MARINE ENVIRONMENTAL IMPACT ASSESSMENT FOR THE PROPOSED DESALINATION PLANTS AROUND THE CAPE PENINSULA, SOUTH AFRICA

Marine Specialist Report

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EXECUTIVE SUMMARY

Advisian: WorlyParsons Group (WSP) was appointed by the City of Cape Town (CoCT) to prepare Coastal water Discharge Permit (CWDP) applications for eleven proposed Reverse Osmosis (RO) desalination plants on the West Coast, the Cape Peninsula and in False Bay. Advisian contracted Anchor Environmental Consultants (Pty) Ltd (Anchor) to summarise available information on marine and coastal habitats and species assemblages that may be affected by brine effluent discharge at each site, to assess potential environmental impacts on these communities, to identify measures to mitigate identified impacts as appropriate, and to design an environmental monitoring programme that can confirm compliance with legislative requirements.

Effluent dispersal

The proposed RO plants will obtain seawater from offshore marine waters and will discharge concentrated brine effluent through existing pipeline infrastructure where possible. The water will pass through a pre-treatment process to remove suspended solids and other matter, then through membranes to separate the salts from the water. Brine and backwash water will be discharged into the ocean via subtidal benthic pipelines, the design of which will be site specific. The final effluent is expected to be negatively buoyant relative to ambient and will sink to the sea bottom unless mixed with a large volume of freshwater effluent in the case of existing storm water or sewage effluent discharges.

WML Marine was contracted to model likely effluent dispersion for the proposed RO sites. US-EPA software was used to predict the geometry of and the dilution characteristics within the Recommended Mixing Zone (RMZ) for each offshore discharge scenario to determine whether the effluent is likely to comply with regional Water Quality Guidelines (WQGs) under worst-case conditions. These were identified on a case by case basis and include stagnant conditions and extreme events. Secondary offshore dilutions and surf-zone discharges were assessed using the Brooks analytical method (Brooks 1960). Dispersal modelling results indicated that dilution is likely to be acceptable for offshore pipelines (Green Point and Hout Bay) as well as for inshore discharges (Strandfontein and Monwabisi) for average sea conditions. Modelling results for the remaining sites are still pending.

Receiving environment

There are six identified habitat types associated with the thirteen different RO plant options, including sandy beaches, subtidal sandy benthic habitat, rocky reefs, rocky intertidal, pelagic habitat and artificial habitat. Of particular importance is the presence of a resident population of Heaviside's dolphins at Granger Bay and a breeding population of African penguins near Simons Town.

According to the National Biodiversity Assessment or NBA (Sink *et al*. 2012), the ecosystem threat status analysis classified close to 50% of the inland buffer zone along the South African coastline as 'endangered' (i.e. ecosystems have lost a significant amount of their natural habitat and a significant deterioration in ecological condition, structure and function has been experienced), the nearshore environment as 'critically endangered' (i.e. very little habitat is left in good ecological condition), and the offshore environment as 'least threatened' (i.e. ecosystem in good ecological condition).

As the NBA assessed the vulnerability of the coastline at a very broad national scale, the habitats were also assessed through sites visits and Google Earth imagery as part of this study. The southern African shoreline consists of approximately 25% rocky shore, 40% sandy beach, and 30% mixed shore (sand on the upper shore, above a wave-cut rocky platform) (Griffiths *et al*. 2010). Rocky shores comprise approximately 20% of the shoreline habitat along the Western side of the peninsula and approximately 25% within False Bay. False Bay is considered more biodiverse and species rich than the West Coast of South Africa, while the West Coast typically has greater biomass and productivity (Griffiths *et al*. 2010). Baseline studies are scant for both areas, with the last comprehensive published survey of False Bay conducted by Field (1970, 1971). Few invertebrate species are rare or vulnerable locally or even regionally, with the exception of abalone (*Haliotis midae*). Sandy beach habitat makes up approximately 80% of total shoreline habitat in the West Coast section of the study area and approximately 75% within False Bay. Subtidally, sandy benthic habitats are generally not as diverse as offshore rocky reefs; however, they do host an assemblage of species not found in rocky areas. The majority of offshore habitat within False Bay consists of subtidal sandy benthic communities with scattered patches of reef, while offshore reef is common along the West Coast between Table Bay and Llandudno. Soft bottom habitats adjacent to rocky reef communities are generally more diverse than areas consisting solely of sand.

Existing beneficial uses

The proposed West Coast outfalls are located in close proximity to Blue Flag beaches and other popular recreation sites (e.g. picnic facilities, parking areas, ablutions, paved walkways, children's entertainment areas, safe swimming areas, recreational shore and boat angling sites, camping facilities, surfing spots) and important commercial and subsistence fishing areas (West Coast rock lobster fishery, line fishing, trek netting, shore angling etc.).

The Port of Cape Town is a working harbour, which handles cargo and provides ship maintenance and repair services. It houses the Royal Cape Yacht Club and supports fish processing units, which receive the catches of deep-sea fishing vessels on a regular basis. The V&A Waterfront retail and entertainment complex, the Two Oceans Aquarium and sites of historical and cultural value such as the Robben Island Museum, draw large crowds of people to the area and boost tourism. Seawater abstracted directly out of the Port is used for cooling of the Clocktower Precinct, while Victoria Basin seawater is used by the Two Oceans Aquarium for the upkeep of the marine fauna and flora exhibits. The Granger Bay Marina is used as a boat launch site by the Two Oceans Aquarium, recreational boaters, yachtsmen, kayakers, boat building companies, Air Sea Rescue (NSRI ASR) and the CPUT Survival Training Centre; while the Oceanic Power Boat Club (OPBC) launch site is heavily utilised by a wide range of user groups including commercial fishing boats, recreational boaters and jet skis, researchers, kayakers, diving charters, film industry vessels and emergency services such as Police, NSRI and the SA Navy.

Hout Bay Harbour supports a wide range of industrial activities with commercial fishing vessels (i.e. purse seiners, long lining vessels and lobster traps) making up the majority of harbour users. Leisure and recreational users include charter fishing, yachting, scuba diving and seal island boat trips; while the sheltered bay environment provides an area for a range of recreational activities including swimming, sea kayaking, stand-up paddle (SUP) boarding and dingy sailing. Other recreational activities include recreational fishing, snorkelling and SCUBA diving. The cliff roads around the Bay (specifically Chapman's Peak) are highly valued by tourists and locals for their aesthetic quality and are an important drawcard for local and international tourists.

False Bay is positioned close to the international tourist destination of Cape Town and its satellite towns and townships, and the area is heavily utilised for tourism. Ecotourism and eco-sport tourism activities are prevalent, and include SCUBA dive operators, kayak tours, high speed and environmental boat charters, boat based whale watching, and white shark cage diving. All of these activities promote the sustainable use of the Bay's marine resources and generate income through job creation. Large numbers of recreational water users (e.g. surfers, divers, bathers, sailors, etc.) and consumptive marine resource users (commercial, small-scale and recreational) form part of the diverse coastal society that makes up the False Bay community. The beach and tidal pools of Monwabisi, Harmony Park and Strandfontein are extremely important recreational areas for the local communities and surrounds in terms of beach access, bathing, recreational fishing, surf angling and subsistence trek net fishing. The sites offer parking, safe bathing, lifeguards, disability access, picnic and braai facilities, as well as dog walking areas. Recreational activities in the area include SCUBA diving and recreational fishing, surfing, kayaking, sailing and boating.

Impact assessment

This project assesses the potential impacts of the construction of temporary, emergency RO plants and the likely effects of short-term brine discharges from the operation of these RO plants. Temporary water relief solutions currently being considered include containerised RO plants and Seawater Reverse Osmosis Systems housed either on offshore SWRO vessels or on moored barges. Impacts will be dependent on the type of outfall, thus RO site options were grouped into three categories: 1) offshore outfalls, 2) harbour outfalls, and 3) surf zone/mixed habitat outfalls.

Potential impacts during the construction phase and the decommissioning phase (if relevant) include the disturbance of intertidal and subtidal habitat, the mobilisation of benthic sediment, coastal and marine pollution, spillage of harmful chemicals, and impacts of increased noise and vibration. Before mitigation, identified impacts ranged from 'medium' to 'insignificant'. After the implementation of recommended mitigation, risks will likely have a 'low' to 'insignificant' effect on the environment (Table 1.1).

Table 1.1 Construction/decommissioning phase impacts before and after the implementation of recommended mitigation.

Construction/decommissioning phase impact	Offshore	Harbour	Mixed habitat	After mitigation
Impact 1: Disturbance of intertidal habitat	VERY LOW	INSIGNIFICANT	LOW	Not required
Impact 2: Disturbance of subtidal habitat	VERY LOW	VERY LOW	VERY LOW	Not required
Impact 3: Mobilisation of benthic sediment	INSIGNIFICANT	n/a	INSIGNIFICANT	Not required
Impact 4: Disposal of solid waste	MEDIUM	MEDIUM	MEDIUM	LOW
Impact 5: Hydrocarbon spills	VERY LOW	INSIGNIFICANT	LOW	INSIGNIFICANT
Impact 6: Noise and vibrations	INSIGNIFICANT	INSIGNIFICANT	INSIGNIFICANT	Not required

During the operational phase, the following impacts were identified as being of concern: mortality of marine life due to seawater intake (entrainment and entrapment); sediment scouring and shifts in sediment movement patterns; reduced physiological functioning due to elevated salinity, elevated temperature, decreased dissolved oxygen and reduced pH; the discharge of co-pollutants in backwash water; and the displacement of recreational users. Identified impacts associated with RO plant operation ranged from 'medium to 'insignificant' before mitigation and 'low' to 'insignificant' after mitigation.

Table 1.2 Operational phase impacts before and after the implementation of recommended mitigation.

Operational phase impact	Offshore	Harbour	Mixed habitat	After mitigation
Impact 1: Seawater intake	VERY LOW	VERY LOW	LOW	VERY LOW
Impact 2: Sediment movement	LOW	n/a	MEDIUM	INSIGNIFICANT
Impact 3: Increased salinity	VERY LOW	MEDIUM	MEDIUM	VERY LOW
Impact 4: Elevated temperature	INSIGNIFICANT	INSIGNIFICANT	INSIGNIFICANT	Not required
Impact 5: Decreased dissolved oxygen	INSIGNIFICANT	INSIGNIFICANT	INSIGNIFICANT	Not required
Impact 6: Pollutants in co-discharge	LOW	MEDIUM	MEDIUM	VERY LOW
Impact 7: Reduced pH	VERY LOW	VERY LOW	VERY LOW	Not required
Impact 8: Recreational users	n/a	n/a	LOW	Not required

Mitigation

The City of Cape Town has been granted an exemption from the requirements of the NEMA and the EIA regulations for the installation of emergency desalinisation plants owing to the fact that the Western Cape has been declared a disaster area due to the prevailing drought. This notwithstanding, the City of Cape Town is still bound by the duty of care principal contained in NEMA (Chapter 7, Part 1 "Heading" amended by Section 2 of Act 46 of 2003) and every effort should be made to mitigate potential impacts on the environment associated with the installation and operation of these emergency desalination plants. Recognising that these plants will need to be installed as rapidly as possible, full consideration of potential impacts and possible mitigation may not be possible prior to installation. Thus, it is strongly recommended that an adaptive management approach is followed and that the effects of the project are very carefully monitored to mitigate any emerging negative impacts as they come to light. This will require detailed and comprehensive monitoring in the receiving environment and willingness on the part of the applicant to implement additional or new mitigation measures if required. Provisional recommendations designed to mitigate likely environmental impacts that have been identified at this stage are summarised below.

Mitigation measures related to the construction phase require the development of an Environmental Management Plan (EMP). To minimise the chances of the effluent from the RO plants from forming a dense brine layer over the seafloor, a diffuser should be positioned at least 1 m from the seafloor at the end of each outfall pipe and angled upwards. This will assist in rapid dilution during the jet plume stage of mixing. As dilution increases with depth, deeper outfalls are preferable; however; construction and maintenance costs may become prohibitive. Careful consideration of the trade-offs between minimising impacts on the environment and other beneficial uses thereof and project costs will be important. From an environmental perspective, it is generally accepted that the minimum requirement for an outfall of this nature is for the discharge to be positioned beyond the surf zone. This is to protect against retentive circulation, which may result in the effluent moving back towards the shore or being retained within the nearshore zone.

However, at the Strandfontein and Monwabisi sites, the emergency situation may justify the discharge of effluent into the surf zone as a short term, emergency measure for **Phase 1** (a guaranteed 2Ml/day)**, provided that the duration is kept to a minimum (< six months), the footprint is small (< 1 km) and the discharge volumes do not exceed the modelled brine dispersal results for Phase 1.** Careful, intense monitoring will be of crucial importance to ensure that these requirements are met. The effluent discharge pipeline must be extended beyond the surf zone to cope with the increased brine volumes of proposed for **Phase 2** (a guaranteed 7Ml/day).

As no limits currently exist for RO anti-scalant compounds or for coagulants, the use of these substances should be limited as far as possible, at least until toxicity testing has been completed. While cleaning-in-place chemicals are only likely to be used in small quantities and infrequently (frequency not specified by client), these chemicals may be harmful to marine life and must be used sparingly. Should it not be possible to implement the essential mitigation measures discussed in this report, the 'no-development' option must be followed.

Monitoring

A Coastal Water Discharge Permit (CWDP) is required for marine outfalls of this type. Dispersion modelling is used to determine whether the effluent is likely to meet Water Quality Requirements (WQRs) at the edge of the Recommended Mixing Zone (RMZ). The RMZ is an administrative construct which defines a limited area or volume of the receiving water where the initial dilution of a discharge is allowed to occur. In practice, it may occur within the near-field or far-field of a hydrodynamic mixing process and depends on source, ambient, and regulatory constraints.

Compliance monitoring is required as part of a CWDP and is specific to the permit conditions. Two concurrent methods of monitoring are recommended for each RO plant: 1) monitoring of effluent just before discharge into the marine environment (also referred to as end of pipe monitoring), and 2) monitoring at the edge of the Recommended Mixing Zone (RMZ).

For compliance, it is recommended that weekly and monthly monitoring of the effluent is performed before discharge to minimise environmental impacts. These data must be submitted to DEA: Oceans and Coasts on a monthly basis along with pump capacity records. These will be used to ensure that each plant is not operating above maximum permit capacity. In addition, samples must be analysed by an independent, accredited external auditor every six months and reports must be submitted to DEA biannually. These data will be available for analysis for future water quality studies. If discharged effluent exceeds the end of pipe values at any time, the operation will be in violation of the CWDP and the cause of poor effluent quality must be identified, reported and rectified immediately.

Toxicity testing of RO plant effluent to determine minimum acceptable dilution must be undertaken for a full range of operational scenarios (i.e. shock-dosing) to ensure complete confidence in the potential effects of co-discharged constituents and anti-scalants. As waste brine may contain low amounts of heavy metals that tend to accumulate in sediments, it is recommended that the effluent be monitored once annually for heavy metals and results compared to the end of pipe GDA limits.

A monitoring program at the edge of the RMZ should be implemented to determine compliance with WQGs. This can be achieved by mooring data logging instruments (CTDs) 1 m above the ocean bottom at the edge of the RMZ surrounding each outfall that can record conductivity, temperature, dissolved oxygen, total suspended solids (TSS), pH and depth. This will enable the determination of ambient water quality as well as assist with determining whether or not WQGs are being met at the edge of the RMZ in terms of the parameters listed above. The CTDs should initially be moored at the edge of the RMZ for one month prior to brine discharge to obtain baseline data. Data should then be collected for two month period during full RO plant operation. In the event that salinity is above 36 PSU or DO levels are depressed by more than 20% from the pre-start baseline, monitoring should continue for at least another month during which the rate of brine discharge should be reduced until these limits are no longer exceeded.

In order to better understand and predict the impacts of desalination effluent on the marine environment, a structured Before-After/Control-Impact (BACI) monitoring programme is recommended. Firstly, a baseline study covering the affected marine habitats (rocky intertidal, sandy beach, surf zone, sandy subtidal and subtidal reef) at each discharge site should be conducted using standard sampling techniques. These assessments should be repeated after approximately six months of full operation of the RO plant and a comparison study made between the two data sets.

In addition to surveying the marine biota, a range of water quality parameters should be monitored over a period of at least three months. This should be undertaken during three separate field trips where water column profiling for physico-chemical water quality parameters is undertaken (conductivity, temperature, dissolved oxygen, turbidity and pH) and surface and bottom water samples are collected from a boat using a Niskin bottle. Water samples should be submitted to an accredited analytical laboratory for analysis of trace metals (As, Cd, Cu, Cr, Fe, Hg, Ni, Mn, Pb, Zn) and for any biocides and CIP chemicals that are used in the plant(s). Water column profile measurements and water samples should be collected from a suite of sites extending from the edge of the RMZ inwards towards the outfall. Samples of sediment and bivalve (mussel) tissue should also be collected from strategic locations surrounding the outfall and should be tested for the same suite of trace metals as for the water samples.

If the results indicate that the species richness and abundance of biota at stations at the edge of the RMZ are within 80% of those recorded during the baseline, and that salinity is not elevated nor oxygen levels depressed by more than 20% from the baseline 100 m from the discharge point, no further surveys should be required. However, if the change in the biotic communities, particularly in sensitive or ecologically significant habitats, exceeds 80% and/or water quality changes are evident beyond the edge of the RMZ, monitoring surveys should be repeated at six monthly intervals and consideration should be given to reducing the volume of brine production, blending additional seawater into the effluent prior to discharge, or modifying the design of the outfall (e.g. extending the length of the discharge pipe).

GLOSSARY

Alien species	Species that become established in areas outside their natural, native range.
Amphipod/a	Crustaceans with no carapace and a laterally compressed body
Anaerobic bacteria	Unicellular organisms that do not require oxygen to function
Annelid/a	Segmented worms including earthworms, leeches, and a large number of mostly marine worms known as polychaetes.
Anthropogenic	Environmental pollution originating from human activity
Arthropod/a	An arthropod is an invertebrate animal with an exoskeleton, a segmented body and jointed appendages. Arthropods form the phylum Arthropoda, which includes crustaceans.
Ascidian	Primitive chordates resembling sac-like marine filter feeders, also known as sea squirts.
Avifauna	The birdlife of a particular region or habitat.
Baseline	Information gathered at the beginning of a study which describes the environment prior to development of a project and against which predicted changes (impacts) are measured.
Benthic	Pertaining to the environment inhabited by organisms living on or in the ocean bottom
Biodiversity	The variety of plant and animal life in a particular habitat.
Biological monitoring survey	A scientific study of organisms to assess the condition of an ecological resource, involving the collection and analysis of animal and/or plant samples which serve as indicators to the health/recovery of an affected system.
Biota	Living organisms within a habitat or region
Biomass	The mass of living biological organisms in a given area or ecosystem.
Bioregion	A region defined by characteristics of the natural environment rather than by man-made divisions.
Blue Flag beach	An internationally recognised accreditation initiative that acknowledges excellence in maintaining the highest standards of environmental management, safety, services and amenities at beaches.
Brachiostoma	Lancelets are small eel-like animals. They are close relatives of vertebrates and belong to the family Branchiostomidae.
Chart datum	Chart Datum is level on the shore corresponding with the Lowest Astronomical Tide (LAT) as from 1 January 2003.
Chordata	The phylum Chordata contains all animals that possess, at some point during their lives, a hollow nerve cord and a notochord, a flexible rod between the nerve cord and the digestive track.
Copepod	A group of small crustaceans found in the sea and nearly every freshwater habitat. Some species are planktonic (drifting in the water column), while some are benthic (living on the ocean floor).
Construction phase	The stage of project development comprising site preparation as well as all construction activities associated with the development.
Crinoid	Feather stars belong to the phylum Echinodermata. As juveniles, they are attached to the sea bottom by a stalk with root-like branches. In the adult stage, they break away from the stalk and move about freely.
Coralline	Corallines are red algae in the order Corallinales. They are characterized by a thallus that is hardened by calcareous deposits contained within the cell walls.

Crustacea/n	Generally differ from other arthropods in having two pairs of appendages (antennules and antennae) in front of the mouth and paired appendages near the mouth that function as jaws.
Cumulative impacts	Direct and indirect impacts that act together with current or future potential impacts of other activities or proposed activities in the area/region that affect the same resources and/or receptors.
Diatom	A major group of algae that makes up the most common type of phytoplankton. Most are unicellular but they can group together to form colonies.
Dinoflagellate	A large and diverse group of unicellular protists, most of which are marine, and that can either be free-living in the plankton, or benthic.
Dissipative beach	Waves break further offshore and lose energy (dissipate) across the wide surf zone. At a dissipative beach high waves and a wide surf zone restrict most bathers to the inner swash zone.
Dolos	Concrete blocks of a complex geometric shape weighing up to 20 tons, used in great numbers to protect harbour walls from the erosive force of ocean waves.
Echinoderm/ata	Marine invertebrates with fivefold radial symmetry, a calcareous skeleton and tube feet (e.g. starfishes, sea urchins, sea cucumbers)
Echiuroids	Spoon worms
Elasmobranchs	Sharks, skates and rays
Encrusting algae	A type of coralline algae that grows in low carpets on rocky shores.
Endemicity /endemism	A species unique to a defined geographic location. Organisms that are indigenous to an area are not endemic if they are found elsewhere.
Environment	The external circumstances, conditions and objects that affect the existence of an individual, organism or group. These circumstances include biophysical, social, economic, historical and cultural aspects.
Environmental Authorisation	Permission granted by the competent authority for the applicant to undertake listed activities in terms of the NEMA EIA Regulations, 2014.
Environmental Impact Assessment	A process of evaluating the environmental and socio-economic consequences of a proposed course of action or project.
Environmental Management Programme	A description of the means (the environmental specification) to achieve environmental objectives and targets during all stages of a specific proposed activity.
Epibiotic	An organism that lives on the surface of another living organism without causing harm to its host.
Epiphyte	An organism that grows on the surface of a plant.
Farfield	The region of the receiving water where buoyant spreading motions and passive diffusion control the trajectory and dilution of the effluent discharge plume.
Faunal community	A naturally occurring group of native animals that interact in a unique habitat.
Gastropod/a	Molluscs (e.g. snails and slugs)
Groyne	A low wall or sturdy timber barrier built out into the sea from a beach to reduce erosion and drifting.
Harmful Algal Blooms	HABs (or ‘red tides’) occur when colonies of algae proliferate under favourable conditions. They may result in toxic or harmful effects on people, fish, shellfish, marine mammals and birds.
High shore	The section of the intertidal zone reaching from the extreme high water spring tide to the mean high water neap tide.
Hydroid	Colonial coelenterates (i.e. jellyfish, corals, sea anemones) having a polyp rather than a free-swimming form as the dominant stage of their life cycle.
Ichthyoplankton	The eggs and larvae of fish, which are usually found in the sunlit zone of the water

	column (epipelagic/photic zone).
Impact	A change to the existing environment, either adverse or beneficial, that is directly or indirectly due to the development of the project and its associated activities.
Important Bird and Biodiversity Area (IBA)	An area identified using an internationally agreed set of criteria as being globally important for the conservation of bird populations. The program was developed and sites are identified by BirdLife International. Currently there are over 12 000 IBAs worldwide.
Inert	Unreactive or non-threatening
Intertidal zone	The section of the marine environment that lies exposed at low tide and submerged at high tide.
Infauna	The assemblage of organisms inhabiting the seafloor.
Invasive species	Alien species capable of spreading beyond the initial introduction area and have the potential to cause significant harm to the environment, economy or society.
Invertebrate	An animal without a backbone (e.g. a starfish, crab, or worm)
Lethal concentration (LC_{50})	A standard measure of the toxicity of the surrounding medium that will kill half of the sample population of a specific test-animal in a specified period through exposure via inhalation (respiration).
Lipophilic	Mix more easily with oil than water.
Liquefaction	Saturated sediment substantially loses strength in response to an applied stress, causing it to behave like a liquid.
Longshore current/drift	The movement of material along a coast by waves that approach at an angle to the shore but recede directly away from it.
Low shore	The section of the intertidal zone reaching from the mean low water neap tide to the extreme low water spring tide.
Macrofauna	Animals larger than 0.5 mm.
Macroscopic	Visible to the naked eye.
Marine Protected Area	An area of sea and coastline that is dedicated to the protection of biodiversity and natural and cultural resources and is managed in a structured and legal manner. Different levels of MPAs exist, ranging from complete no-take zones (where nothing may be disturbed, caught or removed) to partial-take MPAs which have a suite of regulations that determine what activities may take place in which zone.
Meiofauna (meiobenthos)	Small benthic invertebrates that are larger than microfauna but smaller than macrofauna.
Microscopic	So small as to be visible only with a microscope.
Microtidal	A term applied to coastal areas in which the tidal range is less than 2 m.
Mitigation measures	Design or management measures that are intended to minimise or enhance an impact, depending on the desired effect. These measures are ideally incorporated into a design at an early stage.
Mixing zone	An administrative construct which defines a limited area or volume of the receiving water where the initial dilution of a discharge is allowed to occur, until the water quality standards are met. In practice, it may occur within the nearfield or farfield of a hydrodynamic mixing process and therefore depends on source, ambient, and regulatory constraints.
Mollusc/a	Invertebrate with a soft unsegmented body and often a shell, secreted by the mantle.
Nearfield	The region of a receiving water where the initial jet characteristic of momentum flux, buoyancy flux and outfall geometry influence the jet trajectory and mixing of an effluent discharge.

Nearshore	Zone extending seawards of Chart Datum to a point where the seabed is less than 10 m depth at Chart Datum, or the distance offshore from Chart Datum is less than 500 m, whichever is greater.
Negative buoyancy	The measure of the tendency of an effluent discharge to sink in a receiving water body.
No-take zone	A type of MPA where no fishing is allowed
Offshore	The area seaward of the nearshore environment boundary.
Operational phase	The stage of the works following the Construction Phase, during which the development will function or be used as anticipated in the Environmental Authorisation.
Ophiurida	An order of echinoderms known as the brittle stars.
Pelagic	Within the water column.
Phytoplankton	Ocean dwelling microalgae that contain chlorophyll and require sunlight in order to live and grow.
Polychaete (Polychaeta)	Segmented worms with many bristles (i.e. bristle worms).
Population fragmentation	A form of population segregation often caused by habitat fragmentation and may lead to a decrease in genetic variability.
Red tide	See 'Harmful Algal Blooms'.
Regulatory Mixing Zone (RMZ)	An administrative construct which defines a limited area or volume of the receiving water where the initial dilution of a discharge is allowed to occur, until the water quality standards are met. In practice, it may occur within the near-field or far-field of a hydrodynamic mixing process and therefore depends on source, ambient, and regulatory constraints. The following recommendations have been tabled for South Africa (Anchor Environmental Consultants 2015): 300 m in an offshore environment, 100 m in a nearshore open coast environment, 30 m in sheltered coastal environments and special management areas, 0 m for outfalls in established or proposed MPAs, the surf zone and estuaries
Revetment	A retaining wall or facing of masonry or other material, supporting or protecting a wall or other structure.
Rotifer	Small zooplankton that occur in freshwater, brackish, and marine environments and feed on microalgae.
Semi-diurnal tides	When there are two high tides and two low tides within a day that are about the same height,
Site fidelity	A species with high site fidelity is likely to occupy a single home range, with limited movement beyond the boundaries of that site. Birds returning to the same location to breed, year after year also have high site fidelity.
South African Sustainable Seafood Initiative (SASSI)	In 2004, the World Wide Fund for Nature (WWF) established the South African Sustainable Seafood Initiative (SASSI) to inform and educate all participants in the seafood trade, from wholesalers to consumers, about sustainable seafood. By using a colour-coded system, the SASSI list categorises selected South African and imported seafood species according to their conservation status.
Scoping	A procedure to consult with stakeholders to determine issues and concerns and for determining the extent of and approach to an EIA and EMP (one of the phases in an EIA and EMP). This process results in the development of a scope of work for the EIA, EMP and specialist studies.
Specialist study	A study into a particular aspect of the environment, undertaken by an expert in that discipline.
Species	A category of biological classification ranking immediately below the genus, grouping related organisms. A species is identified by a two part name; the name of the genus

	followed by a Latin or Latinised un-capitalised noun.
Species richness	The number of different species represented in an ecological community. It is simply a count of species and does not take into account the abundance of species.
Stakeholders	All parties affected by and/or able to influence a project, often those in a position of authority and/or representing others.
Subtidal	The marine habitat that lies below the level of mean low water for spring tides.
Supratidal	The area above the spring high tide mark that is not submerged by seawater. Seawater penetrates these elevated areas only at high tide during storms.
Surficial sediments	Calculated conservatively as the upper 20 cm of sediment for the purposes of offshore disposal.
Surf zone	Zone extending seawards of the high water mark to a point where the largest waves begin to break, off any section of coast defined as “sandy coast” or “mixed coast” on the National Coastline Layer, available from the South African National Biodiversity Institute’s BGIS website (http://bgis.sanbi.org).
Trophodynamics	The dynamics of nutrition and metabolism.
Wind forcing	The movement of surface waters and the resulting transfer of energy to deeper waters by the predominant wind (i.e. a strong easterly wind will result in an eastward flowing surface current).

LIST OF ABBREVIATIONS

ADCP	Acoustic Doppler Current Profiler
Anchor	Anchor Environmental Consultants
BA	Basic Assessment
BACI	Before-After/Control-Impact
BCS	Benguela Current System
BMSL	Below Mean Sea Level
CoCT	City of Cape Town
CDOM	Coloured dissolved organic matter
CIP	Clean In Place
CSIR	Council for Scientific and Industrial Research
CTD	Conductivity, temperature, depth
CWDP	Coastal Water Discharge Permit
DEA: O&C	Department of Environmental Affairs: Oceans and Coasts
DDT	Dichlorodiphenyltrichloroethane
DEAT	Department of Environmental Affairs and Tourism
DO	Dissolved Oxygen
EA	Environmental Authorisation
EDTA	Ethylenediaminetetraacetic acid
EIA	Environmental Impact Assessment
EMPr	Environmental Management Programme
ERL	Effects Range Low
ERM	Effects Range Median
GA	General Authorisation
GDA	General Discharge Authorisation
H_2SO_4	Sulphuric acid
HABs	Harmful Algal Blooms
IBA	Important Bird and Biodiversity Area
ICMA	Integrated Coastal Management Act (No. 24 of 2008)
IEM	Integrated Environmental Management
IUCN	International Union for Conservation of Nature
LC_{50}	Lethal concentration 50%
LOEC	Lowest Observed Effective Concentration
MDC	Marine Data Consultants
MIA	Marine Impact Assessment
MPA	Marine Protected Area
MSL	Mean Sea Level
NBA	National Biodiversity Assessment
NAL	National Action List
NEMA	National Environmental Management Act (No. 107 of 1998, as amended)
NOAA	National Oceanic and Atmospheric Administration

NOAC	No Observed Effect Concentration
NWA	National Water Act (No. 36 of 1998)
OPBC	Oceana Power Boat Club
PAH	Poly-aromatic hydrocarbon
PNEC	Predicted No Effect Concentration
RMZ	Recommended Mixing Zone
RO	Reverse Osmosis
RWQ	Receiving Water Quality
SASSI	South African Sustainable Seafood Initiative
SLS	Sodium lauryl sulphate
STPP	Sodium tripolyphosphate
TMNP	Table Mountain National Park
TOC	Total Organic Carbon
TRC	Total Residual Chlorine
TSP	Trisodium phosphate
TSS	Total Suspended Solids
UES	Uniform Effluent Standard
WCRL	West Coast Rock Lobster
WML	Waste Management Licence
WQBEL	Water Quality Based Effluent Limits
WQG	Water Quality Guidelines
WUA	Water Use Authorisation
WWTW	Waste Water Treatment Works
V&A Waterfront	Victoria & Alfred Waterfront

1 INTRODUCTION

1.1 Project background

Advisian: WorlyParsons Group (WSP) was appointed by the City of Cape Town (CoCT) to prepare Coastal water Discharge Permit (CWDP) applications for eleven proposed Reverse Osmosis (RO) desalination plants on the Cape West Coast and within False Bay on the Cape Peninsula (Figure 1.1). Advisian contracted Anchor Environmental Consultants (Pty) Ltd (Anchor) to summarise available information on marine and coastal habitats and species assemblages that may be affected by brine effluent discharge at each site and to assess potential environmental impacts on these communities.

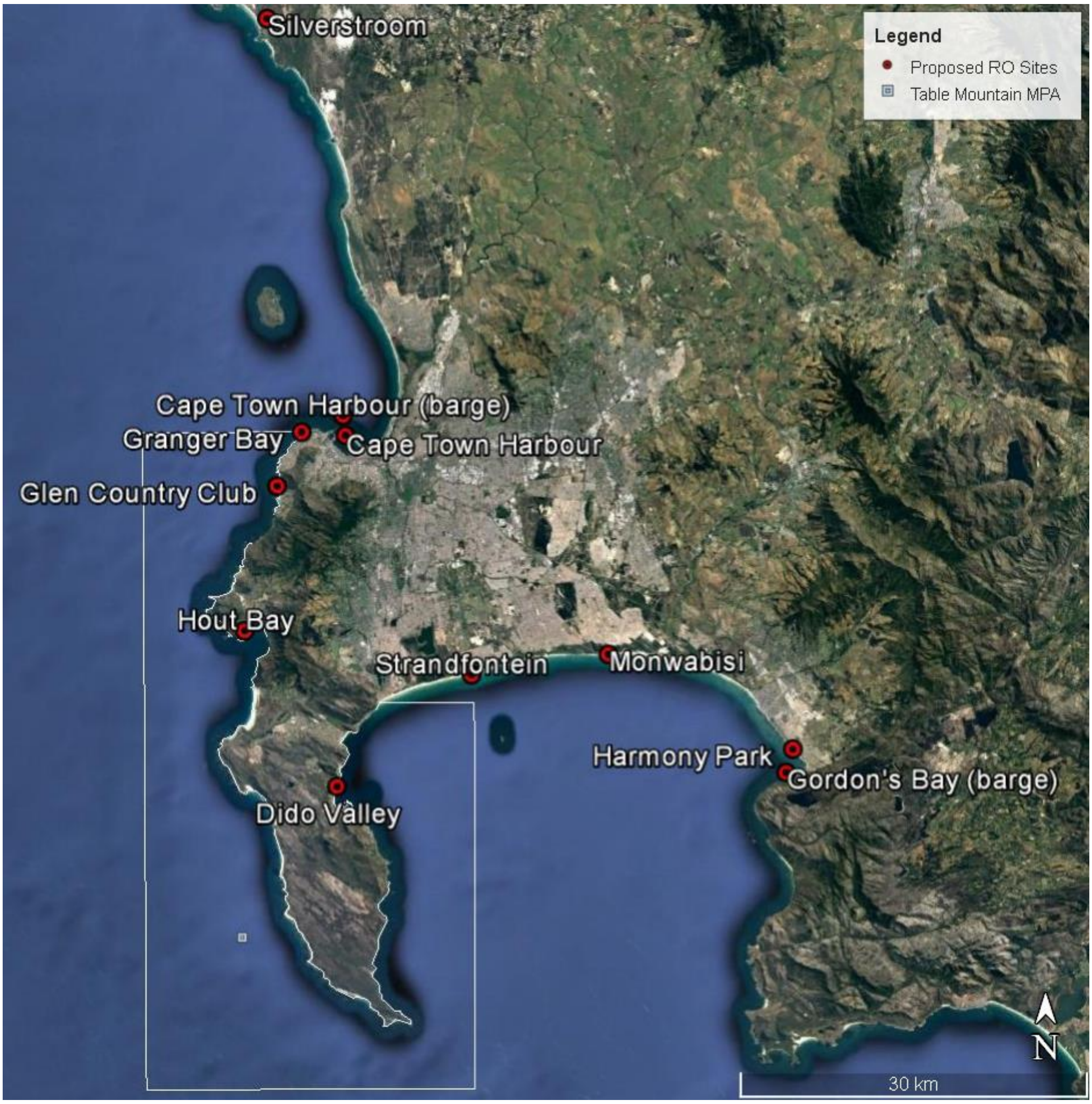

Figure 1.1 Location of the proposed temporary emergency CoCT RO plants (Google Earth 2017). The white line indicates the extent of the Table Mountain National Park Marine Protected Area (MPA).

The proposed RO plants will obtain seawater from offshore marine waters and will discharge concentrated brine effluent through existing pipeline infrastructure where possible. The water will pass through a pre-treatment process to remove suspended solids and other matter, then through membranes to separate the salts from the water. Brine and backwash water will be discharged into the ocean via subtidal benthic pipelines, the design of which will be site specific. The final effluent is expected to be negatively buoyant relative to ambient and will sink to the sea bottom unless mixed with a large volume of freshwater effluent, in the case of storm water or sewage effluent.

WML Marine was contracted to model likely effluent dispersion for the proposed RO sites. US-EPA software was used to predict the geometry of and the dilution characteristics within the Recommended Mixing Zone (RMZ) of each offshore discharge scenario to determine whether the effluent is likely to comply with regional Water Quality Guidelines (WQGs) under worst-case conditions. These were identified on a case to case basis and include stagnant conditions and extreme events. Secondary offshore dilutions and surf-zone discharges were assessed using the Brooks analytical method (Brooks 1960). Dispersal modelling results indicated that dilution is likely to be acceptable for offshore pipelines (Green Point and Hout Bay) as well as for inshore discharges (Strandfontein and Monwabisi) for average sea conditions. Modelling results for the remaining sites are still outstanding.

Table 1.1 Position of proposed outfall sites for the CoCT RO Plants.

Site	Approximate outfall distance offshore (m)	Approximate discharge depth (m)	Max discharge of RO plant effluent (ML/day)	Current wastewater discharge (ML/day)	Latitude	Longitude
Silwerstroomstrand	28	0	Unknown	n/a	33° 35.421' S	18° 21.576' E
Table Bay (barge)	Unknown	Unknown	Unknown	n/a	33° 53.271' S	18° 26.211' E
Port of Cape Town	10	Unknown	Unknown	n/a	33° 55.126' S	18° 26.958' E
Green Point	1 570	28	10	25	33° 53.272' S	18° 23.457' E
Glen Country Club	548	Unknown	Unknown	Unknown	33° 56.706' S	18° 21.908' E
Hout Bay	735	37	3.1	5	34° 04.099' S	18° 20. 736' E
Dido Valley	40	1.5	2.4 to 2.5	2.2	34° 10.646' S	18° 25.607' E
Strandfontein	170	1.5	8.6	n/a	34° 05.288' S	18° 33.513' E
Monwabisi – Phase 1	50	1.5	8.6	n/a	34° 04.372' S	18° 41.528' E
Monwabisi – Phase 2	245	Unknown	8.6	n/a	34° 04.451' S	18° 41.614' E
Harmony Park – Phase 1	245	1.5	2.4 to 2.5	n/a	34° 08.271' S	18° 50.502' E
Harmony Park – Phase 2	600	5	9.8	n/a	34° 08.380' S	18° 50.311' E
Gordon's Bay (barge)	Unknown	Unknown	Unknown	n/a	34° 09.800' S	18° 50.912' E

1.2 Terms of Reference

Advisian contracted Anchor Environmental Consultants (Pty) Ltd (Anchor) to summarise available information on marine and coastal habitats and species assemblages that may be affected by brine effluent discharge at each site, to assess potential environmental impacts on these communities, to identify measures to mitigate identified impacts as appropriate, and to design an environmental monitoring programme that can confirm compliance with legislative requirements.

Deliverables for this report include:

1. A description of the receiving environment.
2. An assessment of potential impacts on the marine ecology around the proposed pipelines.
3. Identification of appropriate and feasible mitigation measures to reduce negative impacts of project related activities on marine habitats and species in the vicinity of the maintenance site.
4. A brief outline of an appropriate monitoring programme.

2 DESCRIPTION OF THE RECEIVING ENVIRONMENT

2.1 Regional oceanography

The physical oceanography of an area, particularly water temperature, nutrients, oxygen levels, and wave exposure, are the principal driving forces that shape marine communities.

The south-western South African coastline is influenced predominantly by the cold Benguela upwelling system of the west coast which reaches as far as Cape Agulhas (Figure 2.1). However, the coastline as far west as Cape Point (and sometimes even beyond this) is also influenced by the strong-flowing Agulhas current that moves down the east coast of South Africa (Figure 2.1). The presence of the two currents is the principal reason for the diverse range of coastal and marine flora and fauna for which South Africa is famous.

