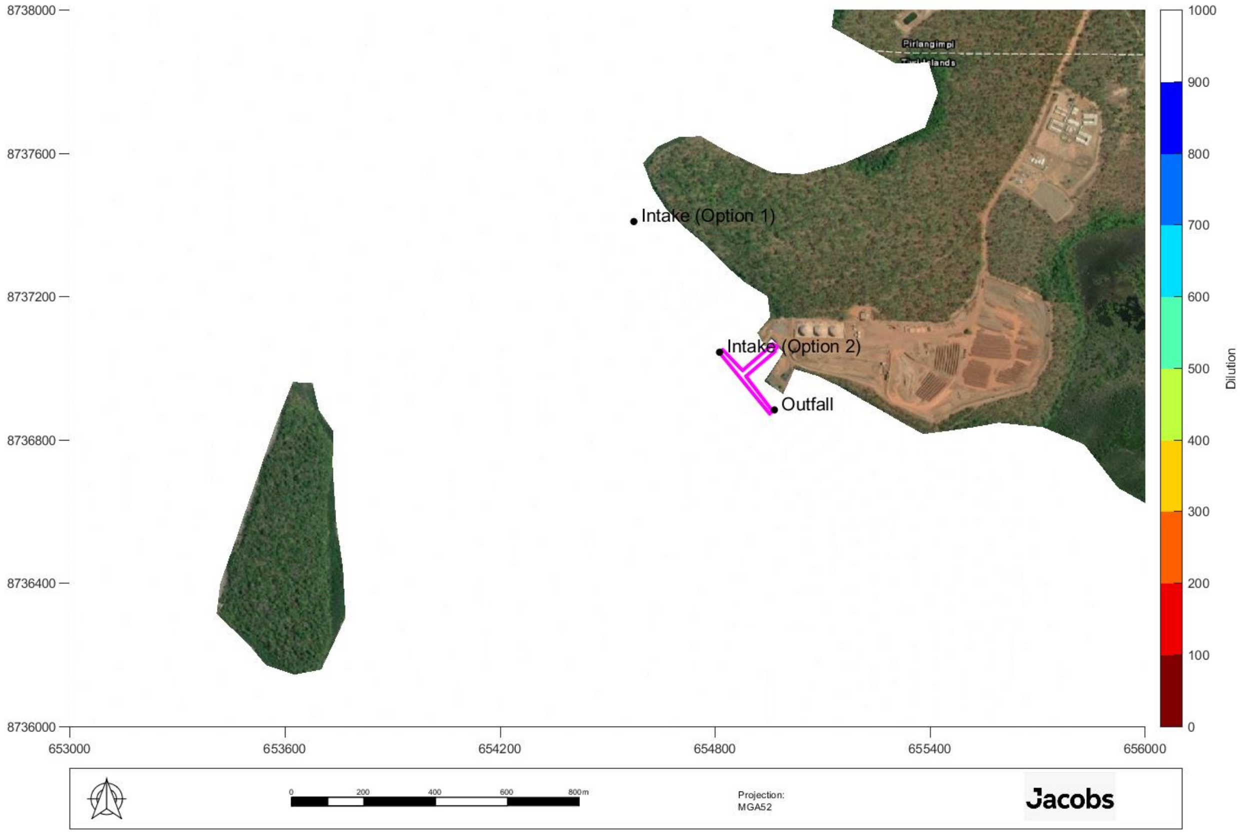
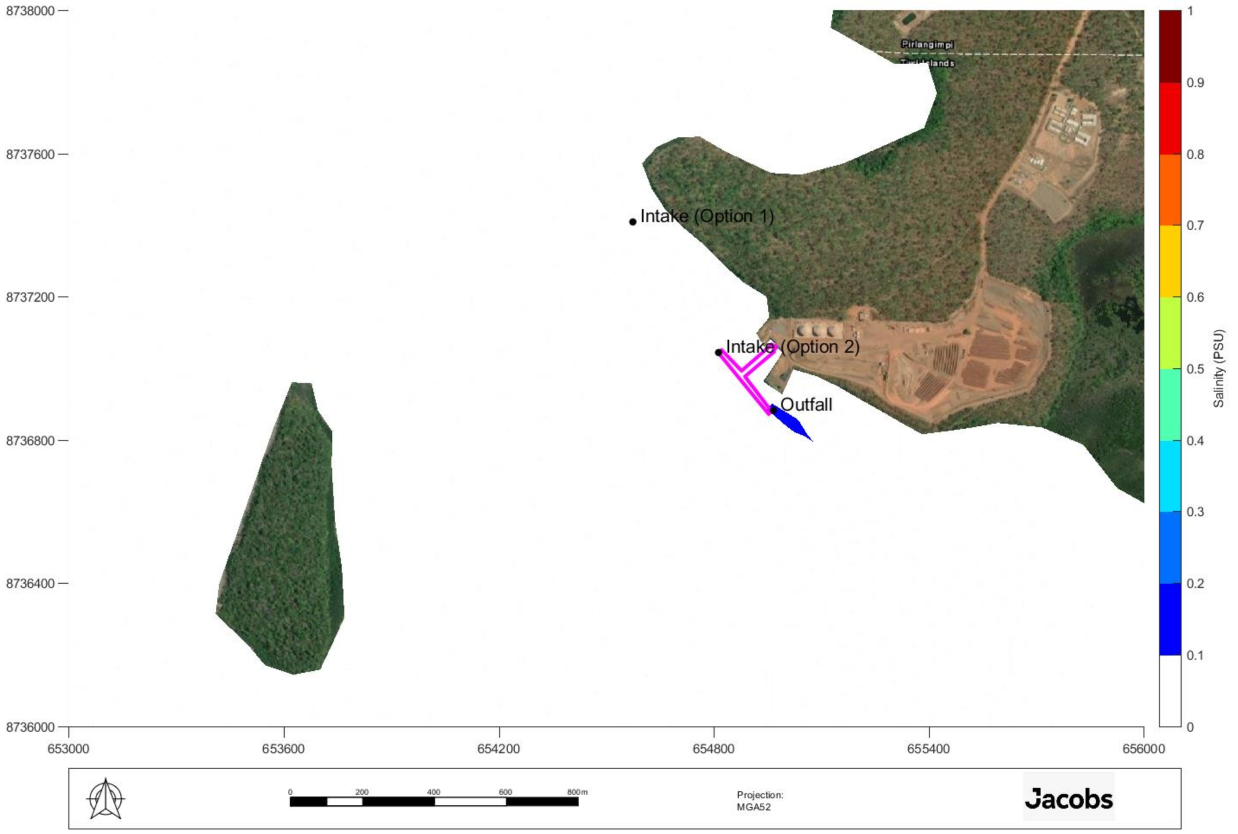
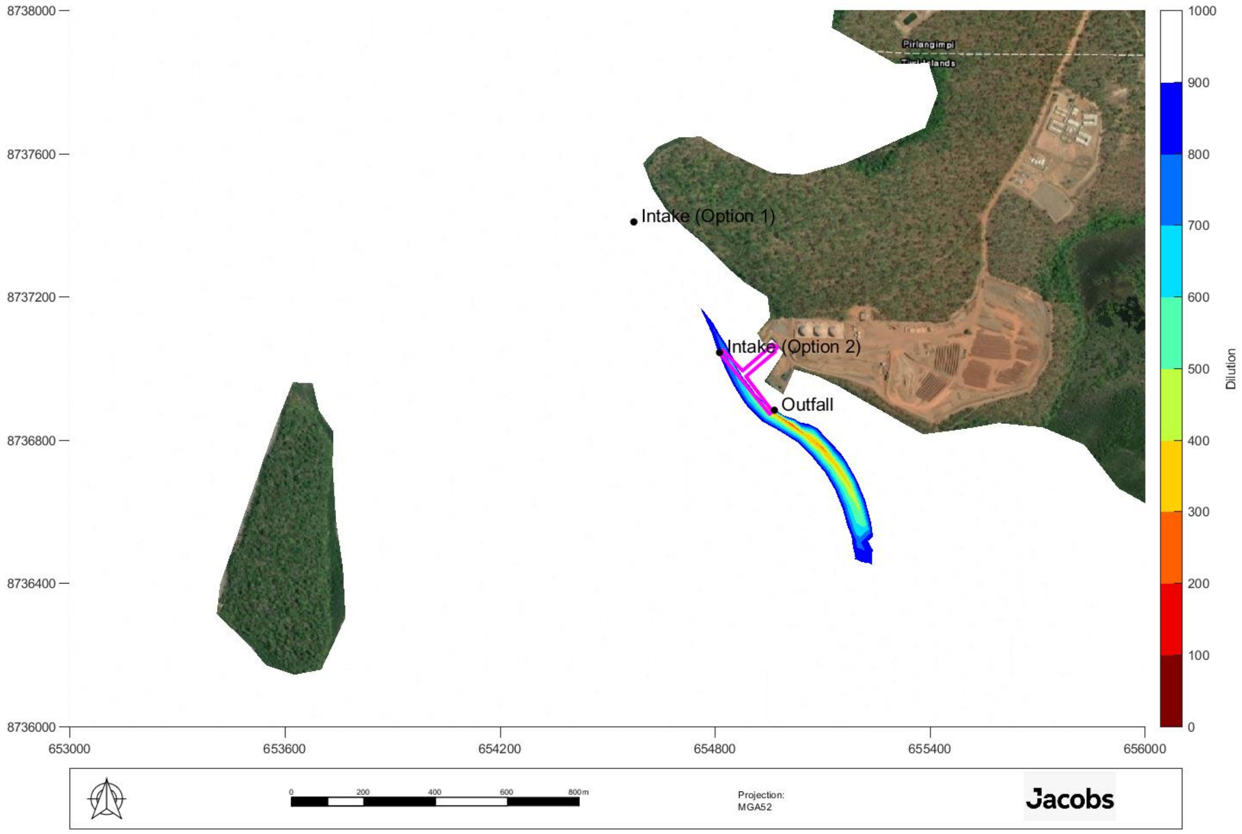


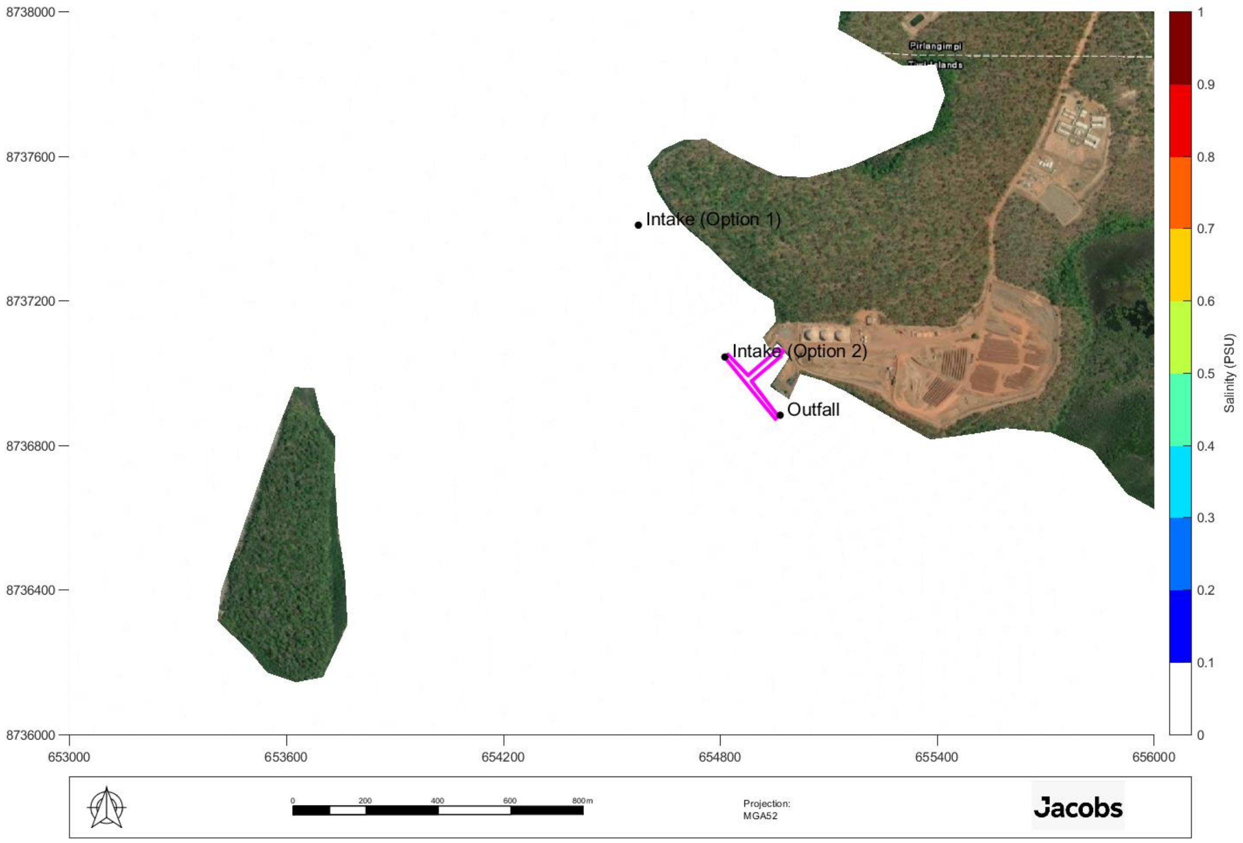
