PROPOSED COEGA 3000 MW
INTEGRATED GAS-TO-POWER PROJECT

Marine Ecology Assessment

Prepared for:

srk consulting

On behalf of

COEGA
DEVELOPMENT CORPORATION

September 2020

PISCES ENVIRONMENTAL SERVICES (PTY) LTD

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INTEGRATED GAS-TO-POWER PROJECT

MARINE ECOLOGY ASSESSMENT

Prepared for

SRK Consulting (South Africa) (Pty) Ltd

Prepared by

Andrea Pulfrich
Pisces Environmental Services (Pty) Ltd

September 2020

Contact Details:

Andrea Pulfrich
Pisces Environmental Services
PO Box 302, McGregor 6708, South Africa,
Tel: +27 21 782 9553, E-mail: apulfrich@pisces.co.za
Website: www.pisces.co.za

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ABBREVIATIONS and UNITS

ACB	Administration Craft Basin
ANZECC	Australian and New Zealand Environment and Conservation Council
BATNEEC	Best Available Technique Not Entailing Excessive Cost
BCC	Benguela Current Commission
BCLME	Benguela Current Large Marine Ecosystem
BOG	Boil-off Gas
CDC	Coega Development Corporation
CES	Centre for Environmental Studies
CSIR	Council for Scientific and Industrial Research
DEAT	Department of Environmental Affairs and Tourism (now Dept of Environment, Forestry and Fisheries)
DPTI	Department of Planning, Transport & Infrastructure, Government of South Australia
DWAF	Department of Water Affairs and Forestry (now Dept of Human Settlements, Water and Sanitation)
EBSA	Ecologically or Biologically Significant Area
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EPA	Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
FSRU	floating storage and regasification unit
IBAs	Important Bird Areas
ICES	International Council for the Exploration of the Sea
IFC	International Finance Corporation
IMO	International Maritime Oragnisation
IUCN	International Union for the Conservation of Nature
JNCC	Joint Nature Conservation Committee
kV	kiloVolt
LNG	Liquid Natural Gas
LNGC	Liquid Natural Gas Carrier
MMO	Marine Mammal Observer
MPA	Marine Protected Area
NaOCl	Sodium Hypochlorite
NaOH	Sodium hydroxide
NEMA	National Environmental Management Act
NG	Natural Gas
NOAA	National Oceanic and Atmospheric Administration
NOEC	no observed effect concentration
NMFS	National Marine Fisheries Services
NRC	National Research Council
NTU	Nephelometric Turbidity Unit
OTEC	Ocean Thermal Energy Conversion
PAM	Passive Acoustic Monitoring

ppt	parts per thousand
PRDW	Prestedge Retief Dresner Wijnberg
PTS	permanent threshold shifts
RPT	Rapid Phase Transition
RMS	Root mean squared
SEL	Sound Exposure Level
SEZ	Special Economic Zone
SMBS	sodium metabisulfite
SPL	sound pressure levels
SWRO	seawater Reverse Osmosis
TBT	tributyltin
TRC	Total Residual Chlorine
TTS	temporary threshold shifts
UNEP	United Nations Environment Programme
US CG	US Coast Guard
US-EPA	United States Environmental Protection Agency
WHO	World Health Oragnisation

Units used in the report

cm	centimetres
cm/s	centimetres per second
dB	decibels
h	hours
Hz	Herz
kg	kilogram
kHz	kiloHerz
km	kilometres
km^2	square kilometres
m	metres
m^2	square metres
m^3	cubic metres
m/s	metres per second
m^3/h	cubic metres per hour
mg/ℓ	milligrams per litre
mm	millimetres
MW	MegaWatt
NTU	nephelometric turbidity units
µg/ℓ	micrograms per litre
µm	micron
µPa	micro Pascal
ppm	parts per million
%	percentage
‰	parts per thousand (ppt)
<	less than
>	greater than
°C	degrees centigrade