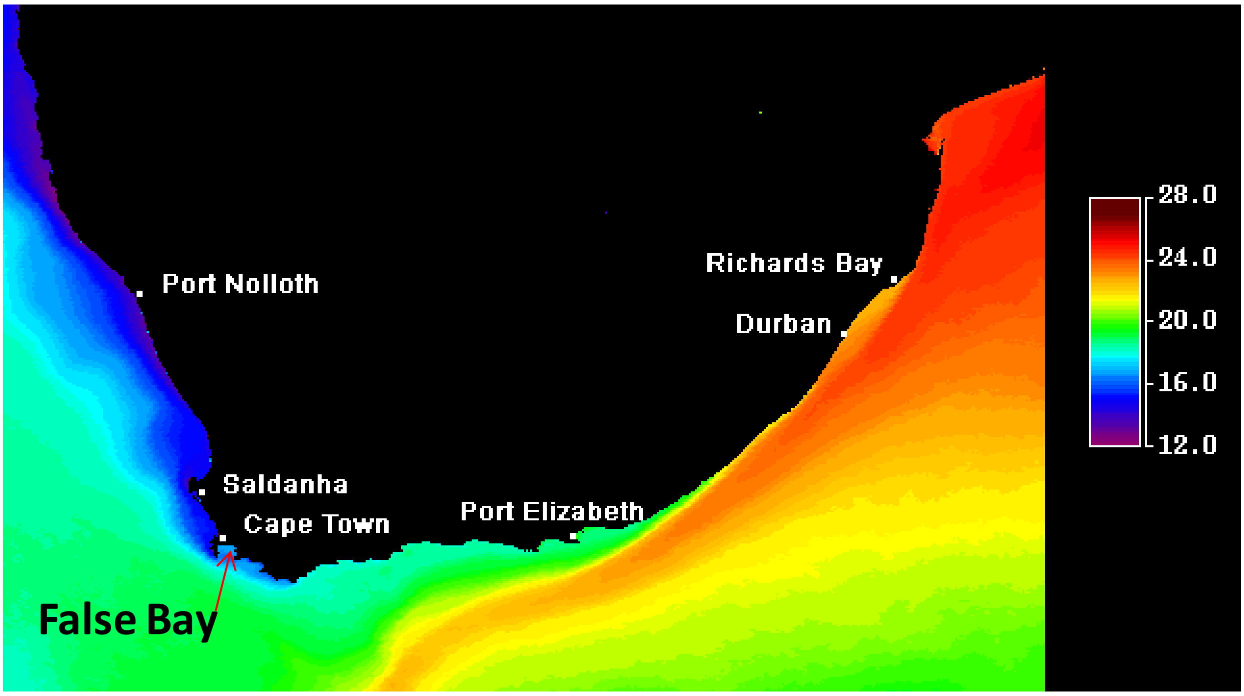

Figure 2.1 Average sea surface temperature (°C) showing the warm-water Agulhas Current moving south westerly along the coast, and the cool Benguela current up the West Coast (AquaMODIS 4km-resolution, nine-year time composite image).

The South African coastline experiences semi-diurnal tides, with each successive high (and low) tide separated by 12 hours. Each high tide occurs approximately 25 minutes later every day, which is due to the 28-day rotational cycle of the moon around the earth. Spring tides occur once a fortnight during full and new moons. Tidal activity greatly influences the biological cycles (feeding, breeding and movement) of intertidal marine organisms, and influences when people visit the coastline to partake in various activities (e.g. relax, bathe, harvest marine resources). Water depth in the nearshore zone can also be profoundly affected by tidal action, changing by as much as 1.7 m between spring low and spring high tide. Baseline salinity in the study site ranges between 33 – 36 PSU.

2.2 Regional water quality, sediment, turbidity and oxygen

2.2.1 West Coast

The CSIR has been monitoring water quality in Table Bay over the last few years as part of the Long-Term Monitoring of the Port of Cape Town (see CSIR 2017a), but there is limited water quality data available for the coastline to the north of Table Bay. Table Bay water quality is generally considered good, despite existing sources of direct contaminant and pollution, which include inputs from the Green Point and Chevron/Caltex outfalls (Monteiro 1997, CSIR 2006a, Van Ballegooyen 2007). In 2016, the overall water quality of the Port of Cape Town was classified as “fair”, despite the substantial input of storm water into the Duncan Dock and the detection of elevated bacterial concentrations. This is largely due to the fact that the effects of “raw sewage seeping into the storm water reticulation system” and ultimately flowing into the Port seemed to be localised (CSIR 2016&2017a).

Currently, the effluent discharged through the existing pipelines of Green Point, Camps Bay and Hout Bay originates from their respective Waste Water Treatment Works (WWTW) owned and operated by the City of Cape Town. This wastewater discharge has undergone limited pre-treatment, the process that removes sand, grit, plastic, paper and other foreign material, while the remaining material is macerated before discharge into the marine environment. Ongoing surface seawater sampling at the Green Point, Camps Bay and Hout Bay outfalls is conducted by CSIR as part of the existing monitoring program for the City of Cape Town (see CSIR 2017b for the latest report). The 2017 report acknowledged that water quality at the edge of the Recommended Mixing Zone (RMZ) periodically does not comply with South African Water Quality Guidelines (WQGs) for Coastal Marine Waters at these sites (DWAF 1995). This was especially prevalent at the Green Point outfall, posing risks to the health of people that are exposed to the effluent (CSIR 2017b). Furthermore, surveys for Green Point and Hout Bay showed that effluent frequently reaches the shoreline before sufficient dilution is achieved (CSIR 2017b); however, toxicity testing of surface water samples beyond the RMZ indicated that the effluent was not acutely toxic to marine life (CSIR 2017b).

Sediment analysis performed for the 2015/2016 survey of the Cape Town outfalls monitoring programme revealed that the soft sediment environment in Table Bay, Camps Bay and Hout Bay comprised largely sand (grains between 0.063 - 2.0 mm diameter) and is contaminated by particulate organic matter, metals, hydrocarbons and polychlorinated biphenyls (CSIR 2017b). Hutchings and Clark (2010) found that the concentrations of eight trace metals in sediments from two Western Cape estuaries discharging into Table Bay were above the thresholds for human and ecosystem health. Despite these findings, no link between pollutant concentration and distance from outfall was evident, making the source of contaminants inconclusive (CSIR 2017b). Total Suspended Solid (TSS) concentrations in Table Bay range between 1 mg/l and 44 mg/l (2003b), while Dissolved Oxygen (DO) concentrations were not measured. Within the Port of Cape Town, DO concentrations vary minimally through the water column during the winter as the water is well mixed, while stratification occurs during the summer (CSIR 2016).

2.2.2 False Bay

In terms of anthropogenic use, the marine environment of False Bay has long been of importance to both the commercial and subsistence fishing industry (fish and shellfish) and the South African Navy (Van der Merwe *et al*. 1991, van Ballengooyen 1991). The sandy and rocky beaches of the Bay are popular tourist areas, and the Bay is also heavily utilised for recreation and water sports (Taljaard *et al*. 2000). In addition, the Bay encompasses multiple areas of conservation importance; many of them designated and legislated (Mdzeke 2004). The quality of the water of False Bay is described as being "crucial to the development of long-term planning of pollution management strategies" and "of major importance that pollution levels be monitored to provide information for the management of the area" (Mdzeke 2004).

There are four circulation pattern types that have been described in False Bay (see Figure 2.2 from Atkins 1970). In summer, the predominant surface currents follow a bay-wide, clockwise circulation (see Type I, Figure 2.2). Type I currents develop outside the Bay through easterly and south-easterly wind forcing, and are deflected into False Bay by the prevailing south-easterly winds at Cape Point (Atkins 1970). Figure 2.2 clearly shows that during this Type I current pattern, anti-clockwise retentive gyres tend to form in the Gordon's Bay area. Type II current patterns (see Figure 2.2) occur rarely, and form as a result of strong north-westerly summer winds and an east-flowing current entering the Bay at Cape Hangklip (Atkins 1970). Types III and IV (see Figure 2.2) appear to be weak tidal forced currents, developing after a period of calm with little to no wind forcing (Atkins 1970).

Although there is limited recent data available on the water quality of False Bay, the CSIR conducted some studies of the status of pollution (CSIR 1982, 1989), as well as chemical and biological outfall impacts (CSIR 1992) in False Bay. Impact assessment studies in False Bay (Eagle 1976, Brown 1975, Bartlett and Hennig 1982) have focused mainly on the effect of individual discharges on the immediate surroundings but there is a lack of cumulative impact work (Taljaard *et al*. 2000).

Brown *et al.* (1991) investigated chemical pollution loading in False Bay, and while most outfalls investigated fell within the prescribed water quality standards of the time for effluent discharges, there were some concerns regarding:

1. the levels of Total Suspended Solids (TSS) at Monwabisi, Mitchell's Plain East (and to a lesser degree, Mitchell's Plain West);
2. phosphorous concentrations at Zeekoevlei and Eerste River;
3. NH_4-H and No_3-N at Mnandi, Strandfontein (and to a lesser degree, Eerste River and Zeekoevlei) and in the Cape Flats Aquifer which seeps into the Bay though the northern beaches;
4. the consistently high loading rates of heavy metals from Mitchell's Plain East; and,
5. lead concentrations at Mitchell's Plain East (and to a lesser degree, Monwabisi).

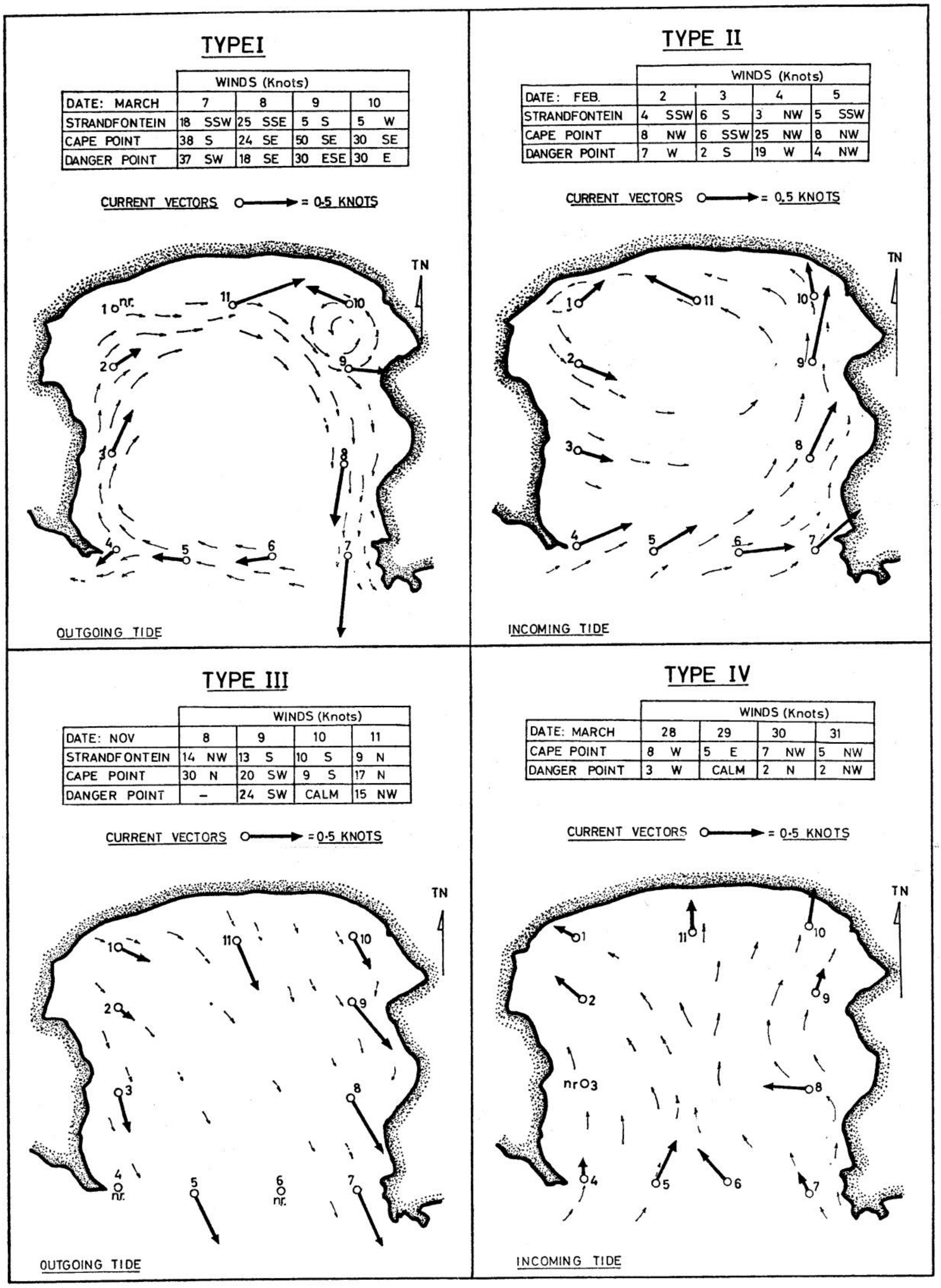

Figure 2.2. Typical surface currents in False Bay as recorded by Atkins (1970) under different wind conditions. Note the development a small gyre in Gordons Bay under Type I conditions.

6.

More recently, Day and Clark (2012) found that 30% of the City of Cape Town's 49 coastal sampling points in False Bay did not comply with intestinal *Enterococci*-based human health criteria for intermediate-contact recreation. Mdzeke (2004) analysed trace metal contaminants in False Bay and found that metals attached to sediment and dissolved in water were highest in areas within close proximity to populated and industrial catchment areas (i.e. between Strand and Muizenberg). Significant spatial variations in these contaminates indicate potential localised contamination points (Mdzeke 2004). Seasonal variability of metal concentrations is likely a result of changes in precipitation and runoff inputs into the Bay throughout the year (Mdzeke 2004). Higher accumulation levels of metals (Cd, Cu, Ni, Pb and Zn) within invertebrate tissues were found in the eastern portion of False Bay when compared to other sections of the Bay (Mdzeke 2004). The concentrations of cadmium, nickel and lead were occasionally higher than the levels recommended by the WQGs (Mdzeke 2004). Soft tissue and shell concentrations of contaminant heavy metals (Cd, Cu, Ni, Pb and Zn) in marine invertebrate tissue sampled from benthic species in False Bay (the top shells *Oxystele tigrina* and *O. sinensis*, the black mussel *Choromytilus meridionalis*, the limpet *Patella oculus,* the sea-star *Patiriella exigua* and the barnacle *Tetraclita serrata*) also showed significant seasonal and spatial variations (Mdzeke 2004). Highest cadmium concentrations were present in *T. serrata* from Rooiels (70.67 µg/g dry weight), while species from Strand had the highest copper and nickel concentrations sampled (70.25 µg/g in *O. tigrina* and 35.75 µg/g in *P. oculus,* respectively) (Mdzeke 2004). The shells of *C. meridionalis* from Muizenberg had the highest concentration of lead (25.75 µg/g) (Mdzeke 2004). When comparing metal concentrations inside and outside the Helderberg Marine Protected Area in the north eastern corner of False Bay, Sparks and Mullins (2016) found that metal contamination (Al, Mn, Cd, Cu and Fe) was similar. Conclusions were that external pollutant sources must be taken into account during the zoning of MPAs. Of particular interest, was evidence of bioaccumulation in mussels, where *Mytilus galloprovincialis* had significantly higher tissue concentrations of As, Mo, Cd, Cu and Zn than the surrounding sediment (Sparks and Mullins 2016).

2.3 Marine Protected Areas

The high levels of diversity within the marine system around the Cape Peninsula are protected by the Table Mountain National Park Marine Protected Areas (TMNP MPA) and a number of other smaller MPAs and fishery reserves, the aim of which is to "promote the conservation and effective management of biodiverse marine areas" (Cape Nature 2016). The TMNP MPA was promulgated in 2004 to ensure the sustainable use of the marine system, both commercially and recreationally. The MPA is located in a transition zone between the South-Western Cape Bioregion and the Agulhas Bioregion, an area which supports a rich diversity of marine species. The TMNP MPA includes 1 000 km^2 of sea and coastline area from Moullie Point in the north to Muizenberg in the south. While fishing is allowed in the majority of the MPA subject to permits, regulations and seasons, it includes six restricted areas, five of which are "no take" zones where no fishing or extractive activities are allowed. These restricted or "no-take" zones constitute important breeding and nursery areas for marine life, the protection of which should result in an increase in the abundance of marine stock and threatened species SANParks (2016).

On the Atlantic side of the Cape Peninsula, Table Bay falls within a rock lobster sanctuary where recreational and commercial lobster fishing is prohibited. While Robben Island is a provincial nature reserve, it has no formal MPA designation (Carter 2006). The Helderberg MPA is situated on the north-eastern side of False Bay and comprises 4 km of sandy beach, and low lying sandstone reefs which extend 500 m out to sea. The beach within the MPA is the least disturbed section of the northern shore of False Bay and supports the last relic population of the giant isopod *Tylos granulatus* south of Yzerfontein (WWF 2017). The Kogelberg Biosphere Reserve (specifically the marine buffer zone) is situated on the eastern side of False Bay and encompasses the coastal area south of Gordon's Bay to the Bot River Estuary. The Kogelberg Biosphere Reserve is not a designated MPA.

2.4 Blue Flag Status

South Africa's Blue Flag Programme is focused on the conservation of marine and coastal habitats and is recognised by the voluntary eco-label of 'blue flag status' for beaches, boats and marinas. The programme is designed to raise environmental education and awareness and increase sound environmental practices among tourists, local populations and beach management. To achieve Blue Flag status, as many as 33 different criteria spanning over four aspects of coastal management have to be met. These include specifications for water quality, environmental education, environmental management, and safety and services. The criteria are set by the international coordinators of the Blue Flag campaign in Europe, the Foundation for Environmental Education (FEE). Each Blue Flag site is compelled to conduct several environmental education activities during the year and to practice effective and efficient conservation management. In order to be awarded Blue Flag status, water quality must comply with 'excellent' water quality standards for bathing (i.e. compliance with requirements for sewage treatment and effluent quality).

During the Blue Flag season the flag must fly at the beach as an indication of compliance. The flag may only be flown during the hours when all Blue Flag criteria are met and there must be adequate signage indicating the time when services (e.g. life-saving) and facilities (e.g. toilets) are in operation.

3 AVAILABLE DATA ON INDIVIDUAL SITES

3.1 Silwerstroomstrand

Oceanography

Silwerstroomstrand is situated approximately 13 km north of Melkbosstrand and 10 km west of Atlantis on the West Coast of South Africa. The marine ecology at this site is predominantly influenced by the Benguela Current System (BCS), which extends along the eastern edge of the southern Atlantic Ocean between Cape Agulhas in South Africa, and Southern Angola. The Benguela is a cool current (10-14°C) characterised by the upwelling of cold, nutrient rich water by strong summer southerly and south-easterly winds that deflect surface water offshore and draw cold, nutrient rich water to the surface through a process called upwelling.

Marine ecology

Wind-driven coastal upwelling is the predominant physical forcing that shapes the high levels of biological productivity in the southern Benguela. It provides nutrients for primary producers and food for diverse fauna, such as pelagic (pilchard, anchovy) and demersal (hake, kingklip) fish stocks, near shore species (linefish, rock lobster, abalone), mammals (seals and whales) and seabirds (penguins, gannets, cormorants etc.). Upwelling makes the West Coast one of the richest fishing grounds in the world (Branch and Branch 1981). This high biological productivity is matched by low species richness and low endemicity. In terms of biogeography, the Silwerstroomstrand site is situated close to the southern-most limit of the Namaqua marine biogeographic region (Sink *et al.* 2012).

The intertidal rocky shore ecology and faunal communities at Silwerstroomstrand are considered representative of the greater West Coast region (Lane and Carter 1999, Branch and Griffiths 1988, McQuaid *et al.* 1985). The rocky shores of the West Coast are heavily invaded by the most invasive marine invertebrate species in South Africa, the Mediterranean mussel *Mytilus galloprovincialis*. This alien has displaced the indigenous mussel species *Aulacomya ater* and *Choromytilus meridionalis* (Hockey and Van Erkom Schurink 1992) and has substantially increased the mussel biomass along the coastline (Robinson *et al.* 2005). The higher mussel biomass and subsequent abundance of food has resulted in the recovery of black oystercatcher populations and has substantially increased the diversity and biomass of infauna within the mussel beds.

Upwelled nutrients brought to the euphotic zone support both microscopic primary producers (phytoplankton) and macroscopic algae (kelps), which occur in dense forests around the West Coast. The kelp species *Ecklonia maxima* and *Laminaria pallida* dominate the subtidal rocky reefs, while more sheltered areas allow the growth of the delicate *Macrocystis angustifolia* (Branch and Griffiths 1988). The faunal community within these kelp forests includes carnivores such as sea stars, anemones, whelks, polychaetes, crabs and rock lobster, the latter of which feeds almost exclusively upon the abundant mussels (Carter 2003). Less common are grazers and debris feeders, including sea urchins, patellid limpets, giant periwinkles, abalone, as well as isopods and amphipods (Carter 2003). The fish fauna includes the endemic hottentot *Pachymetopon blochii*, twotone fingerfin *Chirodactylus brachydactylus*, redfinger *Cheilodactylus fasciatus*, blacktail *Diplodus sargus capensis*, galjoen *Dichistius capensis*, maned blennies *Scartella emarginata*, and various klipfish, among others. The kelp forests thin out further offshore, and are replaced with faunal communities of sea urchins, filter-feeding mussels, sponges and sea cucumbers (Velimirov *et al.* 1977, Field *et al.* 1980, Branch and Griffiths 1988). Silwerstroomstrand intertidal sediment is marked by the presence of the familiar scavenging *Bullia* gastropods and adults white mussels (*Donax serra*).

Most beaches on the West Coast of South Africa are exposed to strong wave action and are typically steep and narrow with well-sorted fine to medium-sized sediments, although the steepest beaches may have coarser sand (Branch and Griffiths 1988, McLachlan *et al.* 1993). The Silwerstroomstrand beach has a moderately steep slope and is calmer and more sheltered than the typical West Coast beach. It is anticipated that Silwerstroomstrand beach faunal communities are comparable to other beaches of a similar profile along the West Coast, given that the entire Benguela region shows a remarkably consistent sandy beach fauna (Field and Griffiths 1991). Detailed community analyses for the Benguela can be found in the review by Lane and Carter (1999), as well as in Christie (1976), Bally (1983, 1987) and Branch and Griffiths (1988).

Similarly, the Silwerstroomstrand pelagic communities are likely to be typical of those found throughout the southern Benguela system. Phytoplankton communities are dominated by large celled diatoms and dinoflagellates (Shannon and Pillar 1985) and Harmful Algal Bloom (HAB) species occur episodically (Pitcher and Calder 2000). Pelagic zooplankton communities predominantly consist of crustacean copepods, while Euphausiid species are common in the nearshore (Shannon and Pillar 1985, Hutchings *et al.* 1991). Ichthyoplankton in the southern Benguela are composed mainly of fish eggs and larvae of small pelagic anchovy and sardine, as well as hake and mackerel (Shannon and Pillar 1985). Nearshore fish species include harders/mullet, silverside and white stumpnose, among others (Clark 1997a&b). Offshore catches are likely to be dominated by snoek, while other species landed include hottentot *Pachymetopon blochii*, long fin tuna *Thunnus alalunga* and chokka *Loligo vulgaris reynaudii*.

Marine mammals common to the southern Benguela are frequently sighted, including migratory species that are threatened by ship strikes and disturbance by vessel traffic. These include southern right whales (May to November) and migrating humpback whales *Megaptera novaeangliae*. Cape fur seals *Arctocephalus pusillus pusillus* are also common visitors. The nearest seal breeding colonies are at Robbensteen between Koeberg and Bok Punt on the West Coast (Wickens 1994).

Existing beneficial uses

Silwerstroomstrand is a well-established and popular recreational site for the communities of Atlantis, Malmesbury and Table View. The site has picnic facilities, a large parking lot, several ablution blocks, paved walkways, an entertainment area for children, and offers beach access for people with disabilities. Silwerstroomstrand has been awarded Blue Flag beach status for six consecutive years from 15 December to 15 January (WESSA 2016), indicating that the beach continues to meet high quality, peak season water quality standards. The protected, gently sloping sandy beach is popular for swimming, as is the tidal pool. The site is adjacent to a popular local campsite and surf spot, prized for its undisturbed and aesthetic value. The rocky areas provide ideal conditions for West Coast Rock Lobster (WCRL) fishing and shore angling is popular, particularly during January and February. It is proposed that the RO container is placed on the recreational area between the parking area and the tidal pool as indicated in Figure 3.2. It is recommended that the container rather be positioned in an area that will not impact on recreational activity.

Significance and sensitivity

Approximately 2 km north of the discharge point is the Cape West Coast Biosphere Reserve Marine Buffer zone, while the Koeberg Private Nature Reserve is 10 km to the south and has been recognised as an area of conservation importance for seabirds and shorebirds. Breeding seabird colonies, including the African penguin (*Spheniscus demersus*), bank cormorant (*Phalacrocorax neglectus*), crowned cormorant (*P. coronatus*), Cape cormorant (*P. capensis*) and the African black oystercatcher (*Haematopus moquini*) are situated on Robben Island 20 km to the south of Silwerstroomstrand (BirdLife 2015). African black oystercatchers are listed as 'Near Threatened' by the IUCN (BirdLife International 2016), however, populations have increased and stabilised since the 1980's. Population increases are partly due to improved management plans put into place to protect these birds as well the additional food source provided by the spread of the alien Mediterranean mussel that lead to an increase in breeding success (Hockey 2009). In addition, reduced human disturbance and the near-eradication of predator populations on islands played a huge role in increasing the birds' population on islands. There are no other notably rare or endangered species that are known to occur in the immediate area.

The Silwerstroomstrand benthic fauna of both subtidal and intertidal rocky and sandy substrata is considered typical of the greater southern Benguela West Coast region. Biodiversity concerns pertaining to the construction of intake pipes, and the discharge of brine at this site include the mortality of rocky shore species and the negative effects on white mussels (*Donax* spp.) living along intertidal zone on beach. However, these impacts are of moderate concern and are not considered a fatal flaw.

Potential for dispersal

The proposed discharge site is to the north-west of Springfontein se Punt and will be exposed at low tide. Typically, long sandy beaches on the West Coast are subject to some degree of longshore drift. Longshore drift transports sediments along the coast parallel to the shoreline, a process which is usually dependent on an oblique onshore swell and wind direction. As the predominant wind direction at the site is from the southeast, longshore drift across the beach (i.e. north along the shore from the rocky outcrop 'Wintersteen') is likely. The current proposed position of the discharge pipeline may result in the entrainment of the brine effluent across the beach, trapping the brine within the surf zone. The limited dispersal potential of the site is compounded by the gentle bathymetry at the discharge site as the shallow water will reduce the dilution potential of the effluent (Figure 3.1). In order to mitigate impacts, it is recommended that the outfall be repositioned perpendicular to the shore and extended past the end of the rocky headland as illustrated in Figure 3.2.

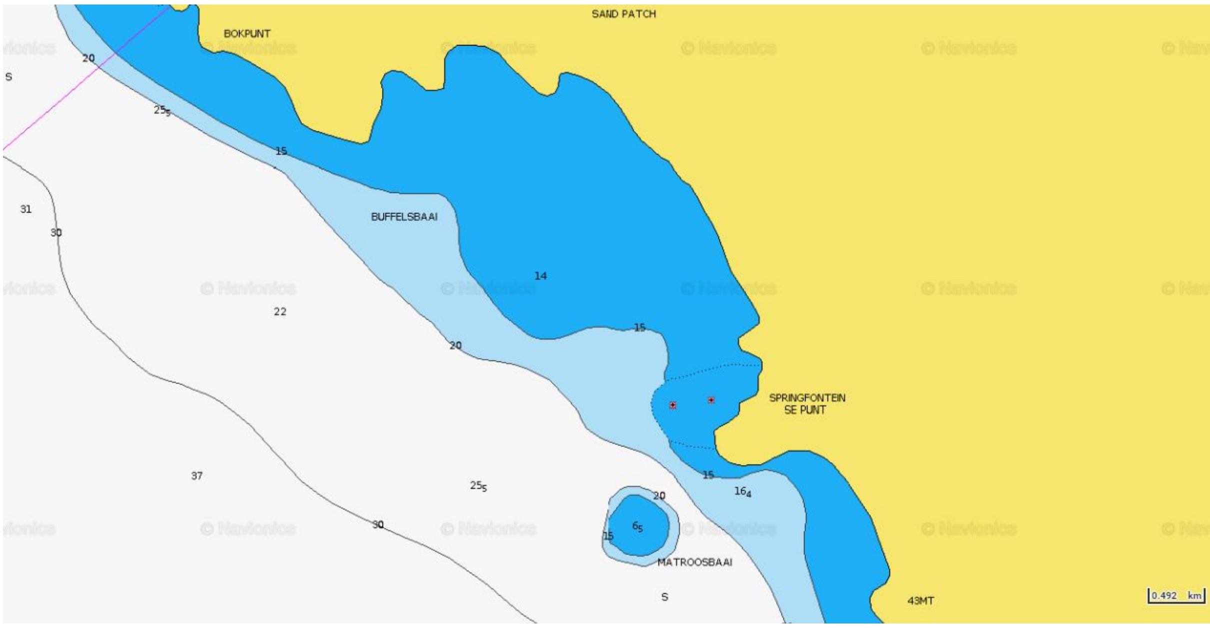

Figure 3.1 Bathymetry in the vicinity of Silwerstroomstrand (Source: webapp.navionics.com).

Figure 3.2 **Sensitivity map for Silwerstroomstrand showing proposed and recommended pipeline locations and sensitive environments (Google Earth 2017).**

3.2 Port of Cape Town and Table Bay

The Port of Cape Town is the southernmost commercial port in Africa, located at the apex of a major international shipping route on the northern edge of the Cape Peninsula. The Port is situated on the south-western coastline of South Africa in Table Bay, a relatively shallow open embayment that encompasses Robben Island and is surrounded by the Cape Town metropole. The Port of Cape Town consists of the Victoria and Alfred Basins, the Duncan Dock and the Ben Schoeman Dock.

Oceanography

Table Bay falls within the nutrient rich and productive Benguela upwelling system of the cool temperate west coast region and is central to the South-Western Cape inshore ecoregion. Strong south-easterly summer winds drive an anti-clockwise circulation in Table Bay, which reverts to a clockwise circulation in winter. Within the Port, recorded water velocities are very sluggish with wave action dampened by the protection of the main breakwater. Summer wind forcing and subsequent upwelling results in a highly stratified water column in both Table Bay and the Port, while winter storms and the relaxation of upwelling leads to a well-mixed water column. Table Bay is generally poorly flushed, with a relatively long residence time of bottom water (± four days).

The water quality in Table Bay is generally considered to be 'good', despite numerous effluent outfalls (e.g. the Green Point and Chevron/Caltex outfalls) discharging offshore (Monteiro 1997, CSIR 2006a, Van Ballegooyen 2007). Sediment quality within the Port of Cape Town is generally 'fair' in both winter and summer, while benthic sediment quality in Duncan Dock is 'poor' due to the contamination of sediment with metals, Polycyclic Aromatic Hydrocarbons (PAHs), Dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyls, and butyltins. While the water in the Port has been shown to have a high load of suspended sediments and a higher level of turbidity than that which is expected for the West Coast, there appears to be no significant trace metal pollution in the water column and inorganic nutrient concentrations within the water column are not significantly different to those in the Bay (Carter *et al.* 2003, Anchor 2013).

The range of suspended sediment concentrations in Table Bay is estimated at between 1 mg/L and 44 mg/L (2003b). In contrast, the water and sediment within the Port of Cape Town are considered comprised because the Port is a working harbour with various operations including the synchro-lift, fish factories, previous oil storage sites (CMS 1995b), and urban run-off from the City of Cape Town (including stormwater flow into Duncan Dock, the repository of all city bowl stormwater). Historically, suspended sediment concentrations were reported to be very high (around 50 mg/L, CSIR 1998) which is comparable to areas of significant anthropogenic nutrient flows and subsequent eutrophication; however, recent surveys indicate that in general, turbidity was low and generally varied minimally through the water column, and that total suspended solids concentration in surface water at most stations was relatively low (CSIR 2016). Water quality in the Port of Cape Town has generally been classified as "good" in terms of both turbidity and suspended solids as per CSIR Coastal Systems research group water quality classification criteria (CSIR 2016).

Within the Port of Cape Town, the dissolved oxygen concentration and saturation varies minimally through the water column during the winter, as the water is well mixed (CSIR 2016). In contrast, summer readings show that dissolved oxygen concentration and saturation levels can vary considerably between stations in the Port, with high readings in the Victoria Basin, the entrance basin and in the outside marine environment, as a result of phytoplankton photosynthesis (surface water dissolved oxygen and chlorophyll-a concentration were reported to be very strongly positively correlated, CSIR 2016). The CSIR Coastal Systems research group found that levels of dissolved oxygen in the surface and bottom waters were moderate and classified water quality as "good" or "fair" in both summer and winter (CSIR 2016).

On the 8th of August 2017 Lwandle collected *in situ* water quality samples from Table Bay and Granger Bay at the sites indicated in Figure 3.3. Conductivity, temperature and depth data were recorded using a CTD and are graphically depicted in Figure 3.4.

Figure 3.3 Sampling locations for Table Bay and Granger Bay sampled on 8 August 2017 (Lwandle 2017a).

The relatively large variations in temperature with depth indicate a stratified water column at most of the sites, although inshore samples (CTH6 and CTH10) show an isothermal water column indicating good mixing at these sites (Figure 3.4). Low variability in average temperature, salinity and dissolved oxygen was recorded at all sites, while turbidity increased dramatically with depth at Granger Bay (GrB2) indicating a potential disturbed or nepheloid layer on the sea floor where a maximum of 16.4 NTU was recorded (Lwandle 2017a).

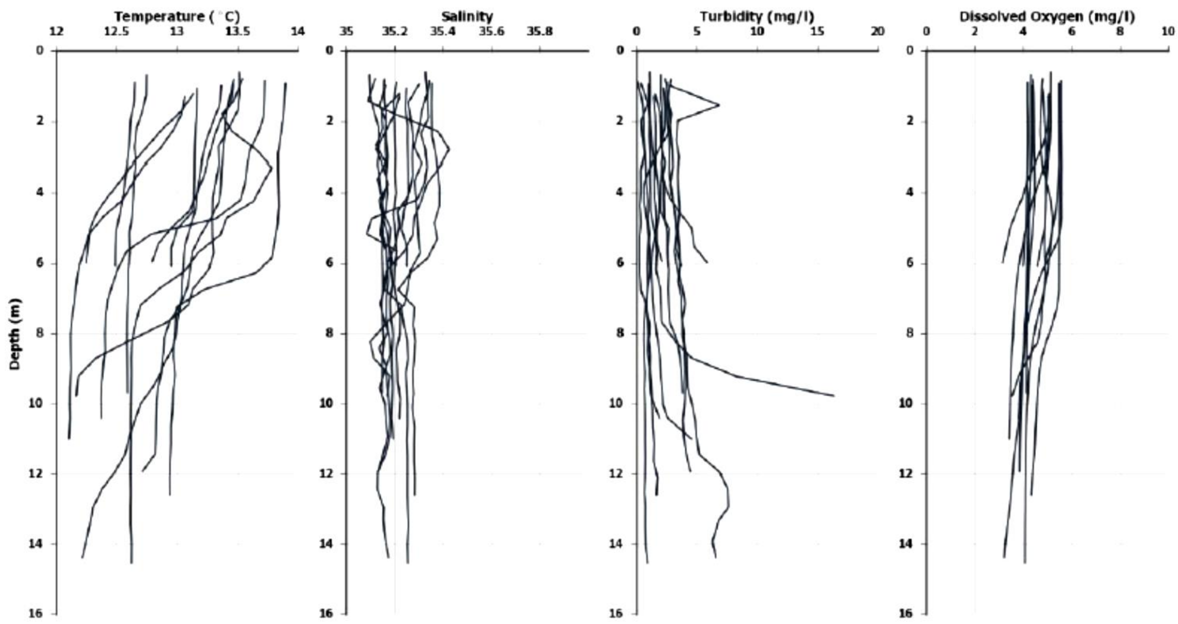

Figure 3.4 CTD profiles for water quality sites sampled on 8 August 2017.

Sediment quality in the Port of Cape Town was classified by CSIR (2016) as poor at all stations in the V&A Marina and Alfred Basin, and poor at one station and fair at two others in Victoria Basin. Sediment across Duncan Dock and in the Royal Cape Yacht Club basin was classified as being either fair or poor, but good in Ben Schoeman Dock and the entrance basin. The fair and poor sediment quality reflects significant to severe contamination of sediment in parts of the port by metals, polycyclic aromatic hydrocarbons, DDT, polychlorinated biphenyls, and/or butyltins (CSIR 2016). Concentrations of most metals in sediment samples collected from the Port of Cape Town in 2015 fell within baseline model upper and lower prediction limits or below baseline cadmium concentration i.e. concentrations are within the expected range for sediment in the port that is essentially uncontaminated by metals (CSIR 2016). There are local exceptions, though; barium, cadmium, copper, cobalt, chromium, mercury, nickel, lead and zinc concentrations in sediment at two stations in the Alfred Basin and one station in the Victoria Basin were rated as high to extremely high (CSIR 2016, 2017). It is highly probable that these metals have an anthropogenic source, given that the most severely metal contaminated sediment occurrs alongside or near vessel and oil rig repair facilities (CSIR 2016, 2017).

Previous measured nitrogen concentrations (ammonium plus nitrates) in the Port have been considered equivalent to those measured in Cape West Coast nearshore waters. Given that dissolved oxygen levels appear to be mostly near saturation levels with only isolated instances of super saturation or hypoxia, there appears to have been no overall eutrophication of the water body (CMS 1995b, CSIR 2005). In addition, the CSIR (2016) classified the waters of the port as "good" or "fair", in terms of their criteria for surface water quality for dissolved inorganic nitrogen.

The sediments of the Ben Schoeman dock are considered mildly anoxic (CMS 1995b, CSIR 2005). A study by Centre for Marine Studies (CMS 1995a&b) showed the sediments of the Victoria Basin to be black, anoxic and contaminated by hydrocarbons. In addition, the highest ever Polycyclic Aromatic

Hydrocarbon (PAH) sediment concentrations ever recorded in a South African Port occurred at a station alongside the synchrolift in Alfred Basin (CSIR 2016). Other sources of PAH pollution include oil leaked from vessels, the illegal discharge of contaminated bilge water from vessels, and the entrainment of oil leaked onto hard surfaces into the Port by stormwater runoff (CSIR 2016). Analysis of the sediments of the Port of Cape Town as per the 2017 CSIR Long-Term Monitoring of the Port of Cape Town report indicate that pollutants such as metals, PAHs, organochlorine pesticides, polychlorinated biphenyls and/or tributyltin are present at such concentrations as to be acutely toxic to sediment-dwelling macrofauna, based on comparisons with sediment quality guidelines (CSIR 2017a).

Marine ecology

With the exception of Robben Island, marine habitats within Table Bay consist of communities that are typical to the Southern Benguela system, and are neither ecologically unique, nor classified as locally, regionally or internationally important biodiversity resources. The ecology of the Port of Cape Town resembles an impoverished version of a sheltered rocky shore typical of the South-Western Cape Bioregion (Sink *et al.* 2012). The rocky shore region of the Bay and the Port of Cape Town itself is predominantly artificial and is heavily invaded by invasive species. Table Bay, specifically Robben Island, which is 12 km from the Port, is host to numerous seabird species, including ± 1 669 breeding pairs of African penguin (*Spheniscus demersus*), ± 93 breeding pairs of bank cormorant (*Phalacrocorax neglectus*), ± 74 breeding pairs of crowned cormorant (*P. coronatus*), ± 2 166 breeding pairs of Cape cormorant (*P. capensis*) and ± 266 African Black Oystercatchers (*Haematopus moquini*) (BirdLife 2017).

The entirety of Table Bay falls within a rock lobster closed area in which no lobsters may be caught recreationally or commercially. The outer harbour wall of the Port of Cape Town and the subtidal rocky reefs at Mouille Point have been identified as nursery reefs for rock lobster (Hazell *et al.* 2002, Carter 2006). Lobsters have been found to grow slower within the Port when compared to those living at Mouille Point, potentially due to the reduced abundance of mussels, which are less common on the harbour wall, although dive surveys showed similar densities and sizes of lobsters within the sanctuary when compared to non-sanctuary sites (Mayfield and Branch 1999).

There is currently no published information on pelagic communities within the Port of Cape Town and information is primarily anecdotal. Carter (2006) observed that euphausiids do occasionally occur in the Port, reaching densities sufficiently high to clog the Two Oceans Aquarium seawater intakes. He also notes that small shoals of harder/mullet occur in the outer harbour area, particularly along the seawalls between the entrance to Duncan Dock and the western breakwater. Vagrant dolphins do occasionally move into the harbour, and box jellies are occasionally seen in the surface waters. There is a non-breeding, semi-resident population of Cape fur seals in the Port that appear to forage mainly in the Victoria Basin (Anchor 2013).

Existing beneficial uses

The major human influences on Table Bay are currently land based sources of pollution, coastal engineering structures, shipping activities and ship derived pollution. Six categories were defined by Carter (2006) as outlined in Table 3.1.

Table 3.1 Human uses of Table Bay (adapted from Carter 2006 and Van Ballegooyen 2007).