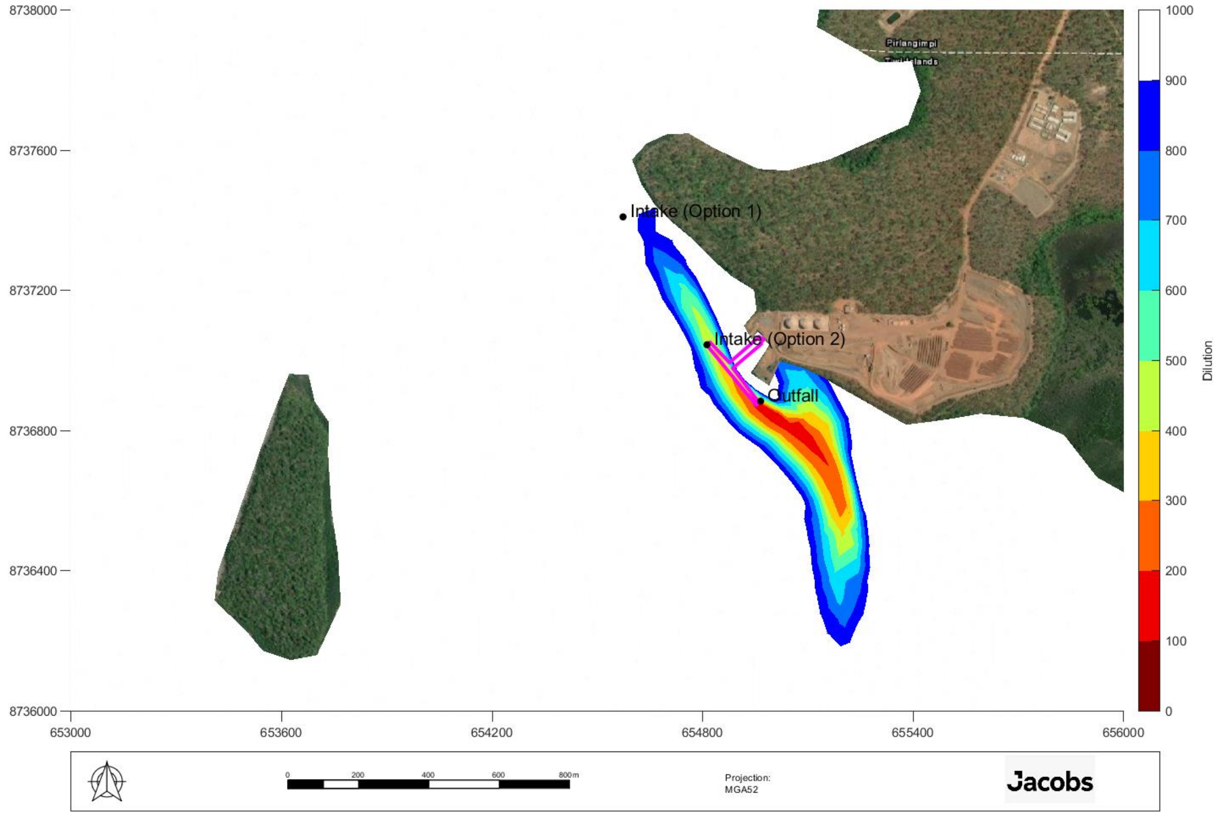
Figure B-4 Modelled 90th percentile near bed dilution rate – Model scenario: Intake Option 2, no wind, vertical scaling