GLOSSARY

Barg	a unit of gauge pressure, i.e. pressure in bars above ambient or atmospheric pressure.
Benthic	Referring to organisms living in, or on, the sediments of aquatic habitats (lakes, rivers, ponds, etc.).
Benthos	The sum total of organisms living in, or on, the sediments of aquatic habitats.
Benthic organisms	Organisms living in, or on, sediments of aquatic habitats.
Biodiversity	The variety of life forms, including the plants, animals and micro-organisms, the genes they contain and the ecosystems and ecological processes of which they are a part.
Biomass	The living weight of a plant or animal population, usually expressed on a unit area basis.
Biota	The sum total of the living organisms of any designated area.
Bivalve	A mollusc with a hinged double shell.
Community structure	All the types of taxa present in a community and their relative abundance.
Community	An assemblage of organisms characterized by a distinctive combination of species occupying a common environment and interacting with one another.
Dilution	The reduction in the concentration of a substance due to mixing with water.
Dissolved oxygen (DO)	Oxygen dissolved in a liquid, the solubility depending upon temperature, partial pressure and salinity, expressed in milligrams/litre or millilitres/litre.
Ecosystem	A community of plants, animals and organisms interacting with each other and with the non-living (physical and chemical) components of their environment
Effluent	Liquid fraction after a treatment process (*i.e.* preliminary, primary, secondary or tertiary) in a wastewater treatment works.
Environmental impact	A positive or negative environmental change (biophysical, social and/or economic) caused by human action.
Environmental quality objective	A statement of the quality requirement for a body of water to be suitable for a particular use (also referred to as Resource Quality Objective).
Epifauna	Organisms, which live at or on the sediment surface being either attached (sessile) or capable of movement.
Habitat	The place where a population (*e.g.* animal, plant, micro-organism) lives and its surroundings, both living and non-living.

Infauna	Animals of any size living within the sediment. They move freely through interstitial spaces between sedimentary particles or they build burrows or tubes.
LC (Lethal Concentration)	the dose or concentration which produces a specified level of mortality in the test population within a specified time, e.g. LC_{50} is the median lethal concentration or the concentration of a substance at which 50% of the test population are killed. Typical levels are LC_{10}, LC_{25}, LC_{50}, LC_{75}, LC_{100}.
Macrofauna	Animals >1 mm.
Macrophyte	A member of the macroscopic plant life of an area, especially of a body of water; large aquatic plant.
Meiofauna	Animals <1 mm.
Mariculture	Cultivation of marine plants and animals in natural and artificial environments.
Marine discharge	Discharging wastewater to the marine environment either to an estuary or the surf-zone or through a marine outfall (*i.e.* to the offshore marine environment).
Marine environment	Marine environment includes estuaries, coastal marine and nearshore zones, and open-ocean-deep-sea regions.
Pollution	The introduction of unwanted components into waters, air or soil, usually as a result of human activity; *e.g.* hot water in rivers, sewage in the sea, oil on land.
Population	The total number of individuals of the species or taxon.
Pseudofaeces	Pseudofaeces production is a process of particle selection whereby less nutritious particles are rejected and the quality of the ingested material improved proportionately.
Recruitment	The replenishment or addition of individuals of an animal or plant population through reproduction, dispersion and migration.
Sediment	Unconsolidated mineral and organic particulate material that settles to the bottom of an aquatic environment.
Species	A group of organisms that resemble each other to a greater degree than members of other groups and that form a reproductively isolated group that will not produce viable offspring if bred with members of another group.
Sludge	Residual sludge, whether treated or untreated, from urban wastewater treatment plants.
Subtidal	The zone below the low-tide level, *i.e.* it is never exposed at low tide.
Surf zone	Also referred to as the ‘breaker zone’ where water depths are less than half the wavelength of the incoming waves with the result that the orbital pattern of the waves collapses and breakers are formed.