Use	Description
Shipping	• Container and cruise vessels. • Small boat activity. • Navigation areas, anchorages and offloading.
Commercial fishing	• Boat based line fishery for snoek, hottentot and tuna in and around Table Bay. • Prior to closure of the fishery, abalone was dived for in the shallow rocky subtidal zone south of Mouille Point and around Robben Island.
Collection of white mussel (*Donax serra*)	• Human consumption and bait on beaches from Milnerton to Blouberg.
Recreation	• Water sports such as yachting, kayaking, wind and kite surfing, surfing, diving, swimming, beach and coastal recreation. • Marine ecotourism (e.g. whale watching).
Industrial	• Marine outfalls (Green Point pipeline and Chevron/Caltex pipeline). • Industrial cooling water use at the Koeberg power station. • Sea cables with landfalls at Milnerton and Melkbosstrand (Schoonees 2006). • Granger Bay Marina, Murray's Harbour on Robben Island, and the Port of Cape Town.
Nature conservation	• TMNP managed 'multi-use' MPA from Mouille Point to Cape Point coastline up to 14 km offshore. Commercial and recreational fishing is allowed within the boundaries of the MPA but fishing prohibited in 'no take' sanctuaries. • Table Bay is also a rock lobster sanctuary.

The Port of Cape Town is a working harbour, which handles cargo and offers ship maintenance and repair services (Carter 2006). The Royal Cape Yacht Club and other small craft facilities are situated within the Port precinct, while fish processing units and other industries are also located in the complex. The V&A Waterfront is a large retailing, leisure and entertainment complex which is a marked tourist attraction, as is the Two Oceans Aquarium and the Robben Island Museum to name a few. Intakes include a seawater abstraction point for cooling of the Clocktower Precinct and abstraction within the Victoria Basin which pumps seawater directly into the Two Oceans Aquarium exhibits (Anchor 2013).

Nearshore fish species include harders/mullet, silverside, and white stumpnose, among others (Clark 1997a&b). Offshore catches within Table Bay include most commercially important species, dominated by snoek, while other species landed include hottentot, long fin tuna and chokka (*Loligo vulgaris reynaudii*) (Carter 2006). Table Bay falls within an important recruitment area for epi-pelagic species such as sardine and anchovy and forms part of the seasonal migration pathway of these fish to spawning grounds on the western Agulhas Bank (Carter 2006). The area of habitat encompassed within Table Bay is relatively small compared to the overall foraging and recruitment habitat utilised by these species. While the relative importance of Table Bay to these fish is unknown, it is likely of low significance (Carter 2006).

There are 1 405 properties along the southern Table Bay area between Melkbosstrand and the Port of Cape Town (CSIR 2003 & 2010). This stretch of coastline has residential, businesses and public sector properties with a valuation of R 2.08 billion and a rates contribution of R 13.4 million per annum (Colenbrander 2016, Cartwright 2016). The coastal area is of high social value, prized by multiple stakeholders for both recreational use and aesthetic value (Colenbrander 2016).

Significance and sensitivity

Table Bay has been subject to much development and disturbance and is in a severely modified state, largely due to land reclamation. The area experiences constant vessel traffic and boat activity and the Bay is subject to urban pollution via storm water runoff, subtidal outfalls and oil spills. There are two major river outflows: the Salt and Diep Rivers, both of which face large scale anthropogenic pressures. The coastal region is largely anthropogenic and non-native invertebrate species are prevalent in the Port.

The proposed anchorage of the SWRO Vessel is approximately 2 km south of the coastal Rietvlei Wetland that is part of the Table Bay Nature Reserve, an area of importance to avifauna. Within the southern Benguela system, Table Bay is not considered ecologically unique and cannot be classified as locally, regionally or internationally important biodiversity resources (CSIR 2003a&b). The Table Bay benthic fauna of both subtidal and intertidal rocky and sandy substrata are considered typical of the greater southern Benguela West Coast region. The benthic communities within the heavily modified environment of the Port of Cape Town are impoverished and dominated by alien species, which are of minimal conservation value. While Table Bay falls within a rock lobster closed area and the outer harbour wall of the Port provides nursery areas for juveniles, dive surveys showed similar densities and sizes of lobsters within closed and open access sites.

Table Bay is an important habitat for seabirds with Robben Island being a critically important breeding site for endangered African penguins. In 2015, the island hosted approximately 6% of the total African penguin breeding population in South Africa. The penguins forage up to 20 km offshore of Robben Island, thus the health of the greater Table Bay area is of critical importance in the maintenance of this population (Van Ballegooyen 2007). Robben Island also hosts a large bank cormorant colony (BirdLife 2017). Both species are “significant biodiversity resources” due to their population size, endemism and conservation classification (Van Ballegooyen 2007).

Potential for dispersal

Four outfall options have been proposed for Table Bay: 1) offshore discharge from a SWRO vessel anchored in Table Bay, 2) discharge from a land-based pipe into the Elliot Basin in the Port of Cape Town, 3) discharge from a moored RO barge into the Ben Schoeman Dock, and 4) discharge from a land-based pipe into the Salt River (Figure 3.6). The Department of Environmental Affairs (DEA): Oceans and Coasts rejected the Salt River option pre-application, thus this will not be discussed further.

Table Bay is a relatively shallow open embayment. Bathymetry around the Port of Cape Town is illustrated in Figure 3.5. The long residency time of bottom waters in Table Bay is likely to reduce the potential for dispersal of effluent, a factor which must be taken into account when assimilating anthropogenic waste within the Bay (Quick and Roberts 1993). The dispersal potential for brine discharge from the proposed SWRO outfall is relatively good though, given that brine is negatively buoyant and mixing will be promoted as the effluent sinks down to the seafloor. Water residence time within the Port ranges from one to seven days in the Victoria and Alfred Basins, while water residency time within the Duncan and Ben Schoeman docks is unknown. An outfall positioned in the Elliot Dock is considered unacceptable as mixing potential is highly limited due to weak flushing of the area. There is concern that brine discharged into the Duncan Dock by a moored SWRO Vessel may become trapped within the Port. Placing a surface discharge at the end of the eastern breakwater will encourage mixing, while regular tidal movement should promote dispersion, provided that the effluent does not become trapped in the corner between the breakwater and the shore. Concerns about intake water quality can be addressed by installing a longer pipeline. However, given the depauperate and largely modified state of the benthic communities in the basins, any alterations to these communities will be of low significance.

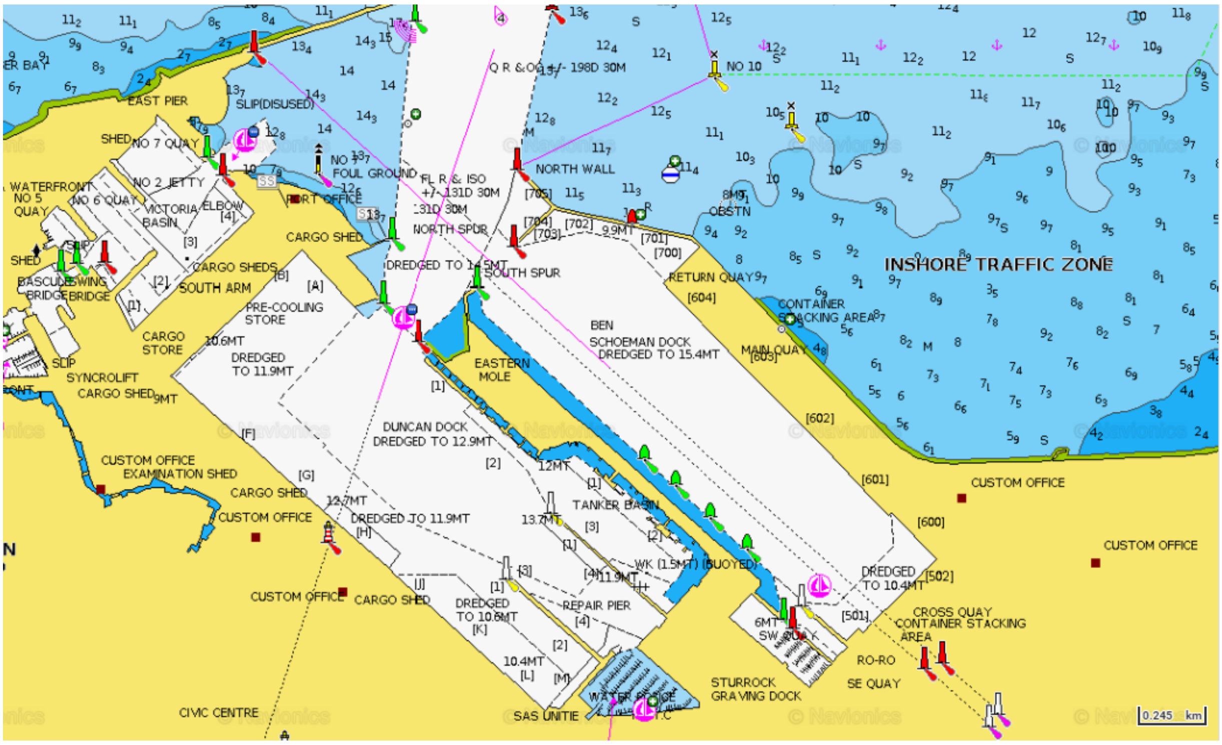

Figure 3.5 **Bathymetry in the vicinity of the Port of Cape Town (Source: webapp.navionics.com).**

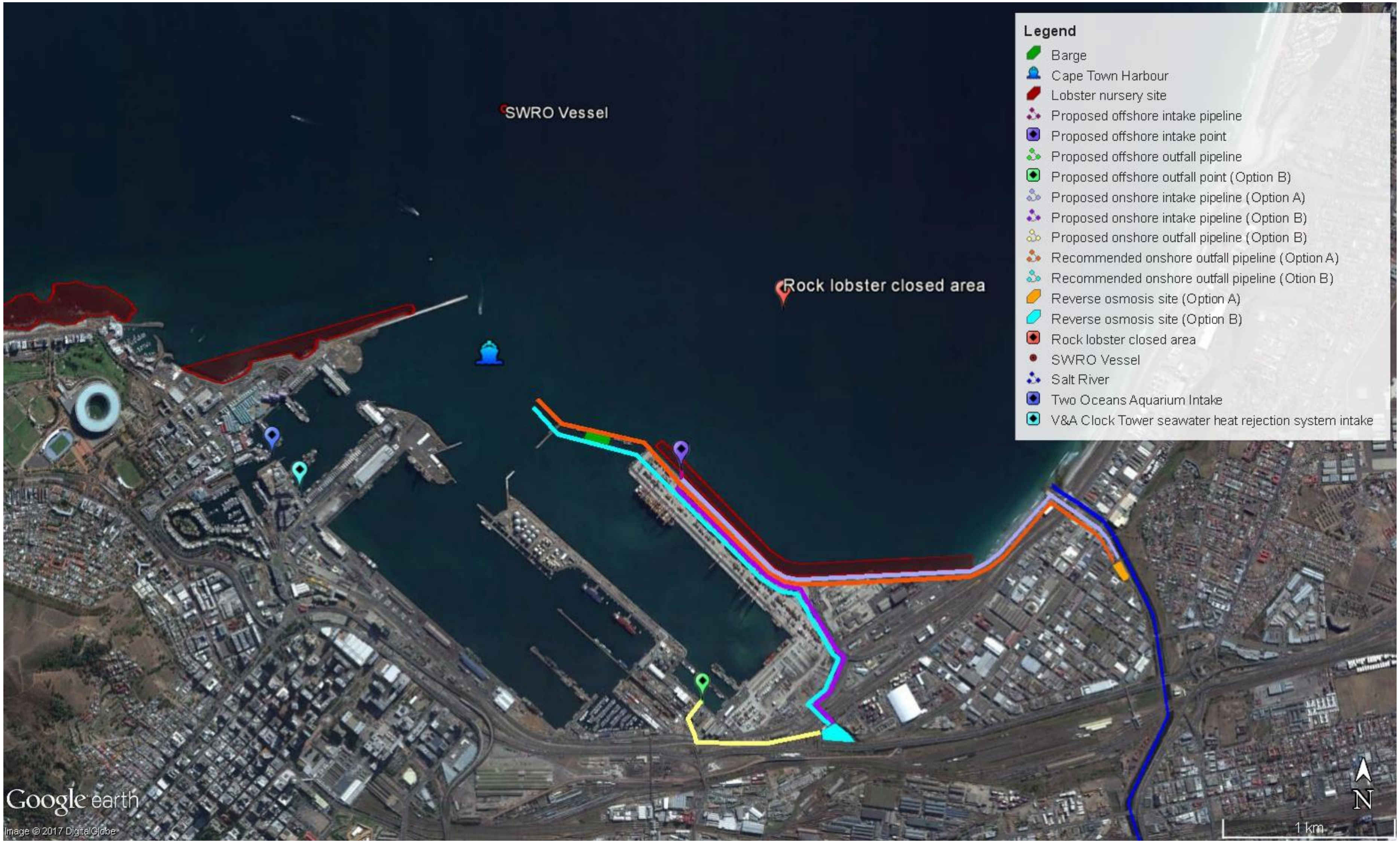

Figure 3.6 **Sensitivity map for Table Bay showing proposed and recommended pipeline locations and sensitive environments (Google Earth 2017).**

3.3 Granger Bay

Granger Bay is a small north facing embayment situated at the southern extent of Table Bay. The shoreline of the Bay has been subject to much development in the past. Prior to development, an embryo dune ran along the coastline, which has been fragmented and highly impacted by urbanisation (Low 2008). Much of the adjacent land on the eastern boundary of the Bay has been reclaimed and is protected by a dolos revetment. The coastline in the middle reaches of the Bay comprise a temporary rock revetment, which is subjected to abrasion by waves and has led to the formation of a steep gravel beach with a very coarse and pebbly adjacent subtidal area. The area landward of the temporary rock revetment is used for parking by the Victoria and Alfred (V&A) Waterfront and is dependent on the upkeep of the revetment for protection. The western extent of the Bay comprises a rubble embankment, a sheltered boat launch site managed by the Oceana Power Boat Club (OPBC), and the Granger Bay Marina (The Water Club).

Oceanography

Granger Bay is situated at the most south-westerly edge of Table Bay on the west coast of South Africa. The Bay falls within the nutrient rich and productive Benguela upwelling system of the west coast. Table Bay is relatively shallow, reaching a maximum depth of 35 m, with generally weak currents that are predominantly wind driven. The dominant northerly current (anti-clockwise) is driven by south-easterly winds and has a surface flow of about 0.2 to 0.3 m/s (Quick and Roberts 1993). Tidal currents and outside shelf currents have little influence on overall current patterns. The velocity of the wind-generated surface currents decreases with depth and 80% of the time there is no noticeable bottom current in the Table Bay (Quick and Roberts 1993). As a result, the bottom waters of Table Bay are poorly flushed and the average residence time of water is approximately four days (Quick and Roberts 1993). The tidal variation in the vicinity of Cape Town usually ranges between 0.25 m (relative to the chart datum) at mean low water springs and 1.74 at mean high water springs, with the highest and lowest astronomical tide being 0.03 m and 2.02 m, respectively. Periodic storm surges occasionally result in the water reaching substantially higher levels. Waves predominantly approach Table Bay from the southwest (Carter *et al.* 2003) and wave energy increases during winter months. Winter storms have resulted in severe coastal erosion and flooding in the past.

Marine ecology

According to Sink *et al.* (2012), Table Bay is situated within the South-western Cape inshore ecozone in the Southern Benguela ecoregion and it has been found that Table Bay is not ecologically unique in the context of the southern Benguela system (CSIR 2003). Almost all of the intertidal zone of Granger Bay exists as artificially developed shore (Anchor 2014). The gravel and pebble substratum adjacent to the gravel beach is unlikely to support a significant benthic community as the substrate is very unstable. The rocky reefs on either side of the gravel beach and along much of the embankment comprise mostly rubble and some flat rock. The reefs are sand inundated in patches and pioneer invertebrate communities are present in areas not covered by sand. This rocky reef has a relatively low abundance and diversity of biota compared to other subtidal reefs in the region such as Mouille Point and Sea Point. Other habitats within the Bay include kelp forests, which are likely to support a range of fish and invertebrate species, and pelagic open water areas.

Granger Bay falls within the Table Bay rock lobster closed area. A resident group of Heaviside dolphins (*Cephalorhynchus heavisidii*) utilise the area surrounding Table Bay, particularly during the winter months, and southern right whales (*Eubalaena australis*) are known to frequent Granger Bay between June and December (Carter 2006). Other mammals include the Cape fur seal and the Cape clawless otter.

Hartlaub's gulls (*Larus hartlaubii*) are frequently seen sheltering or resting on or around the gravel beach. Breeding pairs of the African black oystercatcher (*Haematopus moquini*) are found within the Granger Bay Marina (*Ridwa Desai pers. comm.*). Other bird species frequently seen in the Granger Bay area include the kelp gull (*Larus dominicanus*), the white-breasted cormorant (*Phalacrocorax carbo*), the swift tern (*Sterna bergii*) and the Cape cormorant (*Phalacrocorax capensis*).

Existing beneficial uses

Granger Bay is situated at the south western end of Table Bay within a highly developed urban environment adjacent to the Port of Cape Town. It is surrounded by The Water Club, a high-class exclusive apartment complex, and the CPUT Survival Training Centre. The Granger Bay marina has been awarded Blue Flag status for six consecutive years (WESSA 2016).

The Bay supports a range of water based recreational activities and provides a safe and relatively sheltered passage for small craft moving in and out of launching and mooring facilities at OPBC and The Water Club. OPBC slipway has been deregistered as a Public Boat Launch Site (PBLS), with the registered PBLS immediately adjacent (*Pers. Comm.* Gregg Oelofse CoCT). This is the only registered commercial launch site in the Table Bay area and is used by a large proportion of the commercial linefish fleet within Management Zone A (Orange River to Cape Infanta).

The Water Club launch site is heavily utilised by a wide range of user groups, including commercial fishing boats, recreational boaters and jet skis, the Mammal Research Institute (that have receivers for acoustic tags stationed within Granger Bay), the Two Oceans Aquarium (that launch their research boat for collection dives), ± 150 OPBC kayaks, research bodies (CSIR and UCT Oceanography), boat building companies (that frequently test boats within the Granger Bay area), diving charters, film industry vessels, the CPUT Survival Training Centre, and emergency services such as Police, NSRI, Navy and Air Sea Rescue (NSRI ASR). A sailing academy has recently been established and operates out of OPBC, while power boat racing takes place in the vicinity of Granger Bay. Three Anchor Bay, immediately to the west of Granger Bay, is a popular launching site for sea kayaks.

Significance and sensitivity

The coastline of Granger Bay has been subject to much development and is in a severely modified state. The Granger Bay shoreline has been severely altered by construction and land reclamation and the beach habitat is in no way representative of the natural or pristine beach habitat expected within Table Bay. The diversity and abundance of biota is expected to be very low given the coarse sediment, steep beach and abrasive action of the pebbles rolling in the waves. The rocky shore communities are in an early pioneer state, dominated by a few fast growing species with a low biomass and species diversity (Anchor 2014). This is indicative of high levels of disturbance most likely due to movement of the boulders, sediment scour and ongoing shoreline maintenance operations. The species found on the rocks during a survey in 2013 were all common to the region (Anchor 2014).

Granger Bay is the southernmost high use area for the resident Heaviside's dolphin (Elwen and Gridley 2014). As Granger Bay is critical habitat for these cetaceans, brine discharge mixing must be sufficient to ensure effluent does not impact dolphins or their prey.

Potential for dispersal

The existing Green Point marine outfall was commission in 1993 and extends approximately 1.5 km offshore (Figure 3.7). The pipe discharges primarily treated sewage effluent through 16 diffusers in approximately 28 m of water. Given the moderately sloped bathymetry of the Bay (Figure 3.7), the dispersal potential for brine discharge through the Green Point outfall is good, provided that the effluent does not become trapped within Granger Bay. Brine discharge through existing infrastructure would result in dilution of the existing freshwater discharge and subsequently, a denser effluent than that currently being discharged (see Figure 3.8).

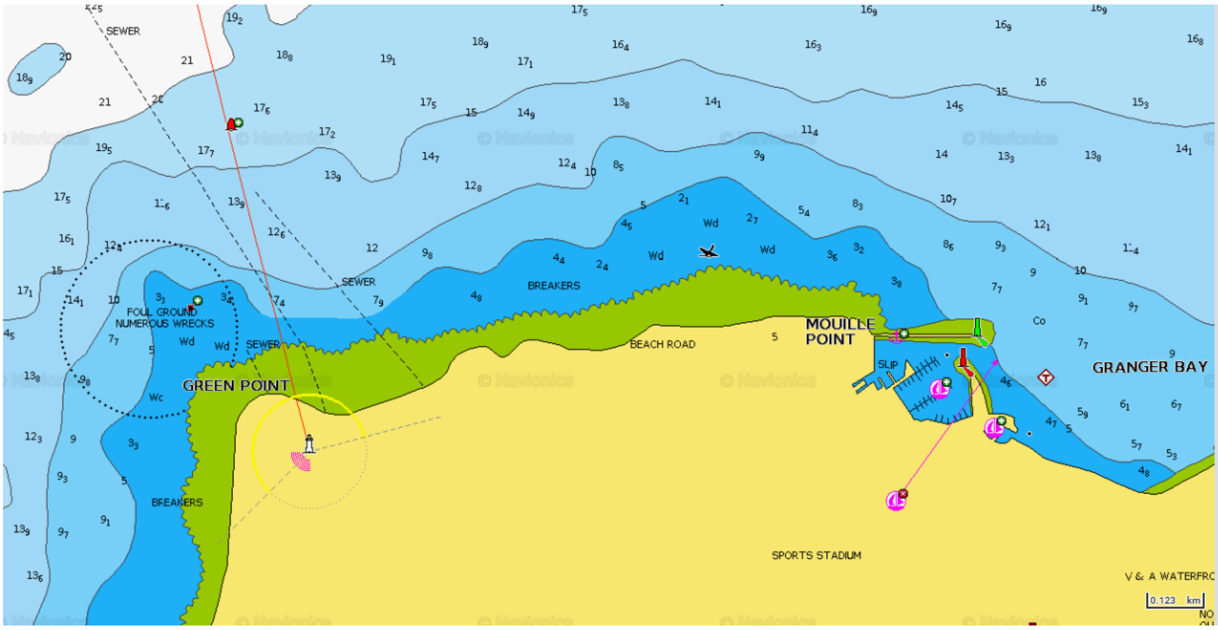

Figure 3.7 Bathymetry in the vicinity of Granger Bay and Green Point (Source: webapp.navionics.com).

Figure 3.8 **Sensitivity map for Granger Bay showing proposed pipeline locations and sensitive environments (Google Earth 2017).**

3.4 Glen Country Club (Camps Bay)

Oceanography

Camps Bay is situated on the Atlantic Seaboard around the western edge of Table Bay, approximately 7.5 km from Cape Town. Camps Bay is a relatively small bay (approximately 850 m wide) bounded by rocky headlands. The Glen Country Club is located north of Camps Bay beach, adjacent to Glen Beach, and immediately south of Clifton 4th beach. Beaches at Camps Bay and Clifton are moderately sloped, and characterised by very fine sand (0.063 to 0.125 mm grains), whilst medium sand (0.250 to 0.500 mm grains) occurs further offshore (Quick and Roberts 1993). The beach is bounded by rocky intertidal shores and subtidal reefs, while the seabed is a mixture of sand, exposed bedrock and boulders (CSIR 2017). Closer inshore, the substratum is predominately sand (Eagle *et al*. 1977). The Atlantic seaboard from Green Point to Camps Bay lies directly in the path of the predominantly south-westerly swell and Camps Bay beach is frequently exposed to big waves. The area to the north and south of Camps Bay beach comprises pocket beaches between rocky headlands and rocky shores. Clifton Beach is more sheltered as it faces to the north.

Marine ecology

The intertidal rocky shore ecology and faunal communities at the proposed Glen Beach intake site are considered representative of the greater southern Benguela region (Lane and Carter 1999, Branch and Griffiths 1988, McQuaid *et al*. 1985). The alien Mediterranean mussel is found on rocky areas around Camps Bay, attracting African black oystercatchers and providing refuge for marine invertebrate fauna. Upwelled nutrients brought to the euphotic zone support phytoplankton and macroscopic algae, which occur in dense kelp forests on the subtidal reefs close to the shore of the site. The kelp forests thin out further offshore and are replaced with a more predator dominated faunal community (Velimirov *et al*. 1977, Field *et al*. 1980, Branch and Griffiths 1988). Subtidal cold water corals occur on deeper reefs. Camps Bay falls within the marine reserve for West Coast rock lobster (*Jasus lalandii*) that extends 12 nautical miles from the shore. Dive surveys conducted in 1999 at shallow (<10 m depth) and deep water sites within Camps Bay (20-30 m depth) recorded the highest lobster densities within the Table Bay reserve (Mayfield and Branch 1999).

Existing beneficial uses

The existing Glen Country Club outfall lies just to the north of Camps Bay Beach, which has been awarded Blue Flag status for 9 consecutive years (WESSA 2016). The Camps Bay Blue Flag season runs for two months from 1 December to 31 March. Camps Bay Drive is popular with tourists that also patronise restaurants, hotels and shops in the area. The residential suburb is associated with a high value property market. Clifton 4th Beach is a Blue Flag beach and is arguably the most famous recreational beach in Cape Town. Camps Bay beach is heavily utilised by bathers and people engaged sports and picnicking, while the bay is utilised for recreational activates such as power boating, yachting, angling, SCUBA diving, swimming, shellfish collection and parasailing. Glen Beach, which is in close proximity to the proposed intake site, is a popular beach-break surf spot. The Glen Country Club is a private and corporate function venue that is also host to a number of different sporting codes. Shore angling and spearfishing are popular in this area.

Significance and sensitivity

Marine fauna and flora at Camps Bay are considered typical of the greater southern Benguela West Coast region. The high densities of rock lobster surveyed at Camps Bay suggest that the site is an important area for the species. The importance of this site from a recreational perspective (beach and water sports) also needs to be taken into consideration.

Potential for dispersal

Primary treated sewage effluent is currently being discharged into the TMNP MPA in the middle of the Bay (see Figure 3.10). The Camps Bay outfall was constructed in 1977 to replace an older and insufficient outfall (Eagle *et al*. 1977). The existing outfall has eight diffusers and discharges effluent subtidally approximately 1.5 km from the shoreline in approximately 28 m water depth (CSIR 2017). Given the moderately steep bathymetry of Camps Bay (Figure 3.9) and the opportunity to mix the dense brine with freshwater effluent, the dispersal potential for RO effluent discharged from this outfall is good, provided that the effluent does not become trapped in the Bay with onshore winds. The sediment in the Camps Bay area is predominantly coarse-grained sand (CSIR 2017), which indicates the presence of strong currents that will assist in the effective dilution and dispersion of effluent. Brine discharge through the existing infrastructure would result in dilution of the current effluent and subsequently, a denser plume. This increased density may reduce the occasional visibility of the currently buoyant plume, which has resulted in numerous media reports and investigations that have raised public concern about the health and safety of the beach.

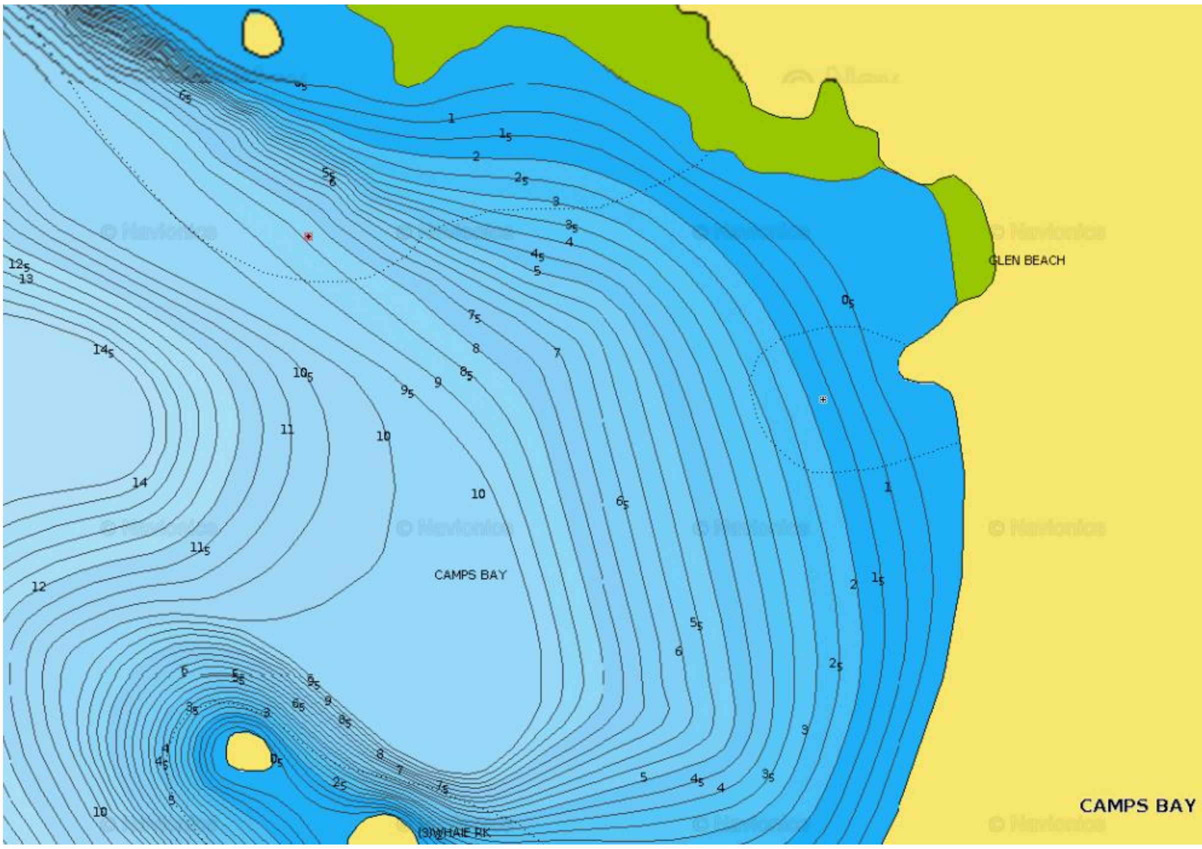

Figure 3.9 Bathymetry in the vicinity of Glen Country Club and Camps Bay (Source: webapp.navionics.com).

Figure 3.10 Sensitivity map for Glen Country Club showing proposed pipeline locations and sensitive environments (Google Earth 2017).

3.5 Hout Bay

Hout Bay is a suburb approximately 17 km south of Cape Town on the Atlantic seaboard of the Cape Peninsula. The southward opening bay is sheltered and is surrounded by mountains to the east and west (Chapman's Peak and the Sentinel respectively) with the southern Atlantic Ocean to the south (MacHutcheon 2012). Hout Bay is bordered by Table Mountain National Park (TMNP) to the north, west and east and falls within the TMNP Marine Protected Area (MPA). Hout Bay consists of an active fishing harbour and coastal residential town, including two informal settlements, Imizamo Yethu and Hangberg. The Bay is considered a typical representative of the coastline between Cape Columbine and Cape Agulhas (MacHutcheon 2012).

Oceanography

The marine ecology of Hout Bay is predominantly influenced by the cool Benguela Current System, characterised by the upwelling of cold, nutrient rich water by strong summer southerly and south-easterly winds, high productivity and biomass, and low biodiversity and species richness (Branch and Branch 1981). Hout Bay is typical of a microtidal coastline (Cooper 2001), with a recorded tidal range of 2 m (Davies 1980). The dominant swell is from the southwest, which refracts around the headland towards Hout Bay Beach due to the submerged Tafelberg Reef adjacent to the internationally acclaimed surf spot 'Dungeons". The wind regime is dominated by southeast or northwest winds, corresponding to the typical Cape Peninsula summer/winter pattern (MacHutcheon 2012). The subtidal benthos within the Bay is dominated by sand and gravel (MacHutcheon 2012) surrounded by sand beach to the north and rocky shores and shallow subtidal reefs to the east and west. Subtidal and exposed reef formations and kelp beds dominate just outside the Bay at Duiker Island.

Sediment transport investigated by MacHutcheon (2012) showed that currents are forced to divide at the Tafelberg Reef complex off the Sentinel Peak headland (MacHutcheon 2012). One section of the bifurcated current continues along the western flank of the Bay and is "reintroduced into the northward migrating longshore drift on the seaward side of the offshore reef complex" (MacHutcheon 2012). There is also water movement in and out of the harbour with tidal fluctuations, and water residency time within the harbour is estimated to be the length of a tidal cycle. Multibeam echosounder surveys show that the bathymetry of Bay ranges from 5 m below sea level (BSL) in the protected north eastern part of the bay to 52 m BSL in the south western Bay with a slope of between 1 – 1.5 degrees dipping towards the south-west (MacHutcheon 2012).

On the 11th of August 2017 Lwandle collected *in situ* water quality samples from Table Bay and Granger Bay at the sites indicated in Figure 3.11. Conductivity, temperature and depth data were recorded using a CTD and are graphically depicted in Figure 3.12.

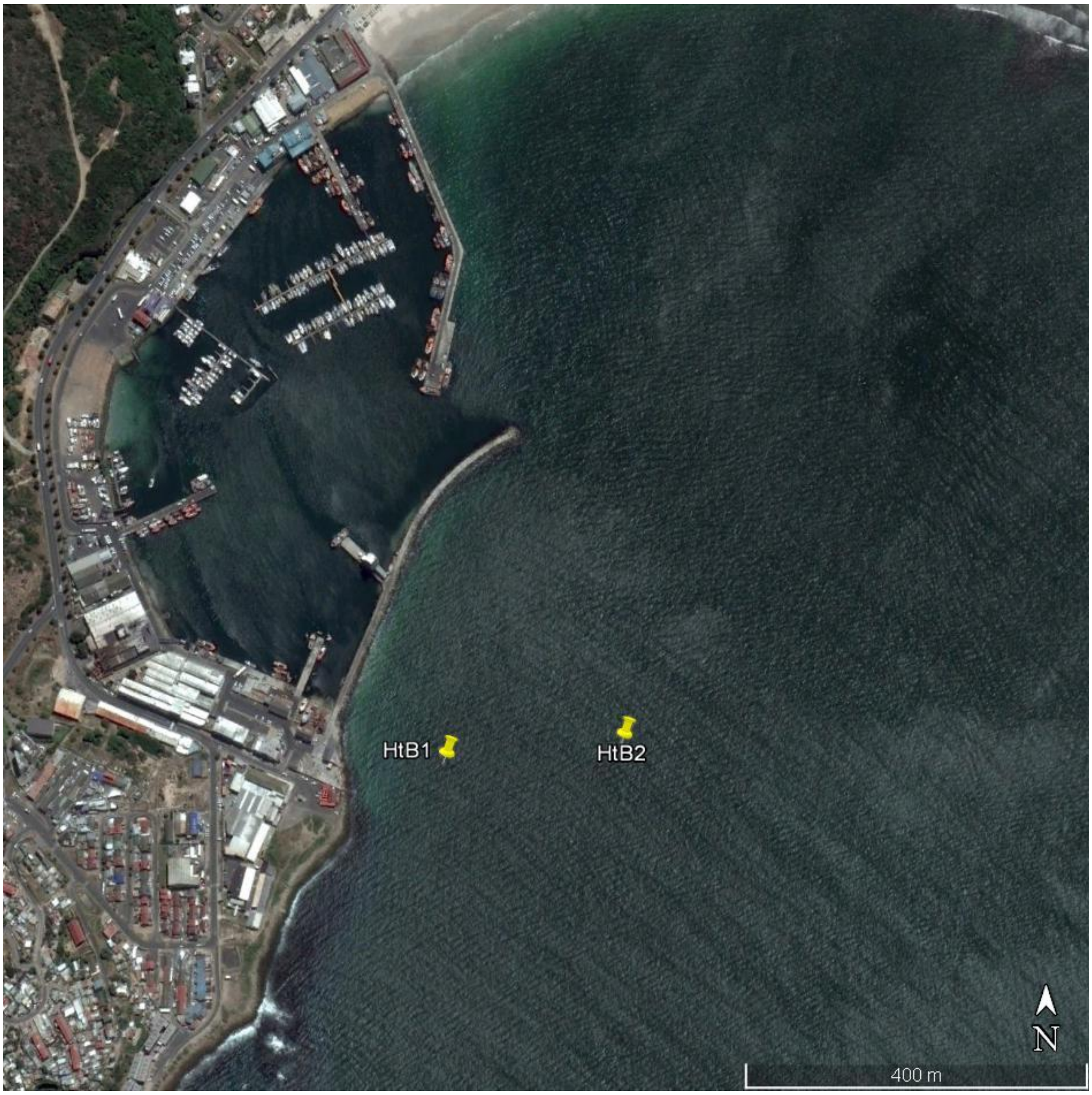

Figure 3.11 Sampling locations for Hout Bay sampled on 11 August 2017 (Google Earth 2017).

The water column in Hout Bay was well mixed and well oxygenated during the sampling event. Low temperature, salinity and dissolved oxygen variability was recorded with depth (Figure 3.12). Turbidity measurements indicated a potential disturbed or nepheloid layer on the sea floor where a maximum of 11.439 NTU was recorded (Lwandle 2017b).

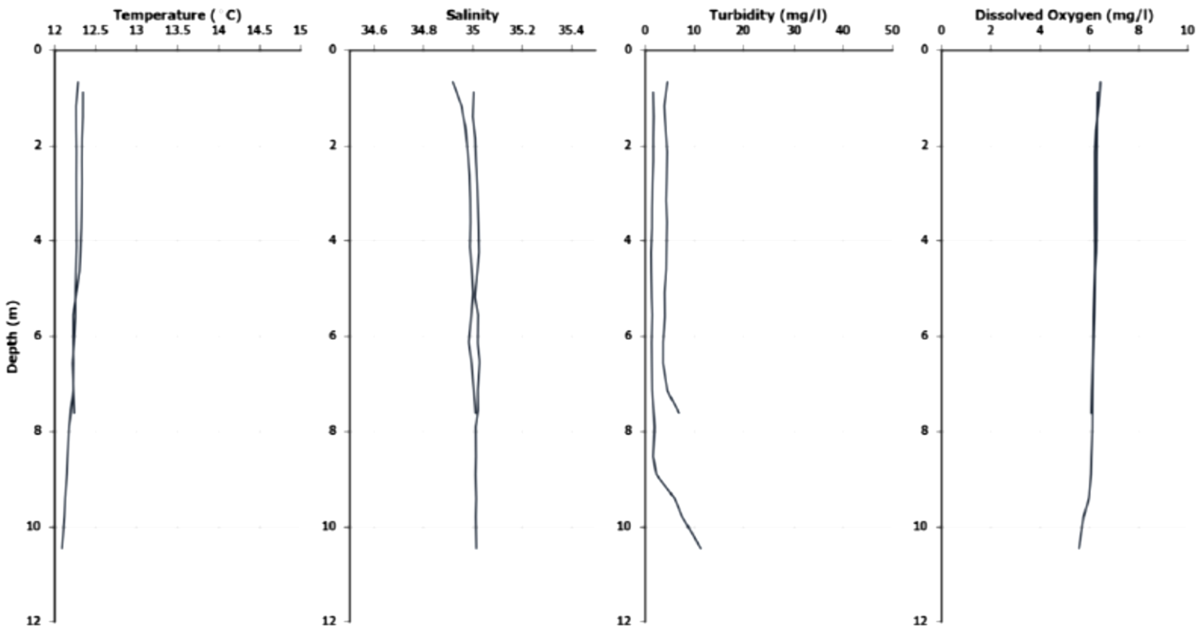

Figure 3.12 CTD profiles for water quality sites sampled on 11 August 2017.

Marine ecology

Hout Bay is situated within the South-Western Cape inshore ecoregion (Sink *et al.* 2012). The marine communities within the Bay are considered typical of the southern Benguela system and similar to that of Table Bay (see Section 3.2). Some unique features of the Bay include intertidal reefs and a breeding seal colony on Duiker Island. The Bay is also frequented by non-resident cetaceans.

Existing beneficial uses

Hout Bay is host to a wide range of industry and is in frequent use. Commercial fishing vessels are the majority harbour users with netting and long lining vessels launching from the protected harbour. Recreational use includes private vessels, as well as charter fishing, scuba diving and seal island boat trips. The sheltered white sandy beach is a popular attraction for tourists and locals alike. It is very safe for swimming and numerous water sports such as sea kayaking, sailing, SUPing etc. are popular. Other recreational activities include recreational fishing and SCUBA diving. Chapman's Peak cliff road is a key tourist attraction to the area and is valued by tourists and locals for its aesthetic quality.

Significance and sensitivity

Hout Bay has been subject to much development and disturbance over the years. Sources of marine pollution include fuel and discarded debris from the constant vessel traffic and boat activity, urban pollution via storm water runoff from the adjacent suburb and factories, as well as litter and an existing sewage outfall. The Disa River flows into the Bay in winter, flushing pollution and litter into the Bay and increasing the risk of bathers contracting a bacterial infection from waterborne pathogens. As is the case with most harbour environments, Hout Bay harbour is heavily populated by invasive species. Within the southern Benguela system, Hout Bay is not considered ecologically unique and cannot be classified as a locally, regionally or internationally important biodiversity resources (CSIR 2003); although the TMNP MPA affords protection to subtidal reefs and marine life targeted by fishers.

