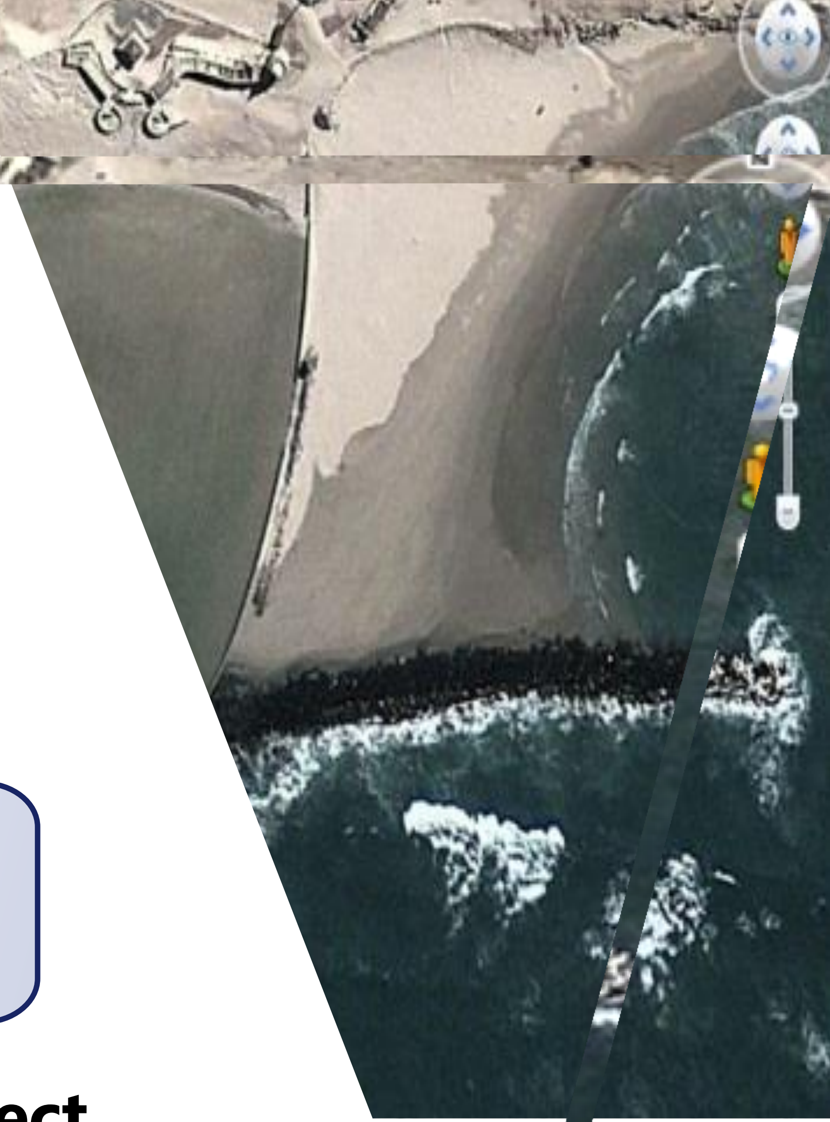

DRAFT

Desalination Project

Monwabisi Outfall – Technical Memo

19-Sep-2017

31 Allen Drive
Loevenstein
Cape Town 7530
South Africa

C00686-ZB-CS-REP-0001

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WorleyParsons Group

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Project No: C00686-ZB-CS-REP-0001 – Desalination Project: Monwabisi Dispersion Modelling Report

Rev	Description	Author	Review	Advisian Approval	Date
A	Issued for Internal Review	MIR	FS	GM	19-Sep-2017

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Appendix List

1 Introduction

1.1 Background

The City of Cape Town, South Africa, is currently experiencing the worst drought since 1904 and the Premier of the Western Cape has declared the City and other areas in the Western Cape as a disaster area.

Because of the drought, the city's dam levels have dropped substantially and the City of Cape Town wants to augment the city's potable water supply by using reverse osmosis (RO) and desalination plants at several sites along the coastline.

WorleyParsons has been appointed to develop the design of the marine desalination pipelines and structures, prepare technical tender documents for the appointment of a contractor to construct the works and administer and monitor the construction works.

There are 9 potential desalination sites being investigated. The current document focuses on Monwabisi one of the potential sites where the brine can be discharged to the marine environment via a surf zone outfall. (see Figure 1-1).

The current scope of work includes providing the Contactors with sufficient information and detail to undertake a detailed design of a seawater desalination intake and outfall systems to be erected at Monwabisi. The Contractor's scope includes the Design, Supply, Establish, Commission, Operate and later Decommission of a Sea Water Reverse Osmosis (SWRO) Plant at Monwabisi, to Supply SANS 241:2015.

The proposed desalination plant at Monwabisi comprise two phases. Phase 1 is for the works to supply a guaranteed 2Ml/day. Phase 2 is for the works to supply a guaranteed 7Ml/day. Phase 1 and Phase 2 construction operations are expected to commence simultaneously, however operation of Phase 1 is scheduled to commence end November 2017 and operation of Phase 2 is scheduled to commence end February 2018.

General layouts for Phases 1 and 2 are illustrated in Figures 1-1 and 1-2. Note, the layouts are indicative only since the Supplier shall develop the final layout of the plant and marine works.

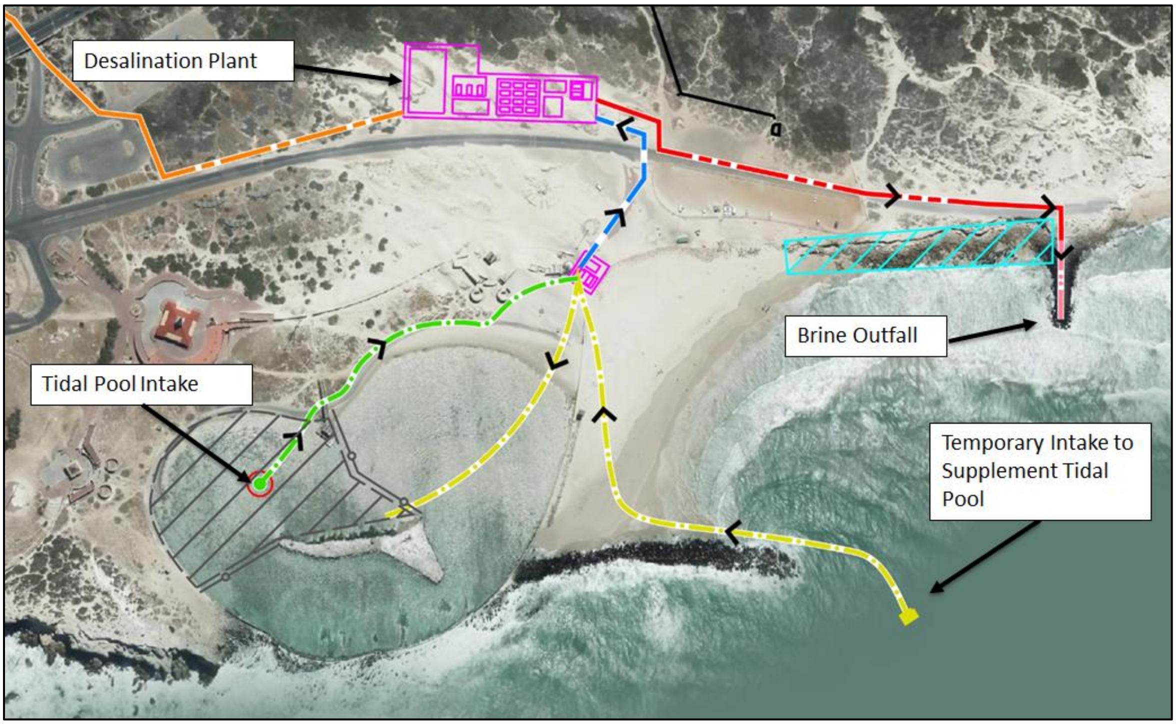

Figure 1-1: General layout of proposed desalination plant at Monwabisi (Phase 1).