Suspended material	Total mass of material suspended in a given volume of water, measured in mg/ℓ.
Suspended matter	Suspended material.
Suspended sediment	Unconsolidated mineral and organic particulate material that is suspended in a given volume of water, measured in mg/ℓ.
Taxon (Taxa)	Any group of organisms considered to be sufficiently distinct from other such groups to be treated as a separate unit (*e.g.* species, genera, families).
Toxicity	The inherent potential or capacity of a material to cause adverse effects in a living organism.
Turbidity	Measure of the light-scattering properties of a volume of water, usually measured in nephelometric turbidity units.
Vulnerable	A taxon is vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium-term future.

EXPERTISE AND DECLARATION OF INDEPENDENCE

This report was prepared by Dr Andrea Pulfrich of Pisces Environmental Services (Pty) Ltd. Andrea has a PhD in Fisheries Biology from the Institute for Marine Science at the Christian-Albrechts University, Kiel, Germany.

As Director of Pisces since 1998, Andrea has considerable experience in undertaking specialist environmental impact assessments, baseline and monitoring studies, and Environmental Management Programmes / Plans relating to marine diamond mining and dredging, hydrocarbon exploration and thermal/hypersaline effluents. She is a member of the South African Council for Natural Scientific Professions, South African Institute of Ecologists and Environmental Scientists, and the International Association of Impact Assessment (South Africa).

This specialist report was compiled on behalf of SRK Consulting (South Africa) (Pty) Ltd (SRK) for their use in preparing the Environmental Impact Assessments for the proposed Coega 3000 MW Integrated Gas-to-Power Project. I do hereby declare that Pisces Environmental Services (Pty) Ltd is financially and otherwise independent of the Applicant and SRK.

Andrea Pulfrich

Dr Andrea Pulfrich

1. GENERAL INTRODUCTION

The Coega Development Corporation proposes to develop an integrated Gas-to-Power solution and associated infrastructure within the Coega Special Economic Zone (SEZ) and the Port of Ngqura. The proposed project will comprise amongst others:

- A liquid Natural Gas (LNG) terminal consisting of a jetty connecting to a berth with off-loading arms within the Port, cryogenic pipelines, storage and handling facilities and regasification modules. Up to two floating storage and regasification units (FSRUs) within the Port are proposed followed by possible land-based options.
- Cryogenic gas pipelines for the transmission, distribution and reticulation of gas from the LNG offloading facility to the new power plants and to a designated off-take point for road transport of LNG & Natural Gas (NG).
- Three 1000 MW Gas to Power Plants, two of which would have seawater-cooled power cycles. Two power plants are proposed in zone 10 (coastal) and one in zone 13 (inland) of the SEZ, with each of the power plants requiring separate authorisations.

The Coega Development Corporation (CDC) proposes to develop three gas-to-power plants and associated infrastructure for gas import and distribution within the Coega Special Economic Zone (SEZ) and the Port of Ngqura. To facilitate the required environmental authorisation process, the CDC has appointed SRK Consulting (South Africa) (Pty) Ltd to conduct an Environmental Impact Assessment (EIA) in terms of the National Environmental Management Act.

As developers and their chosen technologies have not yet been identified, various technologically feasible options are applied for in each EIA, and the assessment presented will be based on the worst-case option for each impact. The aim of this approach is to identify the envelope limits within which the project impacts will fall, and which will be acceptable to the receiving environment with the implementation of mitigation measures where relevant.

In accordance with the requirements of the NEMA 2014 EIA regulations, as amended, the proposed project requires a full Scoping and EIA process to be conducted.