Potential for dispersal

The existing Hout Bay marine outfall pipe discharges at a depth of approximately 27 m (Figure 3.13). This pipeline will be able to accommodate brine effluent from the proposed temporary RO facility and is an attractive option as the potential for mixing in deep water is high compared to surf zone discharges. However, there is a localised bathymetric depression at the termination point of the pipeline, probably caused by the scouring action of the effluent pumped through the pipeline as it discharges out to sea (MacHutcheon 2012). This warrants concern and must be assessed (a new diffuser may be required) as the brine could become trapped in this depression, and not disperse effectively. In addition, the potential of the brine to be trapped within the harbour needs to be assessed in the context of tidal fluctuations and subsequent water movement in and out of the harbour. Concerns have already been raised about the existing plume being pushed towards shore by the dominant southwest swell. Brine discharge through existing infrastructure would result in dilution of existing sewage effluent, although mixing may be reduced due to a less buoyant effluent that may result in benthic attachment. On the other hand, co-discharge would result in a less visible plume.

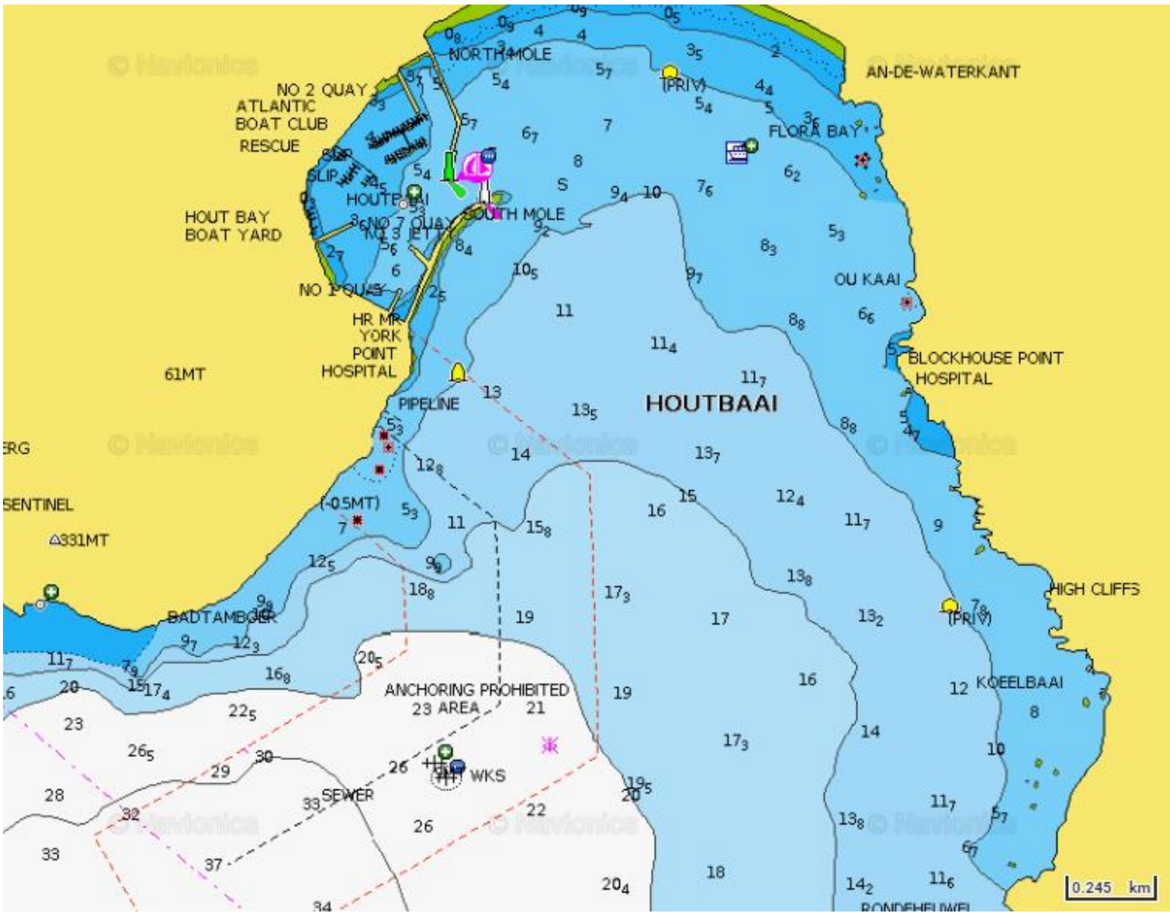

Figure 3.13 Bathymetry in the vicinity of Hout Bay (Source: webapp.navionics.com).

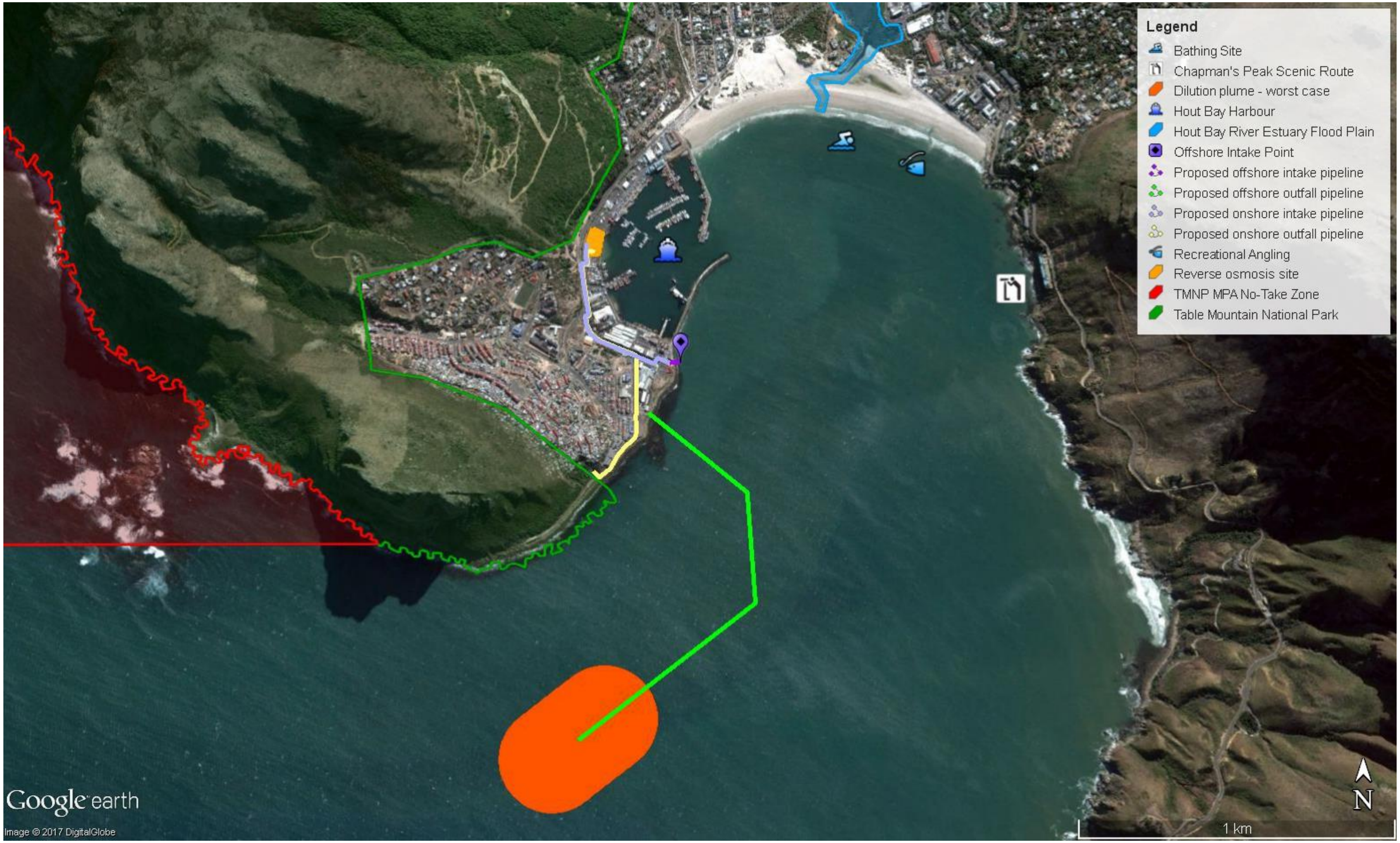

Figure 3.14 Sensitivity map for Hout Bay showing proposed pipeline locations and sensitive environments (Google Earth 2017).

3.6 Dido Valley

Dido Valley is a relatively undisturbed site on the False Bay coast of the Cape Peninsula, approximately 40 km south of Cape Town and 3 km north of Simon's Town. A short intertidal sandy beach less than 400 m in length lies between patches of rocky shore.

Oceanography

Covering approximately 1 000 km^2, False Bay is the largest true bay within the South African marine environment (Gründlingh and Largier 1991). The square shaped Bay faces the Atlantic Ocean, and is flanked by mountain ranges to the west and east, with the Cape Flats to the north. Sandy beach systems dominate almost the entire northern boundary of the Bay between Muizenberg and Strand, while the eastern and western margins are typically rocky shores with an occasional stretch of sandy beach. The sandy bottom slopes towards the south, reaching a depth of over 100 m between Cape Point and Cape Hangklip (Terhorst 1971). False Bay is classified as a semi-diurnal microtidal environment, with weak tidal driven currents (Terhorst 1971). Simon's Town experiences a spring-tide range of 1.48 m (South African Navy tide-tables).

South-easterly winds produce clockwise current direction within the Bay about 50% of the time, northerly winds create an anticlockwise current direction <10% of the time, and tidal currents dominate during calm periods (Gründlingh and Largier 1991). False Bay is exposed to swells from the south-west, south, and south-southeast (Gründlingh and Largier 1991) with the northern beaches of False Bay usually experiencing the highest wave energy. Dido Valley is generally sheltered by the Cape Peninsula from south-west swells but is exposed to south-southeast swells.

The interaction of the Agulhas and Benguela currents, as well as seasonal wind driven circulation, results in a fairly wide water temperature range in False Bay. Summer water temperatures typically vary between 12-20^{o}C and winter water temperatures between 10-14^{o}C (Smith 1999). Cape Point to Cape Agulhas is part of the wind driven coastal upwelling regime of the Benguela Current (Hutchings 1994) with the coldest south-west coast upwelling cells found at Cape Hangklip (11-12° C) and Danger Point (12-13° C). Upwelling at Cape Hangklip produces cold water plumes that extend westward and join the larger Cape Peninsula upwelling plumes (Boyd *et al.* 1985, Jury 1988). Dido Valley is sheltered from south-westerly swells and generally protected from south-easterly swells.

On the 11th of August 2017 Lwandle collected an *in situ* water quality sample from Dido Valley at the shore site indicated in Figure 3.15. Conductivity, temperature and depth data were recorded using a CTD, which was placed in an intertidal rock pool. Temperature was recorded at 14.24°C, salinity 35.19 PSU, turbidity 5.49 NTU and DO 6.58 mg/L (Lwandle 2017b).

Figure 3.15 Water quality sampling location at Dido Valley sampled on 11 August 2017 (Google Earth 2017).

Marine ecology

False Bay is situated on the western edge of the Warm Temperate Region/Agulhas Bioregion (Sink *et al.* 2012). The Bay is home to marine fauna and flora characteristic of this region as well as those of the South-Western Cape and Namaqua Bioregions (Turpie *et al.* 2009). Records indicate that warm water species have been historically present in the Bay, but have declined as a result of over exploitation and environmental change (Attwood and Farquhar 1999).

False Bay has a high diversity of habitats including rocky headlands, wave-cut platforms, sandy beaches, pocket beaches, kelp forests, estuaries, subtidal reefs and pelagic habitat (Clark *et al.* 2004). Such habitat diversity is conducive to high biological diversity (Clark *et al.* 2004) as demonstrated along the majority of the South-Western Cape coast.

False Bay is an important locality for breeding and foraging seabirds and 12 of the 15 seabirds that breed in southern Africa nest at localities around False Bay. Six of these are endemic to the region including the endangered African penguin (*Spheniscus demersus*), Cape gannet (*Morus capensis*), Cape cormorant (*Phalacrocorax capensis*), bank cormorant (*P. neglectus*), crowned cormorant (*Microcarbo coronatus*) and Hartlaub's gull (*Larus hartlaubii*). The kelp gull (*Larus dominicanus* *vetula*), greater crested (swift) tern (*Thalasseus bergii bergii*), great white pelican (*Pelecanus onocrotalus*), white-breasted cormorant (*P. lucidus*), grey-headed gull (*L. cirrocephalus*) and Caspian tern (*Sterna caspia*) are also found in False Bay. The Boulders Beach African penguin colony is in close proximity to the proposed Dido valley site. This ecologically important population occupies nesting habitat from Windmill Beach to Seaforth, a habitat which has been encroached upon by residential housing. The Boulders colony is of enormous conservation significance as it is home to approximately 5% of South Africa's breeding African penguins (Birdlife 2017). While breeding populations west of Cape Point collapsed in the 21st century following the south-eastern shift of their two main prey species sardine (*Sardinops sagax*) and anchovy (*Engraulis encrasicolus*) (Hockey *et al*. 2005, Roy *et al*. 2007, Coetzee *et al*. 2008), the penguin population in False Bay remained stable (Crawford *et a*l. 2011).

Currently there are 24 known marine invertebrate alien species within False Bay, 83% of which are considered invasive. Three of these invasive species are notable for their abundance and impacts on native systems (Mead *et al.* 2011, Robinson *et al.* 2016). These include the Mediterranean mussel (*Mytilus galloprovincialis*) with an average biomass of 10.2 kg/m^2 on the mid-shore of the western shores of False Bay, the acorn barnacle (*Balanus glandula*) with 700 individuals/m^2 in False Bay (Robinson *et al.* 2015) and the estuarine polychaete worm (*Ficopomatus enigmaticus*) with 56.80 tons in the Zandvlei Estuary in 2012 (McQuaid and Griffiths 2014).

While kelp was not originally present in False Bay (Field *et al.* 1977, Velimirov *et al.* 1977, Field *et al.* 1980, Branch 2008), kelp forests now extend from Cape Point to St James. Kelp is absent from the north-western most part of the Bay where water temperatures are warmest and rocky reefs disappear but appear again along the south-eastern shores of the Bay, extending eastwards (*Blamey, Pers. Comm*.). False Bay kelp forests differ from those on the West Coast in numerous ways. West Coast kelp forests are characterised by red algae, mussels and rock lobster (Field *et al.* 1980, Branch and Griffiths 1988), while east of Cape Point encrusting corallines and benthic herbivores dominate and understory algae are less abundant (Anderson *et al.* 1997). Sea urchins (*Parechinus angulosus*) are the most abundant herbivore in False Bay kelp forests, followed by sea snails (*Turbo cidaris*, *T. sarmaticus* and *Oxystele sinensis*), a few Patellid limpets and abalone (*Haliotis midae*) (Field *et al.* 1980, Anderson *et al.* 1997). West Coast rock lobsters are the major benthic predators on shallow subtidal reefs where they feed predominantly on mussels (Newman and Pollock 1974, Pollock 1979, Griffiths and Seiderer 1980); while east of Cape Point where mussels are scarce subtidally (Field *et al.* 1980), urchins and juvenile abalone are the preferred prey (Mayfield *et al.* 2001).

In terms of top predators, Seal Island in False Bay is a key habitat for the South African white shark (C*archarodon carcharias*) population (Barnard 1925, Wallet 1978). Although white sharks are not resident at Seal Island, a range of between 12 and 287 individuals has been estimated per year (Hewitt 2014). Dido Valley area is frequented by feeding great white sharks (*Carcharodon carcharias*) in summer.

Cetaceans visiting False Bay include the migratory southern right (*Eubalaena australis*) and humpback whales (*Megaptera novaeangliae*) and the non-migratory Bryde's whale (*Balaenoptera brydei*), which is the only baleen whale species known to regularly feed in the Bay). Heaviside's dolphins (*Cephalorhynchus heavisidii*), dusky dolphins (*Lagenorhynchus obscurus*), Indo-Pacific bottlenose (*Tursiops aduncus*), orca (*Orcinus orca*) and the endangered Indian Ocean humpback (*Sousa plumbea*) dolphin have also been encountered (Best 2007).

The offshore area adjacent to Dido Valley provides habitat for a crucially important white steenbras (*Lithognathus lithognathus*) population. White steenbras are slow-growing, long-lived, late maturing and estuarine-dependent seabreams endemic to South Africa (Mann *et al*. 2014). They have been extensively fished and as a result, the stock is currently regarded as collapsed. Drastic management measures have been implemented in order to rebuild the stock, including the establishment of several 'no-take' MPAs throughout their range (Mann *et al*. 2014). Despite white steenbras being listed as a 'no-sale' fish in South Africa, the species is threatened by illegal fishing and non-compliance of minimum recreational landing sizes. Catches taken by the south-western Cape shore fishery have decreased by 55% and landings have declined by 83% over 36 years from 1960 to 1996. The species is listed as 'Endangered' under IUCN (2016) based on population declines in excess of 55% extrapolated over three generations (i.e. 39 years) and the continuing decline of mature individuals in their limited area of occupancy. Moreover, current exploitation and degradation of estuarine habitat may indicate further population declines of this species (Mann *et al*. 2014).

Recommended conservation measures prescribed by the IUCN (Mann *et al*. 2014) include:

- additional marine/estuarine protected areas,
- a closed fishing season;
- MPA angling closures;
- improvement in law enforcement and compliance; and
- reduction in illegal fishing in spawning grounds.

A network of estuarine protected areas and the establishment of no-take areas in the sandy lower reaches of estuaries was recommended by Mann *et al*. (2014) to aid the protection of juvenile fish. Close monitoring of white steenbras is necessary as further population declines may warrant listing in a higher extinction risk threshold by 2019 (Mann *et al*. 2014).

Existing beneficial uses

It is estimated that tourists spend up to 5.3 million visitor days per year in False Bay, with a total expenditure of ±135 million Rand along this 35 km stretch of coast in 2007 (Turpie and de Wet 2007). Ecotourism and eco-sport tourism activities are significant human uses of False Bay and include SCUBA dive operators, kayak tours, boat based whale watching and white shark cage diving. Large numbers of recreational water users (e.g. surfers, divers, bathers, sailors, etc.) and consumptive marine resource users (commercial, small-scale and recreational) form part of the diverse coastal society that makes up the False Bay community. The False Bay Yacht Club is a certified Blue Flag marina with a Blue Flag season from 1 November to 31 October.

A range of recreational and commercial activities including fishing, trek netting, SCUBA diving (particularly at the historical wreck site of the *SS Clan Stuart*), bathing, surfing, kayaking, sailing and boating take place around the Dido Valley site. Recreational fishing (estuarine, shore and boat based angling, spearfishing and cast-netting) is the largest sector in the Bay by number of participants (>200 000 fishers), although commercial fisheries are also very active in the Bay. Most of the shore angling effort pre-1960 was concentrated on the deep water eastern and western shores of False

Bay, targeting reef fish such as red stumpnose (*Chrysoblephus gibbiceps*) and red roman (*C. laticeps*) (Bennett 1991). Over the next three decades, effort shifted to the northern sandy beaches due to declining catches at historic sites and improvement in gear, leading to the catch composition shifting towards kob (*Argyrosomus* spp.), white steenbras (*Lithognathus lithognathus*) and slender bellman (*Umbrina robinsoni*). In 1985, new catch limitations and closed areas were implemented to counteract dramatic stock collapses and declining catches. The closest no-take zone is 2 km east of the Dido Valley site.

Historically, two commercial beach seine (trek net) crews operated in the study area, one off Long Beach and the other at Dido Valley beach. Beach-seine fisheries are South Africa's oldest commercial fisheries established in the early 1700s (Lamberth *et al*. 1994). Harders (*Liza richardsonii*) are the main species targeted by trek netting, accounting for 86% of the catch, but fishers also land substantial quantities of linefish, including white steenbras (Lamberth *et al*. 1994 &1995). False Bay is the only region in the country where net fishers are legally allowed to land linefish species such as yellowtail (*Seriola lalandi*). Some trek fishing equipment remains at Dido Valley but no fishing has taken place at this site since the historical permit holder failed to secure a long-term right in 2008. Octopus and whelk traps have in the past been deployed in close proximity to the Dido Valley site, although the whelk fishery currently exists as an exploratory fishery and is not a full commercial operation.

Significance and sensitivity

Dido Valley falls within the TMNP MPA and the Boulder's Beach restricted/no-take zone occurs within 2 km of the proposed discharge site. Fisheries in the Bay have been impacted by environmental changes, waste water discharges and subsequent eutrophication, and the degradation of estuaries crucial to the recruitment of many fish species caught by beach-seines and shore-anglers (e.g. white steenbras are estuary-dependent for the first year of life). Only two of the 11 False Bay estuaries still support reasonable levels of fish recruitment.

The world famous African penguin breeding colony centred around Boulders Beach, is a popular tourist attraction within Simon's Bay. This penguin colony received over half a million visitors in 2009/10, generating R 14.5 million in park revenue (Lewis 2011). The Boulders colony is of enormous conservation significance as it is home to approximately 5% of South Africa's breeding African penguins (Birdlife 2017). The Boulders MPA and penguin colony both fall within 10 km of the proposed Dido Valley discharge site and discharge of brine into the system may have a devastating effect on the fragile penguin population at Boulders.

Despite being classified as an endangered, endemic SASSI red list species that is rated as 'not-for-sale' within South Africa (SASSI 2017), white steenbras are still targeted by shore anglers. The species is noted as 'declining' by the IUCN (IUCN 2017). In 2014 the stock was assessed at <25% of the pristine biomass with spawner biomass per recruit estimated at 6% of the pristine stock (Mann *et al*. 2014). These figures constitute a collapsed stock no longer suitable for exploitation. Work by Bennet (1993) showed that larger individuals preferentially frequent Simon's Bay in deeper water during summer. Given that the species has high site fidelity (Mann *et al*. 2014), the protection of this habitat in the vicinity of the proposed Dido Valley site is of crucial importance.

Potential for dispersal

Offshore water depth at Dido Valley averages ±20 m with a moderate slope (Gründlingh and Largier 1991, see Figure 3.16). Sheltered from large scale wind driven mixing in the water column, and relatively shallow, this site is considered to provide poor mixing potential for effluent. A marine outfall pipe that terminates at a depth of approximately 4.5 m and originates at the now defunct Marine Oil Refiners of Africa Ltd was originally considered for disposal of effluent from the proposed Dido Valley desal plant. As this outfall is no longer in use and does not provide for land-based dilution of effluent, it has been proposed that brine effluent rather be combined with wastewater effluent currently being discharged from the Dido Valley WWTW outfall approximately 250 m south of the proposed intake position (see Figure 3.17). The existing WWTW pipeline extends subtidally to a discharge depth of approximately 1.5 m. As this outfall is positioned within the surf zone, it may result in entrapment of the brine discharge within surf zone. An outfall positioned beyond the surf zone will improve the dispersal potential of the brine effluent by providing a lower risk of brine entrapment close to shore.

The motivation for a brine discharge at Dido Valley is poor, due to the site's location within a MPA, the proximity to highly sensitive biota (i.e. white steenbras and African penguins), and the sheltered nature of the local site circulation dynamics. In addition, Harmful Algal Blooms (HABs), caused by the proliferation of toxin producing dense dinoflagellate blooms are particularly prevalent at this site in late summer and autumn when the Bay is strongly stratified (Horstman *et al.* 1991, Pitcher and Calder 2000), and are cause for concern for the desalination plant intake water quality.

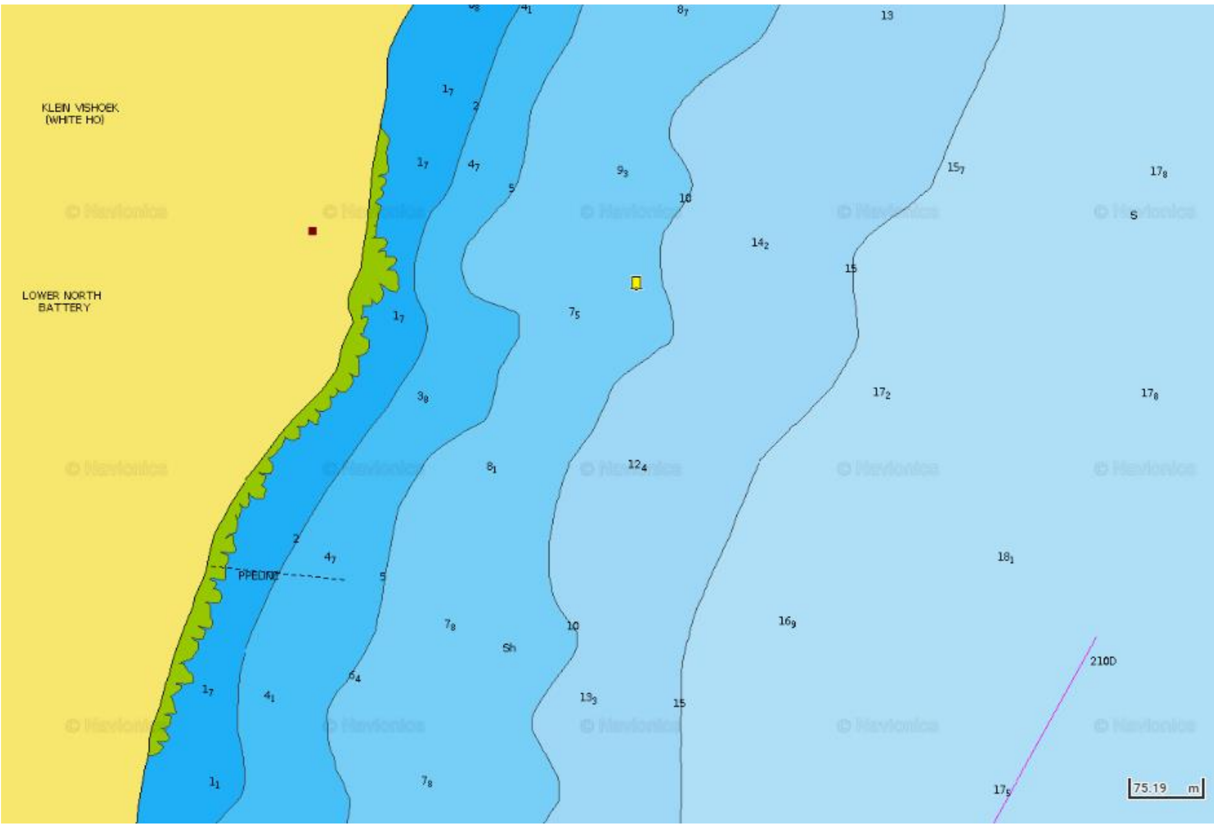

Figure 3.16 Bathymetry in the vicinity of the existing Dido Valley outfall (Source: webapp.navionics.com).

Figure 3.17 Sensitivity map for Dido Valley showing proposed pipeline locations and sensitive environments (Google Earth 2017).

3.7 Strandfontein Tidal Pool

The proposed Strandfontein site lies approximately 12 km west of the Monwabisi site along the northern, sandy, wave-exposed perimeter of False Bay.

Oceanography

Local current patterns have not been investigated in detail, however, as with other exposed northern sandy beaches False Bay, the site is characterised by an eastbound longshore drift along the shoreline due to dominant south-easterly wind forcing. The dissipative beach has a gentle slope and a wide, shallow surf zone. The oceanography of Strandfontein is similar to that of the Monwabisi site (see Section 3.8).

On the 15th of August 2017 Lwandle collected *in situ* water quality samples from Strandfontein and Monwabisi at the sites indicated in Figure 3.18. Conductivity, temperature and depth data were recorded using a CTD and are graphically depicted in Figure 3.19.

Figure 3.18 Sampling locations at Strandfontein and Monwabisi sampled on 15 August 2017.

The water column was well mixed at both locations on the day of sampling (Figure 3.19). Water temperature at Monwabisi was on average 2°C cooler compared to Strandfontein. The water column was relatively isothermal with depth at both sites. Salinity varied slightly between the two locations, with a higher average salinity at Strandfontein. As expected for exposed, high energy shores, dissolved oxygen levels were relatively high (over 100% saturation) and increased turbidity levels were recorded at shallower depths in both locations (Lwandle 2017c).

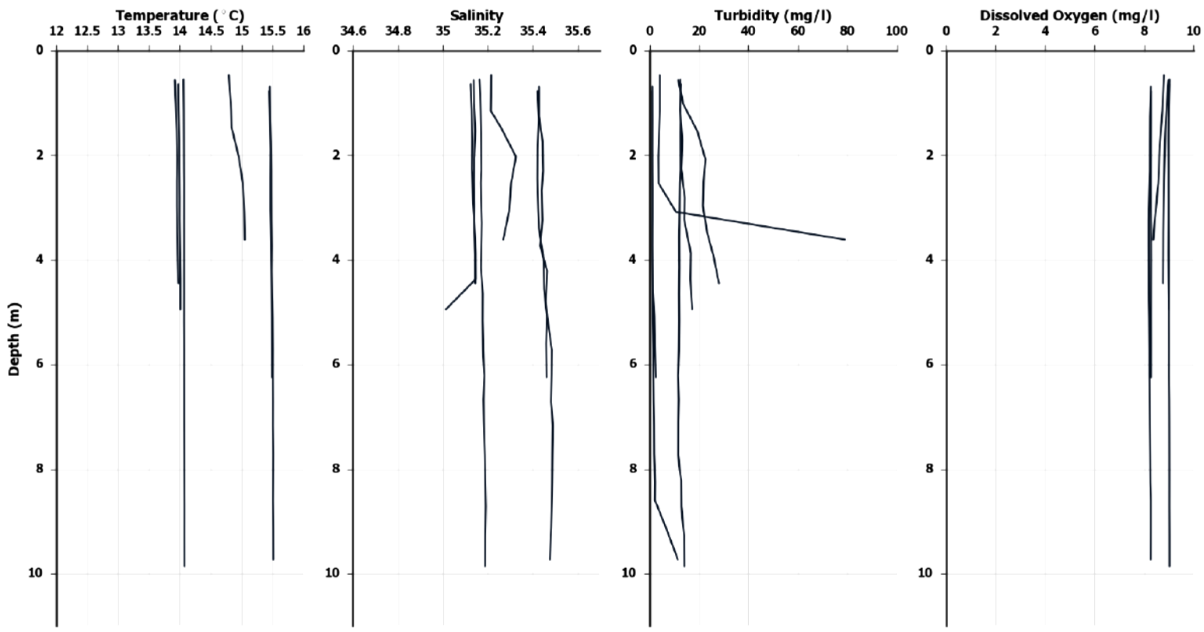

Figure 3.19 CTD profiles for water quality sites sampled on 15 August 2017.

Marine ecology

Intertidal scavengers that feed on dead animals and detritus washed up on the beach are common along this stretch of coastline. They follow the tide down the shore as it recedes to avoid be eaten by terrestrial predators. Important aquatic scavengers include plough whelk (*Bullia* spp.), three spotted swimming crabs (*Ovalipe punctatus*), and several species of burrowing polychaete worms (*Nephytys capensis*, *Lumbrinereis tetraura, Glycera tridactyla*, *Scolelepis squamata and Arabella irricolor*) (Branch *et al*. 2010). The dominant aquatic filter feeders on False Bay beaches are sand mussels (*Donax serra* and *D. sordidus*) that occur buried on the low and mid-shore and feed on small organic particles they suck in through siphons that protrude above the sand (Branch *et al*. 2010). A small crustacean, the surf mysid (*Gastrosaccus psammodytes*), is also very abundant on sandy beaches in the area. This species burrows in the sand during the day and emerges into the water column at night (Branch *et al*. 2010). Mysids and sand mussels are important components in the diet of many surf zone fish.

Air breathing scavengers live high on the shore and feed on kelp and other seaweeds that have been washed up, as well as dead and decaying animal matter. These species complete their life cycles out of water, emerge from the sand during low tide when there is less risk of being washed away, and are almost strictly nocturnal to avoid desiccation and predation. The dominant species in this group are amphipods (e.g. *Talorchestia capensis* and *Talorchestia quadrispinosa)* and isopods (e.g. *Tylos capensis*, *Euridice longicornis* and *Pontogeloides latipes*). These species are important for the breakdown of sea weeds and provide a major food source for shore birds and fish that feed on sandy beaches. Meiofauna (organisms < 1mm in size) are by far the most abundant of the animals found on sandy beaches, as their small size enables them to live between sand grains. The two most common groups are nematode worms and harpacticoid copepods (Wooldridge and Coetzee 1998).

Biota of soft sediments in False Bay have been studied and described by Morgans (1962) and Field (1971). Common species in soft sediments in the surf zone include plough whelks, sand mussels (*Schizodesma spegleri* and *Donax serra*), surf mysids (*Gastrosaccus psammodytes*, *Mysidopsis similes* and *Acathomysis indica),* amphipods (*Urothoe grimaldii* and *Perioculodes longimanus*)*,* and clams (*Tellini gilchristi*). The composition of macroinfaunal communities changes beyond the surf zone, with species such as hermit crabs (*Diogenies extricates*) becoming more common.

Temperate subtidal rocky reefs support diverse assemblages of life, although stresses from wave action and sedimentation result in a high turnover of invertebrate competitors in these habitats. Many of the fish associated with these reefs are important recreation or commercial linefish species. Many of the reef-associated fish and crustaceans not only forage directly on the reef but also on the adjacent sandy bottom areas. As a result, the rocky reef community structure influences macrobenthic distribution and abundance in the adjacent soft bottom habitats (Barros *et al.* 2001). In addition, large predators such as fish and sharks are attracted to the rocky reefs in this area and form an important component of these ecosystems (Barros *et al*. 2001).

Rocky reefs provide substratum to which kelp (*Ecklonia maxima*) attach, providing food and shelter for many organisms. As light is the limiting factor for plant growth, kelp beds only extend down to approximately 10 m depth. Many other algal species live underneath the floating canopy of kelp, especially inshore where the light is abundant and the water shallow. A sub-canopy of *Laminaria pallidae* grows beneath the *Ecklonia* in deeper waters and dense communities of mussels, sea urchins, rock lobster and abalone live between the plants. Herbivores graze on algae and are in turn consumed by predators (du Toit and Attwood 2008).

Fish species common in the surf zone off sandy beaches in False Bay include the silverside (*Atherina breviceps*), mullet (*Liza richardsonii*), white stumpnose (*Rhabdosargus globiceps*), blacktail (*Diplodus sargus*), the False Bay klipvis (*Clinus latipennis*), and sand steenbras (*Lithognathus mormyrus*). Important shore angling species such as galjoen (*Dichistius capensis*)*,* white steenbras (*Lithognathus lithognathus*), silver kob (*Argyrosomus inodorus*) and bellman (*Umbrina robinsoni*) also occur in False Bay surf zones (Lamberth *et al*. 1994).

Further offshore, Seal Island lies 5 km seaward of Strandfontein. The island is home to 60 000 seals, which makes it a prime feeding area for great white sharks between April and September when seal pups spend are learning to swim. The predators have been observed surging up from deep water to attack seals from below, a behaviour known as breaching. During the summer months, white sharks patrol the shallower, sandy areas of False Bay in search of fish and rays. Cetaceans reported from the site include the southern right (*Eubalaena australis*), humpback (*Megaptera novaeangliae*) and Bryde's whales (*Balaenoptera brydei*), as well as Heaviside (*Cephalorhynchus heavisidii*), dusky (*Lagenorhynchus obscurus*), Indo-Pacific bottlenose (*Tursiops aduncus*) and Indian Ocean humpback (*Sousa plumbea*) dolphins (Best 2007). Orca (*Orcinus orca*) have also been sighted in False Bay on occasion.

Existing beneficial uses

Strandfontein is an important recreational area due to the large, well-protected tidal pool and nearby Blue Flag beach. The facility boasts the largest tidal swimming pool south of the equator and has braai sites and grassed terrace picnic sites. The day-resort is backed by a pavilion which hosts events during the summer season. Bathing is a popular recreational activity at the site. Lifeguards are on duty during peak periods and the National Sea Rescue Institute (NSRI) Station 16 is adjacent to the tidal pool. This site is a nine-time certified Blue Flag beach, with a Blue Flag season from 1 December to 31 March (WESSA 2016). The site is very popular with anglers that target white steenbras and galjoen as well as subsistence trek net fishers and commercial line fishers.

Significance and sensitivity

While many sandy beach species are endemic to False Bay, the Strandfontein benthic fauna of both subtidal and intertidal rocky and sandy substrata are considered typical of False Bay. An Important Bird and Biodiversity Area (IBA) occurs immediately east of the proposed desalination site and forms part of the False Bay Nature Reserve. This site provides important roosting areas for a number of seabirds that forage in False Bay. The shallow subtidal reefs offshore of Strandfontein are ecologically important for a host of fish species such as white steenbras and belman, the populations of which would likely diminish if these reefs were to deteriorate due to anthropogenic disturbance. The extent of these reefs is not well known (indicated roughly on Figure 3.21) and should ideally be delimited properly with a detailed bathymetric or side sonar scan survey.

Potential for dispersal

The proposed desalination plant at Strandfontein comprises of 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. The general layout of proposed desalination plant at Strandfontein for Phases 1 and 2 is shown in Figure 3.22.

The proposed Phase 1 outfall currently under consideration consists of an outfall positioned within the surf zone (see Figure 3.21). This design is not recommended is it may result in entrapment of brine within the wide and relatively shallow, gently sloping surf zone at Strandfontein (Figure 3.20). In addition, the predominantly eastbound longshore current at the site may result in the entrainment of the discharged brine further down the beach, trapping the effluent in the surf zone and impacting on sandy beach fauna. An outfall positioned beyond the surf zone will improve the dispersal potential of the brine effluent by lowering the risk of brine entrapment close to shore (DWAF 2004, Anchor 2015). It is suggested that the brine discharge be incorporated into one of the existing WWTW effluent discharge points in the area. However, the emergency situation may justify the discharge of effluent into the surf zone as a short term, emergency measure for **Phase 1, provided that the duration is kept to a minimum (< six months), the footprint is small (< 1 km) and the discharge volumes do not exceed the modelled brine dispersal results for Phase 1.** Monitoring will be of crucial importance to ensure that these requirements are met. The effluent discharge pipeline must be extended beyond the surf zone to cope with the increased brine volumes of proposed for **Phase 2**.

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 (see Figure 3.23):

- The discharge point shall be at minimum water depth of -1 m CD
- No discharge allowed within the tidal pool
- No discharge allowed eastwards and westwards of demarcated areas.

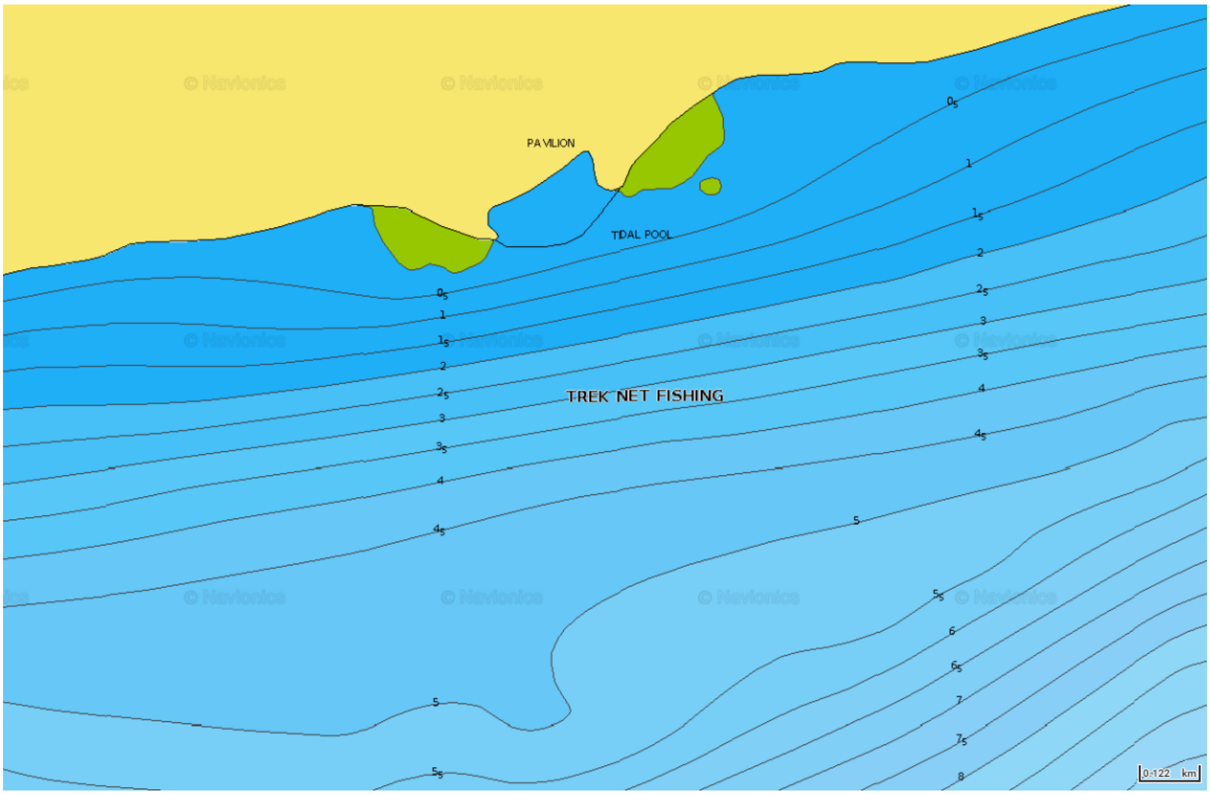

Figure 3.20 Bathymetry in the vicinity of the Strandfontein Tidal Pool (Source: webapp.navionics.com).