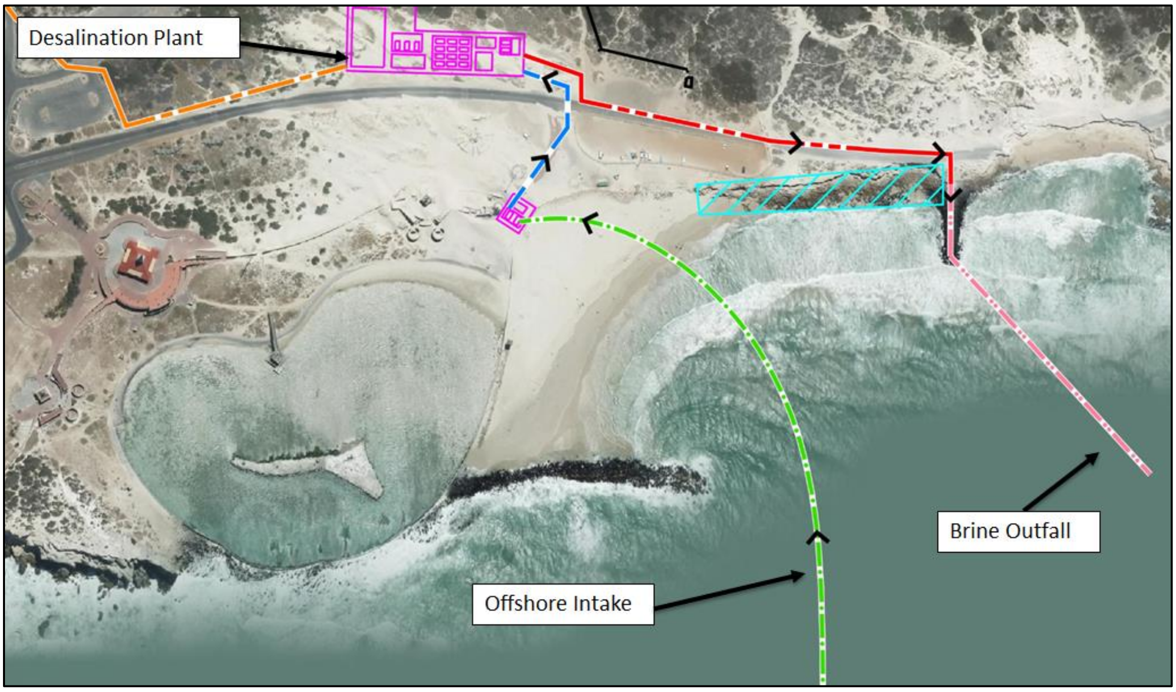

Figure 1-2: General layout of proposed desalination plant at Monwabisi (Phase 2).

1.2 Scope of Work

This technical/scientific assessment was a desktop study, using available information and data. The approach followed for this investigation adheres to requirements as prescribed by DEA, namely:

- Review information with regards to the legislative requirements for the discharge of treated waste water effluents to the marine environment,
- Review site specific information which determined the fate of the discharged effluents to the surf zone, i.e. the dynamic processes (wind, waves, near-shore circulation, water column properties) and physical features (coastline configuration),
- Define the water quality objectives for the relevant effluent constituents of the two outfalls: The assessment will be based on the Receiving Water Quality Objectives (RWQO) approach which requires the definition of site-specific water quality objectives related to the designated beneficial uses of the area, and recommended water quality guidelines,
- Effluent characteristics: Effluent discharge rates and effluent quality of proposed desalination plant.
- Determine required dilutions: Determination of the required dilutions of the effluent with regards to the water quality objectives,
- Achievable dilutions: Achievable dilutions in the surf zone,
- Compliance to water quality objectives: Determine and quantify the adherence to the water quality objectives.
- Consider future investigations.

1.3 Project Datum and Projections

Unless otherwise specified, the horizontal projection used in this study is UTM34S, spheroid WGS84, and the vertical datum is Chart Datum (CD).

1.4 Abbreviations

The abbreviations that are summarised in Table 1-1 are used throughout this report.

Table 1-1: Abbreviations.

Abbreviation	Definition
CD	Chart Datum
CoCT	City of Cape Town
CORMIX	Cornell Mixing Zone Expert System

Abbreviation	Definition
CSIR	Council for Scientific and Industrial Research
DEA	Department of Environmental Affairs
HAT	Highest Astronomical Tide
LAT	Lowest Astronomical Tide
MHWN	Mean High Water Neap
MHWS	Mean High Water Spring
ML	Mean Level
MLWN	Mean Low Water Neap
MLWS	Mean Low Water Spring
MWQG	Marine Water Quality Guideline
NFR	Near-Field Region
NOAA	National Oceanic and Atmospheric Administration
PPT	Part Per Thousand
PSU	Practical Salinity Units
RMZ	Regulatory Mixing Zone
SANHO	South African Navy Hydrographic Office
SI	International System of Units
TSS	Total Suspended Solids
WWTW	Wastewater Treatment Works

1.5 Units

The project shall use the International System of Units (SI) for all project documentation. Table 1-2 provides a list of the units used by the Project.

Table 1-2: Units.

Parameter	Unit
Rainfall	mm
Humidity	%
Temperature	°C
Water Depth	m
Current & Wind Speed	m/s
Current & Wind Direction	°N
Discharge	m^3/s
Salinity	PSU

2 Site description and available data sources

2.1 Site description

A summary of the relevant available environmental characteristics for the Monwabisi site is outlined in the sub-sections that follow.

2.2 Bathymetry

Offshore bathymetric data was provided by digitised South African Navy Hydrographic Office (SANHO) Admiralty nautical charts. Additionally, local bathymetric data for Monwabisi was surveyed in September 2017 by the Council of Geoscience, which was also digitised and added to the SANHO charts.

The local bathymetric data for Monwabisi are presented in Figure 2-1 the vertical datum is referenced to Chart Datum.