This Marine Ecological Specialist Study deals only with the potential marine impacts of the construction and operational phases of the gas infrastructure components of the project (i.e. those covered by the Gas Infrastructure EIA (DEFF reference no 14/12/16/3/3/2/2013)), **facilitating the supply of gas to the power plants, and gas and LNG to third party off-takers.**

1.1. Summary description of project components

The proposed gas infrastructure will consist of all key supporting infrastructure required for the operation of the CDC's proposed gas to power plants in the Coega SEZ. This will be made up specifically of infrastructure for the import, storage and transmission of LNG *via* the Port of Ngqura (Figure 1), to the various power plants, and seawater for cooling to and from the zone 10 power plants (should they be seawater cooled), and heating water to the onshore storage and regasification unit at the gas distribution facility. The additional capacity of supply of LNG and natural gas (NG) to third party offtakers, will also be included. The key infrastructure includes the following:

- A floating storage and regasification unit (FSRU) moored in the Port, which will receive, store and regasify the LNG from the LNG carrier (Phase 1). It is proposed that onshore storage and regasification facilities will replace the FSRU once the demand for NG reaches a point where onshore storage and regasification is the more feasible option, at which point the FSRU will be removed;
- A new jetty with offloading platform and berthing and mooring dolphins in the Port of Ngqura (Figure 2);
- A trestle structure to support the gas and cryogenic pipelines running within the port from the offloading platform parallel to the eastern breakwater, to the point where the pipelines cross under the breakwater near the admin craft basin;
- Once the FSRU is no longer the most feasible option, an LNG and gas hub, consisting of storage and regasification facilities will be developed as part of Phase 2 of the project. This will include a truck delivery centre for third party offtakers;
- Gas (for transmission of NG) and cryogenic (for transmission of LNG) pipelines from the FSRU and jetty to the three proposed power plants, as well as to the boundary of the Dedisa power plant in Zone 13;
- Pipelines for the transmission of seawater from the abstraction point in the port, to the zone 10 power plants (if seawater cooled) and regasification plant at the LNG and gas hub; and
- Connecting powerlines between the individual gas to power plants and the 400 kV bulk powerlines in the services corridor running between zone 10 and zone 13 of the SEZ.

Gas infrastructure is expected to include the use of seawater from within the port for heating and re-gasification of the LNG (with associated release of the cooled water from this process).