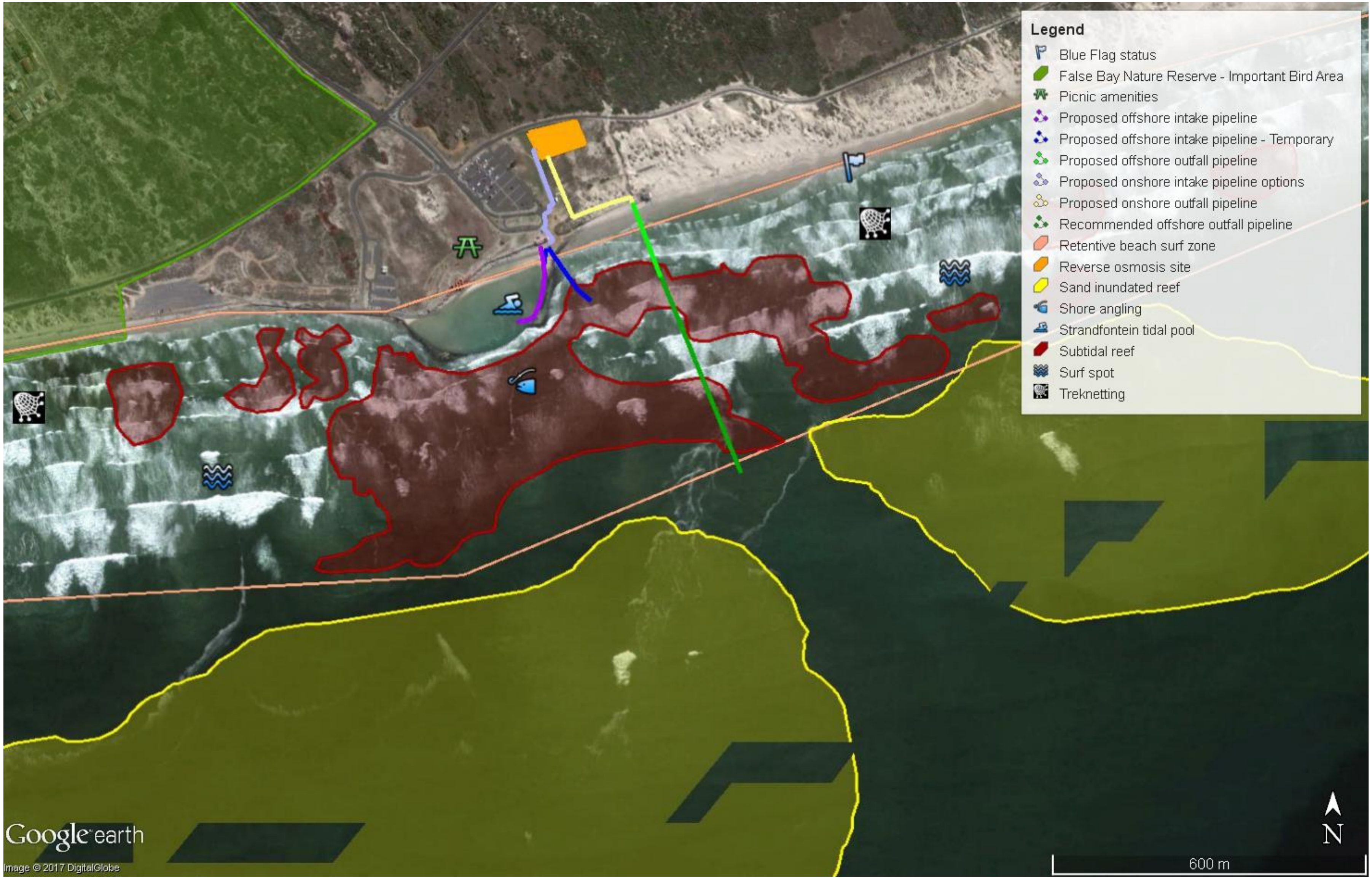

Figure 3.21 **Sensitivity map for Strandfontein showing proposed and recommended pipeline locations and sensitive environments (Google Earth 2017).**

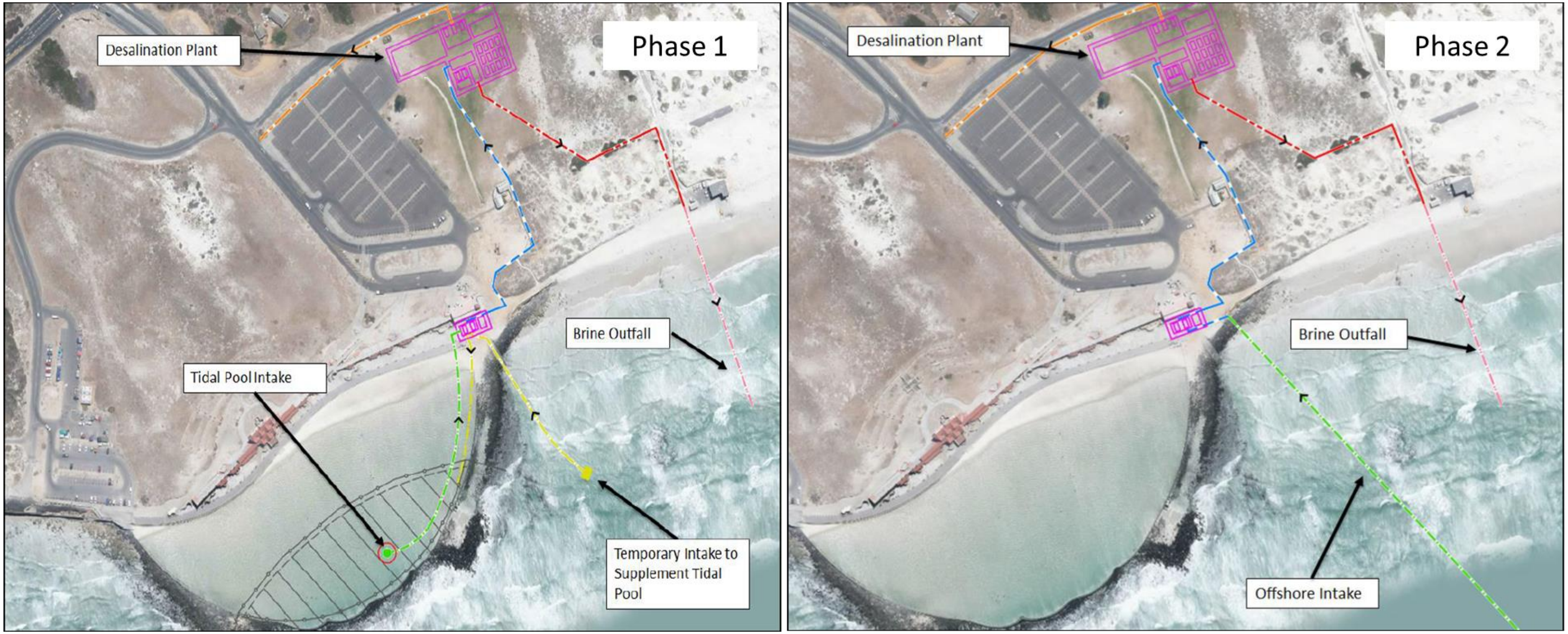

Figure 3.22 **General layout of proposed desalination plant at Strandfontein (Phase 1 and Phase 2) (Advisian 2017) (note that this layout is indicative only, since the Supplier shall develop the final layout of the plant and marine works).**

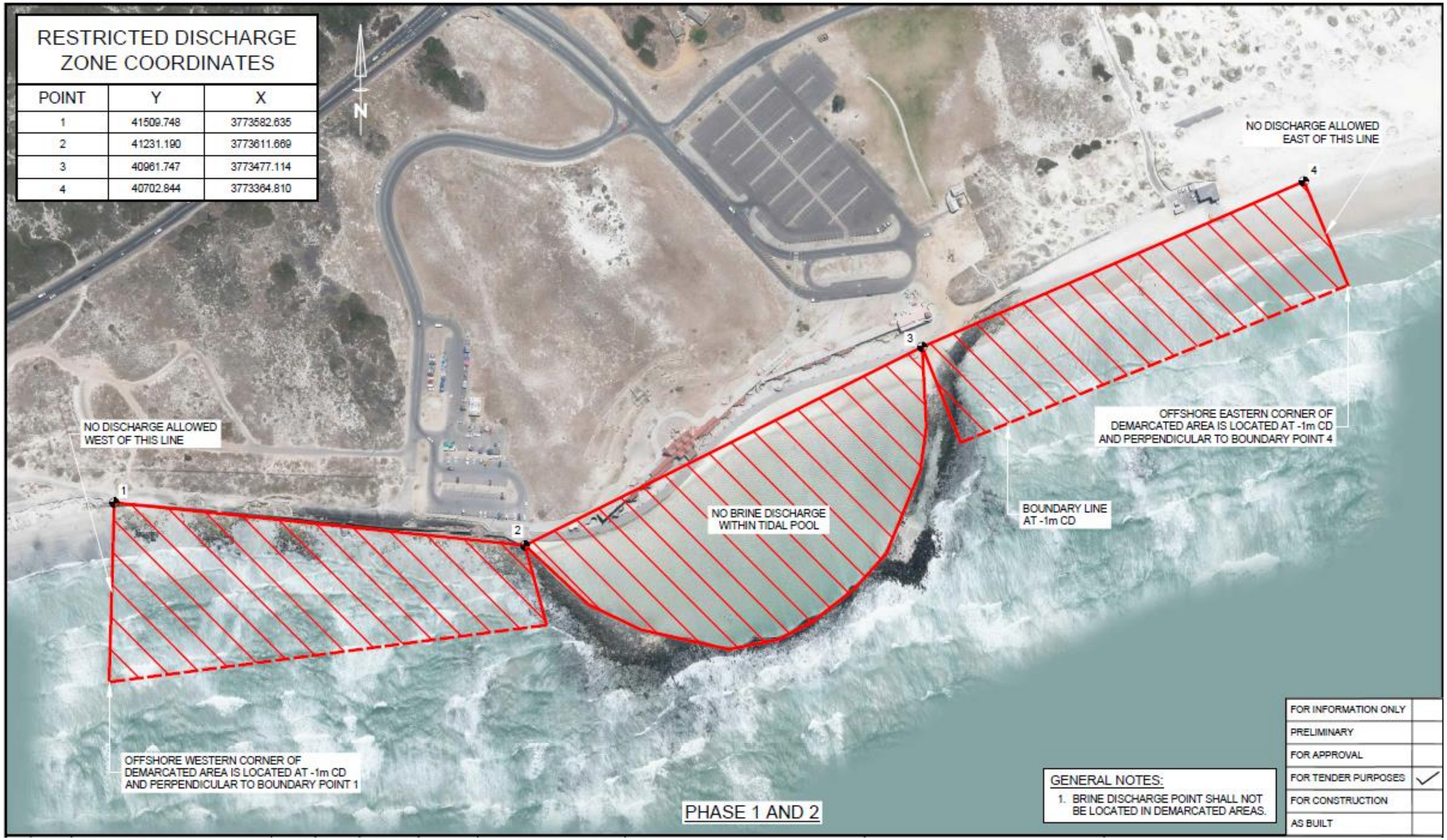

Figure 3.23 Strandfontein brine discharge point exclusion zones (Phases 1 & 2) (Advisian 2017).

3.8 Monwabisi Tidal Pool

Approximately 40 km from Cape Town and 20 km from Strand, Monwabisi is a beach resort located on the northern wave-exposed perimeter of False Bay. This site is an important recreational area for the Khayelitsha community as well as for people who live further inland. Partially within the littoral zone, Monwabisi visitors have access to both a sandy beach and a very popular tidal pool, which was built in 1987 on the mixed rocky/sandy shoreline. A 170 m longshore breakwater was built seaward of the existing tidal pool to further enhance safely. In addition, a short groyne was built perpendicular to the shoreline approximately 350 m east of the tidal pool wall.

Oceanography

The Monwabisi nearshore consists mostly of flat, rocky areas interspersed with sections of sand. Eastwards there are more sandy areas, while the shoreline west of Monwabisi consists entirely of rocky shore. The subtidal benthos is predominately rocky (approximately 70% rocky and 30% sandy), with intermittent rocky outcrops within the surf zone (CSIR 1984, 1986, 1989 &1995b, Swart and Schoonees 1994).

Dominant swell direction is southerly to south-westerly (Theron and Schoonees 2007) and average wave heights measure 2.9 m in 10 m of water (Schoonees *et al.* 1999), however, weather forcing can result in occasionally swamping of the coast parallel road which is 3 m above MSL. The nearshore slope is flat, with a wide surf zone of between 270 and 530 m (Theron and Schoonees 2007) in which waves break numerous times, dissipating energy and resulting in a relatively protected shore zone.

While the exposed northern sandy beaches of False Bay are typically characterised by an eastbound coast parallel longshore drift due to dominant south-easterly wind forcing, the construction of the Monwabisi breakwater has resulted in a local reversal of the typical longshore current. This westward longshore current is particularly prominent during strong south-easterly winds (the dominant summer wind direction) and results in a "wave-generated counter-clockwise eddy current" on the beach directly adjacent to the tidal pool (Theron and Schoonees 2007). This circulation cell is dangerous for swimmers as it creates a strong rip current along the sheltered side of the breakwater (Kistner 2016). Towards the head of the breakwater, the water depth rapidly increases, posing additional risk for unwary bathers. Unfortunately removal of the breakwater is not conducive with the existence of a safe tidal pool as it protects the pool against wave overtopping and scouring (Kistner 2016).

Marine ecology

Sink *et al.* (2012) identified three distinct False Bay habitat types, including sandy coasts, rocky coasts, subtidal unconsolidated sediments and reefs, all of which are incorporated in the Monwabisi site. Both sandy beach and rocky shore habitats are likely representative of those typical of False Bay. The marine ecology of Monwabisi is similar to that of the Strandfontein site (see Section 3.7).

Existing beneficial uses

The beach and tidal pool of Monwabisi are extremely important recreational areas for the people of Khayelitsha and surrounds in terms of beach access, bathing, recreational fishing and surf angling.

Subsistence trek net fishing and commercial line fishing is also dependant on the area. A site of historical importance exists at Monwabisi; a wooden sailing vessel called the *Drietal Handelaars* was wrecked near Swartklip Rocks in 1789 (Webley 2009).

Significance and sensitivity

While a number of the invertebrate species living on the sandy beach are likely to be endemic to False Bay (see Section 3.7), they are considered common within the Bay. The shallow subtidal reefs offshore of Monwabisi and Strandfontein are ecologically important for a host of fish species such as white Steenbras and belman, the populations of which would likely diminish if these reefs were to deteriorate due to anthropogenic disturbance. The extent of these reefs is not well known (indicated roughly on Figure 3.25) and should ideally be delimited properly with a detailed bathymetric or side sonar scan survey.

Potential for dispersal

The proposed desalination plant at Monwabisi is comprised of 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 (Figure 3.26).

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 (see Figure 3.27 and Figure 3.28):

- The discharge point shall be at minimum water depth of -1 m CD (exception made for Phase 1, refer to Figure 3.27).
- No discharge allowed within the tidal pool.
- No discharge allowed eastwards and westwards of demarcated areas.

The proposed **Phase 1** effluent discharge for Monwabisi includes a surf zone discharge from the gryone (Figure 3.27). There is cause for concern as the wide and relatively shallow, gently sloping surf zone may result in limited dilution (Figure 3.24). The design currently under consideration consists of a pipeline laid over an existing artificial groyne to the east of the tidal pool (sees Figure 3.25). This outfall will be positioned within the surf zone and may result in entrapment of brine discharge. Furthermore, the predominantly westward longshore current at the site may potentially result in entrainment of the discharged brine into the local retentive gyre that recirculates water in the corner between the tidal pool and beach. However, the emergency situation may justify the discharge of effluent into the surf zone as a short term, emergency measure for **Phase 1, provided that the duration is kept to a minimum (< six months), the footprint is small (< 1 km) and the discharge volumes do not exceed the modelled brine dispersal results for Phase 1.** Monitoring will be of crucial importance to ensure that these requirements are met. The effluent discharge pipeline must be extended beyond the surf zone to cope with the increased brine volumes of proposed for **Phase 2**.

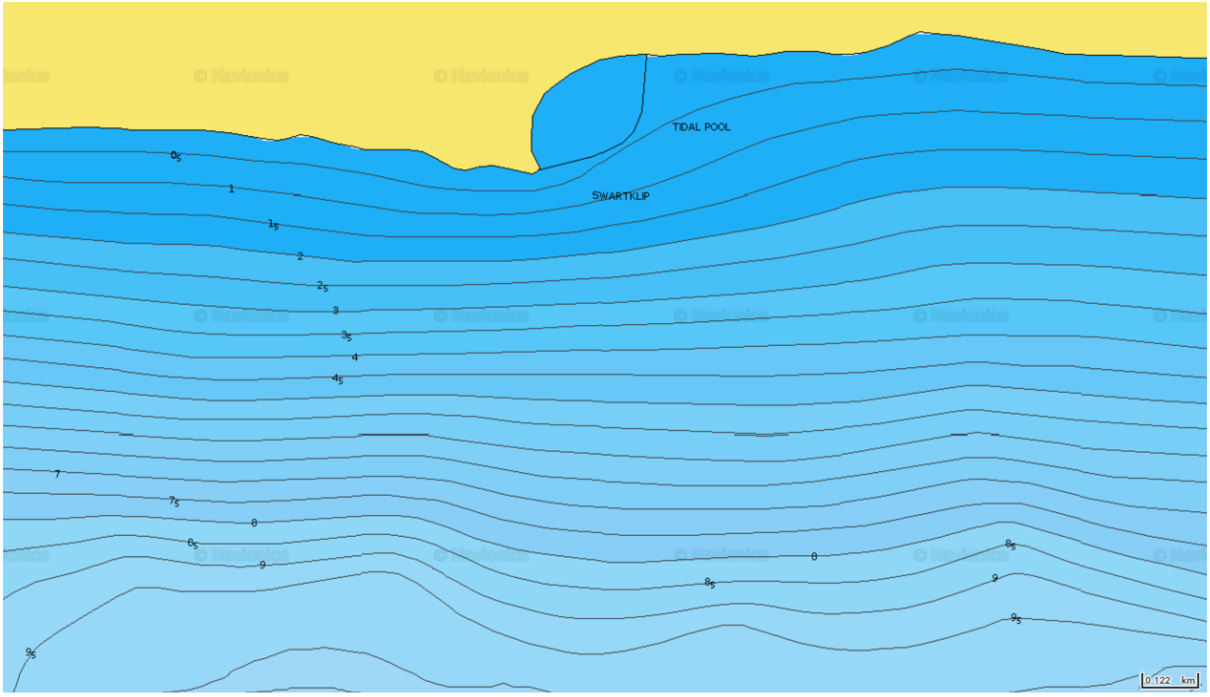

Figure 3.24 Bathymetry in the vicinity of Monwabisi Tidal Pool (Source: webapp.navionics.com).

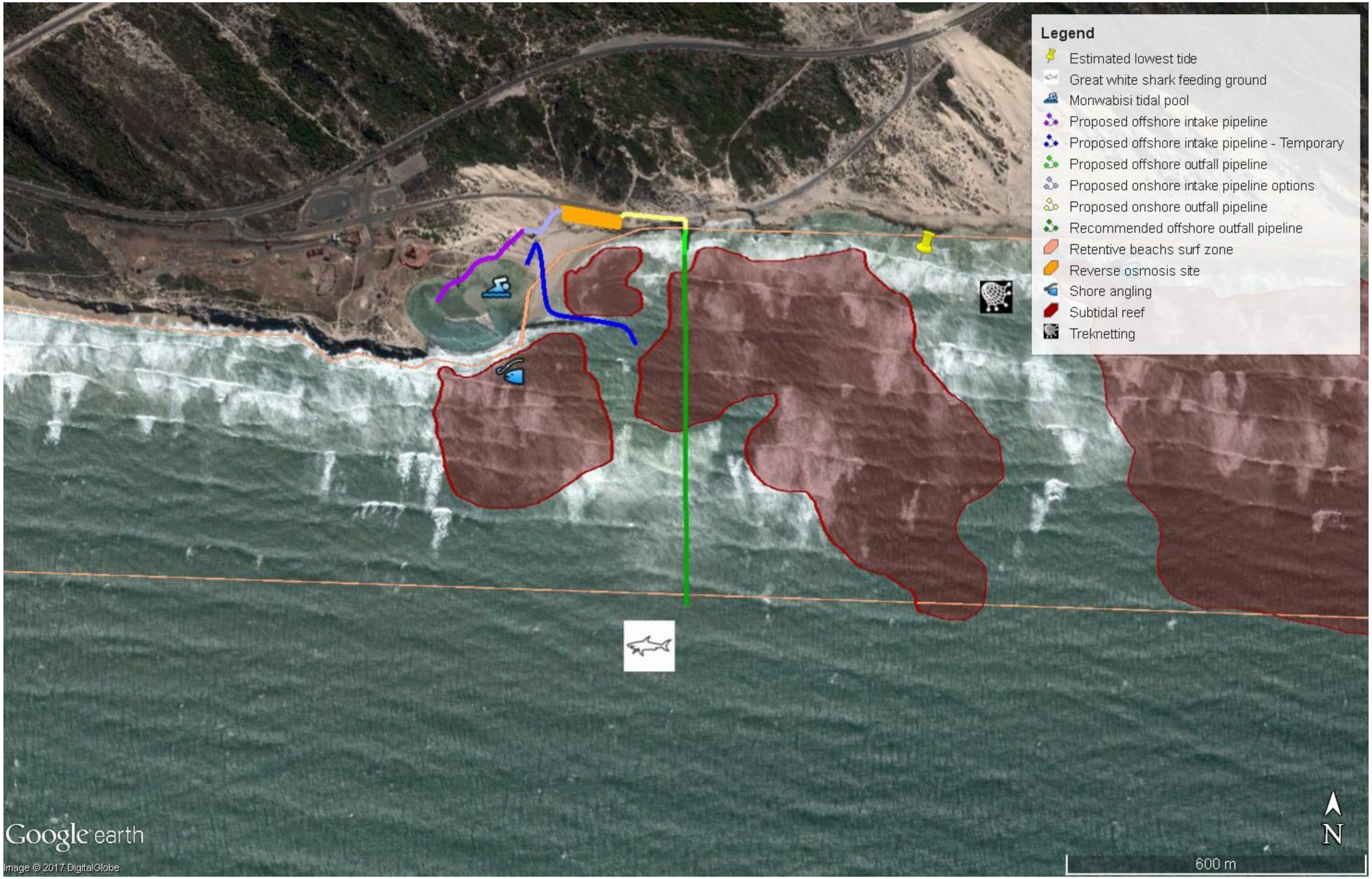

Figure 3.25 **Sensitivity map for Monwabisi showing proposed and recommended pipeline locations and sensitive environments (Google Earth 2017).**

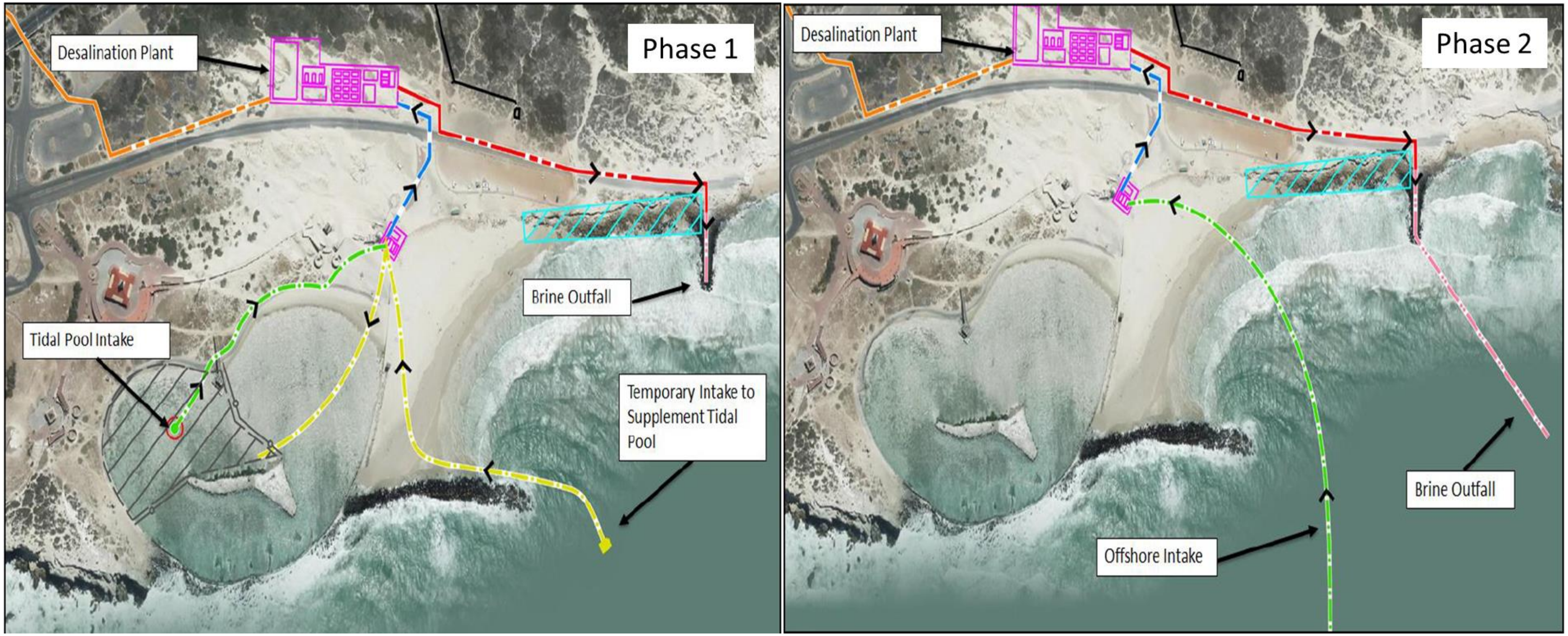

Figure 3.26 General layout of proposed desalination plant at Monwabisi (Phase 1 and Phase 2) (Advisian 2017) (note that this layout is indicative only, since the Supplier shall develop the final layout of the plant and marine works).

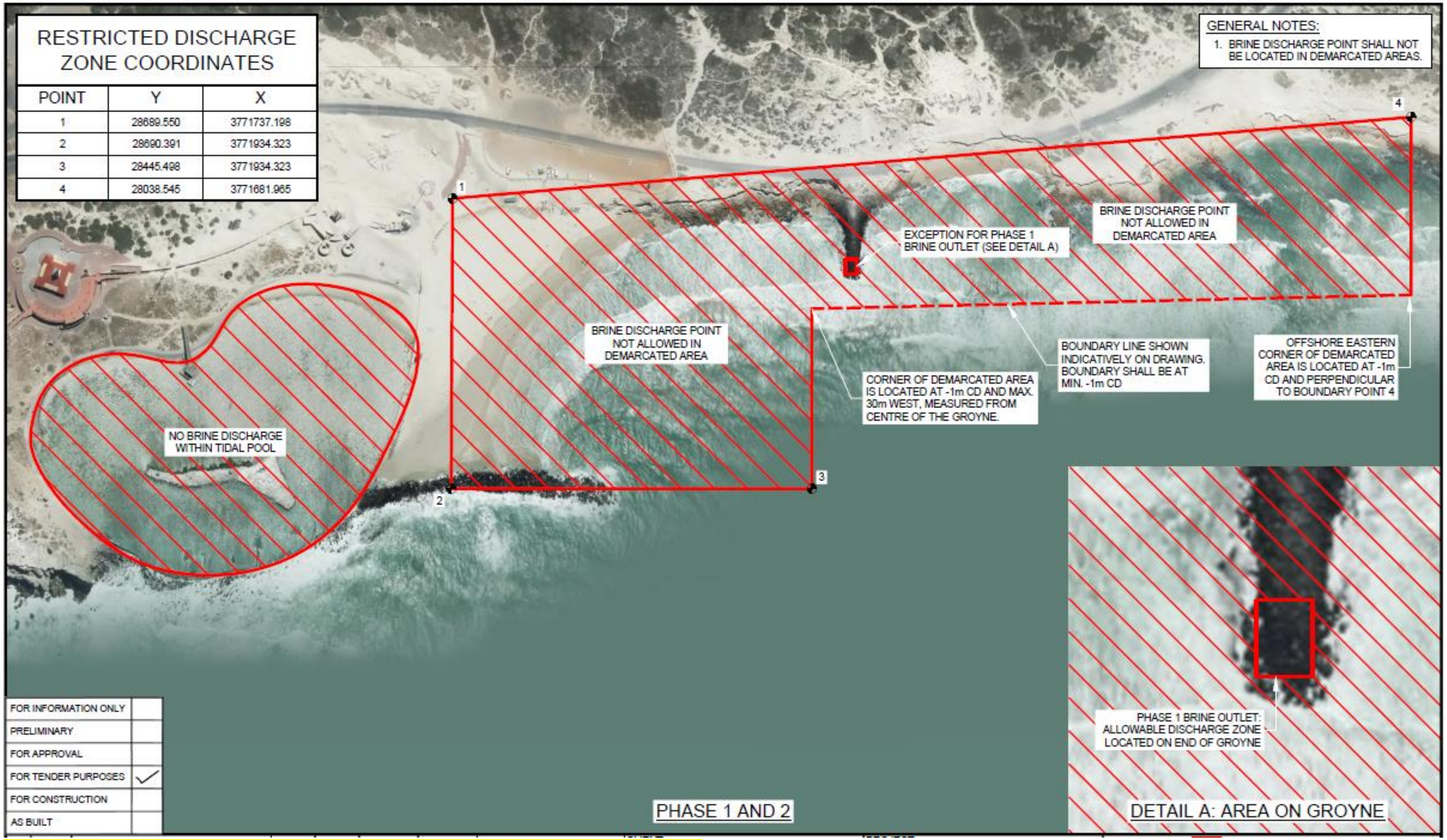

Figure 3.27 Monwabisi brine discharge point exclusion zones (Phase 1) (Advisian 2017).

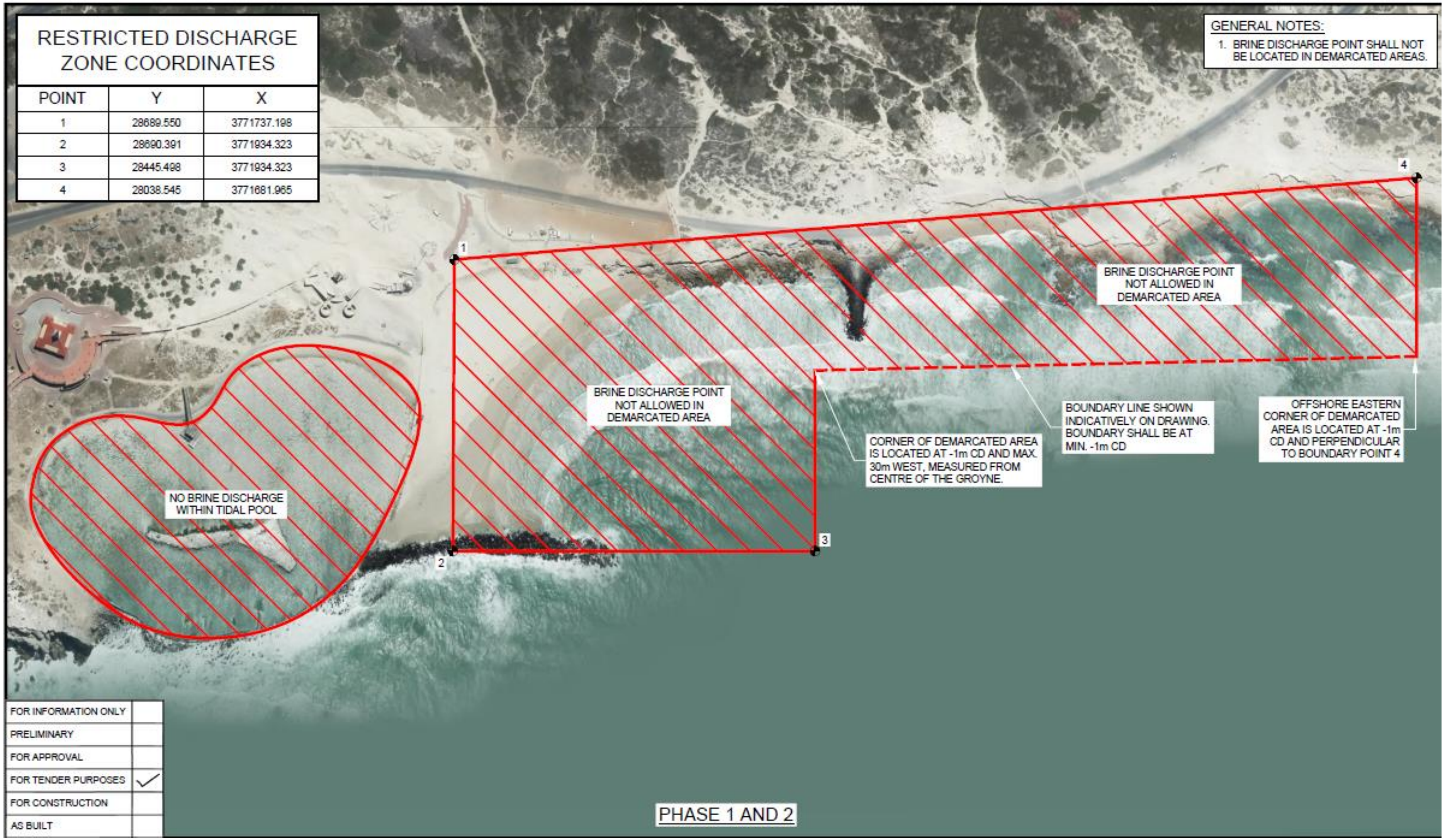

Figure 3.28 Monwabisi brine discharge point exclusion zones (Phase 2) (Advisian 2017).

3.9 Harmony Park and Gordon's Bay

Gordon's Bay is a harbour town situated on the north-eastern corner of False Bay about 50 km from Cape Town and close to Strand. Harmony Park is a popular coastal day resort approximately 4 km west of Gordon's Bay. The main features of the facility are a tidal pool, a pavilion and a fishing pier.

Oceanography

Of particular oceanographic importance to the proposed effluent outfall site is the presence of a semi-enclosed local circulation cell off the shallow waters of Gordons Bay (Atkins, 1970). The cell is relatively independent of the circulation of the greater False Bay and results in the entrapment of water in the north-eastern corner of the Bay (Atkins 1970, Pitcher *et al*. 2008). An example of the effects of this gyre was shown by Rundgren (1992) who investigated the distribution and composition of subtidal litter in False Bay. The results showed that litter densities were greatest along the northern shore of the Bay, particularly in the north-eastern corner at Gordon's Bay due to the predominantly easterly longshore current that runs along the northern shore.

The Bay is usually calm and is protected from incoming swells by the gently shelving bottom as well as by shore parallel rocky reefs located between 200 and 500 m offshore (Clark *et al*. 1996). The water depth off Gordon's Bay is very shallow and 20 m depth is achieved approximately 5 km from shore (Figure 3.31). The shore is comprised of elongated sedimentary rocky outcrops interspersed with gently sloping sections of sand on the high shore and pebbles on the low shore (Clark *et al*. 1996).

On the 14th of August 2017 Lwandle collected *in situ* water quality samples from Harmony Park and Gordon's Bay at the sites indicated in Figure 3.29. Conductivity, temperature and depth data were recorded using a CTD and are graphically depicted in Figure 3.30. The water column at both locations was well mixed on the day of sampling, displaying isothermal and isohaline properties with depth. The water column was well oxygenated at all sites; although the average dissolved oxygen within the Yacht Club was lower (not significantly) than the other sites (88% saturation and 5.19 mg/L). A high degree of variability in turbidity values was experienced between sites and a disturbed or nepheloid layer appeared to be present near the seafloor at GB1, GB2, GB4 and HP2 (Lwandle 2017d).

Figure 3.29 Sampling locations at Harmony Park and Gordon's Bay sampled on 14 August 2017.

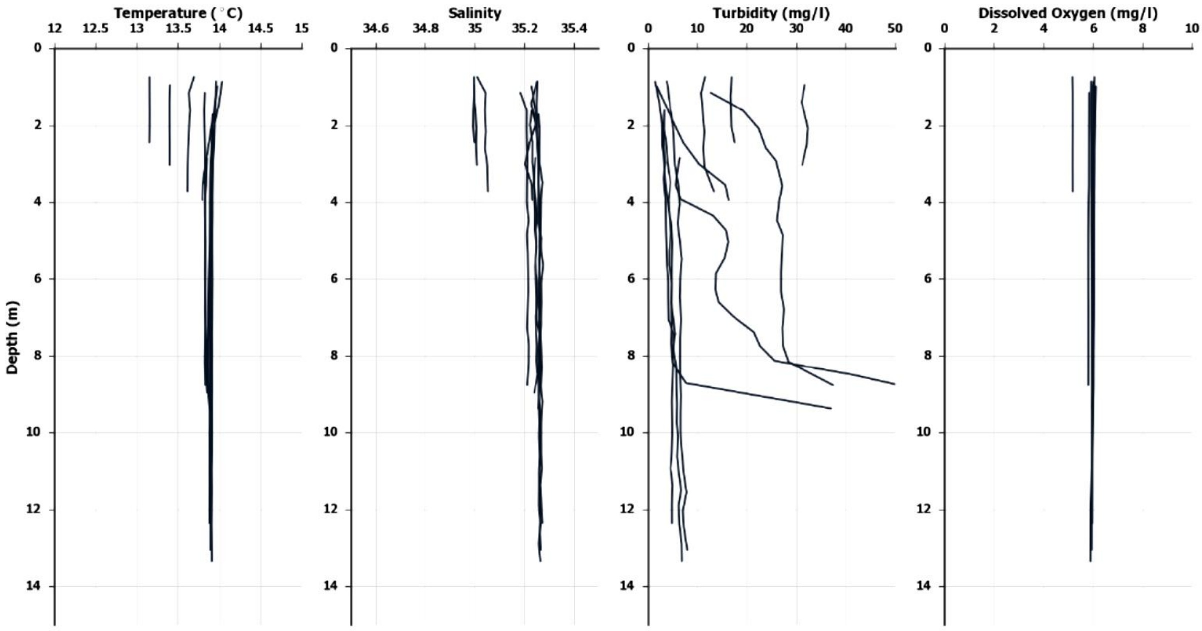

Figure 3.30 CTD profiles for water quality sites sampled on 14 August 2017.

Marine ecology

The marine ecology of Gordon's Bay is characteristic of the larger False Bay area (see Section 3.6 and Section 3.7). This site provides an import nursery area for juvenile fish and boasts the highest species richness of surf zone fish recorded in False Bay with over 31 species recorded in 1996 (Clark *et al*. 1996). The Gordon's Bay intertidal rocky shore and sensitive subtidal reef invertebrate communities are typical of the greater False Bay region (see Section 3.7). Alien invertebrates are found along the shoreline, especially within the harbour environment.

Existing beneficial uses

The scenic drive from Gordon's Bay towards Betty's Bay offers spectacular views over False Bay including the Hottentots Holland and Table Mountain ranges. Harmony Park beach and tidal pool provides recreational space for the local community. The site offers parking, safe bathing, lifeguards, disability access, picnic and braai facilities as well as dog walking. Recreational marine activities in the area include SCUBA diving, bathing, fishing, surfing, kayaking, sailing and boating. Bikini Beach has been Blue Flag certified for 13 consecutive years with a Blue Flag season from 1 December to 31 January. Due to the close proximity of restaurants and hotels and the availability of a safe bathing area, Harmony Park is a popular destination for locals and overseas tourists alike. There is disabled access to the beach and lifeguards are on duty during the Blue Flag season.

Significance and sensitivity

Since the Dutch East India Company established a fishing post at Gordon's Bay in 1672, vessel traffic and boat activity has increased rapidly over recent years. The Bay is subject to urban pollution via storm water runoff from the adjacent town, as well as vessel pollution and oil spills. The site is undoubtedly important in terms of surf zone fish habitat and the Koegelberg Biosphere Reserve Marine Buffer Area occurs approximately 2 km south-east from proposed outfall point.

Potential for dispersal

Three options exist for the discharge of RO plant effluent within the Gordon's Bay/Harmony Park area: 1) an offshore discharge north-west of the Harmony Park tidal pool (Figure 3.32), 2) an offshore discharge from a SWRO vessel anchored offshore of Gordon's Bay Harbour (Figure 3.33), and 3) an offshore discharge from a barge moored alongside the northern breakwater of the Harbour (Figure 3.33). In general, the flat, shallow bathymetry of Gordon's Bay and the retentive gyre may decrease the mixing potential of the brine effluent, leading to a pooling of brine within the area. The proposed Phase 1 outfall at Harmony Park will discharge effluent into the surf zone, which may result in entrapment of brine and limit dilution potential (Figure 3.32). Eastbound longshore drift may resulted in brine effluent being trapped in the nearshore environment and may compromise the intake water quality at the proposed intake pipe end, if the discharged brine is not adequately dispersed. An outfall positioned beyond the surf zone is proposed for Phase 2, which should be completed within two years of the initial pipeline construction to improve intake water quality and reduce impacts on marine life.