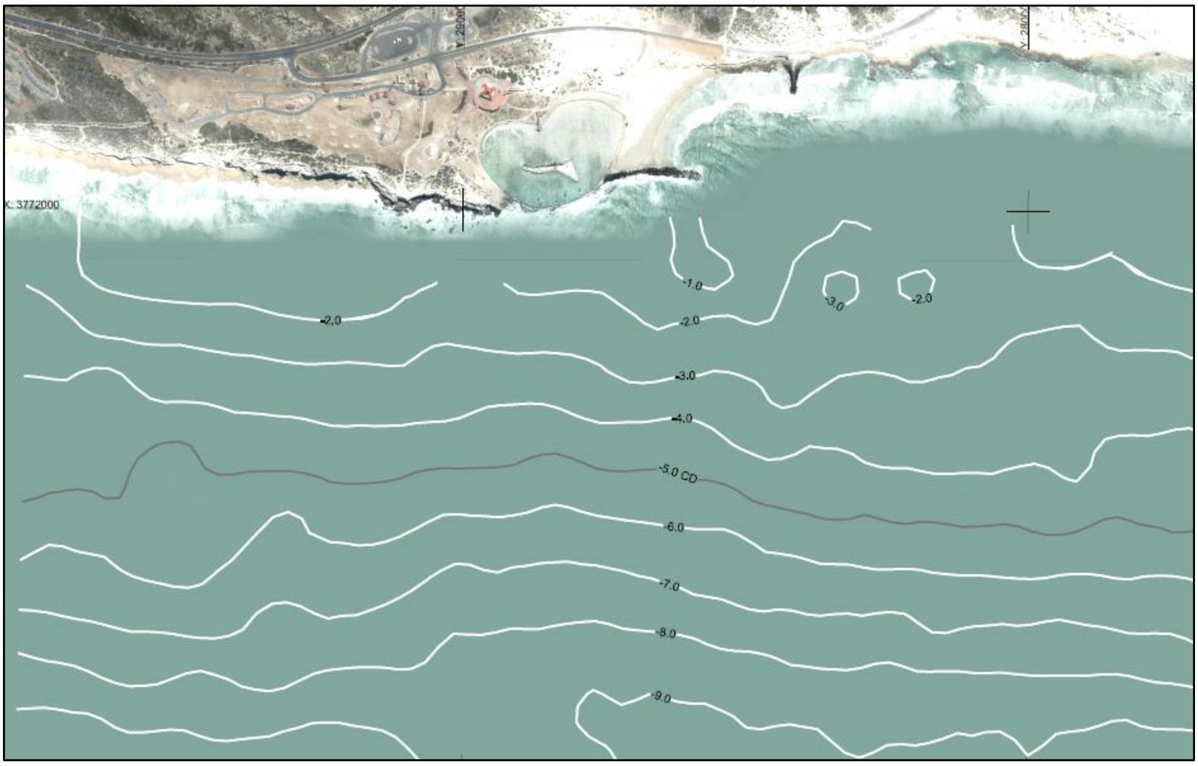

Figure 2-1: Bathymetric data for Monwabisi (m CD). Source: Council for Geoscience

Refer to Appendix A for full coordinated bathymetry drawing of nearshore area.

2.3 Wind

A wind rose for Monwabisi, obtained from www.meteoblue.com, is shown in Figure 1. The strongest winds are predominantly from the north-west and south-east.

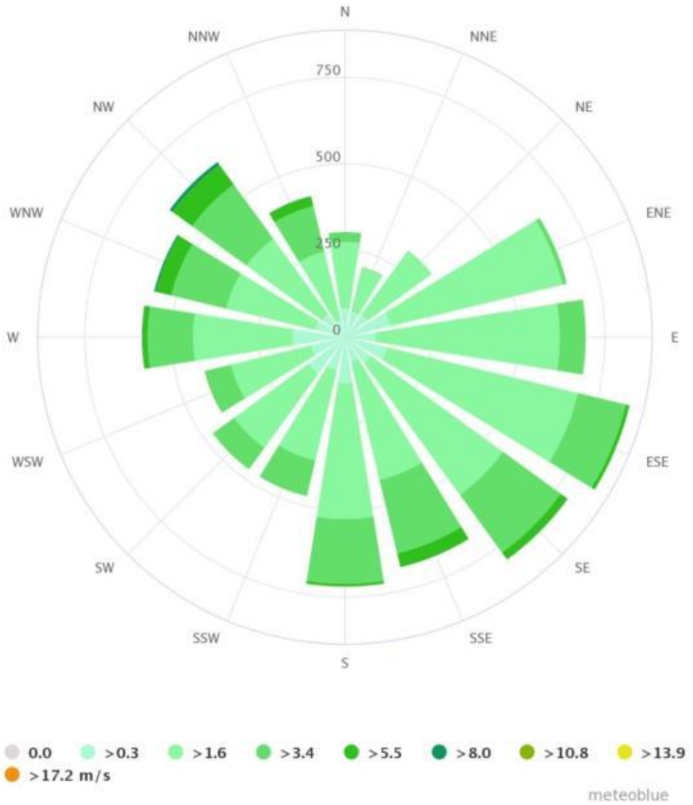

Figure 2-2: Annual Wind Rose for Monwabisi. Source: (2017).

No further wind measurements are available at present.

2.4 Waves

Indicative wave conditions at the project site were estimated at Position 1 and Position 2 shown in Figure 2-3 through numerical modelling.

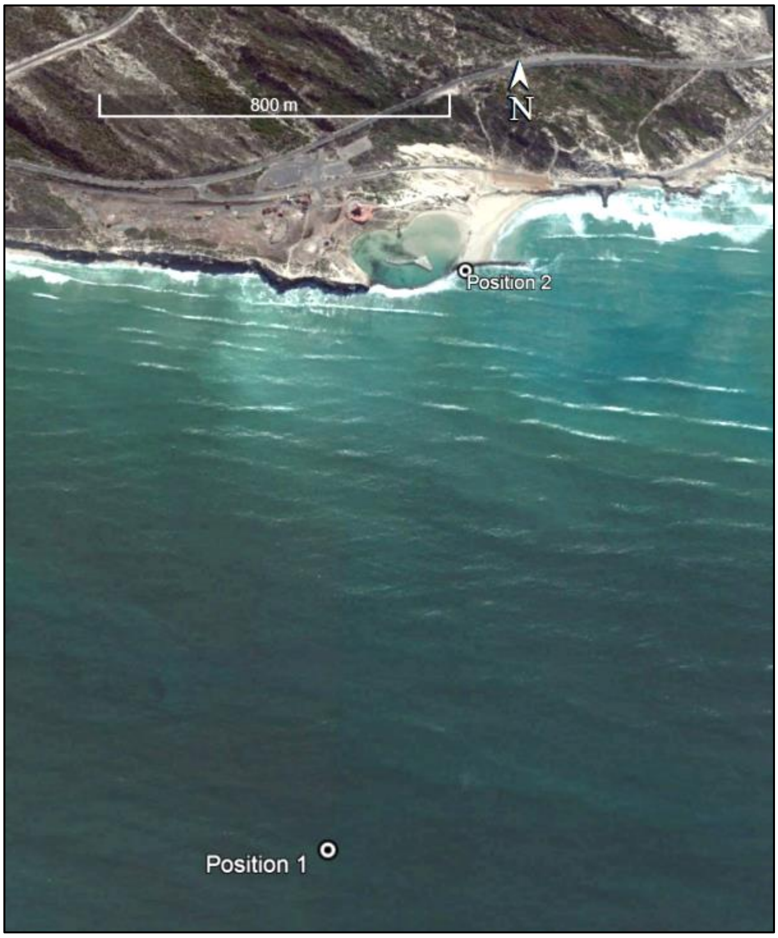

Figure 2-3: Wave extraction locations.

It should be noted that the annual conditions and derived extreme estimated have not been validated and are provided as an indication only.

Indicative annual wave roses for the extraction points are presented in Figure 2-4 and Figure 2-5 whilst Table 2-1 provides a summary of the wave parameters.