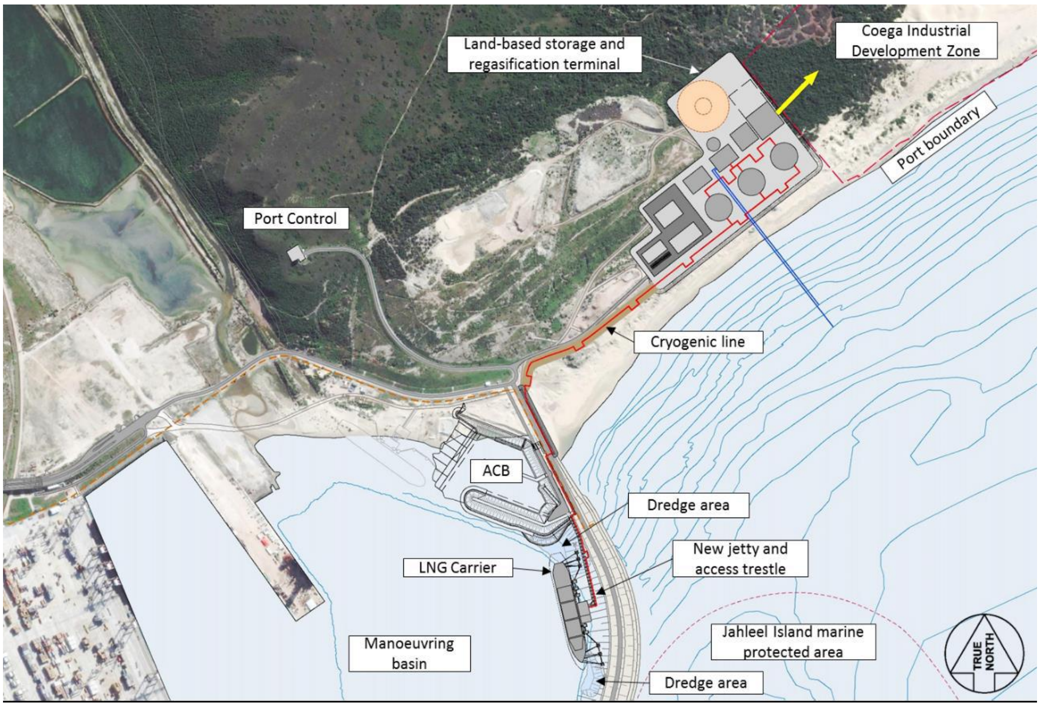

Figure 1: Aproximate locations of the proposed LNG terminal within the Port of Ngqura, indicating the dredge areas, Admin Craft Basin (ACB), jetty and access trestles and cryogening pipeline routing to the proposed future storage and regasification hub.

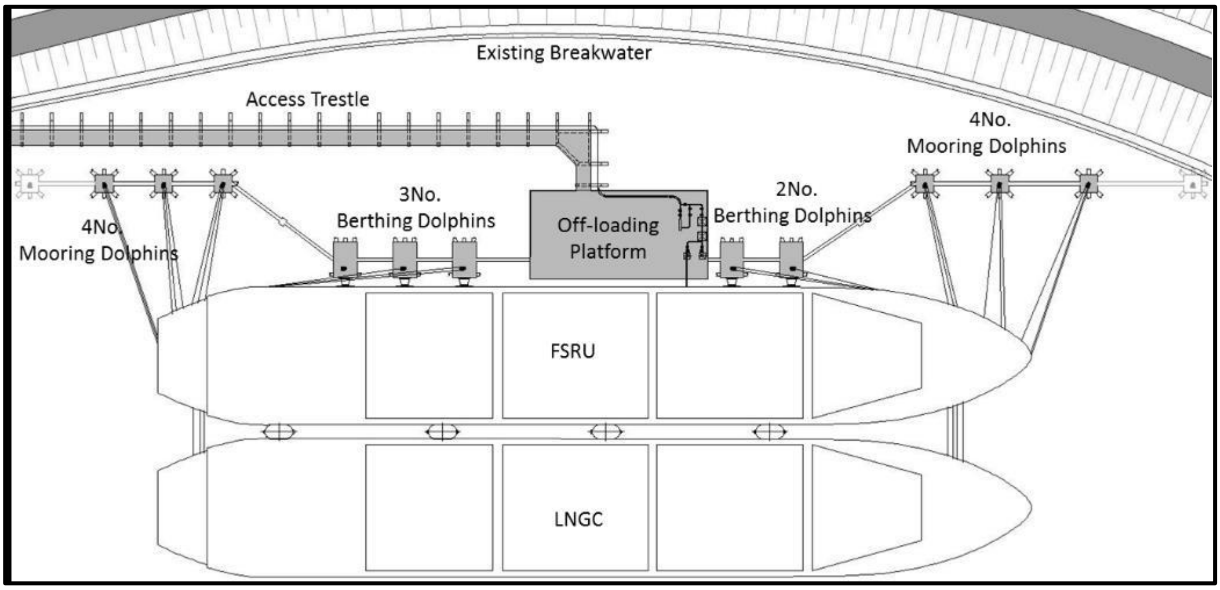

Figure 2: Layout plan of the proposed LNG terminal at the eastern breakwater in the Port of Ngqura.

1.2. Scope of Work

This specialist report was compiled as a desktop study on behalf of SRK, for submission with the scoping report and EIA for the proposed construction of A Liquefied Natural Gas (LNG) terminal and associated infrastructure in the Port of Ngqura.

The scope includes the following:

- FSRU and LNG Carrier berth; and
- Cryogenic pipeline (where relevant to the marine environment).