factor = 0, Horizontal scaling factor = 1.

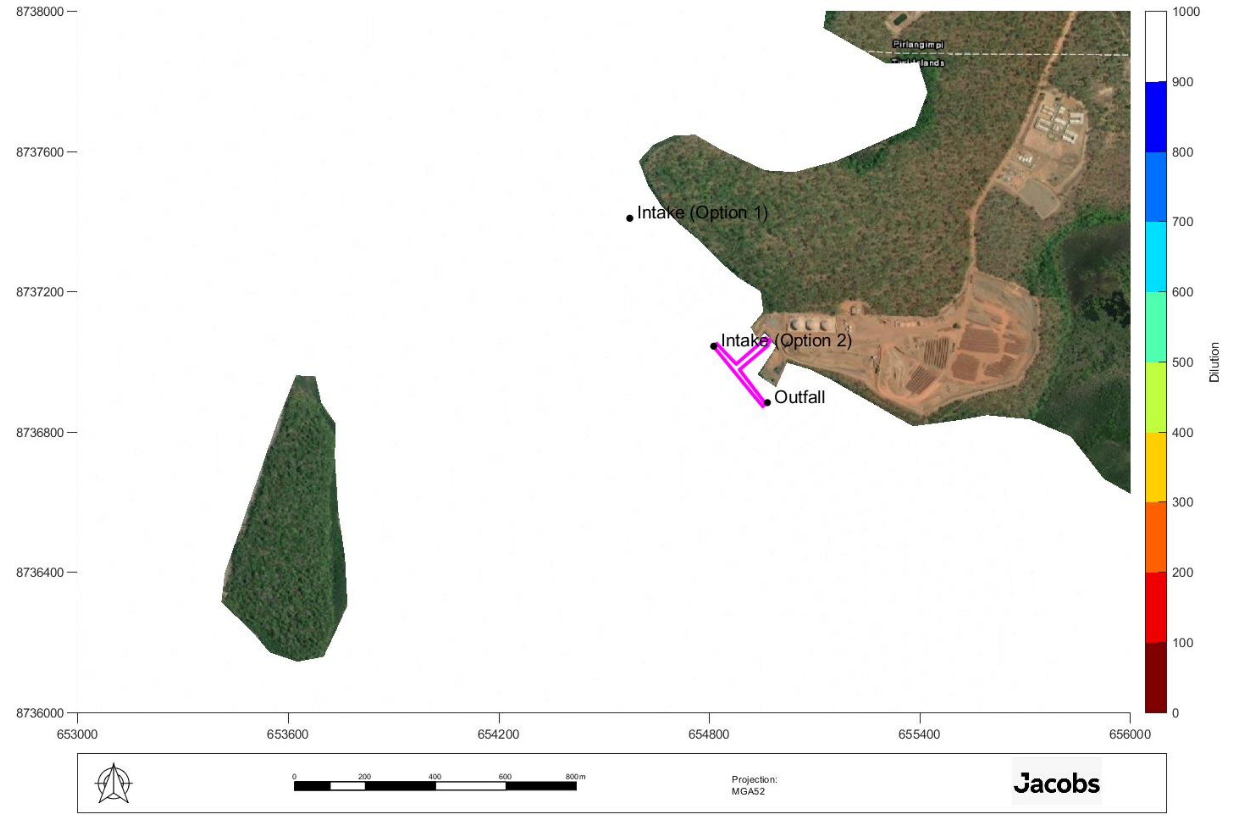
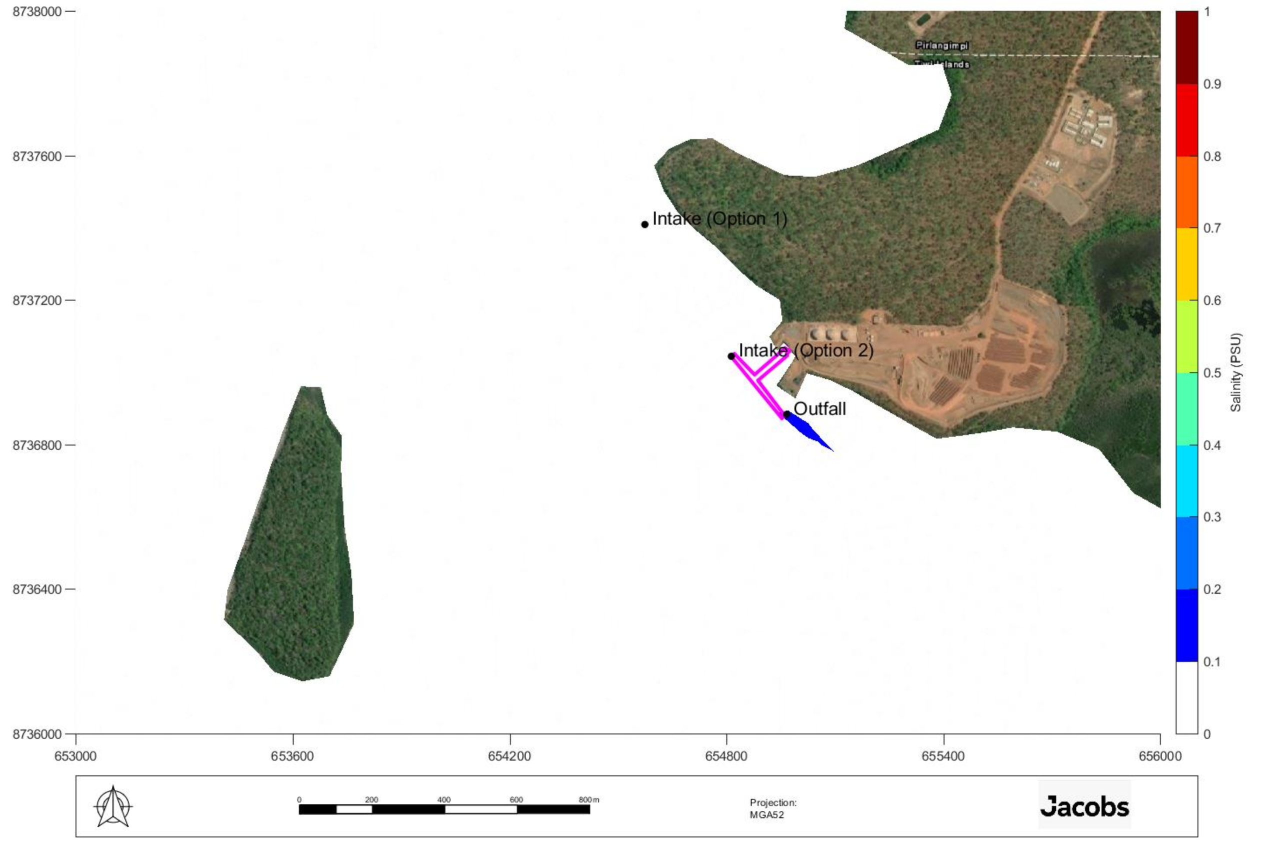
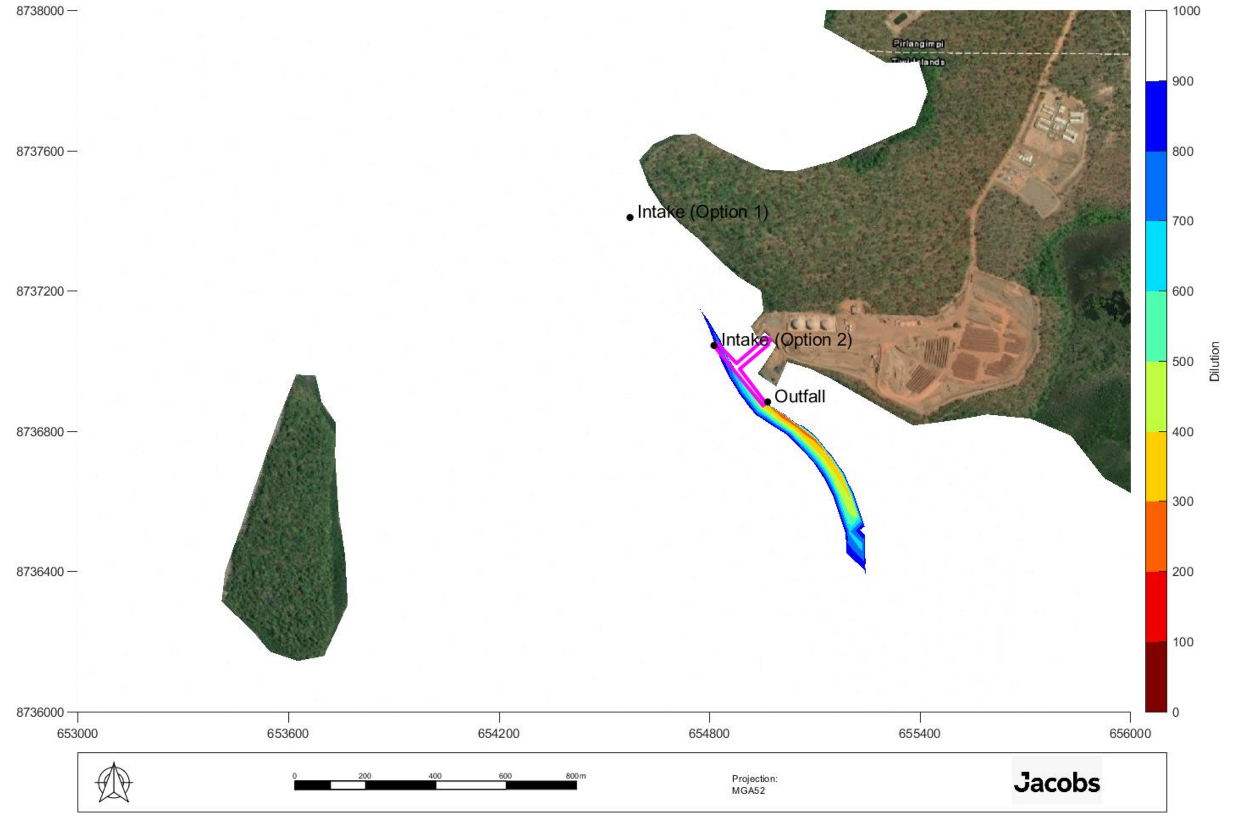
Figure B-5 Modelled 90th percentile near bed dilution rate – Model scenario: Intake Option 2, no wind, vertical scaling factor = 1. Horizontal scaling factor = 1.