The discharge of brine from a SWRO vessel anchored in a deeper and more exposed section of the Bay (see Figure 3.33) will promote mixing through the surface discharge of effluent, the increased depth of the water column, and the positioning of the outfall away from the gyre. A shallow draft barge moored at the Gordon's Bay Harbour (see Figure 3.33) is likely to facilitate sufficient mixing provided that the outfall is positioned well beyond the local circulation cell in deeper water to allow for the effective dispersal of brine. Positioning of the offshore outfall further southwards towards Betty's Bay (beyond the 10 m depth contour, Figure 3.31) will promote mixing due to the steeper bathymetry, increased wave exposure and strong upwelling (Figure 3.31).

Numerous concerns relating to intake water quality exist for this site. Gordon's Bay is relatively turbid compared to the rest of False Bay (Clark *et al*. 1996) as a result of a shallow sandy bottom that is disturbed by rough sea conditions. In addition, the local retentive gyre in the area is responsible for the concentration of harmful pelagic algal species in the north-eastern corner of False Bay, commonly resulting in concentrated HABs (see Section 3.6). These factors should be taken into consideration for intake water quality.

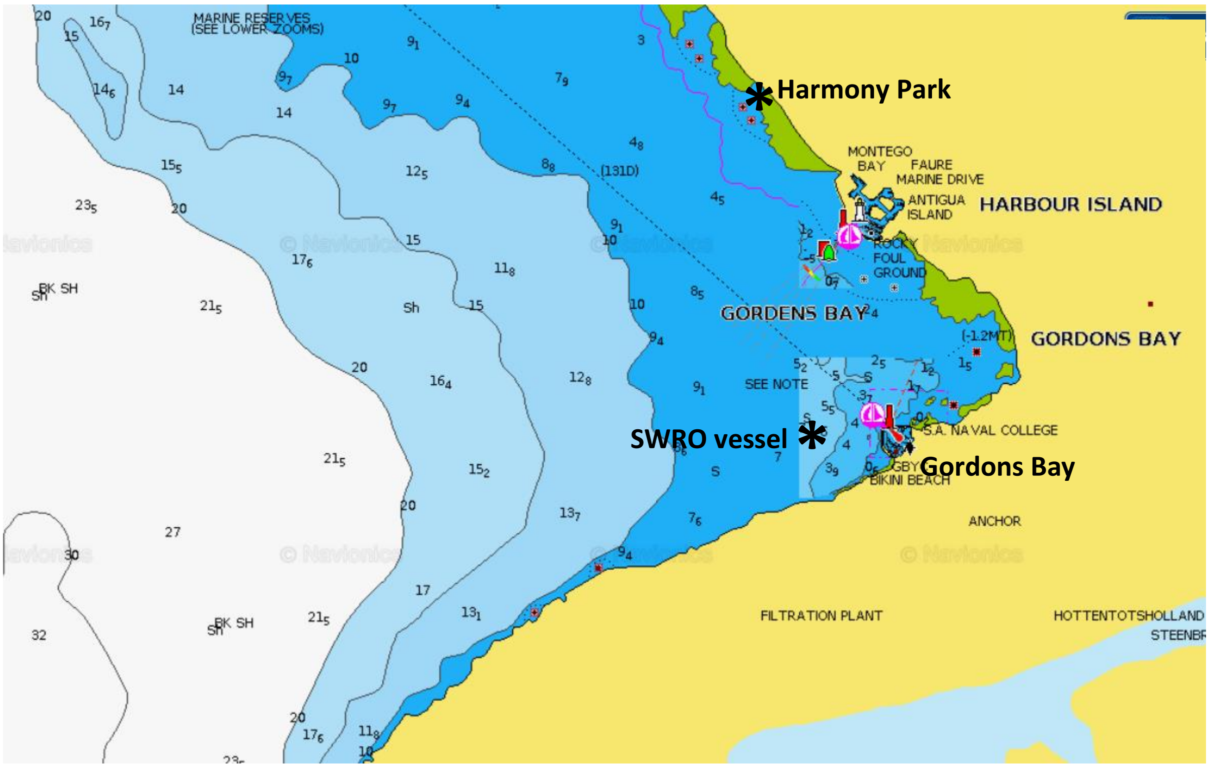

Figure 3.31. Bathymetry in the vicinity of the Harmony Park and Gordons Bay sites (Source: webapp.navionics.com).

Figure 3.32 Sensitivity map for Harmony Park showing proposed pipeline locations and sensitive environments (Google Earth 2017).

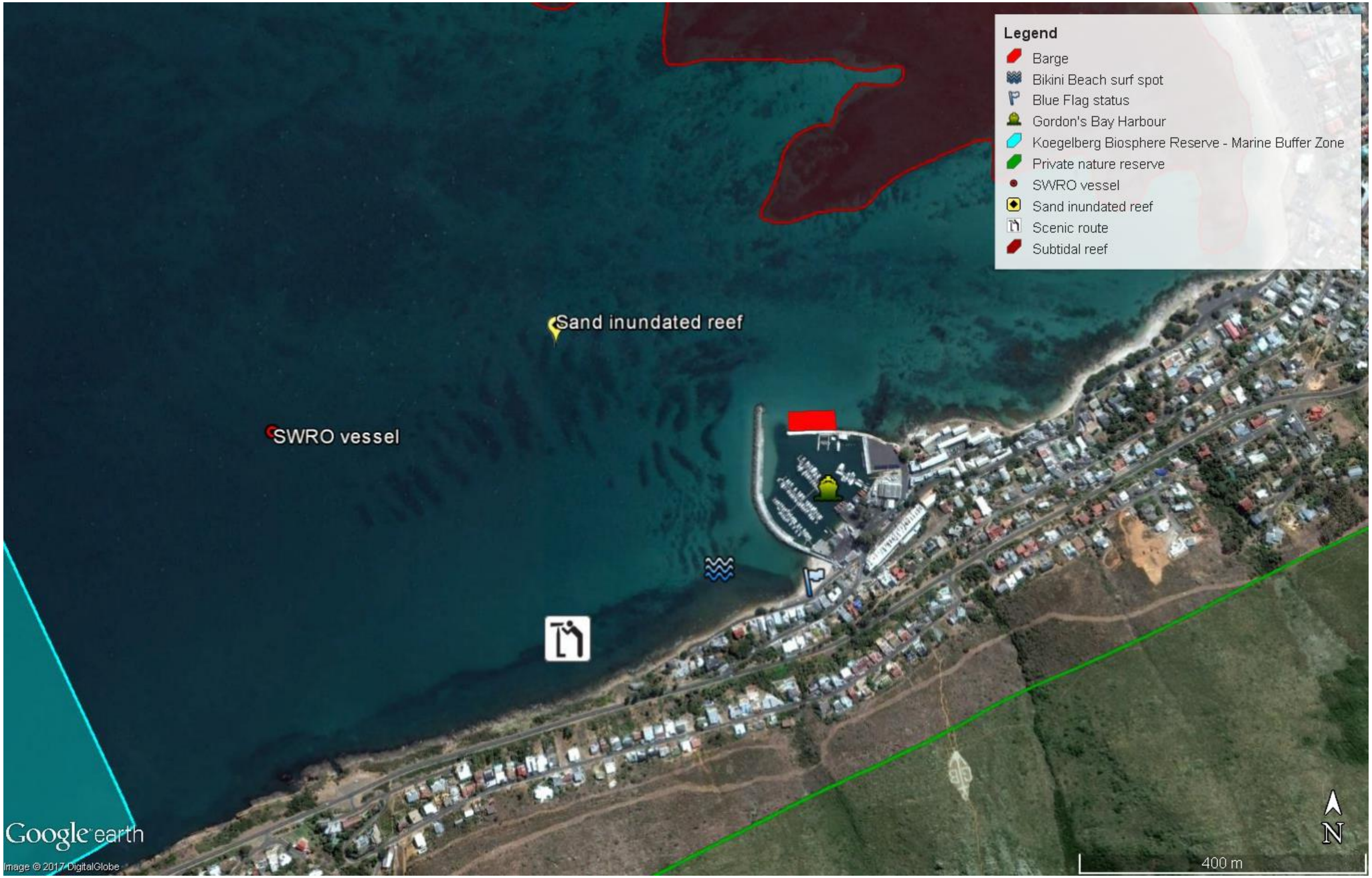

Figure 3.33 Sensitivity map for Gordon's Bay Harbour showing SWRO vessel and barge options as well as sensitive environments (Google Earth 2017).

4 IMPACT ASSESSMENT

The establishment of temporary RO plants around the Cape Peninsula will result in a range of impacts on the marine environment, details of which are described below. Existing habitat types that may be impacted depend on the siting of each proposed RO plant and may include sandy beaches, sandy benthic habitat, rocky reefs, rocky shores, pelagic habitat and artificial habitat. Each of the impacts assessed is likely to affect the associated biota in different ways and at varying intensities depending on the nature of the affected habitat and the sensitivity of the biota. The degree of each impact depends on the duration of disturbance, which is reliant on the life of the operation (two years for temporary container plants, barges and SWRO vessels).

In the marine environment, a disturbance can be relatively short-lived (e.g. construction across sandy beach habitat) but the effect of such a disturbance may have a much longer lifetime (e.g. mortality of organisms by crushing). The assessment and rating procedure described in Appendix 1 addresses the effects and consequences (i.e. the impact) on the environment rather than the cause or the initial disturbance alone. To reduce negative impacts, precautions referred to as 'mitigation measures' are set and attainable mitigation actions are recommended. Interventions to alleviate the severity of the impacts identified were divided into two categories: required and best-practice depending on the severity of the impact.

In this report, the 'construction footprint' is defined as the total area affected during plant establishment, while the 'operational footprint' is defined as the area likely to be affected by the effluent outfall. As impacts are dependent on the position of each outfall, RO site options were grouped into three categories according to the nature of the marine environment closest to the discharge point: 1) offshore outfalls (generally pelagic water and subtidal sand), 2) harbour outfalls (generally artificial substrate), and 3) surf zone outfalls (mixed habitat consisting of intertidal or subtidal sand and rock). Offshore outfalls were defined as being at least 500 m offshore or deeper than 10 m water depth, whichever was greatest. Table 4.1 summarises the dispersal characteristics of each discharge site and their respective impact assessment groupings:

1) Offshore (pelagic water and subtidal sand):
    - Cape Town Harbour - SWRO offshore vessel
    - Green Point (Granger Bay)
    - Glen Country Club
    - Hout Bay
    - Gordon's Bay Harbour – SWRO offshore vessel
2) Harbour (artificial substrate):
    - Cape Town Harbour breakwater
    - Cape Town Harbour - barge moored at container terminal of Ben Schoeman dock
    - Gordon's Bay Harbour – barge moored seaward of northern breakwater
3) Surf zone/mixed habitat (intertidal or subtidal sand and rock):
    - Silwerstroomstrand
    - Dido Valley
    - Strandfontein Tidal Pool (Phase 1 and Phase 2)
    - Monwabisi Tidal Pool (Phase 1 and Phase 2)
    - Harmony Park

Impacts within these categories are unlikely to differ when viewed from a marine environmental perspective, thus one assessment per impact is provided for each category. Habitat types that may be affected from the proposed construction and operations are summarised in

Table 4.2 and Table 4.3 respectively. These habitat types were used to assess the likely severity of impacts as presented in Table 4.4 to Table 4.17. Impact ratings for the construction/decommissioning and operational phase are summarised in Table 4.18 and Table 4.19 respectively.

Table 4.1 Proposed RO sites were categorised according to discharge site characteristics. Note that the distance offshore was estimated from Google Earth imagery.

Site	Category	Distance offshore	Exposure	Dispersal potential	Characteristics of discharge site
1) Silwerstroomstrand	3) Surf zone	6 m	Exposed	Poor	• Longshore drift north along shore • Entrainment in surf zone • Shallow
2a) Cape Town Harbour breakwater	2) Harbour	8 m	Sheltered	Poor	• Trapped within Elliot Basin (water residence time within the Port between 1 and 7 days)
2b) Cape Town Harbour – barge moored at container terminal of Ben Schoeman dock	2) Harbour	0 m	Retentive	Poor	• Trapped within Duncan Dock (water residence time within the Port between 1 and 7 days)
2c) Cape Town Harbour – SWRO offshore vessel	1) Offshore	2.5 km	Exposed	Good	• Deep and far offshore • Moderately steep bathymetry
3) Green Point (Granger Bay)	1) Offshore	1.5 km	Exposed	Good	• Deep and far offshore • Moderately steep bathymetry
4) Glen Country Club	1) Offshore	570 m	Exposed	Good	• Deep and far offshore
5) Hout Bay	1) Offshore	1 km	Semi-exposed	Good	• Plume could be pushed towards shore by the dominant southwest swell and onshore winds
6) Dido Valley	3) Surf zone	80 m	Sheltered	Poor	• Retentive local site circulation dynamics • No existing effluent currently discharged through pipe
7a) Strandfontein Tidal Pool – Phase 1	3) Surf zone	0 m	Retentive	Poor	• Entrapment within surf zone • Eastbound longshore drift and entrainment along beach
7b) Strandfontein Tidal Pool – Phase 2	3) Surf zone	0 m	Retentive	Poor	• Entrapment within surf zone • Eastbound longshore drift and entrainment along beach
8a) Monwabisi Tidal Pool – Phase 1	3) Surf zone	2 m	Retentive	Poor	• Westbound longshore drift and entrapment within the surf zone • Entrainment back into retentive gyre east of tidal pool
8b) Monwabisi Tidal Pool – Phase 2	3) Surf zone	27 m	Retentive	Moderate	• Westbound longshore drift and entrapment within the surf zone

Site	Category	Distance offshore	Exposure	Dispersal potential	Characteristics of discharge site
9) Harmony Park	3) Surf zone	38 m	Retentive	Poor	• Retentive gyre • Pooling of brine within rock pools
10a) Gordon's Bay Harbour – SWRO offshore vessel	1) Offshore	600 m	Semi-exposed	Moderate	• Deep • Plume could be pushed towards shore by the dominant southwest swell and onshore winds
10b) Gordon's Bay Harbour – barge moored seaward of northern breakwater	2) Harbour	0 m	Sheltered	Poor	• Shallow and close inshore • Limited mixing in Bay

Table 4.2 Likely impacts for the construction and decommissioning phases of the proposed RO plants.

Impact			**1) Offshore (pelagic & subtidal sand)**					**2) Harbour (artificial intertidal)**			**3) Surf zone (mixed habitat of sand & rock)**				
Site			Cape Town SWRO	Green Point	Glen Country Club	Hout Bay	Gordon's Bay SWRO	Cape Town breakwater	Cape Town barge	Gordon's Bay Barge	Silwer-stroom	Dido Valley	Strand-fontein	Monwabisi	Harmony park
Option			2c	3	4	5	10a	2a	2b	10b	1	6	7	8	9
Construction and Decommissioning	1	Disturbance of intertidal habitat	n/a	Artificial intertidal	Rocky shore & beach	Artificial intertidal	n/a	Artificial intertidal	Artificial intertidal	Artificial intertidal	Rocky shore & beach	Rocky shore & beach	Artificial intertidal & beach	Artificial intertidal, beach & rocky shore	Rocky shore & beach
	2	Disturbance of subtidal habitat	n/a	Subtidal sand	Subtidal sand & reef	Subtidal sand	n/a	n/a	n/a	n/a	Reef & subtidal sand	Reef & subtidal sand	Subtidal sand, reef & sand inundated reef	Reef, sand inundated reef & subtidal sand	Reef, sand inundated reef & subtidal sand
	3	Mobilisation of sediment	n/a	Subtidal	Intertidal	Subtidal	n/a	n/a	n/a	n/a	Subtidal	Intertidal & subtidal	Intertidal & subtidal	Intertidal & subtidal	Intertidal & subtidal
	4	Waste	Regional	Regional	Regional	Regional	Regional	Regional	Regional	Regional	Regional	Regional	Regional	Regional	Regional
	5	Hydrocarbon spills	Pelagic & subtidal sand	Artificial intertidal & subtidal sand	Rocky shore, beach & reef	Pelagic, artificial intertidal, subtidal sand	Pelagic, subtidal sand & reef	Artificial intertidal, pelagic & subtidal sand	Artificial intertidal, pelagic & subtidal sand	Artificial intertidal, pelagic, subtidal sand & rocky shore	Rocky shore, beach, reef & subtidal sand	Rocky shore, beach, reef & subtidal sand	Artificial intertidal, beach, subtidal sand, reef, sand inundated reef	Artificial intertidal, beach, rocky shore, reef & subtidal sand	Rocky shore & beach, reef, sand inundated reef & subtidal sand
	6	Noise and vibration	Birds, fish, cetaceans, pinnipeds	Birds, fish, cetaceans	Birds, fish, cetaceans	Birds, fish, cetaceans, pinnipeds	Birds, fish, cetaceans	Birds, fish, cetaceans, pinnipeds	Birds, fish, cetaceans, pinnipeds	Birds, fish, cetaceans	Birds & fish	Birds, fish, cetaceans, pinnipeds & sharks	Birds, fish, cetaceans & sharks	Birds, fish, cetaceans & sharks	Birds, fish, cetaceans

Table 4.3 Likely impacts for the operational phase of the proposed RO plants.

Impact			1) Offshore (pelagic & subtidal sand)					2) Harbour (artificial intertidal)			3) Surf zone (mixed habitat of sand & rock)				
Site			Cape Town SWRO	Green Point	Glen Country Club	Hout Bay	Gordon's Bay SWRO	Cape Town breakwater	Cape Town barge	Gordon's Bay Barge	Silwer-stroom	Dido Valley	Strand-fontein	Monwabisi	Harmony park
Option			2c	3	4	5	10a	2a	2b	10b	1	6	7	8	9
Operation	1	Intake of seawater	Pollution	Sediment	Kelp	Pollution	Red tide & turbidity	Pollution	Pollution	Sediment & red tide	Kelp	Red tide	Sediment & red tide	Sediment & red tide	Sediment & red tide
	2	Sediment movement	n/a	Minimal	n/a	n/a	n/a	n/a	n/a	n/a	Possible scouring	Minimal	Minimal	Minimal	Minimal
	3	Discharge of brine	Offshore	Offshore	Offshore	Offshore	Offshore	Offshore	Offshore	Offshore	Surf zone	Surf zone	Surf zone	Surf zone	Surf zone
	4	Elevated temperature	Pelagic & subtidal sand	Subtidal sand & low profile sand inundated reef	Subtidal sand & reef	Subtidal sand	Pelagic, subtidal sand & low profile sand inundated reef	Artificial intertidal, pelagic & subtidal sand	Artificial intertidal, pelagic & subtidal sand	Artificial intertidal, pelagic, subtidal sand & rocky shore	Rocky shore, beach, reef & subtidal sand	Rocky shore, beach, reef & subtidal sand	Artificial intertidal, beach, subtidal sand, reef, sand inundated reef	Artificial intertidal, beach, rocky shore, reef, sand inundated reef & subtidal sand	Rocky shore & beach, reef, sand inundated reef & subtidal sand
	5	Decreased DO													
	6	Co-pollutants													
	7	Reduced pH													
	8	Recreational use	High	Moderate	High	High	Moderate	High	High	Moderate	High	Moderate	High	High	High

4.1 Construction phase

The potential impacts associated with the placement of temporary RO plants and the construction of brine discharge structures need to be addressed as part of the Coastal Water Discharge Permit (CWDP) applications. The installation of intertidal and subtidal sections of intake and discharge pipelines must be considered where applicable. These impacts may or may not apply to SWRO vessels and barges, depending on final engineering designs which are not yet available. In these instances, it is assumed that there will at least be an onshore section of pipe distributing the resulting freshwater to a transport container for delivery to areas in need. Different impacts apply to temporary RO containers placed on beaches or rocky intertidal areas, although issues associated with RO plants located away from the intertidal as well as the associated land-based pipelines leading to and from the plant are not deemed to be of relevance to the marine environment and must be dealt with through terrestrial specialist studies.

4.1.1 Disturbance of intertidal habitat and associated biota

In order to construct coastal and subtidal intake and discharge pipelines and position RO plants, heavy construction vehicles will require access to the intertidal environment. Impacts are expected to be minimal at sites characterised by artificial structures (e.g. harbours) and more intense at sites with mixed or rocky shores, which generally take longer to recover than sandy beaches. As all offshore discharges will be through existing pipelines, the only construction impacts will occur during laying of the intake pipe and placement of the RO plant container if applicable. All intakes for offshore discharge sites and harbour sites will be placed over existing artificial structures with the exception of Glen Country Club, which will be laid over a short stretch of mixed habitat if commissioned.

Due to the innate dynamic nature of sandy beaches, beach macrofauna are tolerant to short-term, localised disturbance. The majority of species found in the intertidal and nearshore areas of a beach tend to be opportunistic pioneer species with high reproductive and growth rates (e.g. small crustaceans and polychaetes) (Newell *et al.* 1998), while populations of long-lived species (e.g. molluscs) take more time to re-establish (Kenny and Rees 1996). This is also true for pioneer and established species living on rocky shore and mixed shore habitats (Branch and Branch 1981). In Table 4.4, pipelines that are laid over artificial structures are rated as 'low' intensity disturbance, while pipelines over mixed habitat are classified as 'high' intensity.

Any birds feeding and/or roosting in or around the construction footprint will be displaced for the duration of construction activities but are expected to return permanently upon completion of pipeline placement. Mortality of intertidal invertebrate fauna through crushing by construction vehicles will be inevitable, thus the area in which these vehicles are allowed to operate should be reduced as far as possible. Pipeline placement will not result in a net loss of sandy habitat as benthic organisms will still be able to burrow in sediment above the pipeline once this has been installed. Small areas of low profile and sand inundated reef may be lost but the surface area is negligible considering the general availability of this habitat.

The relatively small footprint and 'short-term' nature of construction activities will result in the impact being felt over a very limited spatial scale which is not expected to noticeably influence the ecology of the areas in question. As marine invertebrates will start to re-colonise the affected areas through recruitment from adjacent rocky and sandy habitats immediately after construction is completed, the temporary disturbance within each relatively small construction footprint is expected to be 'low' to 'insignificant' and no mitigation is required (Table 4.4).

Table 4.4 **Impact 1: Ecological effects due to disturbance of intertidal habitat during RO plant and pipeline placement.**

Option	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation								
1) Offshore	Local 1	Low 1	Short-term 1	Very low 3	Probable	**VERY LOW**	-ve	High
2) Harbour	Local 1	Low 1	Short-term 1	Very low 3	Improbable	**INSIGNIFICANT**	-ve	High
3) Mixed habitat	Local 1	High 3	Short-term 1	Low 5	Definite	**LOW**	-ve	High

Best-practice mitigation:

- Confine disturbance to the smallest area possible.
- Limit duration of construction activities in the coastal zone.
- Return sandy areas to original state if churned up by heavy vehicles.
- Inform all staff about sensitive marine habitats.

4.1.2 Disturbance of subtidal habitat and associated biota

Benthic sandy and rocky substrata may be affected by the placement of subtidal pipelines, depending on the nature of the marine environment. The offshore discharges and mixed shore discharges under consideration for this project are likely to terminate on sandy substrate, although pipelines will travel over benthic reef and patches of sand inundated reef. In cases where existing offshore pipelines are to be employed for brine discharge, the impact pertains mainly to the laying of intake pipes. The intensity of this impact over reef is rated as 'medium', while pipeline placed over sandy substrate are rated as 'low'.

During pipeline placement, fast swimming mobile fish and elasmobranchs (sharks, rays and skates) will be able to move to adjacent areas, while most slow swimming fish, crabs and benthic infauna should be able to slowly move out of the path of the pipeline. Mortality of these animals is possible but not likely as pipelines are usually laid gradually by lowering sections of pipe from a vessel or pulling a pipe out from the shore using a tug or similar vessel. Given the dynamic nature of soft benthic habitats in depths shallower than thirty meters on exposed coasts, full recovery of benthic fauna should take place rapidly. Hard substrate environments are slower to recover and should be avoided if possible. The area of pipeline resting on the benthos at each site will be relatively small and, over time, the pipeline will be colonised by algae and invertebrates typical of subtidal reefs. This, along with the 'very low' impact rating, obviates the need for mitigation.

Table 4.5 **Impact 2: Disturbance of subtidal habitat and associated biota during laying of pipelines.**

Option	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation								
1) Offshore	Local 1	Medium 2	Short-term 1	Very low 4	Definite	**VERY LOW**	-ve	High
2) Harbour	Local 1	Low 1	Short-term 1	Very low 3	Definite	**VERY LOW**	-ve	High
3) Mixed habitat	Local 1	Medium 2	Short-term 1	Very low 4	Definite	**VERY LOW**	-ve	High

Best-practice mitigation:

- Avoid placing pipelines over subtidal reef if possible.
- Avoid blasting subtidal reefs or securing pipelines using toxic substances.

4.1.3 Mobilisation of benthic sediment during laying of pipelines

The physical action of positioning the pipelines will result in the suspension of sediment particles in sandy areas, which will temporarily increase turbidity. The resulting impacts largely depend on the extent of the turbidity plume as well as the biology of the species affected. For example, increased turbidity levels can impair prey capture in piscivorous fish that rely on visual prey detection methods and autotrophic microphytobenthos and phytoplankton production may decrease due to reduced light penetration. Benthic invertebrates, particularly those that filter-feed, are susceptible to the effects of turbidity as many lack the mobility inherent to fishes. They ingest inorganic material filtered from the water, and elevated levels of sediment in the water column could result in lower growth rates, starvation and, in the worst cases, mortality.

Harbour environments will not be affected by this impact. Offshore sites that have existing discharge pipes will only require the laying of intake pipes, while all other sites will be affected by the laying of both intake and discharge pipes. In all instances, the magnitude of the turbidity plume associated with pipeline placement is likely to be small as each pipe will be laid in sections, limiting the size of the construction footprint at any one time. Construction activities may result in a slight increase in suspended sediments within the surf zone. This could affect light penetration, phytoplankton productivity and algal growth; although the highly productive nature of the Benguela upwelling region will likely override this impact. Furthermore, the associated impacts are extremely localised and of short duration. Natural sand movement is a daily occurrence in shallow surf zone environments such as Strandfontein and Monwabisi, which makes turbidity plumes even less of a concern. In deeper environments, material disturbed on the bottom and/or released into the water column will not be brought up to the surface and will be distributed over the sandy benthic environment by the prevailing currents. As marine sediment is typically relatively coarse, it is expected to settle quickly out of the water column and the significance of increased turbidity on marine life is considered to be 'insignificant' (Table 4.6).

Table 4.6 **<u>Impact 3</u>: Ecological effects due to mobilisation of sediment during pipeline laying.**

Option	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation								
1) Offshore	Local 1	Low 1	Short-term 1	Very low 3	Possible	**INSIGNIFICANT**	-ve	High
3) Mixed habitat	Local 1	Low 1	Short-term 1	Very low 3	Possible	**INSIGNIFICANT**	-ve	High
Best-practice mitigation: • No mitigation necessary.								

4.1.4 Disposal of solid waste

'Solid waste' includes litter (e.g. lunch packaging, cable ties, and empty containers) and construction waste (e.g. unused concrete/gravel, offcuts of pipes, rubble). Objects that are particularly detrimental to marine fauna include plastic bags and bottles, pieces of rope and small plastic particles. Marine organisms are killed or injured daily by becoming entangled in debris or as a result of the ingestion of small plastic particles (Gregory 2009, Wright *et al*. 2013). The problem of litter entering the marine environment has escalated dramatically in recent decades, with an ever-increasing proportion of litter consisting of non-biodegradable plastic materials. To prevent exacerbating the problem, all domestic and general waste generated must be disposed of responsibly. The amount of waste generated must be minimised by applying waste reduction strategies and by reusing waste where possible, rather than sending it to landfill. All reasonable measures must be implemented to ensure that there is no littering by workers and that waste is adequately managed. In order to prevent litter from entering the marine environment, all staff must be regularly reminded about the detrimental impacts of pollution on marine species and suitable handling and disposal protocols must be clearly explained and sign boarded. The 'reduce, reuse, recycle' policy must be implemented.

As the significance of this impact is expected to be the same at all sites, significance ratings are not assessed according to each outfall category. Due to the fact that plastic takes many years to degrade, the extent of the damage caused by pollution (especially plastics) may be 'long-term'. Litter can be lethal to marine organisms when ingested, thus the impact is rated as 'medium' without mitigation and can be reduced to 'low' by implementing mitigation measures outlined in Table 4.7.

Table 4.7 **Impact 4: Effect of solid waste and hazardous substances on the marine environment.**

	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation	Regional 2	Low 1	Long-term 3	Medium 6	Probable	**MEDIUM**	– ve	High
Required mitigation: • Suitable handling and disposal protocols must be clearly explained and sign boarded. • Implement the 'reduce, reuse, recycle' ethos. • All fuel and oil must be stored with adequate spill protection and equipment must be checked for leaks. • A rigorous environmental management and control plan must be available. • Disposal of any substance into the marine environment is strictly prohibited. • Inform all staff about sensitive marine species and the suitable disposal of construction waste.								
With mitigation	Regional 2	Low 1	Long-term 3	Medium 6	Improbable	**LOW**	– ve	High

4.1.5 Hydrocarbon spills

The proposed establishment of RO plants around the peninsula will require the presence of vehicles and vessels in the coastal zone (and possibly offshore) during the placement of RO containers and pipelines. Construction in or near the intertidal poses an increased risk of accidental hydrocarbon spills, which may be hazardous to the health of humans, marine fauna and seabirds through contact or ingestion.

Diesel spills spread very quickly over water and usually evaporate within a few days (NOAA 1998). The remaining diesel will likely be mixed into the water column by wave action in nearshore environments and will adhere to fine-grained suspended sediments that will either be deposited onto the beach or settle onto the seafloor. As a result, shoreline clean-up is often not necessary (NOAA 1998). Although diesel oil is degraded naturally by microbes over a period of one to two months, diesel is considered to be one of the most acutely toxic oil types, killing marine invertebrates on contact (NOAA 1998). As diesel disseminates rapidly following a small spill (500-5,000 gallons), pelagic fish are not expected to be affected; however, filter-feeders and birds are at risk from spills in shallow, nearshore environments (NOAA 1998).

Impact significance was rated according to the pre-defined outfall categories, with impacts on offshore habitat being 'medium', harbour habitats 'low' and mixed habitat 'high' (Table 4.8). As hydrocarbons are toxic to aquatic organisms, all fuel and oil must be stored with adequate spill protection and all equipment must be checked for leaks. A rigorous environmental management and control plan must be available to limit ecological risks from accidents. Disposal of any substance into the marine environment is strictly prohibited and accidental spillages must be immediately contained and reported. The duration of the impact of a particularly severe spill could extend into the 'medium-term' due to diesel being trapped in subtidal sediments. The extent is classified as 'local' because accidental hydrocarbon spills will be restricted to the construction site. With the implementation of the mitigation measures, the significance of the impact is classified as 'insignificant'.

Table 4.8 **Impact 5: Effect of hydrocarbon spills on the marine environment.**

Option	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation								
1) Offshore	Local 1	Medium 2	Medium-term 2	Low 5	Possible	**VERY LOW**	-ve	High
2) Harbour	Local 1	Low 1	Medium-term 2	Very low 4	Possible	**INSIGNIFICANT**	-ve	High
3) Mixed habitat	Local 1	High 3	Medium-term 2	Medium 6	Possible	**LOW**	-ve	High
Required mitigation: • Maintain high safety standards and employ "good housekeeping". This should incorporate plans for emergencies. • All fuel and oil must be stored with adequate spill protection and equipment must be checked for leaks. • No vehicle maintenance or refuelling on beach. • Use drip trays and bunding where losses are likely to occur. • Accidental diesel and hydrocarbon spills must be cleaned up immediately. • Collect and dispose of polluted soil at appropriate bio-remediation sites.								
With mitigation								
All outfalls	Local 1	Low 1	Medium-term 2	Very low 4	Improbable	**INSIGNIFICANT**	-ve	High

4.1.6 Noise and vibration management during construction

Sources of noise and vibration include heavy machinery and vessels operating offshore. As the significance of this impact is expected to be the same at all sites, an overall rating is presented in Table 4.9. Any birds feeding and/or roosting in the area will be disturbed and displaced for the duration of these activities; however, other marine life is unlikely to be unaffected. Fish and mammals are able to temporarily move away from the disturbance, while invertebrates are less sensitive to noise. The duration of this impact is rated as 'short-term' for the construction phase and is considered to be 'insignificant'. As a precautionary measure, mobile equipment, vehicles and power generation equipment should be subject to noise tests, which will be measured against the manufacturer's specifications to confirm compliance before hire.

Table 4.9 **Impact 6: Noise and vibrations caused by heavy vehicles in the coastal zone during construction.**

	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation	Local 1	Low 1	Short-term 1	Very low 3	Possible	**INSIGNIFICANT**	– ve	High
Best-practice mitigation: • Subject mobile equipment, vehicles and power generation equipment to a noise test prior to use.								

4.2 Operational phase

Since the proposed RO plants are temporary and are expected to be in operation for a maximum of two years, impacts are considered over a short-term period but may extend into the medium-term depending on the expected rate of environmental recovery. At each site, seawater will be abstracted and piped to a pre-filtration system at the RO Plant. To control microbiological activity, a non-oxidising biocide will be introduced into the feed line. Coagulant (e.g. ferric chloride) will be injected to assist with the removal of suspended solids and organics, and to reduce turbidity. Sulfuric acid (or similar) will be dosed for pH adjustment and to improve the efficiency of the coagulant. The effluent generated by the plant will be directed to the marine environment via the effluent discharge pipe. It is expected that about 50% of the seawater passing through the RO Plant will be discharged to the sea as brine. Brine is the portion of feed water that does not pass through the membranes in the high pressure pumping system and will have a much higher salinity and a slightly increased temperature compared to the incoming seawater. In addition, the discharge system will allow for the discharge of brine, filter backwash waste and spent membrane cleaning solutions. The cleaning chemicals used for the RO membranes generally constitute relatively small quantities which are still to be confirmed.

Brine is negatively buoyant and will tend to sink towards the seabed and has a low propensity to mix with the overlying seawater due to its differing density. The rate of brine discharge, as well as the discharge infrastructure, should be designed to ensure that the concentrated brine is diluted with seawater as quickly as possible to prevent accumulation in the marine environment. Discharged brine is anticipated to have temperatures approximately 2°C higher than of seawater and a maximum salinity level of 60 PSU (as opposed to typical seawater levels of 36 PSU). See the dispersal modelling report for details on plant design and expected effluent concentrations.

Discharge options considered in the impact assessment for the RO plants are grouped into three categories: 1) offshore discharges that terminate on subtidal sand, 2) harbour discharges that terminate on artificial habitat, and 3) surf zone discharges that terminate on benthic mixed habitat. Impacts assessed relate largely to effluent discharge into the marine environment as summarised below:

- altered flows at the intake resulting in entrainment and impingement of biota;
- discharge flow resulting in changes in natural sediment dynamics;
- elevated salinities due to the discharge of brine effluent;
- release of wastewater of a higher temperature than the receiving environment;
- direct and indirect changes in dissolved oxygen content and changes in remineralisation rates (with related changes in nutrient concentrations in near bottom waters);
- biocidal action of non-oxidising biocides in the effluent;
- the effect of co-discharged wastewater constituents; and
- potential impacts on recreational users.

WML Marine has been contracted to model likely effluent dispersion for the proposed RO sites. Modelling is being undertaken using US-EPA software and will seek to predict the geometry of and the dilution characteristics within the Recommended Mixing Zone (RMZ) of each offshore discharge scenario to determine whether the effluent is likely to comply with regional Water Quality

Guidelines (WQGs) under worst-case conditions. These were identified on a case to case basis and include stagnant conditions and extreme events. Secondary offshore dilutions and surf-zone discharges were assessed using the Brooks analytical method (Brooks 1960). Recommendations on the maximum size of the RMZ for South Africa have been tabled by Anchor Environmental Consultants (2015). The radius of the RMZ is dependent on the location and perceived sensitivity of the receiving environment as follows:

1. 300 m in an offshore environment;
2. 100 m in a nearshore open coast environment;
3. 30 m in sheltered coastal environments and special management areas; and
4. 0 m for an outfall in an established or proposed MPA, the surf zone and estuaries.

It is likely that it will not be possible to meet these specifications for the outfalls under consideration in this study, especially for outfalls discharging into the surf zone and sheltered coastal environments. It will only be possible to establish the extent to which these recommendations can be met, and hence the significance of the impacts associated with each outfall established, once the dispersion modelling work has been completed and the final agreed magnitude of the RMZ is defined. A provisional assessment of the magnitude, extent and significance for each category of outfall is, however, presented below.

Engineering design considerations are highlighted below but are not included within the scope of the environmental study:

- structural integrity of the intake and outfall pipelines related to sand movement and wave action;
- potential re-circulation of brine effluents if intake and discharge pipelines are situated in close proximity to one another; and
- water quality of abstracted water that may require specific mitigation measures or planned flexibility in the operations of the RO plant.

4.2.1 Mortality of marine life due to the intake of seawater

Intake of water directly from the ocean usually results in some mortality of marine species through impingement and entrainment. Impingement refers to injury or mortality of organisms that collide with and are trapped by intake screens, while entrainment refers to organisms that slip through the screens and are taken into the plant with the abstracted water. If screens are in place, entrained material is likely to include smaller organisms such as holoplanktonic organisms (i.e. permanent members of the plankton - copepods, diatoms and bacteria) and meroplanktonic organisms (i.e. temporary members of the plankton - juvenile shrimps and the planktonic eggs and larvae of invertebrates and fish).

Entrained organisms may be killed or injured when water is forced against the filters and RO membranes. While some studies estimated a 100% mortality rate of entrained organisms in power plant cooling systems (CCC 2004), a study by Bamber and Seaby (2004) demonstrated mortalities ranging from 10 to 20%. It is likely that mortality rates in RO plants are greater than those experienced in cooling plants (potentially up to 100% for RO plants) since the seawater is forced at high pressure through filters and membranes to remove particles. While the significance of both impingement and entrainment is related to the location of an intake, impingement is primarily a function of intake velocity, while entrainment depends largely on the overall volume of water drawn into the RO plant. Impingement can be mitigated through structural or operational designs including abstracting seawater at reduced flow rates, the use of velocity caps to angle flow, and the instalment of intake screens. Intake rates should be kept below 0.15 m/s to allow fish and other organisms to escape the intake current. This can be achieved through calculating optimal pumping rates and through intake design. Alternatively, concrete velocity caps can be used to change the predominant intake flow from vertical to horizontal, thereby significantly reducing impacts on fish, which are better able to detect a horizontal change in water velocity. The abovementioned options require little ongoing maintenance once installed.

Further mitigation options involve the installation of screens that are specifically sized to prevent fish from entering the system, while still allowing adequate water flow. Travelling screens installed at the landward end of a pipeline intake enable fish to be transported out of an intake system, through a fish return system, and back to the ocean (CCC 2004). The downside is that these systems involve ongoing maintenance and personnel for operation.

Abstracting water directly from the sea via a pipeline means that the seawater will not be filtered through sediment ~~(as with beach wells)~~ and may still contain high numbers of marine biota that will be trapped within the plant and foul equipment. In addition, the greater proportion of particles in the water will require the injection of more chemicals and biocides in pre-treatment, resulting in increases in backwash volumes, operational costs and environmental contamination.

Table 4.10 assesses the significance of the mortality of marine life due to the intake of seawater. Inshore (mixed habitat) impacts are expected to be more severe than those experienced offshore or in harbour environments. The reasons for this are numerous: fish are attracted to inshore environments where they feed on benthic organisms attached to reef or living just below the sandy surface; many fish species feed in the surf zone, a habitat which is also important for juvenile fish; and harbour environments are far from pristine with natural species assemblages that have been severely altered by artificial habitat and alien species. Consequently, the impact is rated as 'low' in surf zone habitats and 'very low' for harbours and offshore habitats. Mitigation measures must be implemented in mixed habitat sites to decrease this impact to 'very low'.