The Specialist ToR for the Marine Ecology Impact Assessment is as follows:

- Conduct a baseline assessment of the current marine ecological conditions within the Port of Ngqura;
- Reference the findings of previous ecological studies in the area;
- Identify sensitive biological communities and species of special concern that may be affected by the development;
- Assess the impacts of the new LNG terminal taking into consideration that dredging and disposal of spoil, may be required;
- Assess the impact of the piled jetty structure on the seafloor and biological communities;
- Assess the risks and impacts of gas pipeline construction in the littoral active zone;
- Identify any potential impacts arising from the mooring of the FSRU for long periods as well as the increase in port traffic due to the LNG carrier deliveries, on marine ecology;
- Assess the impacts of the intake and discharge of heating water from the FSRU;
- Consider the cumulative impacts of other disturbances to the marine environment including the proposed marine discharge pipeline;
- Consider impacts on the Marine Protected Area to the east of the port;

- Provide monitoring and mitigation recommendations where applicable; and
- Address issues raised by IAP's during the scoping and EIA process.

1.3. Approach to the Study

As determined by the terms of reference, this study has adopted a 'desktop' approach. Further descriptions of the natural baseline environment in the study area are based on a review and collation of existing information and data from scientific literature, and internal reports. The sources consulted are listed in the Reference chapter.

All identified marine and coastal impacts are summarised, categorised and ranked in appropriate impact assessment tables.

1.3.1 Assumptions, Limitations and Information Gaps

As determined by the terms of reference, this study has adopted a 'desktop' approach. Consequently, the description of the natural baseline environment in the study area is based largely on the comprehensive report prepared for the Coega Pipeline Servitude (Laird *et al*. 2016), supplemented by other studies in the area and updated with new information available since the 2016 study. No new data have been collected.

The assumptions made in this specialist assessment are:

- The study is based on the **project description made available to the specialists at the time of the commencement of the study** (engineering designs, construction approaches, discharge volumes, temperatures, *etc*.).
- It is assumed that all heating and cooling water for the FSRU and LNGC is abstracted locally at the LNG berth. For thermal discharges from the FSRU the worst-case scenario of heating water being discharged directly from the FSRU into the Port of Ngqura is assumed.
- Some important conclusions and associated assessments and recommendations made in this study are based on generic descriptions of LNGC and FSRU water requirements, and seawater intake and discharge configurations. Similarly, the thermal footprints associated with discharges from the vessels are based on the results of modelling studies undertaken for similar projects elsewhere in the world. As the extent of such footprints are project-specific and determined by localised oceanographic conditions, field observations and subsequent monitoring would need to be implemented for the current project to determine if predicted discharges at the Ngqura LNG terminal fall within the scale of the predicted footprints. If field observations and monitoring, however, fail to mirror predicted results, the forecasted impacts may need to be re-assessed.
- Potential changes in the marine environment such as sea-level rise and/or increases in the severity and frequency of storms related to climate change are not included in the terms of reference and therefore not dealt with in this report. The climate change assessment has been undertaken by other consultants and is only breifly commented on in this report. Should evidence of such changes become available, the management plans should be re-examined to include the impacts of these anticipated macroscale changes.

1.3.2 Impact Assessment Methodology

SRK's prescribed impact assessment methodology was used to assess the significance of potential impacts. Using this methodology, 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 rated as set out below:

Step 1 - The **consequence** rating for the impact was determined by assigning a score for each of the three criteria (A-C) listed below and then **adding** them.

Rating	Definition of Rating	Score
A. ***Extent***- *the area over which the impact will be experienced*		
None		0
Local	Confined to project or study area or part thereof (e.g. site)	1
Regional	The region, which may be defined in various ways, e.g. cadastral, catchment, topographic	2
(Inter) national	Nationally or beyond	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*		
None		0
Low	Site-specific and wider; natural functions and processes are negligibly altered	1
Medium	Site-specific and wider; natural functions and processes continue albeit in a modified way	2
High	Site-specific and wider; natural functions or processes are severely altered	3
C. ***Duration***- *the timeframe over which the impact will be experienced and its reversibility*		
None		0
Short-term	Up to 2 years (i.e. reversible impact)	1
Medium-term	2 to 15 years (i.e. reversible impact)	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)	0-2	3 - 4	5	6	7	8 - 9
Consequence Rating	Insignificant	Very low	Low	Medium	High	Very high