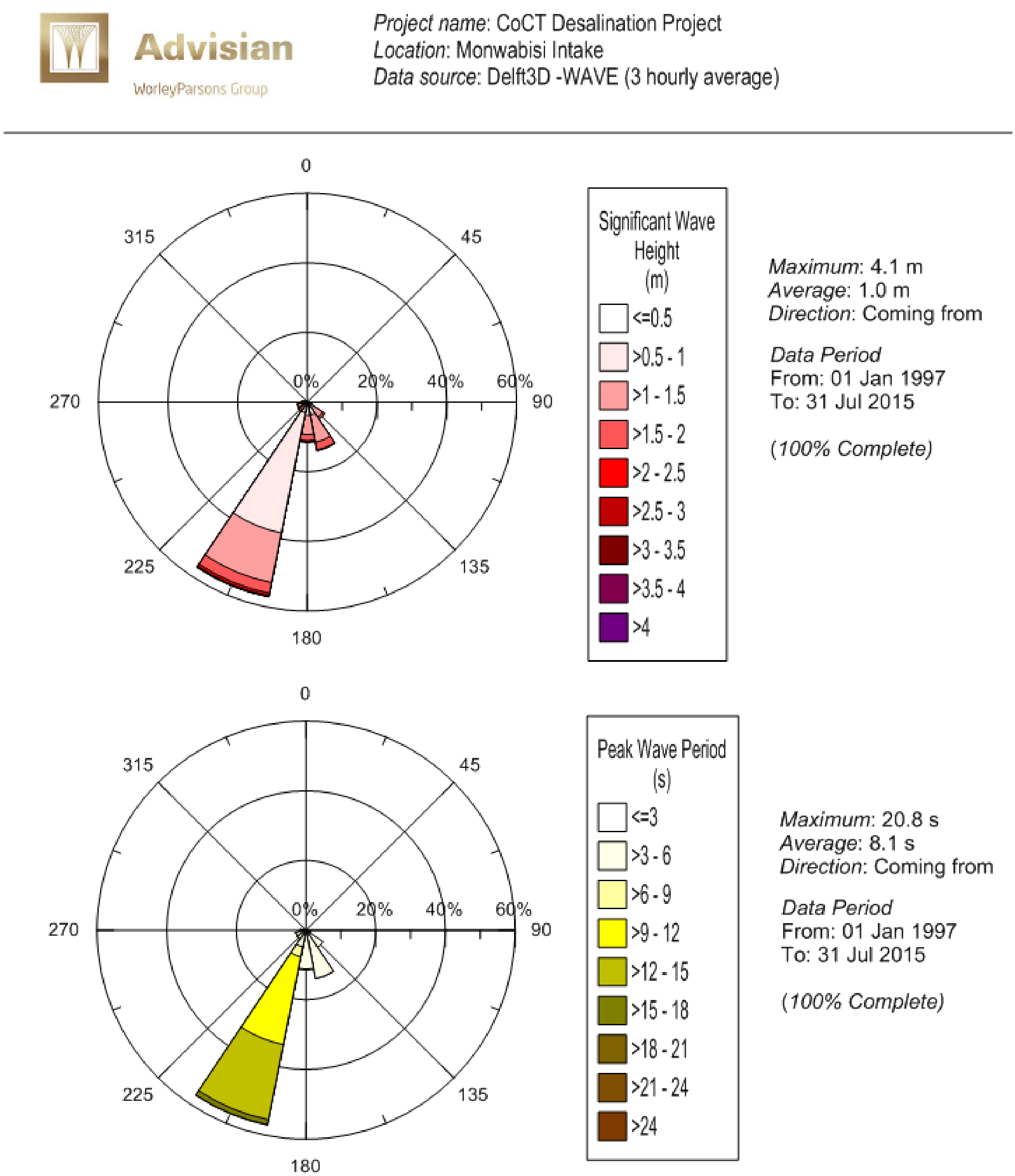

Figure 2-4: Indicative annual wave rose for Position 1, Monwabisi

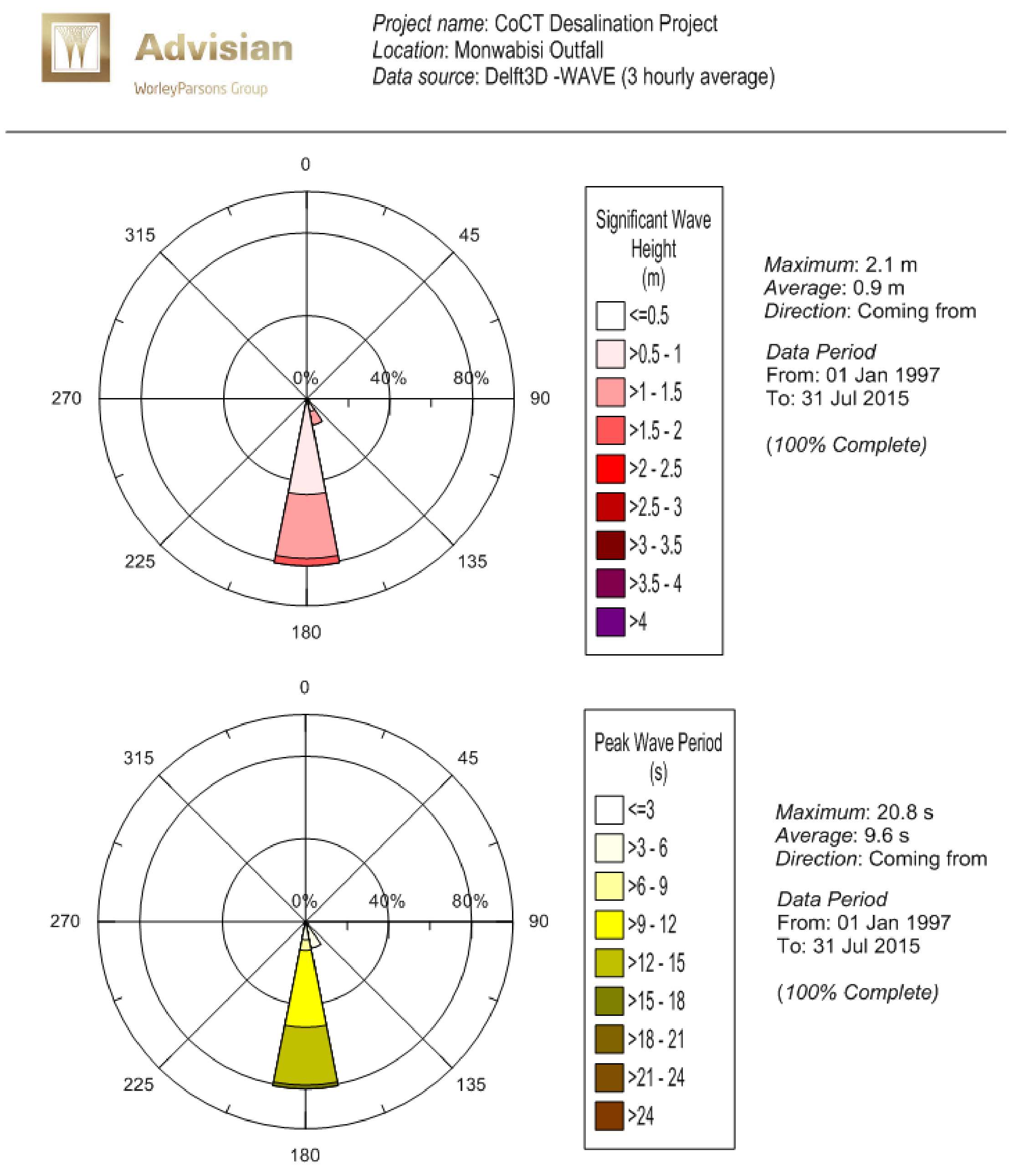

Figure 2-5: Indicative annual wave rose for Position 2, Monwabisi.

Table 2-1: Indicative wave climate for Monwabisi.

Parameter	Position 1	Position 2
Sea bed level	-10.7 m CD	-1.1 m CD
Spectral wave height (H_{mo})		
Annual Maximum	4.1 m	2.1 m
Annual Average	1.0 m	1.0 m
Peak Wave Period (T_p)		
Annual Maximum	19.7 s	20.6 s
Annual Average	8.4 s	10.4 s

2.5 Currents

Limited current data at the project site is available. Drogue current velocities measured by the CSIR (CSIR, 1991) for False Bay indicate that the mean surface velocities are less than 0.17m/s and the mean subsurface velocities at -5m are less than 0.09m/s. The maximum measured surface velocity is 0.41m/s and the maximum measured subsurface velocity is 0.43m/s

2.6 Water levels

Tides in Monwabisi are semi-diurnal. The tidal level range for Monwabisi is expected to be similar to that of Simon's Town.