Table 4.10 **Impact 1: Mortality of marine life due to the intake of seawater.**

Option	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation								
1) Offshore	Local 1	Medium 2	Short-term 1	Very low 4	Definite	**VERY LOW**	-ve	High
2) Harbour	Local 1	Low 1	Short-term 1	Very low 3	Definite	**VERY LOW**	-ve	High
3) Surf zone	Local 1	High 3	Short-term 1	Low 5	Definite	**LOW**	-ve	High
Required mitigation: • Intake velocities must be kept below 0.15 m/s to ensure that fish and other organisms can escape the intake current. • Velocity caps must be used to change the predominant intake flow from vertical to horizontal, thereby significantly reducing impingement of fish. **Best-practice mitigation:** • Travelling screens can be installed at the landward end of a pipeline intake to enable fish to be transported out of the system.								
With mitigation								
All outfalls	Local 1	Low 1	Short-term 1	Very low 3	Definite	**VERY LOW**	-ve	High

4.2.2 Sediment scouring and shifts in sediment movement patterns

Sand movement on beaches is an ongoing natural event whereby sand is continuously eroded and replaced by wave action, tides and storm events. The location of a pipeline on the shore may alter sediment transport pathways in the nearshore environment and may result in the distortion of dune transport pathways if the infrastructure associated with the discharge is located in, or extends through, the mid- and upper shore. Similarly, alongshore marine sediment transport may be affected by subtidal pipelines placed over sandy substrata. To limit interference with these natural processes, pipelines can be trenched through the shore-crossing as well as subtidally.

Subtidally, scouring of sediment around the discharge outlet can become a serious issue for poorly designed pipe ends discharging into shallow receiving water bodies (Carter and van Ballegooyen 1998). The dense brine effluent may collect in the resultant dip, decreasing the potential for mixing and increasing the likelihood that the effluent will spread out over the benthic substratum before meeting WQG. To prevent this occurrence, the diffuser must be angled towards the water surface to enable water to jet upwards into the water column. This design will also prevent bottom attachment, which will reduce potential impacts on benthic sediments and macrofauna. Surf zone habitats will be the only outfall category affected by shifts in inshore sediment movement patterns; however, offshore and surf zone outfalls may be affected by scouring at the pipe end with 'low' and 'medium' impacts respectively (Table 4.11). Significance of this impact must be decreased by implementing appropriate diffuser design.

Table 4.11 **Impact 2: Sediment scouring and shifts in sediment movement patterns affecting sediment deposition.**

Option	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation								
1) Offshore	Regional 2	Medium 2	Short-term 1	Low 5	Probable	**LOW**	-ve	Medium
3) Surf zone	Regional 2	High 3	Short-term 1	Medium 6	Probable	**MEDIUM**	-ve	Medium
Required mitigation: • The diffuser must be angled towards the water surface to prevent scouring of benthic sediment. **Best-practice mitigation:** • Trench discharge pipe under beach sand to prevent interference of dune transport systems (if applicable). • Trench discharge pipe under benthic sand to prevent interference in alongshore sediment transport pathways (if applicable).								
With mitigation								
Offshore and Surf zone	Regional 2	Low 1	Short-term 1	Very low 4	Improbable	**INSIGNIFICANT**	-ve	Medium

4.2.3 Increased salinity due to brine discharge

Discharge of brine into the surf zone will likely result in limited offshore dispersion and potentially inadequate dilution of brine. All marine organisms have a range of tolerance to salinity, which is related to their ability to regulate the osmotic balance of their individual cells and organs to maintain positive turgor pressure. Aquatic organisms are commonly classified in relation to their range of tolerance as stenohaline (able to adapt to only a narrow range of salinities) or euryhaline (able to adapt to a wide salinity range), with most organisms falling into the first category.

Salinity changes may affect aquatic organisms through direct toxicity, which initiates physiological changes (particularly osmoregulation), and indirect toxicity by modifying species distributions. Salinity changes can also cause changes to water column structure (e.g. stratification) and water chemistry (e.g. dissolved oxygen saturation and turbidity). For example, fluctuation in the salinity regime has the potential to influence dissolved oxygen concentrations, and changes in water stratification could result in shifts in the distribution of organisms in the water column and sediments. Behavioural responses to changes in the salinity regime can include escaping in the case of mobile animals such as fish and macrocrustaceans, or avoidance by sessile animals (e.g. barnacles and mussels) by closing shells or by retreating deeper into sediments. In marine ecosystems, a reduction (rather than an increase) in salinity is expected to have adverse effects in species distribution (ANZECC 2000). Very little information exists on the effect of an increase in salinity on organisms in coastal marine systems, with most studies being done either on the effects of a decline in salinity due to an influx of freshwater, or on salinity fluctuations in estuarine environments where most of the fauna are euryhaline.

Sub-lethal effects of salinity stress can include modification of metabolic rate, change in activity patterns, or alteration of growth rates (McLusky 1981). The limited data available include a reported tolerance of adults of the mussel *Mytilus edulis* of up to 60 PSU (Barnabe 1989), and successful fertilization and development (Bayne 1965) of its larvae at a salinity of up to 40 PSU. The alga *Gracilaria verrucosa* can tolerate salinity ranges from 9 to 45 PSU (Engledow and Bolton 1992). The shrimp *Penaeus indicus* was capable of tolerating a salinity range of 1 to 75 PSU if allowed an acclimation time of around 48 hours (McClurg 1974), the oyster *Crassostrea gigas* tolerated salinities as high as 44 PSU (King 1977), and the shrimp *Penaeus monodon* survived in 40 PSU saline water (Kungvankij *et al*. 1986, Kungvankij and Chua 1986). Chen *et al*. (1992) reported a higher moulting frequency in juveniles of the prawn *Penaeus chinensis* at a salinity of 40 PSU. Lethal effects were reported for seagrass species: for example, salinities of 50 PSU caused 100% mortality of the Mediterranean seagrass *Posidonia oceanica*, 50% mortality at 45 PSU, and 27% at 40 PSU. Salinity concentrations above 40 PSU also stunted plant growth and no-growth occurred at levels exceeding 48 PSU (Latorre 2005).

High salinity can also lead to an increase in water turbidity, which is likely to reduce light penetration, an effect that might disrupt photosynthetic processes and reduce the production of plankton, particularly of invertebrate and fish larvae (Miri and Chouikhi 2005). One of the main factors of a change in salinity is its influence on osmoregulation, which in turn affects uptake rates of chemical or toxins. In a review on the effects of multiple stressors on aquatic organisms, Heugens *et al*. (2001) summarize that metal toxicity generally increases with decreasing salinity, while the toxicity of organophosphate insecticides increases with increasing salinity. For other chemicals, no clear relationship between toxicity and salinity has been observed. Some evidence, however, exists for an increase in the uptake of certain trace metals with an increase in salinity (Rainbow and Black 2002).

Very few ecological studies have been undertaken to examine the effects of high salinity discharges from desalination plants on the receiving communities. One example is a study on the macrobenthic community inhabiting the sandy substratum off the coast of Blanes in Spain (Raventos *et al*. 2006), adjacent to a desalination plant discharging brine at 33 707 m^3/day. A visual census before plant start up revealed no significant variation between communities within and outside of the impact area. The same was found for communities after continuous operation of the plant. This was partly attributable to high natural variability as well as to the rapid dilution of the hypersaline brine upon leaving the discharge pipe. Other studies, however, indicated that brine discharges have led to reductions in fish populations and to die-offs of plankton and coral in the Red Sea (Mabrook 1994); and to mortalities in mangrove and marine angiosperms in the Ras Hanjurah Lagoon in the United Arab Emirates (Vries *et al*. 1997).

Effluent water discharged from desalination plants constitute a high salinity brine (expected salinity ±60 PSU) mixed with a co-discharge containing biocide, coagulant and CIP chemical residuals from the RO membrane cleaning processes. The South African WQG (DWAF 1995) set an upper target value for salinity of 36 PSU. At levels exceeding 40 PSU, significant negative effects are expected, including possible disruptions to the recruitment of molluscan bivalves (e.g. mussels, oysters and clams), crustaceans, and possibly fish (Clarke 1992).

Appropriate pipeline design and placement is required to ensure proper dispersion of the concentrated salts in the effluent. Three disposal scenarios exist for this impact:

- Discharge of effluent offshore beyond the surf zone (Category 1)
- Discharge of effluent from harbours or ports (Category 2)
- Discharge of the effluent into the surf zone (Category 3)

Although the operational life of each RO plant is planned for two years, the duration of the impact of brine discharge is rated as 'medium-term' as recovery of marine communities from physiological effects may take more than two years. Should the duration of operation be extended beyond two years, this impact assessment will no longer be applicable.

Offshore discharges

Pipeline design and outflow dynamics must ensure that the effluent meets the WQGs at the edge of the RMZ, in order to limit adverse effects to the immediate area around the discharge point. The size and angle of the diffuser at the end of the discharge pipe plays an important role in the effectiveness of initial mixing and dilution. If discharged horizontally, the effluent will sink to the bottom and spread down the slope of the seabed, resulting in a blanket of dense brine (Bleninger and Jirka 2008). However, if the brine is discharged via a submerged pipeline with an angled nozzle or diffuser, the mixing efficiency is much higher, allowing for better initial dilution and improved offshore transport of the mixed effluent (Bleninger and Jirka 2008). A discharge angle of ±60˚ is recommended by Toms (2010), although exact measurements should be site specific as determined by dispersion modelling. The significance of offshore discharges of brine effluent for the temporary desalination plants is rated as 'very low' and no further mitigation is required. Monitoring should be implemented as per **Error! Reference source not found.** (Option 1) and Section 5.

Harbour discharges

Brine discharges within harbours are discouraged as these environments have limited flushing capacity, certainly much less than that experienced on open coastlines that benefit directly from tidal movements. Complete tidal flushing can take a number of days in environments that have numerous basins, such as the Port of Cape Town, posing obvious limitations on dilution and dispersion. In addition, water within these ports is often used for other purposes. In the Port of Cape Town, these include wash water, cooling water for air conditioning systems and importantly, supply to the Two Oceans Aquarium that relies on clean seawater for the maintenance of healthy exhibits. Placement of discharges above the surface of the water will increase effluent mixing, although this is not expected to be sufficient to meet WQGs at the edge of the RMZ. For these reasons, brine discharge within harbours has been rated as 'medium' significance and requires mitigation as outlined in **Error! Reference source not found.** (Option 2). This advises against the lacement within harbour/port environments. These outfalls should rather be positioned on the seaward side of breakwaters and harbour walls where there is increased dilution potential.

Surf zone discharges

Discharge into the surf zone is likely to have substantial negative effects on the environment due to the limited dispersion potential of inshore waves and longshore currents (DWAF 2004, Anchor 2015). The inshore environment is unlikely to provide sufficient mixing for RO plant effluent as surf zones are generally retentive. It is anticipated that effluent will be trapped within the surf zone and transported alongshore until able to escape through a rip current travelling offshore. Brine discharges into the surf zone are expected to have 'moderately' significant impacts on marine biota in terms of reduced physiological functioning (Table 4.12 Impact 3: Reduced physiological functioning of marine life due to discharge of brine (i.e. increased salinity).Table 4.12 Option 3). By discharging the brine effluent out to sea beyond the surf zone within water of a sufficient depth to maximise mixing, the environmental impacts will be significantly reduced. This will allow the brine to dilute and disperse into deeper offshore water, minimizing the effect of elevated salinity on the physiological functioning of biota in the immediate vicinity of the outfall and reducing the entire footprint of the impact. After implementation of mitigation, the significance of this impact is expected to be reduced to 'very low'. However, at the Strandfontein and Monwabisi sites, the emergency situation may justify the discharge of effluent into the surf zone as a short term, emergency measure for **Phase 1 (guaranteed 2ML/day), provided that the duration is kept to a minimum (< six months), the footprint is small (< 1 km) and the discharge volumes do not exceed the modelled brine dispersal results for Phase 1.** These measures are imperative to ensure that the surf zone discharge is a genuine interim **measure. Monitoring will be of crucial importance to ensure that these requirements are met. Effects** monitoring will need to be expanded upon during the surf zone discharge phase. In addition, t**he effluent discharge pipeline must be extended**

beyond the surf zone to cope with the increased brine volumes of proposed for **Phase 2 (ramped up to a guaranteed 7ML/day).**

Table 4.12 **Impact 3: Reduced physiological functioning of marine life due to discharge of brine (i.e. increased salinity).**

Option	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation								
1) Offshore	Local 1	Medium 2	Medium-term 2	Low 5	Possible	**VERY LOW**	-ve	Medium
2) Harbour	Local 1	High 3	Medium-term 2	Medium 6	Probable	**MEDIUM**	-ve	Medium
3) Surf zone	Local 1	High 3	Medium-term 2	Medium 6	Probable	**MEDIUM**	-ve	Medium

Required mitigation:

- No discharge should be permitted within the surf zone. Pipes must reach beyond the furthest extent of the surf backline. However, at the Strandfontein and Monwabisi sites, the emergency situation may justify the discharge of effluent into the surf zone as a short term, emergency measure for **Phase 1, provided that the duration is kept to a minimum (< six months), the modelled footprint is small (< 1 km) and the discharge volumes do not exceed the modelled brine dispersal results for Phase 1.** Monitoring will be of crucial importance to ensure that these requirements are met, and effects monitoring will need to be expanded upon during the surf zone discharge phase. The effluent discharge pipeline must be extended beyond the surf zone to cope with the increased brine volumes of proposed for **Phase 2**. These mitigation measures do not justify the reduction of the "medium" impact rating for Phase 1.
- Brine discharges within harbours should not be permitted due to high retention times and limited mixing.
- The pipe and outlet must be designed to facilitate rapid mixing and dilution of the effluent at the discharge point through a minimum diffuser angle of 30 degrees.
- A robust pipeline design must be adopted to avoid dislodgement or rupture.
- Should unacceptable environmental effects and high salinity concentrations be detected outside of the RMZ, a reduction in effluent flow and lengthening of the discharge pipe should be considered.

Monitoring (see Section 5):

- A baseline survey of inshore water quality (particularly salinity) and marine biota in the vicinity of the proposed pipeline discharge should be conducted before pipeline construction commences.
- Follow up monitoring of inshore water quality (particularly salinity) and marine biota in the vicinity of the pipeline discharge should be conducted after six months of plant operation.
- Record effluent flow rate daily using a flow rate meter fitted to the effluent pipe.
- Monitor and record water quality (temperature, salinity, pH, DO) before discharge once weekly using a portable water quality meter.
- Monitor and record the concentration of additives (CIPs, anti-scalants etc.) before discharge annually by sending samples to an accredited water quality laboratory. This process should be repeated upon each change of dosage.

Option	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
With mitigation								
Surf zone (Phase 1)	Local 1	High 3	Medium-term 2	Medium 6	Probable	**MEDIUM**	-ve	Medium
Surf zone (Phase 2)	Local 1	Low 1	Short-term 1	Very low 3	Probable	**VERY LOW**	-ve	Medium

4.2.4 Elevated temperature

An increase in water temperature can have a substantial impact on aquatic organisms and ecosystems with the effects influencing the physiology of the biota (e.g. growth and metabolism, reproduction timing and success, mobility and migration patterns, and production) and/or ecosystem functioning (e.g. through altered oxygen solubility). Internationally, a large number of studies have investigated the effects of heated effluent from coastal power stations on the open coast. These concluded that at elevated temperatures of less than 5°C above ambient seawater temperature resulted in little or no effects on species abundance and distribution patterns (van Ballegooyen *et al*. 2005). However, some adverse effects were observed in the development of eggs and larvae (Cook 1978, Sandstrom *et al*. 1997, Luksiene *et al*. 2000) with a temperature increase of less than 5°C, as well as other effects such as alterations in the photosynthesis behaviour of algal assemblages (Martinez-Arroyo *et al*. 2000), decreases in the duration of larval development (Thiyagarajan *et al*. 2003), suppressed growth in the post larvae of the spiny lobster *Panulirus argus* (Lellis and Russel 1990), and increased photosynthetic and biological community metabolism rates (Parsons *et al*. 1977).

The impacts of increased temperature has been reviewed in a number of studies along the West Coast of South Africa, most of which focused on adverse effects experienced in southern African West Coast intertidal (e.g. the white mussel *Donax serra*) or rocky bottom species (e.g. the abalone *Haliotis midae*, the kelp *Laminaria pallida*, mytilid mussels and the commercially important West Coast rock lobster *Jasus lalandii*). Bamber (1995) defined categories for direct effects of thermal discharges on marine organisms: the mean temperature in relation to ambient, the absolute temperature as it approaches lethal levels, short-term fluctuations in temperature, and potential barriers to fish migration. Increased temperatures tend to favour species from warmer areas, while inhibiting stenotherms (cooler-water species). The most pertinent example in Cape waters is that of the alien mussel *Mytilus galloprovincialis*; increased mean temperatures may lead to the invasive mussel outcompeting the native *Choromytilus meridionalis* as the juveniles of the former species grow faster in temperatures between 17 and 22°C (van Erkom Schurink and Griffiths 1993).

Cook (1978) found that adult *J. lalandii* appeared reasonably tolerant of temperatures above 6°C and even experienced an increase in growth rate. The effect on the reproductive cycle of the adult lobster female was more serious, as the egg incubation period shortened and considerably fewer larvae survived through the various developmental stages. Zoutendyk (1989) reported a reduction in respiration rate of adult *J. lalandii* at elevated temperatures. Reported effects on important fish species include an increase in biomass of shallow water hake *Merluccious capensis* and West Coast sole *Austroglossus microlepis* at 18°C (MacPherson and Gordoa 1992). No influence on chub-mackerel *Scomber japonicus* at temperatures less than 17.5°C (Villacastin-Herroro *et al*. 1992) was recorded, while 18°C was found to be the lower lethal limit for larvae and eggs of galjoen *Distichius capensis* (Van der Lingen 1994).

The South African WQGs recommend that the maximum acceptable variation in ambient temperature should not exceed 1°C. This is a relatively conservative value in view of the relatively minor effects of thermal plumes on benthic assemblages reported elsewhere for a temperature increase of 5°C or less, but is more realistic when considering studies of species that suffered detrimental effects from a temperature rise of less than 5°C. Although a natural temperature rise of

1°C above the ambient may have a marked impact on littoral species, any effluent temperature effects will be localized within a small area (Bamber 1995).

Once off, instantaneous seawater temperatures were recorded at Table Bay, Hout Bay, Strandfontein/Monwabisi and Gordon's Bay between the 8th and 14th of August 2017 (Lwandle 2017a-d). Results are summarised in the relevant oceanographic paragraphs in Sections 3.2, 3.5, 3.8 and 3.9 respectively. Although limited, these data indicated an offshore stratified water column in Table Bay (mixed inshore), with a range in temperature between 12.4 and 13.4°C. The waters offshore of Hout Bay, Strandfontein and Monwabisi were well mixed with average temperatures of 12.3, 15.3 and 14°C respectively. For thermal barriers to be effective in limiting or altering migration paths of marine organisms, thermoclines need to be persistent over time and cover a large cross-sectional area of the water body. It is highly unlikely that the brine plume will be large enough to cause such a barrier, thus impacts are limited to physiological effects of sessile macrofauna in the immediate vicinity of the outfall. The intensity of the impact is rated as 'low' for offshore and harbour environments and 'medium' for surf zone outfalls where important fish species and rocky shore communities are more likely to be impacted. Phytoplankton blooms may also be exacerbated in surf zone areas due to a slight increase in temperature, although this is unlikely for such a small plume. The duration of the impact is predicted to be 'short-term' and will cease as soon as brine discharge is stopped. As effluent temperature is expected to be only ±2°C warmer than intake water temperature and will meet WQGs almost immediately following discharge, the impacts were considered to be 'insignificant' (Table 4.13).

Table 4.13 Impact 4: Reduced physiological functioning of marine life due to increased temperature.

Option	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation								
1) Offshore	Local 1	Low 1	Short-term 1	Very low 3	Possible	**INSIGNIFICANT**	-ve	Medium
2) Harbour	Local 1	Low 1	Short-term 1	Very low 3	Possible	**INSIGNIFICANT**	-ve	Medium
3) Surf zone	Local 1	Medium 2	Short-term 1	Very low 4	Possible	**INSIGNIFICANT**	-ve	Medium
Required mitigation: • No mitigation required.								

4.2.5 Decreased dissolved oxygen concentration

Dissolved oxygen (DO) is an essential requirement for most heterotrophic marine organisms. Natural levels in seawater are largely governed by local temperature and salinity regimes, as well as by organic content. Coastal upwelling regions are frequently exposed to hypoxic conditions owing to extremely high primary production and subsequent oxidative degeneration of organic matter. Along the southern African coast, low-oxygen waters are a feature of the Benguela system.

Hypoxic water (defined as concentrations of less than 2 millilitres of oxygen per litre) has the potential to cause mass mortalities of benthos and fish (Diaz and Rosenberg 1995). Marine organisms respond to hypoxia by first attempting to maintain oxygen delivery by increasing respiration rates, by increasing the number of red blood cells, or by increasing the oxygen binding capacity of haemoglobin. They then start conserving energy through metabolic depression, down regulation of protein synthesis and modification of certain regulatory enzymes, and eventually resort to anaerobic respiration upon exposure to prolonged hypoxia (Wu 2002). As a result, hypoxia reduces growth and supresses feeding, which may eventually affect individual fitness. Many fish and marine organisms can detect, and actively avoid hypoxia as seen during rock lobster "walk-outs" and migration of macrobenthos from their burrows to the sediment surface, rendering them more vulnerable to predation. Hypoxia may eliminate sensitive species, thereby causing changes in species composition of benthic fish and phytoplankton communities. Decreases in species diversity and species richness are well documented, and changes in trophodynamics and functional groups have also been reported. Under hypoxic conditions, there is a general tendency for suspension feeders to be replaced by deposit feeders, demersal fish by pelagic fish and macrobenthos by meiobenthos (Wu 2002). Further anaerobic degradation of organic matter by sulphate-reducing bacteria may additionally result in the production of hydrogen sulphide, which is detrimental to marine organisms (Brüchert *et al*. 2003).

Because oxygen is a gas, its solubility in seawater is dependent on salinity and temperature. Increases in these parameters results in a decline of dissolved oxygen levels. For example, saturation levels of dissolved oxygen in seawater decrease with rising salinity from 5.84 ml/L at 15 ˚C and 35 PSU, to 4.90 ml/L at 63 PSU (DWAF 1995). These calculations translate into an approximate 15 to 16% reduction of DO in brine effluent. The South African Water Quality Guidelines for Coastal Marine Waters state that for the west coast, DO should not fall below 10% of the established natural variation at the edge of the RMZ (DWAF 1995). Average instantaneous DO values measured 4.4 mg/L at Table Bay, 4.8 mg/L at Granger Bay, 6.2 mg/L at Hout Bay, 8.4 mg/L at Strandfontein, 8.9 mg/L at Monwabisi and 5.9 mg/L at Gordon's Bay. These values indicate that conditions are far from hypoxic and the health of the environment is unlikely to be compromised through the discharge of effluent with slightly lower levels of DO. Effluent is expected to mix rapidly at the point of outfall and the potential for a reduction in dissolved oxygen will drastically reduce within a few meters of the diffuser.

If sodium metabisulfite is added to the effluent to neutralize the effects of chlorine, oxygen depletion in the brine might be compounded. Should any oxygen scavenging chemicals be added, DO concentrations in the effluent may become a concern unless the effluent is aerated. Indirect changes in dissolved oxygen content of the water column and sediments due to changes in hydrodynamic and ecosystem functioning may occur if chemicals that act as nutrients are added to the effluent (i.e. sodium tripolyphosphate and trisodium phosphate). As a result, these chemicals should not be added to the co-discharge. Changes in seawater temperature associated with brine discharge plumes may also result in indirect effects on DO. As the effluent temperature is expected to measure only 2°C above the ambient, this effect is considered inconsequential. Considering the above, a decrease in slightly depressed DO levels in the discharged brine is not of concern and is assessed as being 'insignificant' for all outfall options (Table 4.14).

Table 4.14 **Impact 5: Reduced physiological functioning of marine life due to decreased dissolved oxygen concentrations.**

Option	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation								
1) Offshore	Local 1	Low 1	Short-term 1	Very low 3	Possible	**INSIGNIFICANT**	-ve	Medium
2) Harbour	Local 1	Low 1	Short-term 1	Very low 3	Possible	**INSIGNIFICANT**	-ve	Medium
3) Surf zone	Local 1	Low 1	Short-term 1	Very low 3	Possible	**INSIGNIFICANT**	-ve	Medium
Required mitigation: • No mitigation required as long as no oxygen scavenging chemicals are added to the co-discharge (i.e. sodium metabisulfite, sodium tripolyphosphate and trisodium phosphate).								

4.2.6 Co-pollutants in backwash water

Anti-scalants, biocides, mineral acids, halogenated by-products and heavy metals are routinely added to the brine discharges of many RO plants. The potential effects of these co-pollutants are discussed below.

Heavy Metals

Corrosion of the interior surfaces of desalination plants can lead to heavy metals passing into solution and being discharged with the brine. Thermal distillation desalination plants tended to discharge relatively high levels of heavy metals along with the effluent and elevated metal concentrations have been detected in sediments tested up to several hundred meters from discharge outlets (Hoepner and Lattemann 2002, Sadiq 2002), however, plastic (e.g. HDPE or PVC) and stainless steel piping is typically used in RO plants. Degeneration of these materials may result in RO effluent to containing traces of iron, nickel and chromium among others, but contamination levels are generally low (Hashim and Hajjaj 2005). Heavy metals tend to attach to suspended material, which settles to the seafloor, potentially affecting soft bottom habitats within the vicinity of the discharge. South African water quality standards only contain recommended levels for Chromium (8 parts per billion) and Nickel (25 ppb) (DWAF 2005). Provided that corrosion resistant materials are used and that the discharge is not in an area of restricted water exchange, environmental impacts of trace metal pollution are expected to be of low significance.

Coagulants

Coagulants (e.g. ferric chloride or $FeCl_3$), coagulant aids (organic substances with high molecular masses that bind particles) and chemicals that control pH levels (e.g. sulphuric acid and sodium hydroxide) may be used to aid filtration. As seawater around the Western Cape coast typically carries a high particulate load, the use of coagulants will be necessary (Burger and du Plessis 2010). Pre-treatment filters will need to be backwashed every few days, which will produce a sludge containing mainly coagulant, sediments and organic matter. Acute and chronic toxic effects are not expected since most of the backwash sludge will comprise matter of marine origin, although this can be confirmed through toxicity testing. Although unlikely, sludge discharged directly into marine waters may lead to increased turbidity and suspended matter, which can result in responses such as reduced primary production or clogging of filter-feeding structures (Sotero-Santos *et al*. 2007).

Anti-scalants

The use of anti-scalants for the operation of RO plants is recommended by Burger and du Plesis (2010), although a specific product is not specified. Anti-scalants are usually organic, carboxylic-rich polymers such as polyacrylic acid and polymaleic acid. Polymer anti-scalants have similar properties to natural humic matter or Coloured Dissolved Organic Matter (CDOM), which are common seawater constituents (Hoepner and Lattemann 2002). They have high molecular weight, multiple carboxylic groups, metal ion binding capacity and a high stability.

LC_{50} values of these compounds generally exceed 1 000 parts per million, which is far above the typical dosage in desalination plants (Hoepner and Lattemann 2002). However, due to low rates of degradability, they have relatively long residence times during which the availability of biologically essential trace metal ions may be limited (Hoepner and Lattemann 2002). It is unlikely that anti-scalants will promote the accumulation of metals in mobile sediments as low dosages are usually required for RO plants. Consequently, environmental risk associated with the release of anti-scalants into the marine environment is expected to be 'very low'.

Biocides

Chlorine is extremely effective as a biocide for marine organisms and is frequently used to prevent the fouling of marine water intakes. Many of the by-products that are formed during seawater chlorination are also harmful to aquatic life (Hoepner and Lattemann 2002, Einav *et al*. 2002). Acute toxicity values provided in South African marine WQGs (DWAF 1995) show that 1 500 µg/L is lethal to some phytoplankton species, 820 µg/L induced 50% mortality for a copepod species and 50% mortality rates were observed for some fish and crustacean species at values exceeding 100 µg/L (ANZECC 2000). The lowest values at which lethal effects have been reported are 10 to 180 µg/L for the larvae of a rotifer, followed by 23 µg/L for oyster larvae (*Crassostrea virginica*). Sublethal effects include valve closure of mussels at values less than 300 µg/L and inhibition of fertilisation of some urchins, echiuroids, and annelids at 50 µg/L. Eppley *et al*. (1976) showed irreversible reductions in phytoplankton production but no change in either plankton biomass or species structure at chlorine concentrations greater than 10 µg/L. Bolsch and Hallegraeff (1993) showed that chlorine at 50 µg/L decreased germination rates in the dinoflagellate *Gymnodinium catenatum* by 50%, whereas there was no discernible effect at 10 µg/L. This indicated that the larval stages of some species may be vulnerable to chlorine pollution. The minimum impact concentrations reported in the South African water quality guidelines are in the range 2 to 20 µg/L at which fertilisation success in echinoderm (sea urchin) eggs is reduced by approximately 50% after five minute exposures. The Australian and New Zealand water quality guidelines proved a more conservative level of 3 µg/L, measured as total residual chlorine (ANZECC 2000).

The chemistry associated with seawater chlorination is complex as chemical reactions with inorganic and organic compounds result in the formation of numerous chlorinated compounds. Brief descriptions are given below, but for more details see White (1986), DWAF (1995) and ANZECC

(2000). Adding sodium hypochlorite to seawater results in the formation of hypochlorous acid. This weak acid undergoes partial dissolution, dependent on the pH and temperature of the water, to form the biocides hypochlorous acid and hypochlorite ions. Chlorine oxidation of the bromide that is naturally present in seawater also results in the formation of hypobromous acid, another effective biocide. In seawater (pH 8), hypobromous acid forms preferentially and represents 83% of the bromine species present, compared with hypochlorous acid at 28%. Hypobromous acid can also disproportionate into bromide and bromate, a process that is accelerated by sunlight. Oxidising reactions between hypochlorous and hypobromous acid with nitrogen containing organic compounds such as ammonia or amino acids results in the formation of organic chloramines and bromanines, but little is known about the biocidal properties of these compounds. In addition to the oxidising reactions described above, chlorine can undergo a variety of other oxidizing reactions with inorganic ions, as well as addition or substitution reactions with organic compounds. The latter result in the formation of halogenated compounds, such as chloroform, and, where hypobromous acid (HOBr) is present, mixed halogenated and brominated organic compounds.

In general, due to the powerful oxidising nature of chlorine, no free chlorine is found in chlorinated seawater where bromide oxidation is instantaneous and quantitative. However, the chlorinated compounds that constitute the combined chlorine, are far more persistent than the free chlorine. After seawater chlorination, the sum of free chlorine and combined chlorine is referred to as Total Residual Chlorine (TRC).

CIP effluent

Cleaning intervals of RO membranes are typically three to six months depending on the quality of the feed-water (Einav *et al*. 2002). The exact amount of Clean-In-Place (CIP) effluent that will be produced is not known but will likely constitute relatively small quantities. In the absence of details of CIP concentrations, the following environmental assessment of typical CIP chemicals used in RO desalination plants is based on that provided by van Ballegooyen *et al.* (2007) for an RO plant in Saldanha. The chemicals sulphuric acid, ethylenediaminetetraacetic acid (EDTA), sodium tripolyphosphate (STPP), trisodium phosphate (TSP), and sodium lauryl sulphate (SLS) are commonly used in RO plants. A brief description of the environmental fates and effects of these chemicals is discussed below.

Sulphuric acid (H_2SO_4) is used to reduce the pH for the acid wash cycle. This strong mineral acid dissociates readily in water to sulphate ions and hydrated protons and is totally miscible with water. Sulphuric acid is likely to be almost totally dissociated and any possible effects will be due to acidification. By causing reduction of water pH, sulphuric acid can be acutely toxic to aquatic life and extended exposures to pH lower than 5.5 is intolerable for most aquatic species. No guideline values are available for sulphuric acid but NOEC values were developed from chronic toxicity tests on freshwater organisms and range from 0.058 mg/L for fish populations to 0.13 mg/L for phytoplankton and zooplankton populations, respectively. As seawater is highly buffered, the limited sulphuric acid discharges from CIP cycles are not expected to have significant impacts in the marine environment.

EDTA is an aminopolycarboxylic salt used as a chelating agent to bind or capture trace amounts of metals. EDTA is used to control water hardness and scale-forming calcium and magnesium ions. EDTA is always likely to be emitted as a metal complex because of the ubiquitous presence of metal ions, although this is dependent on which species of metal is available. EDTA biodegrades very slowly under ambient environmental conditions and is not expected to bioaccumulate in aquatic organisms, adsorb to suspended solids or sediments, or volatilize from water surfaces (EURAR 2004). Toxicity tests have shown that adverse effects on aquatic organisms occur only at higher concentrations - the Lowest Observed Effective Concentration (LOEC) is 22 mg/L and PNEC is 0.64 mg/L (EURAR 2004). However, if trace elements like Fe, Cu, Mn, and Zn are low in the natural environment, an increased availability of essential nutrients caused by the complexing agent EDTA is able to stimulate algal growth. Heavy metal ions in the water are complexed by free EDTA, and a comparison of the toxicity of those compared to the respective uncomplexed metals and free EDTA have shown a reduction in toxicity by a factor of 17 to 17 000 (Sorvari and Sillanpää 1996). Experiments (albeit with significantly higher trace metal concentrations than are typically observed in the environment) indicate that EDTA decreases the accumulation of metals such as Cd, Pb and Cu; however, the absorption of Hg by mussels is seemingly promoted through complexation with EDTA (Gutiérrez-Galindo 1981, as cited in the EURAR 2004). The promotion of metal accumulation in sediments is unlikely to be of concern as EDTA will prevent the attachment of heavy metals onto sediments and may even remobilise metals from highly loaded sediments (EURAR 2004).

Sodium tripolyphosphate ($Na_5P_3O_{10}$) is a common ingredient of household cleaning products and is often present in domestic waste waters. STPP is an inorganic substance that when in contact with water is progressively hydrolysed to orthophosphate by biochemical activity. Ecotoxicity studies have shown that STPP has a very low toxicity to aquatic organisms (all EC/LC_{50} are above 100 mg/L) and this compound is not considered to be an environmental risk (HERA 2003). Orthophosphate, the final hydrolysis product of STPP, can lead to eutrophication of surface waters due to nutrient enrichment. However, phosphate as a nutrient is not usually limiting in marine environments unless there are significant inputs of nitrogen (which is generally the limiting nutrient). In addition, STPP can precipitate in the form of insoluble calcium, magnesium or other metal complex species in the presence of cationic ions (HERA 2003).

Trisodium phosphate (Na_3PO_4) is a cleaning agent highly soluble in water and has an alkaline pH. Phosphate can act as a plant nutrient, stimulating algal growth but is not considered acutely toxic to aquatic organisms (van Ballegooyen *et al*. 2007). Sodium lauryl sulphate ($C_{12}H_{25}NaO_4S$) is an anionic surfactant used for its detergent properties. SLS is biodegradable in surface waters, with biodegradation ranging from 45 to 95% within 24 hours and is classified as a substance of low environmental toxicity with low bioaccumulation (OECD 1997). Products of SLS biodegradation are carbon dioxide or saturated fatty acids.

In RO plants, CIP rinse water should be neutralised and transported to an authorized waste disposal site. More commonly, small quantities are continually injected into the brine and discharged to the sea (Einav *et al*. 2002). Burger and du Plessis (2010) recommend discharging CIP chemical waste and backwash sludge into evaporation ponds, which would obviously have no impact on the marine environment. Should co-discharge with the brine into the sea be undertaken, mitigation by neutralization of extremely alkaline or acidic solutions (e.g. sulphuric acid) and treatment of additional cleaning agents is recommended before release to remove any potential toxicity. Seawater is also highly buffered, which will help neutralise the acidic effluent.

In the absence of information on the specific chemicals to be used at the RO plants, the impacts of co-discharge cannot be fully assessed and the confidence is rated as 'low'. However, the toxicity of the various chemicals most likely to be used in the pre-treatment and CIP process (with the exception of any biocides) is relatively low and suitable mitigation measures, including the removal of particulates from the backwash sludge and neutralization of strong acidic and alkaline solutions, is likely to result in the 'very low' significance of impacts on the marine environment at all sites (Table 4.15). This impact was assessed as 'medium-term' due to this anticipated recovery time of marine communities following exposure.

Table 4.15 **<u>Impact 6</u>: Detrimental effects on marine organisms through discharge of co-pollutants in backwash water.**

Option	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation								
1) Offshore	Local 1	Medium 2	Medium-term 2	Low 5	Probable	**LOW**	-ve	Low
2) Harbour	Local 1	High 3	Medium-term 2	Medium 6	Probable	**MEDIUM**	-ve	Low
3) Surf zone	Local 1	High 3	Medium-term 2	Medium 6	Probable	**MEDIUM**	-ve	Low

<u>Required mitigation:</u>

- Ensure minimal dosing of co-pollutants.
- Diffusers must be designed to facilitate rapid mixing and dilution of the effluent at the discharge point.
- Ensure that all metals used in plant infrastructure have high resistance to corrosion by seawater.
- Use low-toxicity chemicals as far as practicable.
- Limit the use of scale-control additives to minimum practicable quantities.

<u>Best-practice mitigation:</u>

- Operate plant without the use of biocides.
- Avoid anti-scalants that increase nutrient levels (e.g. polyphosphate anti-scalants).

<u>Monitoring (see Section 5):</u>

- A baseline survey of inshore water quality (particularly salinity) and marine biota in the vicinity of the proposed pipeline discharge should be conducted before pipeline construction commences.
- Follow up monitoring of inshore water quality (particularly salinity) and marine biota in the vicinity of the pipeline discharge should be conducted after six months of plant operation.
- Record effluent flow rate daily using a flow rate meter fitted to the effluent pipe.
- Monitor and record water quality (temperature, salinity, pH, DO) before discharge once weekly using a portable water quality meter.
- Monitor and record the concentration of additives (CIPs, anti-scalants etc.) before discharge annually by sending samples to an accredited water quality laboratory. This process should be repeated upon each change of dosage.

Option	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
With mitigation								
Surf zone	Local 1	Low 1	Medium-term 2	Very low 4	Probable	**VERY LOW**	-ve	Medium

4.2.7 Reduced pH

The pH of the discharged seawater will be affected by the CIP chemicals, which are mainly weak acids and detergents. Alkaline cleaning solutions (pH 11-12) are used for removal of silt deposits and biofilms, whereas acidified solutions (pH 2-3) are used to remove metal oxides and scales. Other chemicals that may be added to improve cleaning efficiency are detergents, oxidants, complexing agents or biocides for membrane disinfection. pH will be purposefully adjusted to improve the efficiency of coagulants. Although seawater is highly buffered and has a strong neutralising effect on acids, neutralization of extremely alkaline or acidic solutions and treatment of additional cleaning agents is recommended before discharge to the ocean to remove any potential toxicity (Burger and du Plessis 2010).

Table 4.16 assesses the significance of the impact regarding the reduction in the physiological functioning of biota as a result of a reduction in pH through the release of co-discharges. The effects are considered to be of ‘low’ intensity in offshore environments but ‘medium’ intensity in environments with lower dispersion potential (i.e. harbours and surf zones). Effects will likely remain localised and will persist for the duration of plant operation only. This impact is assessed to be of ‘very low’ significance, although best-practice mitigation is still encouraged.

Table 4.16 <u>Impact 7</u>: Reduced physiological functioning of marine life due to reduced pH.

Option	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation								
1) Offshore	Local 1	Low 1	Short-term 1	Very low 3	Probable	**VERY LOW**	-ve	Medium
2) Harbour	Local 1	Medium 2	Short-term 1	Very low 4	Probable	**VERY LOW**	-ve	Medium
3) Surf zone	Local 1	Medium 2	Short-term 1	Very low 4	Probable	**VERY LOW**	-ve	Medium
<u>Best-practice mitigation:</u> • The neutralization of extremely alkaline or acidic solutions (e.g. sulphuric acid) and treatment of additional cleaning agents is recommended before discharge to remove any potential toxicity.								

4.2.8 Impacts on recreational users

RO plant operations are only likely to affect recreational users if tidal pools will be closed down, if beach access is restricted, and/or if effluent discharge affects the abundance or community composition of fish and invertebrate (bait) assemblages at popular fishing sites. This will limit safe swimming areas and usage of the coastal zone and marine environment for recreational activities such as fishing, bait collecting, swimming, camping etc. As sites are close to the Cape Town metropole and surrounding densely populated areas, the number of recreational users that may be affected is potentially very high. If tidal pool access is affected, the extent of the impact on recreational users will be local, the intensity 'high', the duration 'short-term' and the impact 'low' (Table 4.17). It is recommended that intakes are positioned offshore of tidal pools to prevent displacement of recreational users and every effort be made to limit impacts of brine discharge on the environment.

Table 4.17 **Impact 8: Effects on recreational users.**

Option	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation								
3) Surf zone	Local 1	High 3	Short-term 1	Low 5	Definite	**LOW**	-ve	High
Best-practice mitigation: • Position intakes offshore and not within tidal pools. • Take precautions to minimise impacts of brine discharge on marine biota								

4.3 DECOMMISSIONING PHASE

The operational life of each temporary RO plant is limited to two years. No decommissioning procedures or restoration plans have been compiled at this stage, although impacts are expected to be similar (if not less) to those assessed during the construction phase. The potential impacts during the de-commissioning phase are expected to be minimal in comparison to those occurring during the operational phase, and no key issues related to the marine environment have been identified at this stage.