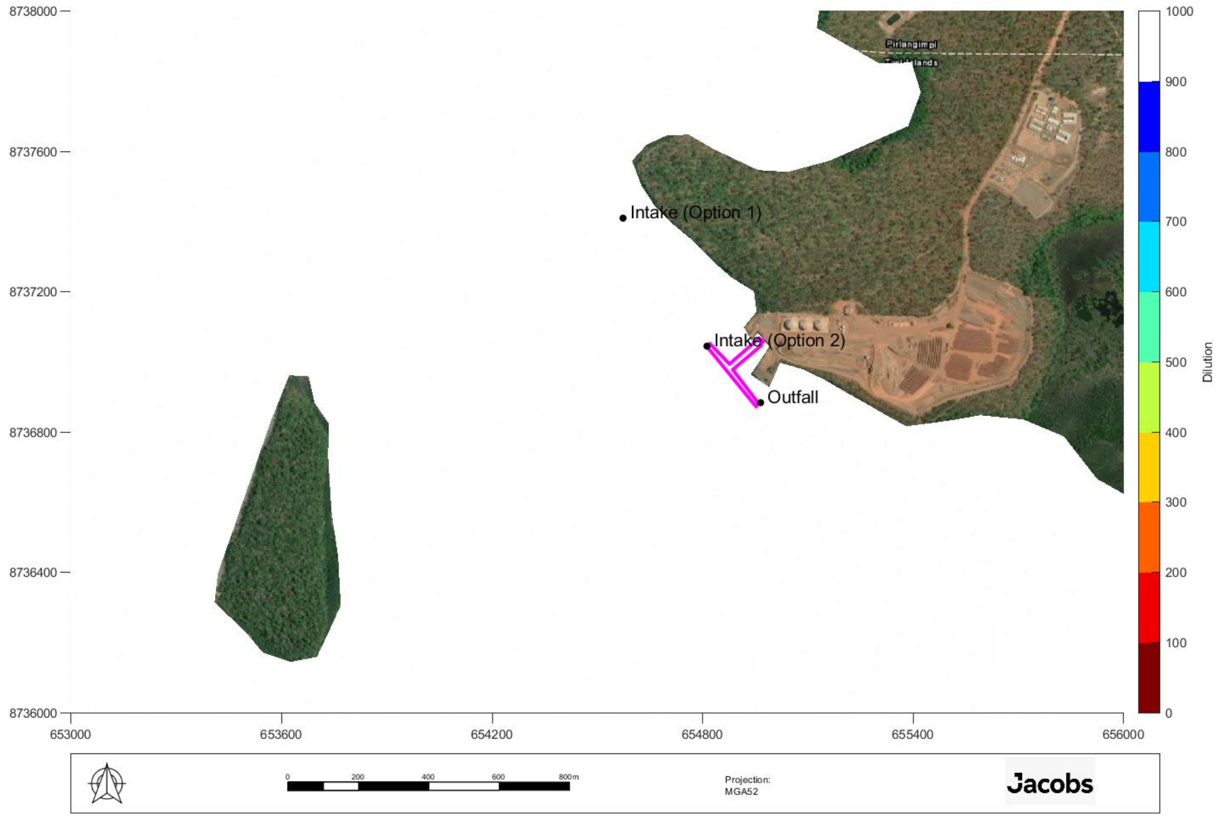
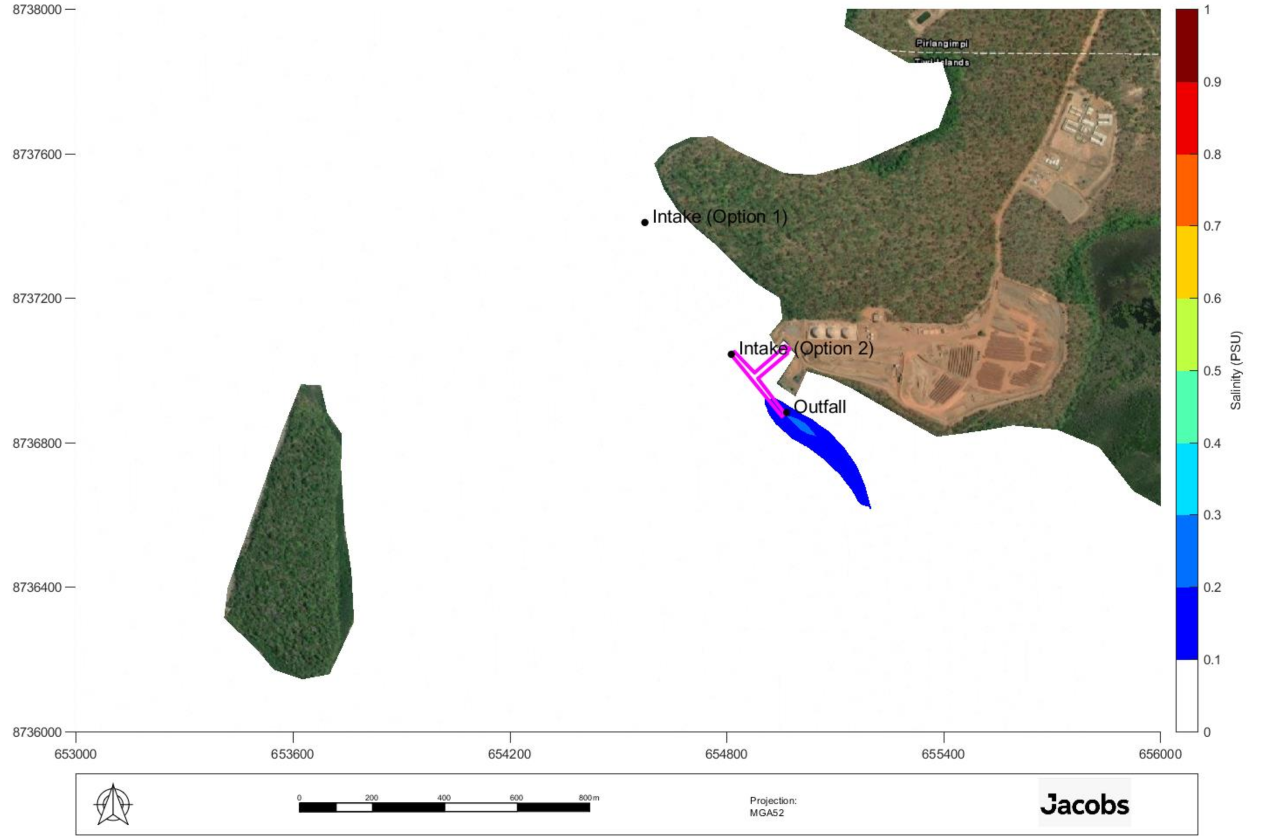
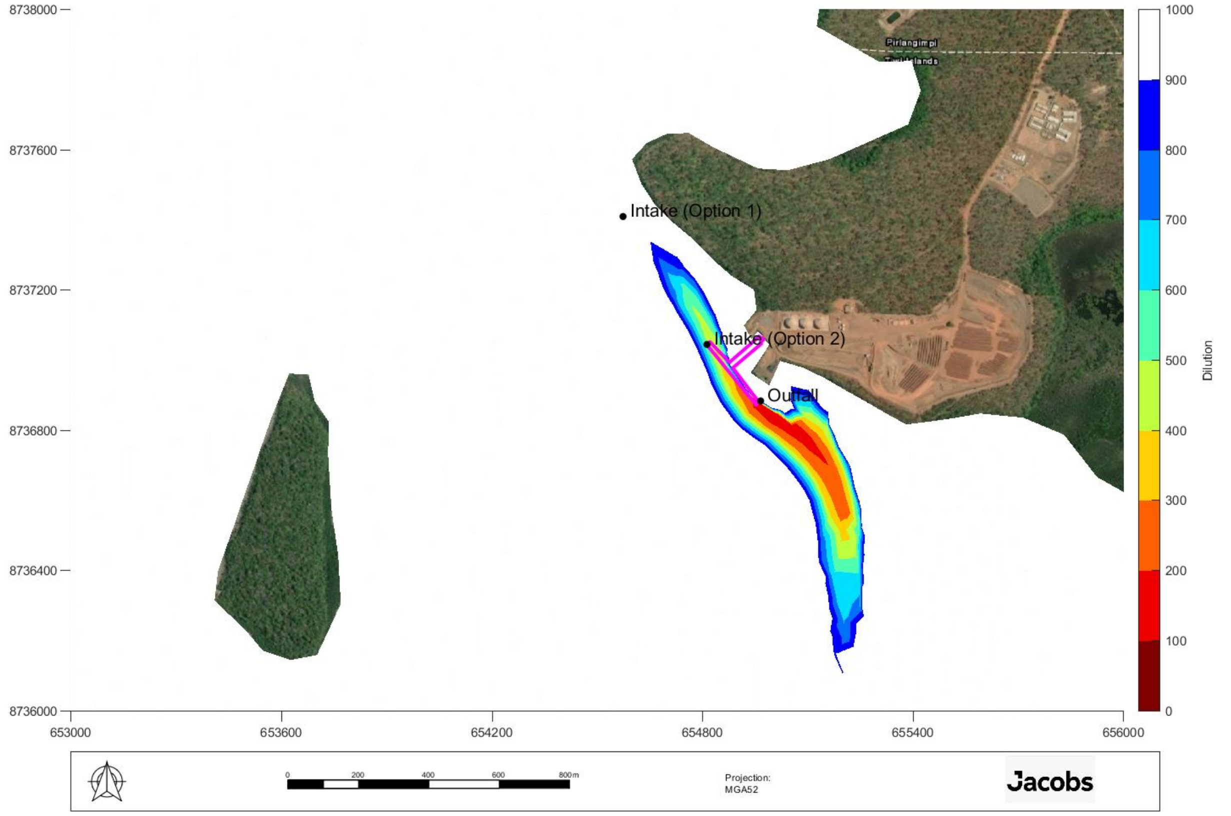
Appendix C – Farfield modelling results

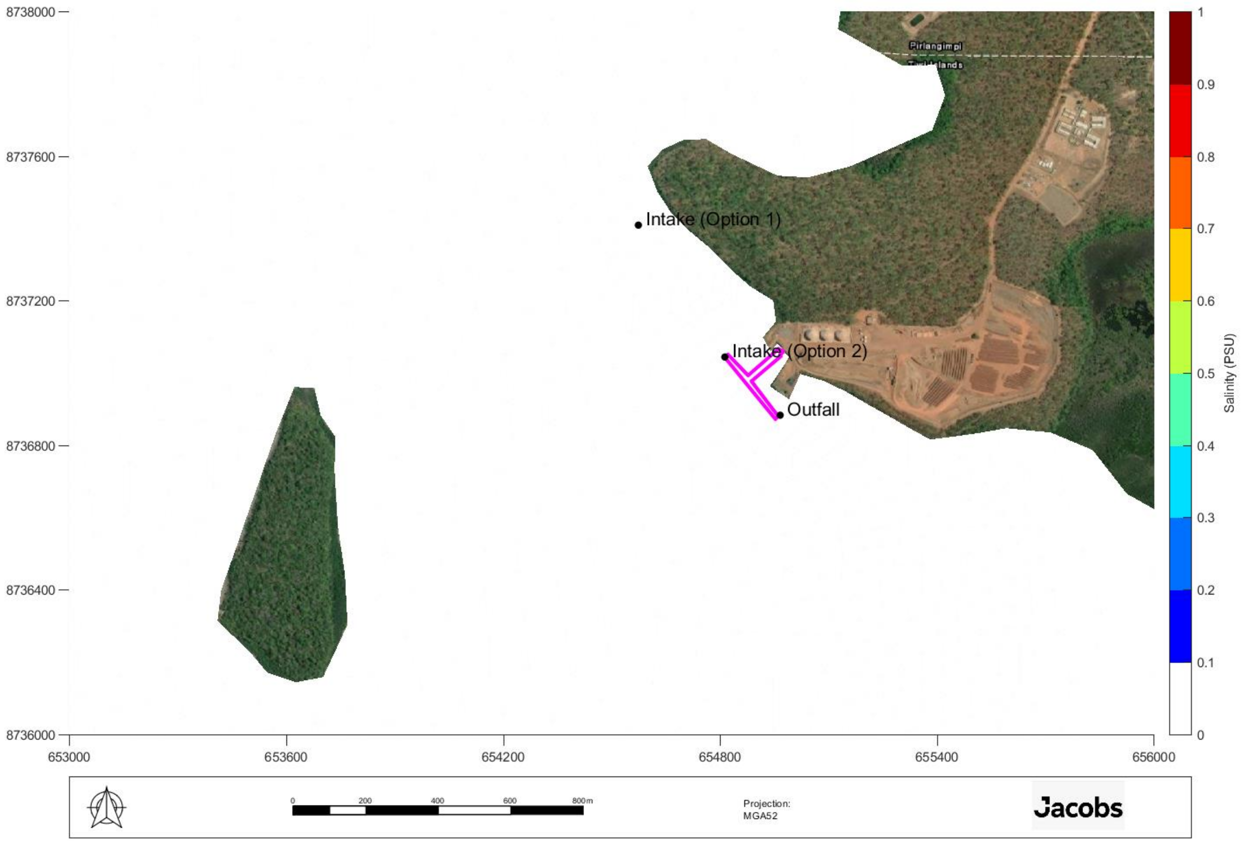
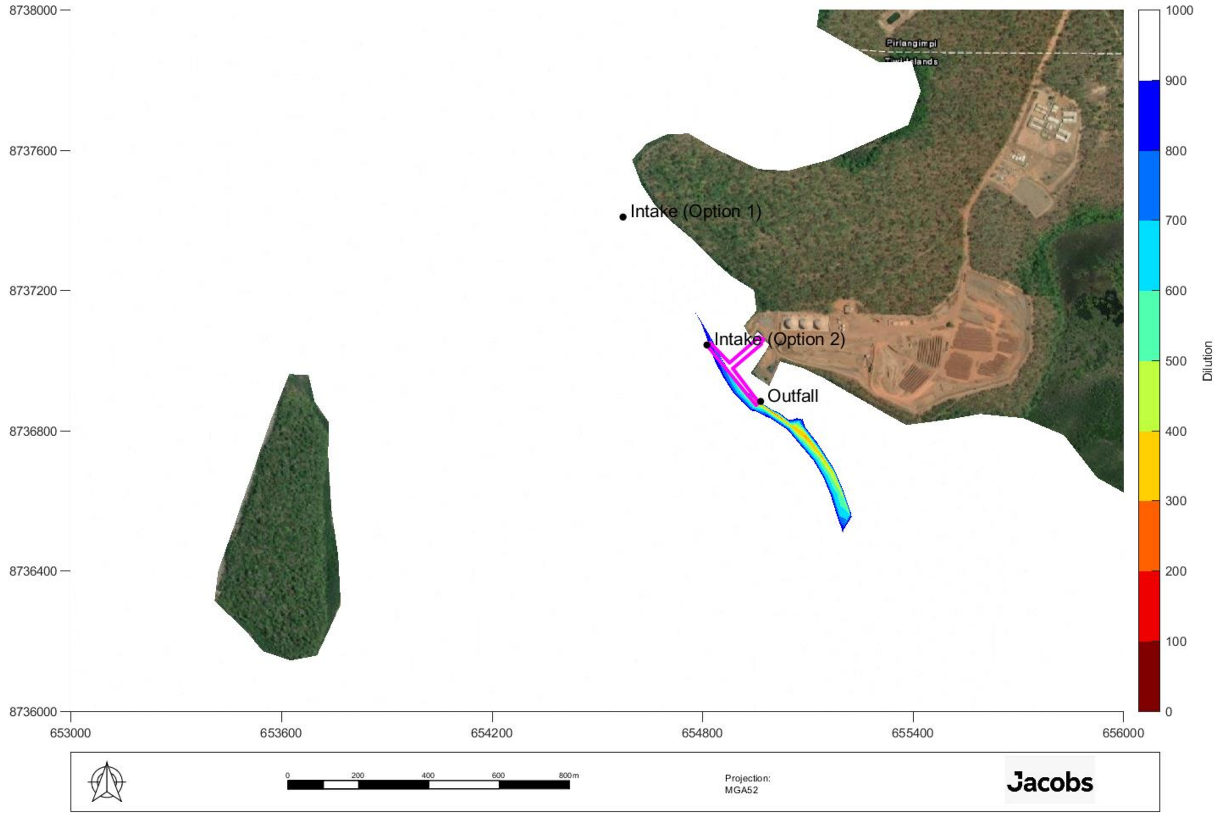
Table C-1 **Model Results Summary – Salinity and Dilution**