Table 2-2 provides the tidal levels related to Chart Datum for Simon's Town.

Table 2-2: Tidal Levels of Simon's Town (The Hydrographer, 2017)

Location	LAT	MLWS	MLWN	ML	MHWN	MHWS	HAT
Simon's Town	0	0.24	0.73	1	1.29	1.79	2.09

It should be noted that meteorological conditions such as wind and atmospheric pressure can cause considerable differences between predicted and actual tides.

3 Water Quality Objectives

3.1 Water Quality Guidelines

The South African Water Quality Guidelines for Coastal Marine Waters provides recommended target values for a range of water quality constituents to prevent negative impacts on the marine ecosystem (DWAF, 1995).

These guidelines are applicable to the entire marine environment. Specific water quality guidelines exists for other beneficial use areas as described in Table 3-1 below. (DWAF, 1995) provides target values for constituents which may have impact on the marine ecosystem or on other beneficial use areas. These target values are listed in Table 3-1.

Table 3-1: Recreational use of coastal marine waters

Recreational use of the coastal marine waters	
Full contact recreation	Activities such as swimming, diving (scuba and snorkeling), water skiing, surfing, paddle skiing, wind surfing, kite surfing, parasailing and wet biking
Intermediate contact recreation	Activities such as boating, sailing, canoeing, wading, and angling, where users may come in contact with the water or swallow water
Non-contact recreation	All recreational activities taking place in the vicinity of marine waters, but which do not involve direct contact, such as sightseeing, picnicking, walking, horse riding, hiking etc.
Basic amenities	Aesthetically acceptable environment.
Mariculture	Refers to the farming of marine and/or estuarine organisms in land-based (i.e. 'off-stream' tanks using pumped seawater) or water-based (i.e. 'in-stream') systems.
Industrial uses	Waste water discharges, cooling water, desalination, and aquariums.

Table 3-2: Target values: South African Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995).

BASIC AMENITIES - all marine & estuarine water	
Constituents	**Guideline (Target Value)**
Aesthetics	Water should not contain floating particulate matter, debris, oil, grease, wax, scum, foam or any similar floating materials and residues from land-based sources in concentrations that may cause nuisance or in amounts sufficient to be unsightly or objectionable. Water should not contain materials from non-natural land-based sources which will settle to form putrescent or objectionable deposits. Water should not contain materials from non-natural land-based sources which will produce colour, odours, turbidity or taints or other conditions to such a degree as to be unsightly or objectionable. Water should not contain submerged objects and other sub-surface hazards which arise from non-natural origins and which would be a danger or cause nuisance or interfere with any designated/recognized use.
Color (turbidity)	Turbidity and colour acting singly or in combination should not reduce the depth of the euphotic zone by more than 10 per cent of background levels measured at a comparable control site. With specific reference to colour, levels should not increase by more than 35 Hazen units above background levels in a particular area. Colour can also be measured in units of mg Pt/l, where 1 mg Pt/l is equivalent to 1 Hazen unit.
Suspended Solids	The concentration of suspended solids (SS) should not increase above 10% of the background concentrations.
MAINTENANCE OF THE ECOSYSTEM - all marine waters	
Temperature	Should not exceed the ambient temperature by more than 1^0C.

PH	The pH should lie within the range of 7.3-8.6.
Dissolved Oxygen	Should not fall below 5 mg/l (Dissolved oxygen should not fall below 5 mg/l (99 per cent of the time) and below 6 mg/l (95 per cent of the time))
Salinity	Salinity should lie within the range 32 to 36.
Dissolved Nutrients in mg/l Phosphates: $P0_4$-P Nitrogen ($N0_2$ and NO_3 and NH_3	Should not cause excessive algae growth and the loads should not exceed the levels which are introduced by natural processes such as upwelling.
Ammonia (mg/l)	0.02 mg N /liter as NH_3 0.60 mg N /liter as NH_3 + NH_4^+
Toxic Inorganics in mg/l	
Arsenic (As)	0.012
Cadmium (Cd)	0.004
Chromium (Cr)	0.008
Copper (Cu)	0.005
Lead (Pb)	0.012
Mercury (Hg)	0.0003
Nickel (Ni)	0.025
Silver (Ag)	0.005

Zinc (Zn)	0.025
ADDITIONAL GUIDELINES FOR DIRECT CONTACT RECREATION - (Specific Areas)	
Faecal coliforms (if limits are exceeded, test for E.coli using same target values)	Maximum acceptable count per 100 ml 100 in 80 percent of the samples 2000 in 95 percent of the samples
ADDITIONAL GUIDELINES FOR FILTER FEEDER COLLECTION - (Specific Areas)	
Faecal coliforms (if limits are exceeded, test for E.coli using same target values)	Maximum acceptable count per 100 ml 20 in 80 percent of the samples 60 in 95 percent of the samples

3.2 Background water quality

3.2.1 Seawater temperature and salinity

The yearly average surface seawater temperature of False Bay water is about 17.8°C. The temperatures vary between 13.8°C and 21.1°C. The salinity for False Bay varies between 34.2 and 36 ppt.

Sea water sampling was undertaken at three locations as shown in Figure 3-1 near Monwabisi on 15th August 2017 by Lwandle (2017). The results are presented in Table 3-3 below.

Figure 3-1: Water sampling locations near Monwabisi

Table 3-3: Mean values for parameters measured at Monwabisi on 15 August 2017. Source Lwandle (2017).

Location	Depth (m)	Temp (C)	Salinity (PSU)	Turb (NTU)	Diss. O_2 %	Diss.O_2(mg/l)
MW1	5.6	13.99	35.12	14.40	108.64	9.00
MW2	4	14.00	35.14	20.84	106.63	8.84
MW3	10	14.07	35.18	12.34	109.07	9.02

3.2.2 Suspended solids

Typically, suspended sediment concentrations in the surf zone are much higher than in the offshore waters. In False Bay high sediment concentrations were observed in the offshore waters also, and according to (Shannon, et al., 1991) related to flows/transport from the northern shores.

For the purpose of determining required dilutions of the brine stream, the background suspended solid concentrations are taken as 15 mg/l, which is considered as conservative approach due to the natural variation of suspended fine sediments along the northern shore of False Bay.

4 Brine Characteristics

4.1 Brine volumes

A summary of the maximum brine volumes for Phases 1 and 2 of the proposed desalination plant is listed in Table 4-1 below:

Table 4-1: Brine volumes for Phases 1 and 2

Phase	Ml/day	m^3/s	Plant operations
1	2.4	0.051	Nov 2017 – April 2018*
2	8.6	0.180	March 2017 – Dec 2019*

* Dates subject to Supplier contract award

4.2 Effluent quality

The final brine quality shall be confirmed by the Supplier upon appointment. The typical composition of the brine stream of a reverse osmosis plant is listed in Table 4-2 below:

Table 4-2: Estimated brine quality (Similar for Phases 1 & 2)

Description	Units	Quantity
Salinity	ppt	66
Change in temperature	Deg Celsius	1 - 2
pH		7.3 – 8.2
Suspended Solids	mg/l	1.67 times ambient
Phosphonate antiscalant	mg/l	4.7
Chlorine	mg/l	0.002
Sodium bisulphate (SMS)		3.14
Spent CIP solution (quarterly and blended in over 12 hours)	mg/l	
Peroxyacetic acid		0.006
Low pH cleaner		0.015
High pH cleaner		0.015
Preservative (sodium metabisulfite) (on shutdown/start-up, and blended in over 12 h)	mg/l	0.028
Coagulant (type and concentration shall be confirmed by Supplier. Note, no coagulants which results in colouration o the brine stream shall be permitted.		