It is anticipated that the following impacts outlined in the construction phase are likely to be repeated during the decommissioning phase (i.e. the removal of shore-based RO plant containers as well as vessels and barges):

- Impact 4 – Disposal of solid waste (see Section 4.1.4)
- Impact 5 – Hydrocarbon spills (see Section 4.1.5)
- Impact 6 - Noise and vibration (see Section 4.1.6)

It is assumed that any intake and discharge pipelines constructed for the plants will not be removed after decommissioning. If intakes, discharges and associated shore-based or intertidal structures are removed, the following construction impacts may be applicable (in addition to those listed above):

- Impact 1 - Disturbance of intertidal habitat and associated biota (see Section 4.1.1)
- Impact 2 – Disturbance of subtidal habitat and associated biota (see Section 4.1.2)
- Impact 3 – Mobilisation of benthic sediment (see Section 4.1.3)

The same mitigation procedures as those explained in the construction phase should be adhered to in the decommissioning phase in order to mitigate for any of the impacts listed above.

4.4 Cumulative impacts

Anthropogenic activities can result in numerous and complex effects on the natural environment. While many of these are direct and immediate, the environmental effects of individual activities or projects can interact with each other in time and space to cause incremental or aggregate effects. Impacts from unrelated activities may accumulate or interact to cause additional effects that may not be apparent when assessing the activities individually. Cumulative effects are defined as the total impact that a series of developments, either present, past or future, will have on the environment within a specific region over a particular period of time (DEAT IEM Guideline 7, Cumulative effects assessment 2004).

Cumulative marine environmental impacts emanating from the proposed project are primarily related to physiological responses of marine biota due to effluent discharge. On the West Coast, the sections of marine habitat that will be impacted by effluent discharges are not limited to the discharge site, although they do constitute sensitive environments that are unique to the area (e.g. deep cold water corals off Glen Beach). Within False Bay, the benthic environment is naturally dynamic and wave action and alongshore currents result in constant sand movement. Although marine organisms utilising the area are accustomed to such disturbance, they may be sensitive to anthropogenic disturbances such as the discharge or brine and co-pollutants. Commercially important fish species such as white steenbras are especially sensitive to changes in water quality in the nearshore sections of the Bay.

Sandy beaches are highly dynamic environments that experience frequent and rapid natural changes in habitat structure. The associated macrofaunal communities appear resilient to changes through their ability to recolonise the affected area relatively quickly. Reef environments are more sensitive, especially deep reefs that support the growth of cold water corals. Temporary disturbance of shallow sand-inundated reefs is unlikely to contribute to cumulative impacts, while deep reefs should be avoided altogether. Provided that the mitigation procedures listed in this report are implemented, it is unlikely that the cumulative impacts will endure beyond the short to medium-term, if at all. Table 4.18 summarises the impacts that may be experienced during RO plant construction and operation before and after mitigation.

Table 4.18. Summary of potential impacts during RO plant construction and decommissioning.

Phase	Impact identified	Consequence	Probability	Significance	Mitigation	Confidence
Construction & decommissioning	**Impact 1:** Disturbance of intertidal habitat and associated biota					
	1) **Offshore**	Very low	Probable	**VERY LOW**	No	High
	2) **Harbour**	Very low	Improbable	**INSIGNIFICANT**	No	High
	3) **Mixed habitat**	Low	Definite	**LOW**	No	High
	Impact 2: Disturbance of subtidal habitat and associated biota					
	1) **Offshore**	Very low	Definite	**VERY LOW**	No	High
	2) **Harbour**	Very low	Definite	**VERY LOW**	No	High
	3) **Mixed habitat**	Very low	Definite	**VERY LOW**	No	High
	Impact 3: Mobilisation of benthic sediment					
	1) **Offshore**	Very low	Possible	**INSIGNIFICANT**	No	High
	3) **Mixed habitat**	Very low	Possible	**INSIGNIFICANT**	No	High
	Impact 4: Disposal of solid waste	Medium	Probable	**MEDIUM**	Yes	High
	With mitigation	Medium	Improbable	**LOW**		High
	Impact 5: Hydrocarbon spills					
	1) **Offshore**	Low	Possible	**VERY LOW**	Yes	High
	2) **Harbour**	Very low	Possible	**INSIGNIFICANT**	Yes	High
	3) **Mixed habitat**	Medium	Possible	**LOW**	Yes	High
	With mitigation	Very low	Improbable	**INSIGNIFICANT**		High
	Impact 6: Noise and vibration management	Very low	Possible	**INSIGNIFICANT**	No	High

Table 4.19. Summary of potential impacts during RO plant operation.

Phase	Impact identified	Consequence	Probability	Significance	Mitigation	Confidence
Operation	**Impact 1:** Mortality of marine life due to seawater intake					
	1) Offshore	Very low	Definite	**VERY LOW**	Yes	High
	2) Harbour	Very low	Definite	**VERY LOW**	Yes	High
	3) Surf zone	Low	Definite	**LOW**	Yes	High
	With mitigation	Very low	Definite	**VERY LOW**		High
	Impact 2: Sediment scouring and shifts in sediment movement patterns					
	1) Offshore	Low	Probable	**LOW**	Yes	Medium
	3) Surf zone	Medium	Probable	**MEDIUM**	Yes	Medium
	With mitigation	Very low	Improbable	**INSIGNIFICANT**		Medium
	Impact 3: Increased salinity due to brine discharge					
	1) Offshore	Low	Possible	**VERY LOW**	Yes	Medium
	2) Harbour	Medium	Probable	**MEDIUM**	Yes	Medium
	3) Surf zone	Medium	Probable	**MEDIUM**	Yes	Medium
	Phase 1	Medium	Probable	**MEDIUM**	Yes	Medium
	Phase 2	Very low	Probable	**VERY LOW**	Yes	Medium
	With mitigation	Very low	Probable	**VERY LOW**		
	Impact 4: Elevated temperature					
	1) Offshore	Very low	Possible	**INSIGNIFICANT**	No	Medium
	2) Harbour	Very low	Possible	**INSIGNIFICANT**	No	Medium
	3) Surf zone	Very low	Possible	**INSIGNIFICANT**	No	Medium
	Impact 5: Decreased dissolved oxygen concentration					
	1) Offshore	Very low	Possible	**INSIGNIFICANT**	No	Medium
	2) Harbour	Very low	Possible	**INSIGNIFICANT**	No	Medium
	3) Surf zone	Very low	Possible	**INSIGNIFICANT**	No	Medium

Phase	Impact identified	Consequence	Probability	Significance	Mitigation	Confidence
Operation	**Impact 6:** Co-pollutants in backwash water					
	1) Offshore	Low	Probable	**LOW**	Yes	Medium
	2) Harbour	Medium	Probable	**MEDIUM**	Yes	Medium
	3) Surf zone	Medium	Probable	**MEDIUM**	Yes	Medium
	With mitigation	Very low	Probable	**VERY LOW**		Medium
	Impact 7: Reduced pH					
	1) Offshore	Very low	Probable	**VERY LOW**	No	Medium
	2) Harbour	Very low	Probable	**VERY LOW**	No	Medium
	3) Surf zone	Very low	Probable	**VERY LOW**	No	Medium
	Impact 8: Effects on recreational users					
	1) Surf zone	Low	Definite	**LOW**	No	High

5 MONITORING

The City of Cape Town has been granted an exemption from the requirements of the NEMA and the EIA regulations for the installation of emergency desalinisation plants owing to the fact that the Western Cape has been declared a disaster area due to the prevailing drought. This notwithstanding, the City of Cape Town is still bound by the 'duty of care principal' contained in NEMA (Chapter 7, Part 1 "Heading" amended by Section 2 of Act 46 of 2003) and every effort should be made to mitigate potential impacts on the environment associated with the installation and operation of these emergency desalination plants. Recognising that these plants will need to be installed as rapidly as possible, full consideration of potential impacts and possible mitigation may not be possible prior to installation. Thus, it is strongly recommended that an adaptive management approach is followed and that the effects of the project are very carefully monitored to mitigate any emerging negative impacts as they come to light. This will require detailed and comprehensive monitoring in the receiving environment and willingness on the part of the applicant to implement additional or new mitigation measures if required.

5.1 Water Quality Guidelines

Contemporary coastal water management strategies around the world focus on maintaining or achieving receiving water quality such that the water body remains or becomes fit for other designated uses. Designated uses of the marine environment include aquaculture, recreational use, industrial use, as well as the protection of biodiversity and ecosystem functioning. This goal oriented management approach arose from the recognition that enforcing end of the pipe effluent limits in the absence of an established context (i.e. not recognising the assimilative capacity and requirements of receiving environments) would reach a point where water bodies would only be marginally fit for their recognised uses. This management approach is referred to as the Receiving Water Quality (RWQ) framework (Anchor 2015) and most countries have adopted this framework. These countries have developed water quality guidelines for a variety of uses, which include target values for a range of contaminants that must be met in the receiving environment. Furthermore, in some countries (currently excluding South Africa) Water Quality Guidelines (WQG) are legislated standards and are legal requirements to be met by every user/outfall. Although the importance of managing water quality through the RWQ framework is undisputed, the degree to which this is implemented differs widely between countries.

In terms of the National Water Act (Act No 36 of 1998), discharging of waste or water containing waste into a "water resource through a sea outfall or other conduit" is listed as a water use for which a license is required. With the promulgation of the National Environmental Management: Integrated Coastal Management Act (No. 24 of 2008) (ICMA) (as amended), responsibility for regulating land-derived effluent discharges into coastal waters was transferred to the Department of Environmental Affairs (DEA). In terms of Section 69 of ICMA, no person is permitted to discharge effluent originating from a source on land into coastal waters except in terms of a GDA or a Coastal Waters Discharge Permit (CWDP). New operators wishing to discharge effluent to coastal waters are required to apply for a CWDP before commencing and are also required to comply with the applicable WQGs. Applications for CWDP are expected to include data on contaminant levels in the effluent to be discharged, as well as results of dilution and dispersion model studies if applicable.

These models are required to estimate the worst-case scenario and indicate maximum expected levels for the same contaminants at the edge of the Recommended Mixing Zone (RMZ). These levels are expected to comply with published guideline levels as defined by other existing, or potential, beneficial uses of the receiving environment (DWAF 1995).

The DEA is currently in the process of developing a permitting system for such effluent discharges and for this purpose, the Assessment Framework for the Management of Effluent from Land Based Sources Discharged to the Marine Environment was recently developed (Anchor 2015). This framework recognises that discharges differ in effluent characteristics (volume and quality) and discharge locality (i.e. biophysical conditions, use of the receiving environment), which ultimately determines the risk that a particular discharge poses to the receiving environment. It was recommended that the potential scope of a GDA, the level of assessment during the application process for a CWDP, as well as licensing conditions should be based entirely on the environmental risk posed by a particular effluent. Accordingly, the guidelines provide a framework within which an effluent can be characterised (effluent components and properties) and potential impacts assessed within the context of the receiving environment (i.e. sensitive versus robust receiving environments).

There are a wide variety of legal instruments that are utilised by countries to maintain and/or achieve WQG in the receiving environment. These include setting appropriate contaminant limits, the banning or restricting of certain types of discharges in specified areas, prohibiting or restricting discharge of certain substances, as well as providing financial incentives to reduce pollution at the source alongside the implementation of cleaner treatment technology. The only effective method, however, that ensures compliance of an effluent with water quality guidelines/standards is to determine site-specific effluent limits that are calculated based on the WQGs (or standards) of a given water body, the effluent volume and concentration, as well as the site-specific assimilative capacity of the receiving environment. This method is also identified as the water quality based effluent limits (WQBEL) approach (Anchor 2015) and recognises that effluent (and its associated contaminants) is rapidly diluted by the receiving waters as it enters the environment. In order to take advantage of this beneficial effect, allowance is generally made for a RMZ which extends a short distance from the outfall point (or pipe end) and is an area in which contaminant levels are "allowed" to exceed the established WQGs (or standards) for the receiving environment. The magnitude of the RMZ should, in theory, vary in accordance with the sensitivity and significance of the receiving environment and the location of the outfall point in the environment, but in practice is usually at a set distance from the pipe end. The WQBEL approach differs from the Uniform Effluent Standard (UES) approach in which fixed maximum concentrations or loads are applicable for contaminants in wastewater discharges for all users or outfalls, irrespective of where they are located (Anchor 2015).

South Africa has adopted the RWQ framework for the management of water quality in both inland (freshwater) and marine water bodies and uses both the WQBEL and the UES approaches to implement the framework. Receiving WQG have thus been published for the full range of beneficial uses for inland water (human consumption, aquaculture, irrigation, recreational use, industrial use, and protection of biodiversity and ecosystem functioning) and also for the marine environment (aquaculture, recreational use, industrial use, and protection of biodiversity and ecosystem functioning).

5.2 Effluent quality monitoring

The applicant is required to apply to DEA: O&C for a CWDP for each proposed outfall. Compliance monitoring is required as part of a CWDP and is specific to the permit conditions. If discharged effluent exceeds the end of pipe values at any time, the operation will be in violation of the CWDP and the cause of poor effluent quality must be identified, reported and rectified immediately. These events must be recorded as per internal procedures and must be reported to the responsible authorities on local, regional, and national levels, including, but not limited to the reporting of emergency incidents in terms of Section 30 of the National Environmental Management Act (NEMA) (1998) (Act No. 108 of 1998).

Two concurrent methods of compliance monitoring are recommended for each RO plant: 1) monitoring of effluent just before discharge into the marine environment (also referred to as end of pipe monitoring), and 2) monitoring to determine whether WQGs are met at the edge of the RMZ.

5.2.1 End of pipe compliance monitoring

The quantity of effluent discharged must be continuously metered and recorded *in situ*. Water quality samples must be collected at a fixed site just before the point of entry to the discharge pipe as stipulated in Table 5.1. Continuous monitoring dissolved oxygen and chlorine (if added) will be required, while all other parameters listed in Table 5.1 must be monitored once a week. Should DO levels drop below 3.97 ml/L, effluent must be aerated before discharge. In addition, bacterial growth should be assessed every six months.

These data must be submitted to DEA: Oceans and Coasts on a monthly basis along with pump capacity records. These will be used to ensure that each plant is not operating above maximum permit capacity. In addition, samples must be analysed by an independent, accredited external auditor every six months and reports must be submitted to DEA biannually. These data will be available for analysis for future water quality studies.

Toxicity testing of the RO plant effluent must be undertaken for a full range of operational scenarios (i.e. including shock-dosing) to ensure complete confidence in the potential effects of co-discharged constituents and anti-scalants. As waste brine may contain low amounts of heavy metals that tend to accumulate in sediments, it is recommended that the effluent water be monitored once annually for heavy metals and results compared to the end of pipe GDA limits.

Table 5.1 End of pipe limits as defined by the South African Water Quality Guidelines (DWAF 1995).

Constituent / parameter	Unit	End of pipe compliance limit (DEA: O&C)	Monitoring frequency at end of pipe	WQGs at edge of RMZ (DWAF 1995)	Monitoring frequency at edge of RMZ
Dissolved oxygen	mg/L	≥ 3.97 mg/L	Continuous	West coast: less than 10 % of the established natural variation	Continuous for at least three months (moored CTDs)
Temperature	^{0}C	1-2 ^{0}C above ambient seawater	Weekly	±1 ^{0}C above ambient seawater	
Salinity	PSU	66 PSU	Weekly	33 to 36 PSU	
pH		7.3 - 8.2	Weekly	7.3 – 8.2	
Turbidity	NTU, meters, Hazen units	≤10 NTU	Weekly	Turbidity should not reduce the depth of the euphotic zone by more than 10 % of background levels. The substances in solution should not exceed background levels by more than 35 Hazen units.	
Total Suspended Solids (TSS)	mg/L	1.67 times the ambient TSS or 20 mg/L, whichever is lower.	Weekly	Ambient TSS +10%	Samples to be collected upon deployment & retrieval of monitoring equipment
Chlorine (if added)	mg/L	0.003 mg/L	Continuous	No target value.	
Anti-scalants, coagulants, CIP chemicals		Undefined	Weekly	Undefined	

5.2.2 Water quality compliance at the edge of the RMZ

A water quality monitoring program at the edge of the RMZ for each plant should be implemented to determine compliance with WQGs. This can be achieved by mooring data logging instruments at the edge of the RMZ 1 m above the ocean bottom that can record conductivity, temperature and depth (CTD), among other parameters. This will enable the determination of ambient water quality as well as assist with determining whether or not WQGs are being met at the edge of the RMZ in terms of salinity, dissolved oxygen, temperature and turbidity. The CTD should initially be moored at the edge of the RMZ for one month prior to brine discharge to obtain baseline data (see Figure 5.1). Data should then be collected for two month period during full RO plant operation. In the event that salinity is above 36 PSU or DO levels are depressed by more than 20% from the pre-start baseline, monitoring should continue for at least another month during which the rate of brine discharge should be reduced or an amount of freshwater seawater added to the discharge stream until these limits are no longer exceeded. Note that recommendations on actual location for monitoring at each site can only be provided once the size of effluent plume has been established for each plant.

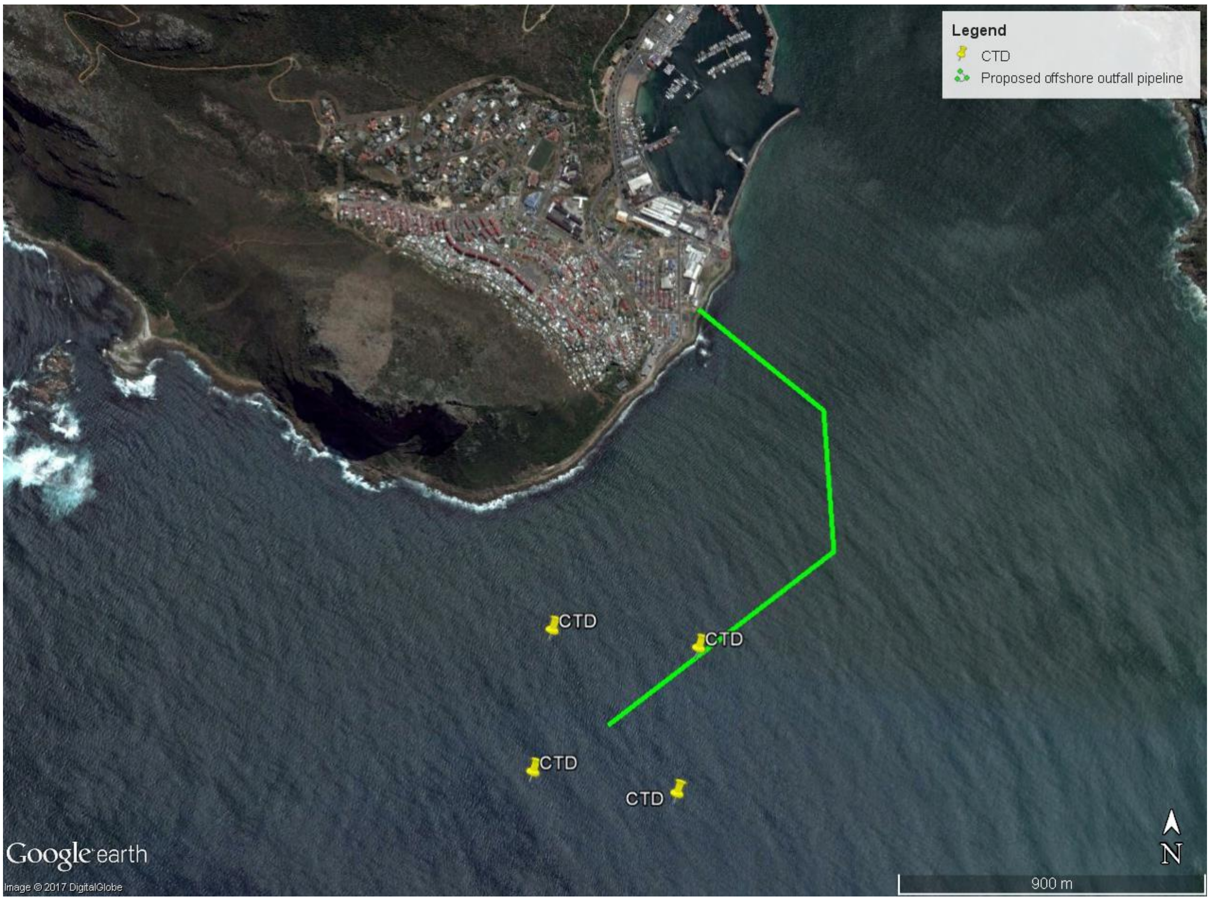

Figure 5.1 **An example of monitoring design layout for an offshore RMZ of 300 m. Moored CTDs are indicated by yellow pins (Google Earth 2017). Location maps for all outfall will be prepared once the final outfall designs have been confirmed.**

5.3 Ecological aspects of the receiving environment

The permit holder must submit a monitoring programme to the Department for approval prior to the commencement of operations. This document must include a summary of the marine impact assessment report, dispersion modelling, and a marine environmental monitoring programme. The monitoring programme must be sensitive to potential changes in biological communities due to the composition of the effluent.

5.3.1 Biological monitoring

In order to better understand and predict the impacts of desalination effluent on the marine environment, a structured Before-After/Control-Impact (BACI) monitoring programme is recommended. Firstly, a baseline study covering the affected marine habitats (rocky intertidal, sandy beach, surf zone, sandy subtidal and subtidal reef) at each discharge site should be conducted. It is recommended that sandy subtidal habitats be surveyed using a Van Veen grab, subtidal rocky reef habitats should be surveyed by SCUBA divers, Remotely Operated Vehicles (ROVs) and/or drop camera mounted to a steel frame (for sessile biota), and/or a Baited Remote Underwater Video System (BRUVS) (for reef fish). Intertidal rocky shore habitats should be surveyed by visually estimating abundance and biomass of intertidal organisms within fixed sized quadrats at different heights on the shore in accordance with methods described by Bustemante *et al.* (1997). Sandy beach macrofauna should be surveyed by excavating sediment (and associated biota) from a series of quadrats (5-10) per transect with three transects in total aligned perpendicular to the shore. Samples must be sieved through a 1 mm mesh in accordance with methods prescribe by Brown and McLachlan (1990). Surf zone and invertebrate assemblages should be assessed using beach seine nets according to methods employed by Lasiak (1984). Assessments should be repeated after approximately six months of full operation of the RO plant and a comparison study made between the two data sets.

5.3.2 Water quality in the receiving environment

In addition to surveying the marine biota, a range of water quality parameters should be monitored over a period of at least three months. This should be undertaken during three separate field trips where water column profiling for physico-chemical water quality parameters is undertaken (conductivity, temperature, dissolved oxygen, turbidity and pH) and surface and bottom water samples are collected from a boat using a Niskin bottle. Water samples should be submitted to an accredited analytical laboratory for analysis of trace metals (As, Cd, Cu, Cr, Fe, Hg, Ni, Mn, Pb, Zn) and for any biocides and CIP chemicals that are used in the plants. Water column profile measurements and water samples should be collected from a suite of sites extending from the discharge point, and around a specified range radiating out from the discharge point until the edge of the RMZ is reached (Figure 5.2). It is recommended that the distances between sampling radii for offshore sites measure 100 m (13 sites in a 300 m radius), while that of inshore sites measure 50 m (9 sites in a 100 m radius).

Monitoring of the effluent quality within the intertidal zone must be done every six months from the commencement of operation for the first two years and thereafter every year. Samples of sediment and bivalve (mussel) tissue should also be collected from strategic locations surrounding the outfall and should be tested for the same suite of trace metals as for the water samples.

If the results indicate that the species richness and abundance of biota at stations at the edge of the RMZ are within 80% of those recorded during the baseline, and that salinity is not elevated nor oxygen levels depressed by more than 20% from the baseline 100 m from the discharge point, no further surveys should be required. However, if the change in the biotic communities, particularly in sensitive or ecologically significant habitats, exceeds 80% and/or water quality changes are evident beyond the edge of the RMZ, monitoring surveys should be repeated at six monthly intervals and consideration should be given to reducing the volume of brine production, blending additional seawater into the effluent prior to discharge, or modifying the design of the outfall (e.g. extending the length of the discharge pipe).

Of particular importance is the careful monitoring of surf zone discharges Effects monitoring, particularly of salinity levels, in the area of discharge (i.e. the surf zone at these sites) needs to be intensified.

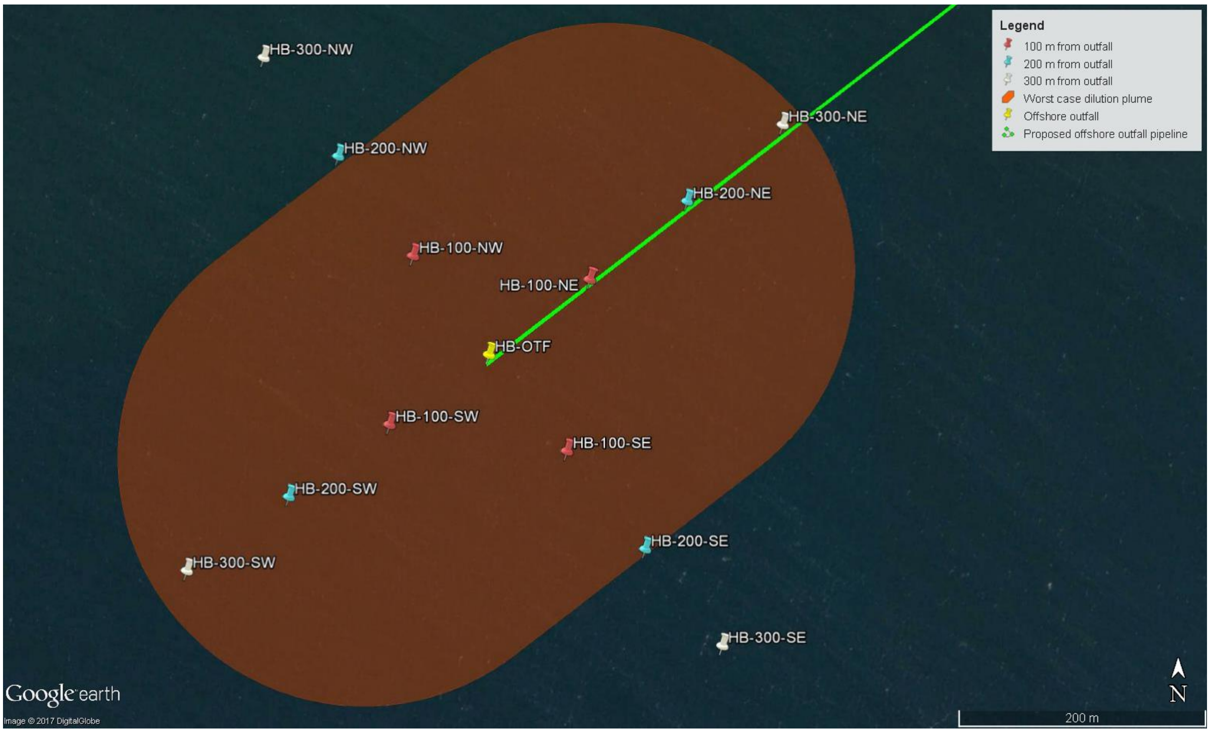

Figure 5.2 **Proposed layout for water quality monitoring of offshore sites. CTD profiles and water quality samples should be taken at each of these 13 sites every monitoring trip (Google Earth 2017).**

5.4 Pipeline integrity

The pipeline above the high water mark must be inspected on a weekly basis to check for any leaks or malfunctions. Records must be kept of such inspections and may be accessed by DEA: O&C if required. For RO plants that become established and remain operational beyond the two year tenure of the proposed temporary plants, a full integrity survey must be conducted within two years of commencement of the operation and again every three years thereafter. This will allow for monitoring the stability of the pipeline infrastructure and assist with detecting mechanical failure. Surveys must assess the integrity along the full length of the marine outfall pipeline and associated structures, the ocean bed directly below the pipe, and corrosion levels of the plant, the intake, outlet and diffuser. Damaged components must be repaired or replaced and maintenance must be ongoing.

5.5 Contingency plan

A contingency plan must be submitted to the Department for approval, and must consist of stipulated procedures, schedules and responsibilities which include:

- standard operating procedures for detection of problems and responding to emergency incidents as well as upset conditions;
- staff schedules;
- programmes for the maintenance replacement and surveillance of the physical condition of equipment, facilities and pipelines;

- alternative personnel and services for the continued operation and maintenance of effluent discharge facilities during employee shortages;
- stocklists and suppliers for chemicals, spare parts and equipment components that can adequately ensure the continued operation of the effluent discharge facility during an emergency or breakdown;
- emergency standby power facilities and pumps for high-risk areas;
- provision for sufficient storage capacity to cope with the normal or typical load for the area during power failures;
- schedule of monitoring and sampling analyses when emergency or upset conditions occur at the plant;
- details on the type of mitigating measures to be implemented if effluent discharge into the coastal environment exceeds the limits prescribed in the CWDP;
- clear action plan(s) on mitigating measures to protect other users of the affected coastal environment (such as site notice boards or media releases) informing users of the potential risks;
- demarcation of polluted areas, if required;
- notification of seawater users (e.g. industrial and marine aquaculture farms), as well as procedures to be followed in assisting with protection of such facilities against pollution; and
- reporting procedures and protocols for events of malfunctioning of the effluent disposal system, as well as pollution events.

6 RECOMMENDATIONS

Desalination effluent is expected to be negatively buoyant relative to the ambient, even after mixing with WWTW effluent in existing pipelines. To minimise effluent from forming a dense brine layer over the seafloor, the diffuser should be positioned at least 1 m from the seafloor and angled upwards. This will assist in rapid dilution during the jet plume stage of mixing. As dilution increases with depth, deeper outfalls are preferable; however; construction and maintenance costs may become prohibitive. As a result, it is important to aim towards recommending a realistic pipeline length. From an environmental perspective, the minimum requirement for an outfall of this nature is for the discharge to be positioned beyond the surf zone. This is to protect against retentive circulation, which may result in the effluent moving back towards the shore.

A total of seven possible impacts were identified for the construction phase, while eight were identified for the operational phase. Where the significance of these impacts is too high, or where the significance can be reduced with minimal intervention, mitigation measures were recommended. Best-practice mitigation is not essential but is advised, while required mitigation is crucial for the project to go ahead. Mitigation measures for both the construction and operational phases of the RO plants are summarised in Table 6.1 and Table 6.2 below.

Should it not be possible to implement the essential mitigation measures discussed in this report, the 'no-development' option must be followed.

Table 6.1 Mitigation measures for the construction and decommissioning phase of temporary RO plants around the Cape Peninsula.

Construction and decommissioning phase	
	Impact 1: Disturbance of intertidal habitat and associated biota
	Best-practice mitigation: • Confine disturbance to the smallest area possible. • Limit duration of construction activities in the coastal zone. • Return sandy areas to original state if churned up by heavy vehicles. • Inform all staff about sensitive marine habitats.
	Impact 2: Disturbance of subtidal habitat and associated biota
	Best-practice mitigation: • Avoid placing pipelines over subtidal reef if possible. • Avoid blasting subtidal reefs or securing pipelines using toxic substances.
	Impact 3: Mobilisation of benthic sediment
	Mitigation: • No mitigation necessary.
	Impact 4: Disposal of solid waste
	Required mitigation: • Suitable handling and disposal protocols must be clearly explained and sign boarded. • Implement the 'reduce, reuse, recycle' ethos. • All fuel and oil must be stored with adequate spill protection and equipment must be checked for leaks. • A rigorous environmental management and control plan must be available. • Disposal of any substance into the marine environment is strictly prohibited. • Inform all staff about sensitive marine species and the suitable disposal of construction waste.
	Impact 5: Hydrocarbon spills
	Required mitigation: • Maintain high safety standards and employ "good housekeeping". This should incorporate plans for emergencies. • All fuel and oil must be stored with adequate spill protection and equipment must be checked for leaks. • No vehicle maintenance or refuelling on beach. • Use drip trays and bunding where losses are likely to occur. • Accidental diesel and hydrocarbon spills must be cleaned up immediately. • Collect and dispose of polluted soil at appropriate bio-remediation sites.
	Impact 6: Noise and vibration
	Best-practice mitigation: • Subject mobile equipment, vehicles and power generation equipment to a noise test prior to use.

Table 6.2 Mitigation measures for the operational phase of temporary RO plants around the Cape Peninsula.

Operational phase	**Impact 1: Mortality of marine life due to the intake of seawater**
	Required mitigation: • Intake velocities must be kept below 0.15 m/s to ensure that fish and other organisms can escape the intake current. • Velocity caps must be used to change the predominant intake flow from vertical to horizontal, thereby significantly reducing impingement of fish. Best-practice mitigation: • Travelling screens can be installed at the landward end of a pipeline intake to enable fish to be transported out of the system.
	Impact 2: Sediment scouring and shifts in sediment movement patterns
	Required mitigation: • The diffuser must be angled towards the water surface to prevent scouring of benthic sediment. Best-practice mitigation: • Trench discharge pipe under beach sand to prevent interference of dune transport systems (if applicable). • Trench discharge pipe under benthic sand to prevent interference in alongshore sediment transport pathways (if applicable).
	Impact 3: Increased salinity due to brine discharge
	Required mitigation: • No discharge should be permitted within the surf zone. Pipes must reach beyond the furthest extent of the surf backline. However, the emergency situation may justify the discharge of effluent into the surf zone as a short term, emergency measure for **Phase 1, provided that the duration is kept to a minimum (< six months), the footprint is small (< 1 km) and the discharge volumes do not exceed the modelled brine dispersal results for Phase 1.** These measures are imperative to ensure that the surf zone discharge is a genuine interim **measure. Monitoring will be of crucial importance to ensure that these requirements are met. Effects** monitoring will need to be expanded upon during the surf zone discharge phase. In addition, t**he effluent discharge pipeline must be extended beyond the surf zone to cope** with the increased brine volumes of proposed for **Phase 2.** • Brine discharges within harbours should not be permitted due to high retention times and limited mixing. • The pipe and outlet must be designed to facilitate rapid mixing and dilution of the effluent at the discharge point through a minimum diffuser angle of 30 degrees. • A robust pipeline design must be adopted to avoid dislodgement or rupture. • Should unacceptable environmental effects and high salinity concentrations be detected outside of the RMZ, a reduction in effluent flow and lengthening of the discharge pipe should be considered.
	Impact 4: Elevated temperature
	Mitigation: • No mitigation required.
	Impact 5: Decreased dissolved oxygen concentration
	Required mitigation: • No mitigation required as long as no oxygen scavenging chemicals are added to the co-discharge (i.e. sodium metabisulfite, sodium tripolyphosphate and trisodium phosphate).
	Impact 6: Co-pollutants in backwash water
	Required mitigation: • Ensure minimal dosing of co-pollutants and use low-toxicity chemicals as far as practicable. • Diffusers must be designed to facilitate rapid mixing and dilution of the effluent at the discharge point. • Ensure that all metals used in plant infrastructure have high resistance to corrosion by seawater. • Limit the use of scale-control additives to minimum practicable quantities. Best-practice mitigation: • Operate plant without the use of biocides. • Avoid anti-scalants that increase nutrient levels (e.g. polyphosphate anti-scalants).
	Impact 7: Reduced pH

	Best-practice mitigation: • The neutralization of extremely alkaline or acidic solutions (e.g. sulphuric acid) and treatment of additional cleaning agents is recommended before discharge to remove any potential toxicity.
	Impact 8: Effects on recreational users
	Best-practice mitigation: • Position intakes offshore and not within tidal pools.

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APPENDIX 1 – IMPACT RATING METHODOLOGY

The significance of all potential impacts that would result from the proposed project is determined in order to assist decision-makers. The significance rating of impacts is considered by decision-makers, as shown below. Note this method does not apply to minor impacts which can be logically grouped into a single assessment.

INSIGNIFICANT: the potential impact is negligible and **will not** have an influence on the decision regarding the proposed activity.
VERY LOW: the potential impact is very small and **should not** have any meaningful influence on the decision regarding the proposed activity.
LOW: the potential impact **may not** have any meaningful influence on the decision regarding the proposed activity.
MODERATE: the potential impact **should** influence the decision regarding the proposed activity.
HIGH: the potential impact **will** affect a decision regarding the proposed activity.
VERY HIGH: The proposed activity should only be approved under special circumstances.

The **significance** of an impact is defined as a combination of the **consequence** of the impact occurring and the **probability** that the impact will occur. The significance of each identified impact was thus rated according to the methodology set out below:

Step 1 – Determine the **consequence** rating for the impact by determining the score for each of the three criteria (A-C) listed below and then **adding** them. The rationale for assigning a specific rating, and comments on the degree to which the impact may cause irreplaceable loss of resources and be irreversible, must be included in the narrative accompanying the impact rating:

Rating	Definition of Rating	Score
A. ***Extent – the area over which the impact will be experienced***		
Local	Confined to project or study area or part thereof (e.g. limits of the concession area)	1
Regional	The region (e.g. the whole of Namaqualand coast)	2
(Inter) national	Significantly beyond Saldanha Bay and adjacent land areas	3
B. ***Intensity – the magnitude of the impact in relation to the sensitivity of the receiving environment, taking into account the degree to which the impact may cause irreplaceable loss of resources***		
Low	Site-specific and wider natural and/or social functions and processes are negligibly altered	1
Medium	Site-specific and wider natural and/or social functions and processes continue albeit in a modified way	2
High	Site-specific and wider natural and/or social functions or processes are severely altered	3
C. ***Duration – the time frame for which the impact will be experienced and its reversibility***		
Short-term	Up to 2 years	1
Medium-term	2 to 15 years	2
Long-term	More than 15 years (state whether impact is irreversible)	3

The combined score of these three criteria corresponds to a **Consequence Rating**, as follows:

Combined Score (A+B+C)	**3 – 4**	**5**	**6**	**7**	**8 – 9**
Consequence Rating	Very low	Low	Moderate	High	Very high

Example 1:

Extent	**Intensity**	**Duration**	**Consequence**
Regional 2	Moderate 2	Long-term 3	High 7

Step 2 – Assess the **probability** of the impact occurring according to the following definitions:

Probability– the likelihood of the impact occurring	
Improbable	< 40% chance of occurring
Possible	40% - 70% chance of occurring
Probable	> 70% - 90% chance of occurring
Definite	> 90% chance of occurring

Example 2:

Extent	**Intensity**	**Duration**	**Consequence**	**Probability**
Regional 2	Medium 2	Long-term 3	High 7	Probable

Step 3 – Determine the overall **significance** of the impact as a combination of the **consequence** and **probability** ratings, as set out below:

		Probability			
		Improbable	Possible	Probable	Definite
Consequence	Very Low	**INSIGNIFICANT**	**INSIGNIFICANT**	**VERY LOW**	**VERY LOW**
	Low	**VERY LOW**	**VERY LOW**	**LOW**	**LOW**
	Moderate	**LOW**	**LOW**	**MODERATE**	**MODERATE**
	High	**MODERATE**	**MODERATE**	**HIGH**	**HIGH**
	Very High	**HIGH**	**HIGH**	**VERY HIGH**	**VERY HIGH**

Example 3:

Extent	**Intensity**	**Duration**	**Consequence**	**Probability**	**Significance**
Regional 2	Medium 2	Long-term 3	High 7	Probable	**HIGH**

Step 4 – Note the **status** of the impact (i.e. will the effect of the impact be negative or positive?)

Example 4:

Extent	Intensity	Duration	Consequence	Probability	Significance	Status
Regional 2	Medium 2	Long-term 3	High 7	Probable	**HIGH**	– ve

Step 5 – State the level of **confidence** in the assessment of the impact (high, medium or low).

Depending on the data available, a higher level of confidence may be attached to the assessment of some impacts than others. For example, if the assessment is based on extrapolated data, this may reduce the confidence level to low, noting that further ground-truthing is required to improve this.

Example 5:

Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Regional 2	Medium 2	Long-term 3	High 7	Probable	**HIGH**	– ve	High

Step 6 – Identify and describe practical **mitigation** and **optimisation** measures that can be implemented effectively to reduce or enhance the significance of the impact. Mitigation and optimisation measures must be described as either:

- **Essential**: must be implemented and are non-negotiable; and
- **Optional**: must be shown to have been considered and sound reasons provided by the proponent if not implemented.

Essential mitigation and optimisation measures must be inserted into the completed impact assessment table. The impact should be re-assessed with mitigation, by following Steps 1-5 again to demonstrate how the extent, intensity, duration and/or probability change after implementation of the proposed mitigation measures.

Example 6: A completed impact assessment table

	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation	Regional 2	Medium 2	Long-term 3	High 7	Probable	**HIGH**	– ve	High
Essential mitigation measures: xxxxx xxxxx								
With mitigation	Local 1	Low 1	Long-term 3	Low 5	Improbable	**VERY LOW**	– ve	High

Step 7 – Prepare a summary table of all impact significance ratings as follows:

Impact	***Consequence***	***Probability***	**Significance**	***Status***	***Confidence***
Impact 1: XXXX	Moderate	Improbable	**LOW**	–ve	High
With Mitigation	Low	Improbable	**VERY LOW**	–ve	High
Impact 2: XXXX	Very Low	Definite	**VERY LOW**	–ve	Medium
With Mitigation:	*Not applicable*				

Indicate whether the proposed development alternatives are environmentally suitable or unsuitable in terms of the respective impacts assessed by the relevant specialist and the environmentally preferred alternative.

Advisian

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