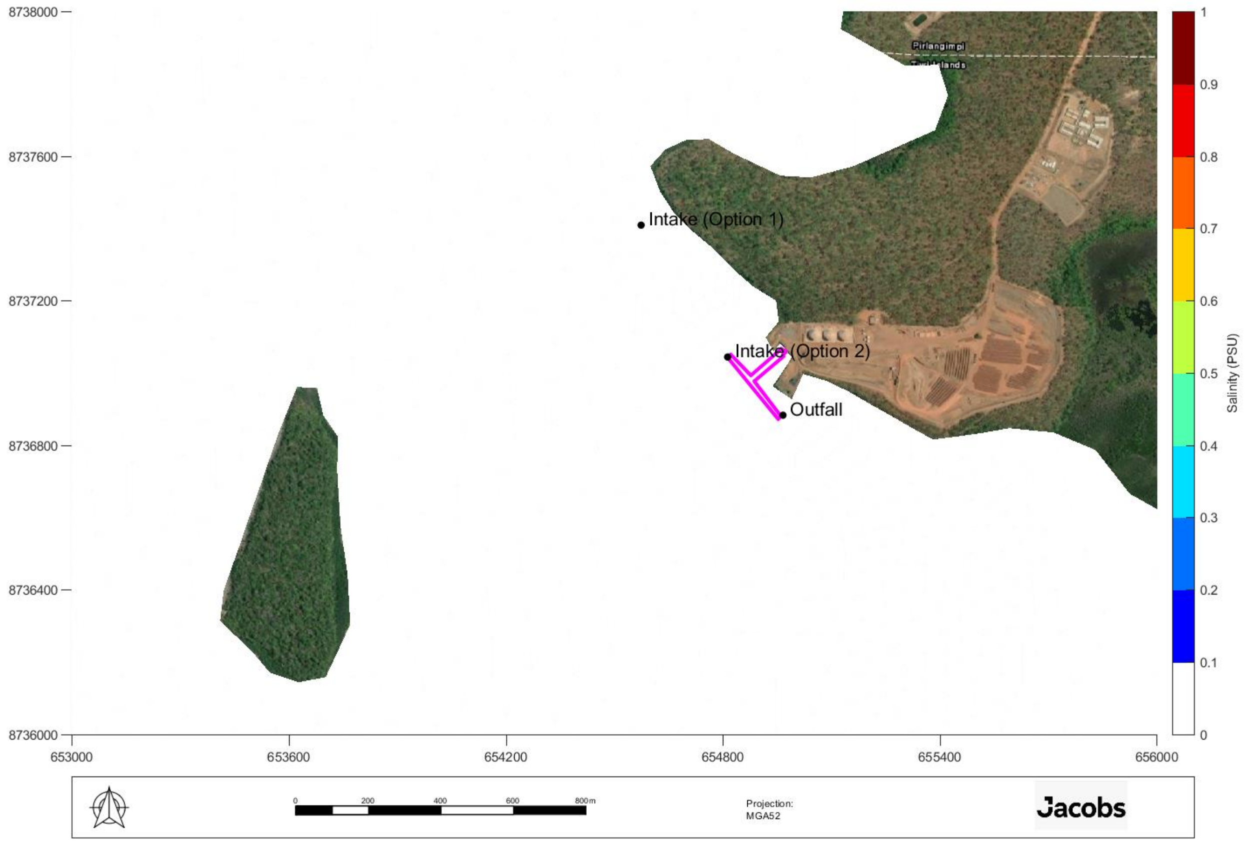
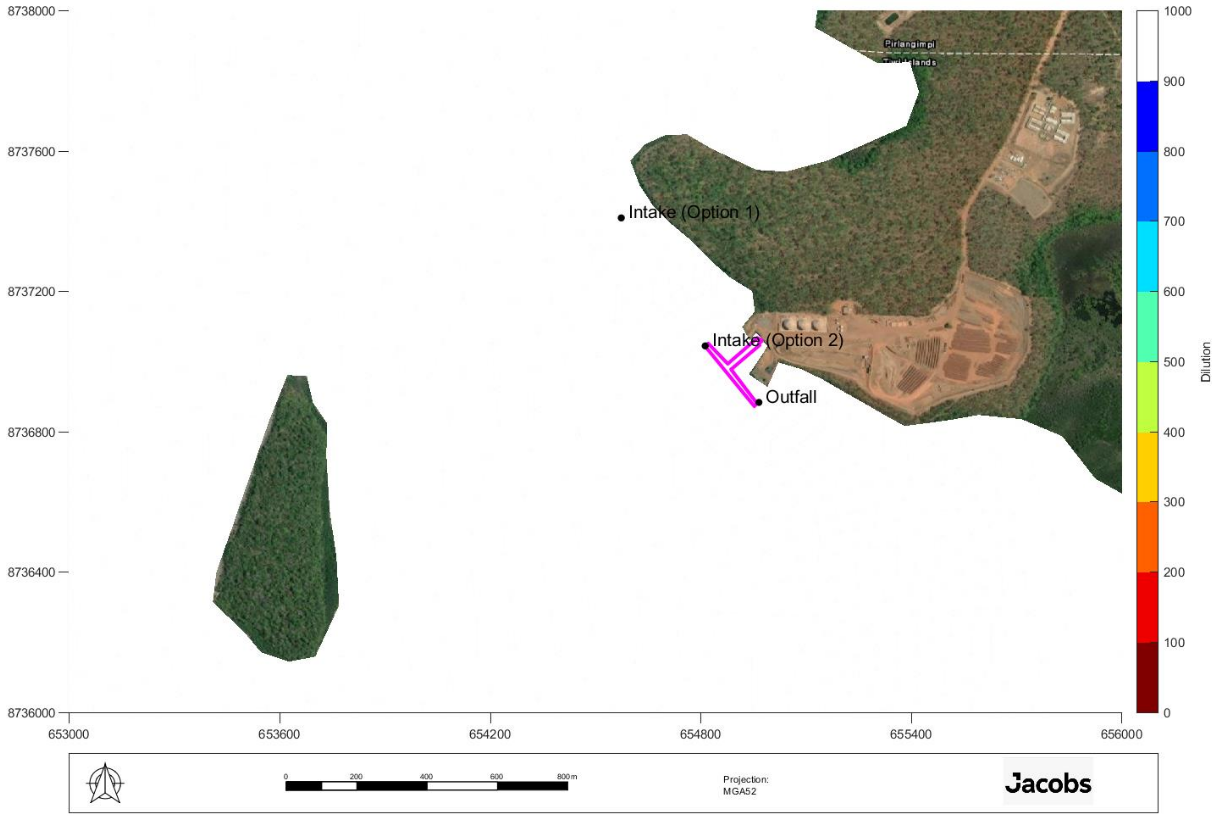
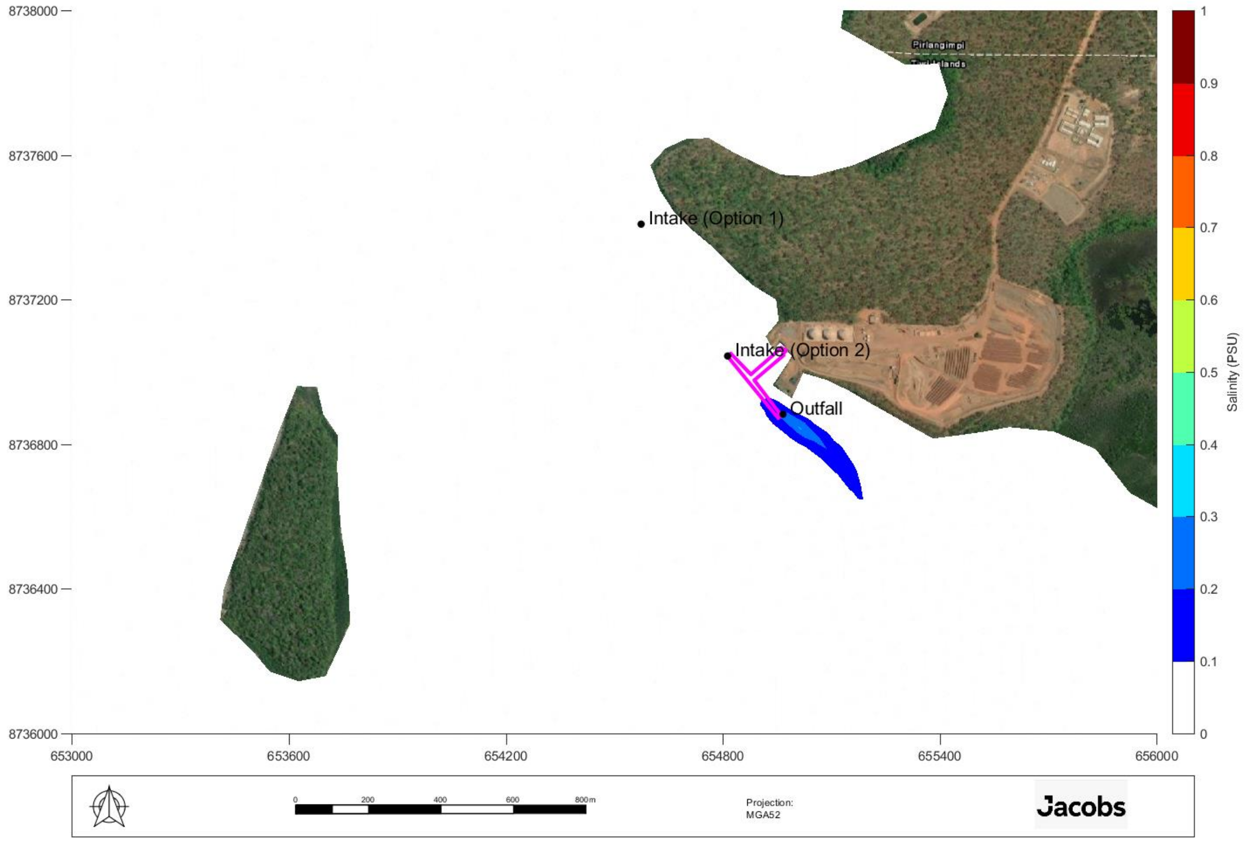
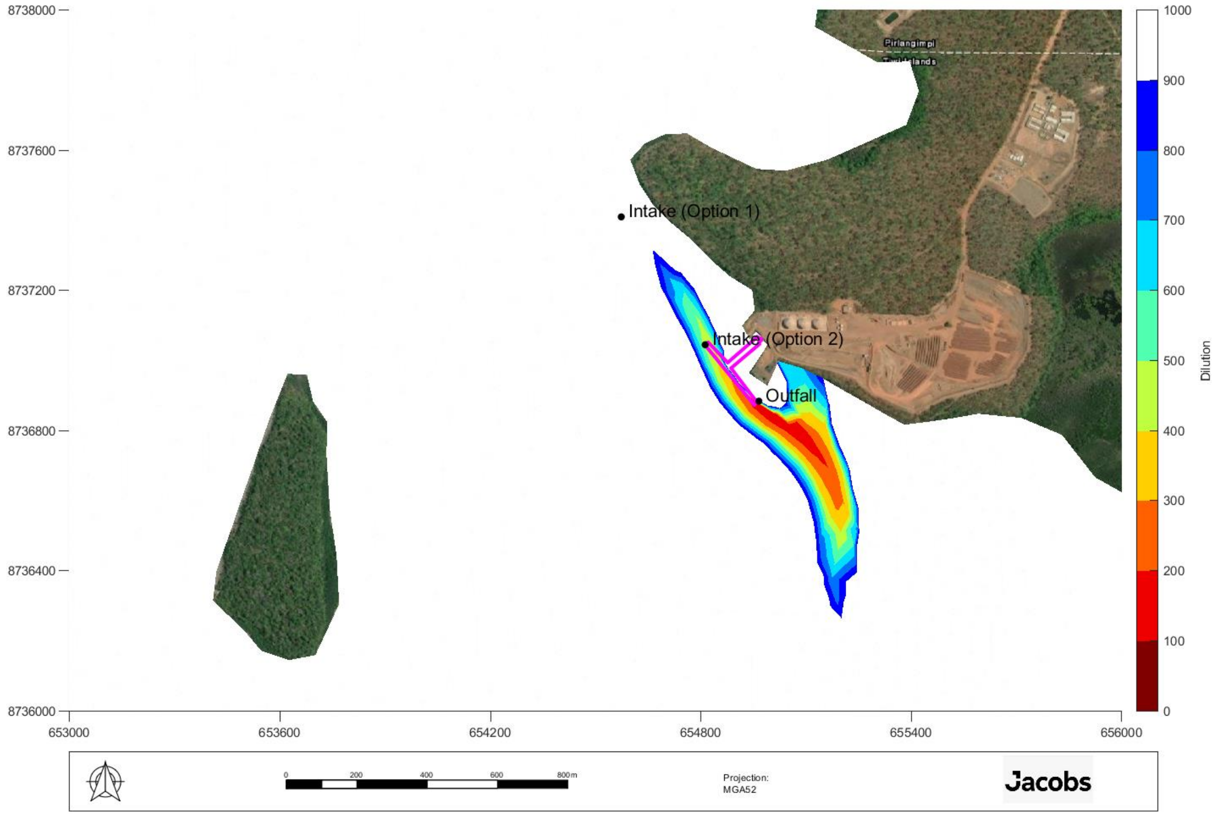
Scenario	Salinity Difference	Dilution Rate
No wind (Surface,70th Percentile)		
No wind (Bottom,70th Percentile)		

Scenario	Salinity Difference	Dilution Rate
No wind (Surface,90th Percentile)		
No wind (Bottom,90th Percentile)		

Scenario	Salinity Difference	Dilution Rate
SE wind (Surface,70th Percentile)		
SE wind (Bottom,70th Percentile)		

Scenario	Salinity Difference	Dilution Rate
SE wind (Surface,90th Percentile)		
SE wind (Bottom,90th Percentile)		

Scenario	Salinity Difference	Dilution Rate
NW wind (Surface,70th Percentile)		
NW wind (Bottom,70th Percentile)		

Scenario	Salinity Difference	Dilution Rate
NW wind (Surface,90th Percentile)		
NW wind (Bottom,90th Percentile)		

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