The constituents which are present in the brine stream and considered as critical (refer to The South African Water Quality Guidelines for Coastal Marine Waters (Table 3-2) are:

- Suspended Solids (Guideline concentration: 10% above ambient conditions).

- Salinity (Salinity should lie within the range 32 to 36)

The other constituents listed can be considered as non-critical for the proposed outfall system. However, upon commissioning of the desalination plant, the City of Cape Town shall perform a toxicity test of the brine stream in order to confirm the toxicity of the other constituent to the marine environment.

5 Required dilutions

The term dilution describes the process of reducing the concentration of effluent constituents by mixing the effluent with uncontaminated ambient seawater and therefore achieving acceptable concentration levels for maintaining ecosystems functioning and recreational human activities (e.g. swimming).

To assess the assimilative capacity of the receiving waters, a straight forward first estimate is based on the required dilutions for a specific constituent in the effluent. The required dilution is a function of the effluent concentration and the 'buffer capacity', which is the difference between a guideline value (target value) and the ambient concentration of the specific constant and can be expressed as follows:

$$\mathbf{S = (C_E - C_A) / (C_T - C_A)}$$

Where:

$\mathbf{S}$	= Required dilution
$\mathbf{C_E}$	= Effluent concentration
$\mathbf{C_A}$	= Ambient (background) concentration
$\mathbf{C_T}$	= Target or guideline concentration (Which should not be exceeded)
$\mathbf{(C_T - C_A)}$	= "Buffer capacity"

It is clear that if $\mathbf{C_A}$ approaches $\mathbf{C_T}$, then ($\mathbf{C_T - C_A}$) will approach 0 and subsequently S (Dilution) >>>> (infinite - not achievable).

Table 5-1: Required Dilutions

Constituent	Background (Ambient) C_b	Guideline C_g	Effluent concentration C_e	Required dilution
Suspended solids (mg/l)	15	16.5	27.3	8
Salinity (ppt)	34.8	36	63.3	24

6 Brine Outfall Location & Configuration

6.1 Location

The Supplier shall specify the exact discharge location of the brine outfall and the coordinates shall be submitted as part of the final specialist report to DEA upon contract award. The following requirements with regards to exclusion zones of the brine discharge point for Phases 1 and 2 were specified as part of the supplier contract documentation:

- The discharge point shall be at minimum water depth of -1 m CD (exception made for Phase 1, refer to Figure 6-1 below).
- No discharge allowed within the tidal pool.
- No discharge allowed eastwards and westwards of demarcated areas.

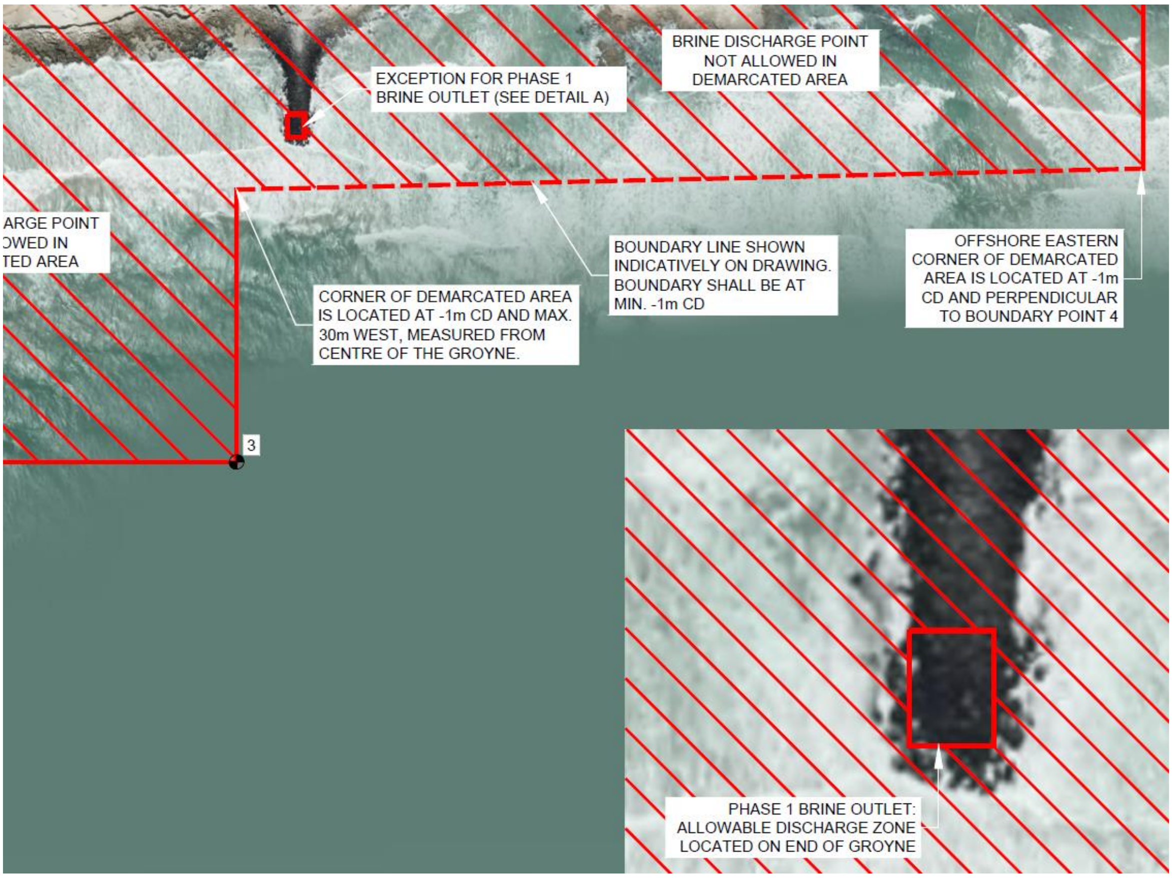

Figure 6-1: Monwabisi brine discharge point exclusion zones (Phase 1)

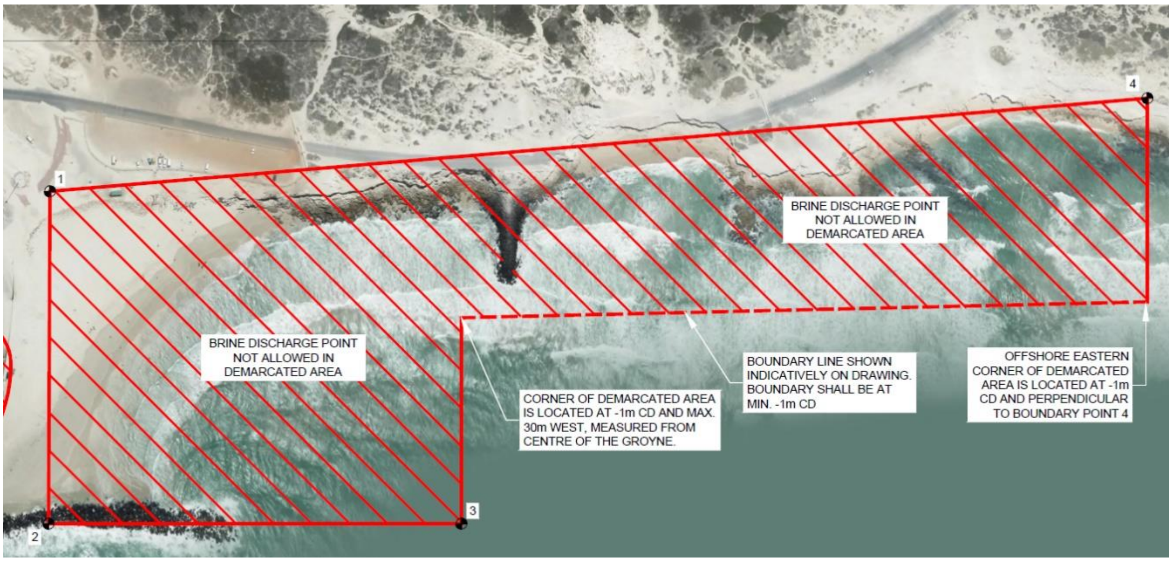

Figure 6-2: Monwabisi brine discharge point exclusion zones (Phase 2)

Refer to Appendix B for the detailed exclusion zone tender drawings for Phases 1 and 2

6.2 Brine pipeline and outlet configuration

The Supplier shall design and specify the brine pipeline and outlet structures. The detail design drawings of the marine components shall be submitted as part of the final specialist report to DEA upon contract award. The following requirements with regards to the hydraulic and structural design of the brine outfall for Phases 1 and 2 were specified as part of the supplier contract documentation:

- The suitability of pipeline routes shall be investigated and validated by the Supplier. The Supplier shall verify and select a pipeline route that suits his design and/ or installation method and minimize impacts on the activities of the recreational beach area. Pipelines through the beach (beach crossing) shall only be located in the zone indicated on the drawings.
- The Supplier shall select the number of intake and outfall pipelines, pipeline materials, sizes and types that suit his designs. The Supplier shall be responsible for designing suitable measures to protect the pipelines from damage caused by wave action, boat propellers and other external forces, and ensure pipeline stability employing appropriate methods such as anchors, collars, concrete coating, sinkers, chains, etc.
- Pipe type and size shall be selected as to minimize the marine growth, prevent sediment deposition and mitigate the potential reduction in hydraulic efficiency of the pipeline. Pipe material shall be able to prevent damage during installation.
- Special attention shall be taken for ensure the stability and protection of the section of the pipeline crossing the surf zone.

- Suppliers shall develop arrangements that ensure adequate dispersion and also minimize brine accumulation in the nearshore and re-circulation to the intake location. Should respondents choose to utilize the configurations adopted in the tender concepts then they shall verify these routes, locations and dimensions prior to adopting them.

- The following shall be applicable to the brine outlet discharge structure/ point in the surf zone:

    - It is recommended for the brine outlet structure to be submerged below the water surface at all times.

    - It is recommended that the open end of the outlet structure be raised above the seabed.

7 Achievable dilutions

For surf zone discharges, the mixing, dispersion and transport of an effluent plume are complex processes which are dependent on a combination of various physical processes such as ambient currents (tidal and wind generated), wave action (breakers), wave generated currents and wind shear. Currents in the surf zone are wave dominated.

When discharging an effluent into the surf zone, the initial dilution is described as cross-shore dilution (dilution into the bore) and the concentration of a constituent after mixing in the bore can be expressed as:

$\mathbf{C_o = C_e/v_x}$

Where v_x is the cross-shore mixing coefficient which from prototype tests by Inman (1971) yielded the following relation:

$\mathbf{v_x = H_{br}.X_b/T}$

Where:

H_{br} = Breaker height (root mean square) (m)

X_b = surf zone width (m)

T = Incident wave period (s)

Refer to Section 2.4, wave heights in the breaker zone at the outfall locations will be most of the time < 1m and wave period < 10 s. The typical cross shore mixing coefficient at Monwabisi and the initial dilution (mixing in the bore) are shown in the Table 7-1 below. Note, following contract award and confirmation of exact discharge location, a detailed hydrodynamic numerical model will be developed in order to confirm the analytical results shown in Table 7-1 below and submitted as part of the final specialist report to DEA.

Table 7-1: Analytical initial dilution results

Monwabisi – Initial mixing in the bore	
Mean wave height	1.0 m
Mean wave period	11 s

Monwabisi – Initial mixing in the bore	
Average surf zone width*	270 m
V_x (initial dilution in bore)	**24**

Longshore transport is driven by wave generated currents and the strength is determined by the wave height, wave period and surf zone bathymetry where the direction is determined by the angle between the wave direction and the shoreline. Longshore dispersion will be brought about during the transport of the waste field alongshore and further be diffused when transported out of the surf zone by rip currents. A portion of the waste field which was transported out of the surf zone my transported back by the approaching waves. Onshore winds and incoming tide will tend to trap water in the surf zone while offshore winds and outgoing tide will tend to transport the effluent away from the coastline.

(Inman, et al., 1971) described the mixing of an effluent in the surf zone as the transport of water between two inshore “circulation cells” and the exchange of water by rip currents from the surf zone to the offshore region. (An idealized nearshore “circulation cell” has been defined as the region between two adjacent rip currents and spanning the surf zone width). These “circulation cells” can be either symmetrical for direct onshore wave conditions and a straight coastline or asymmetrical for inclined wave directions. Symmetrical “cells” can inhibit the transport of an effluent, resulting in stationary waste fields between two rip currents. Due to changing coastline configurations, “cells” may change from asymmetrical to symmetrical, causing the longshore transport to “cease” at a distance from the releasing point.

Longshore currents transport the waste field and at a rip current part of the waste field is transported out of the breaker zone by the rip current and the residue is transported to the next circulation cell and is described by Inman (1971) as:

$$\mathbf{R_R = Q_m/Q_{m-1}}$$

Where:

Q_m = Longshore flow in cell m

Q_{m-1} = Longshore flow in the adjacent cell m-1

The rip current flow is:

$$Q_R = Q_m - Q_{m-1}$$

From field data it was found that R_R ranges from 0 to 0.5, where R_R approaches 0.5 when the longshore current velocity is > 0.4 m/s.

For Monwabisi site, assuming for worst case scenario where the wave direction is perpendicular to the coastline, resulting in symmetrical circulation cells, the effluent will tend to be confined in a circulation cell, and the impact limited to the length of the circulation cell. Because of the effluent being trapped in a circulation cell, a straight forward and conservative estimate is the volumetric dilution, assuming all the seawater in the "cell" will be replaced within 1 day (2 diurnal tidal cycles and rip currents). The maximum daily volume discharged from the proposed desal plant will be 8.6 Ml/day which results in an estimated volumetric dilution of 14 in one circulation cell.

Table 7-2: Estimated volumetric dilution in a circulation cell for Phase 2 (8.6 Ml/day)

Monwabisi – Estimated volumetric dilution in circulation cell	
Surfzone width	270 m
Cell length	150 m
Depth	3 m
Volume	121 500 m3
Volumetric dilution in circulation cell	**14**

8 Impact assessment

The estimated mixing zone (from analytical assessment) is indicated in Figure 8-1 below.

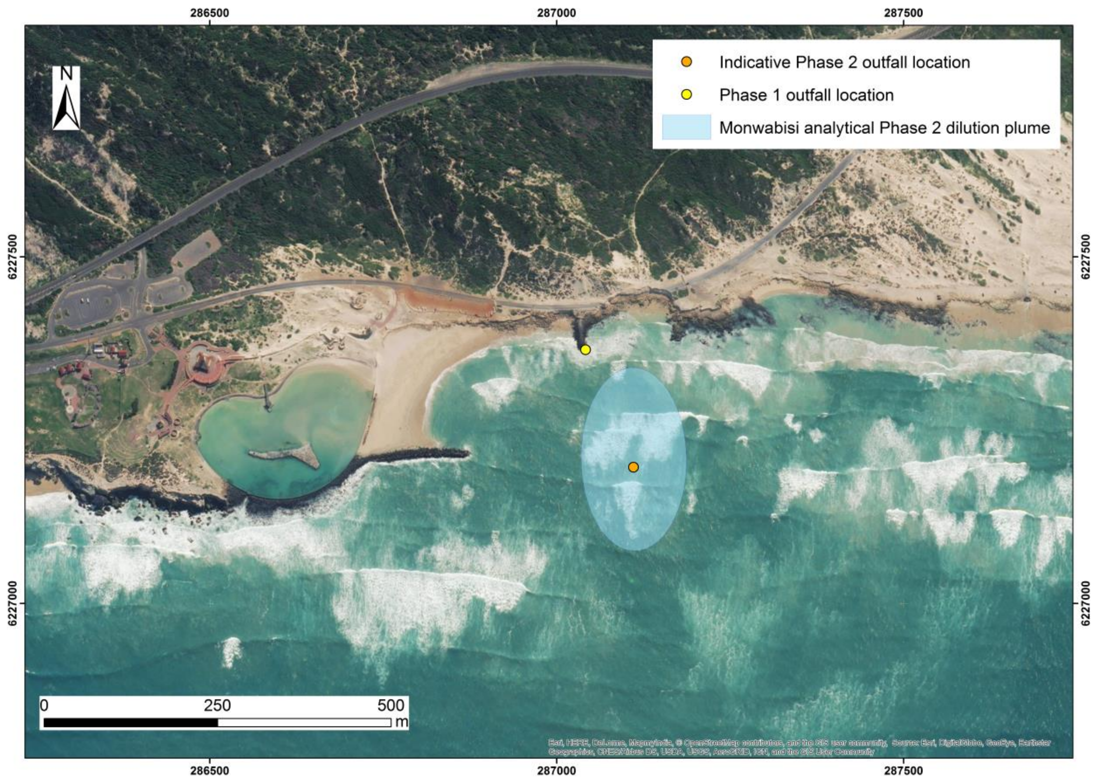

Figure 8-1: Estimated mixing zone (Phase 2)

Refer to Appendix C for the mixing zone drawing.

Preliminary dispersion modelling results for Phase 1 is presented in Figure 8-2. The mixing zone is is limited to the area at the tip of the groyne. For Phase 2, the marine outfall will be situated more offshore from the groyne as the tip of the groyne falls within the exclusion area (Section 6.1). However, a worst case scenario was evaluated where the Phase 2 outfall is also situated at the tip of the groyne. The preliminary results are shown in Figure 8-3. The mixing zone is limited to the area at the tip of the groyne.

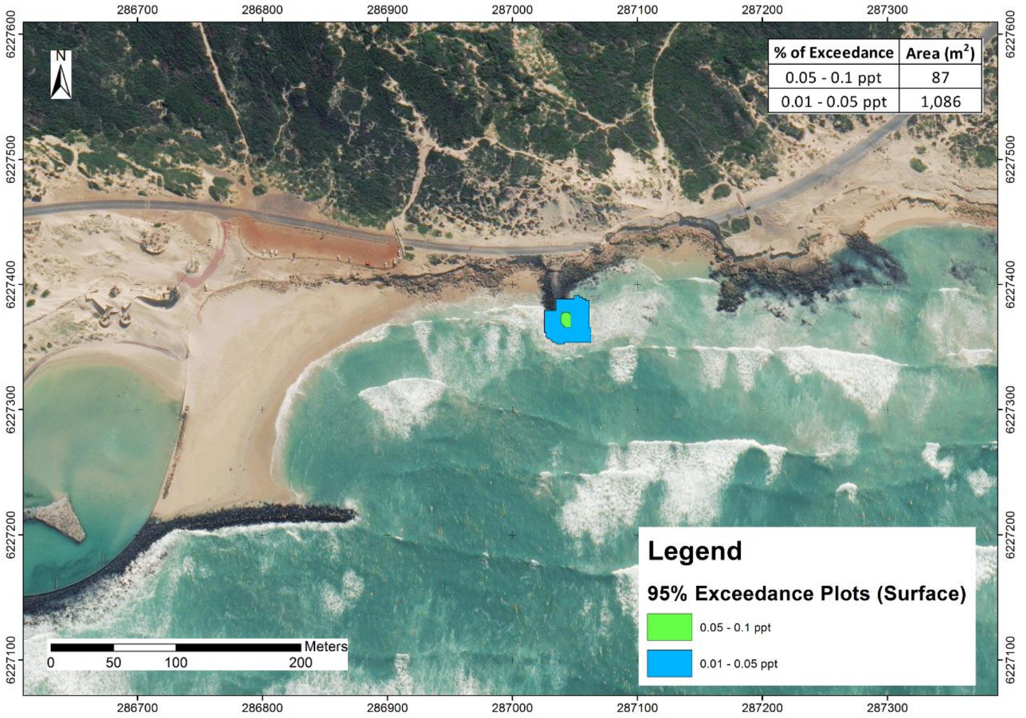

Figure 8-2: 95% Exceedance Plots (Surface) for Phase 1

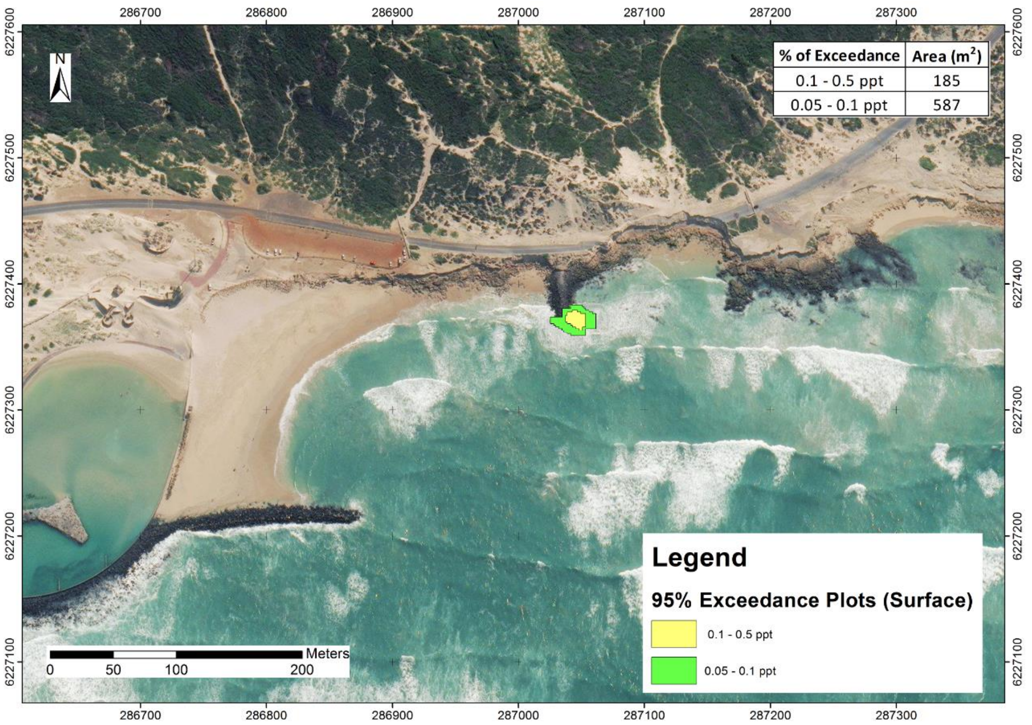

Figure 8-3: 95% Exceedance Plots (Surface) for Phase 1 worst case scenario

9 Conclusions & Recommendations

The environmental impact on the marine environment due to the proposed surf zone brine outfall (over a maximum of two year period) is ….

Upon contract award, xxx

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Appendix A Bathymetry Layout

Appendix B Brine Discharge Point Exclusion Zones