Step 2 -The **probability** of the impact occurring is assessed 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

Step 3 -The overall **significance** of the impact is determined 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**
	Medium	**LOW**	**LOW**	**MEDIUM**	**MEDIUM**
	High	**MEDIUM**	**MEDIUM**	**HIGH**	**HIGH**
	Very High	**HIGH**	**HIGH**	**VERY HIGH**	**VERY HIGH**

The impact significance rating should be considered by authorities in their decision-making process based on the implications of ratings ascribed below:

- **Insignificant**: the potential impact is negligible and will not have an influence on the decision regarding the proposed activity/development.
- **Very Low:** the potential impact is very small and should not have any meaningful influence on the decision regarding the proposed activity/development.
- **Low**: the potential impact may not have any meaningful influence on the decision regarding the proposed activity/development.
- **Medium**: the potential impact should influence the decision regarding the proposed activity/development.
- **High:** the potential impact will affect the decision regarding the proposed activity/development.
- **Very High**: The proposed activity should only be approved under special circumstances.

Step 4 - The **status** of the impact is noted as being either negative or positive.

Step 5 -The level of **confidence** in the assessment of the impact is stated as high, medium or low.

Step 6 - Practical **mitigation** and **optimisation** measures that can be implemented effectively to reduce or enhance the significance of the impact are identified and described as either:

- **Essential**: best practice measures which must be implemented and are non-negotiable; and

- **Best Practice**: recommended to comply with best practice, with adoption dependent on the proponent’s risk profile and commitment to adhere to best practice, and which must be shown to have been considered and sound reasons provided by the proponent if not implemented.

Having inserted *Essential* mitigation and optimisation measures, the impact is then re-assessed assuming 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. *Best practice* measures are also inserted into the impact assessment table, but not considered in the “with mitigation” impact significance rating.

2. DESCRIPTION OF THE PROPOSED PROJECT

2.1. Site Location

A LNG terminal will be constructed at the Port of Ngqura to accommodate the LNG transport/storage vessels and offloading operations. The marine components of the development have been drawn from the Draft Scoping Report (SRK 2020) and are summarised below. In the absence of more details on Liquid Natural Gas Carriers (LNGCs) and Floating Storage and Regasification Units (FSRUs), Generic information on LNGCs and FSRUs was drawn from a number of sources, which are listed in the bibliography. These include FERC (2005, 2015), Songhurst 2017, CCE Environmental Scientists & Engineers (2018a) and ECO Ingenieros & Dillon Consulting 2018.

2.1.1 LNG Terminal

The proposed preferred location for the LNG terminal is on the inside and at the base of the Port of Ngqura's eastern breakwater and seaward of the Admin Craft Basin (ACB) (see Figure 1).

LNG terminals are typically constructed as piled jetty structures and this was considered to also be the most feasible approach for the Coega LNG terminal (PRDW 2016). The proposed terminal would also include:

- A piled access trestle that connects the marine terminal to the shore provides for road access to the loading platform and accommodates the LNG gas or cryogenic pipelines, vapour return lines and general services required on the loading platform (e.g. water, electricity and communications);
- A loading platform that supports the LNG unloading arms, process piping, control rooms, fire-fighting and emergency equipment, power generation, and vehicular and pedestrian access. A firewater pump, hypochlorite generation unit and spill containment systems and facilities would be included. The platform would need to make provision for distribution of natural gas and future conversion to a LNGC terminal for the distribution of cryogenic LNG;
- Mooring and berthing dolphins to limit vessel motion and absorb the berthing energy exerted by a vessel and to maintain the vessel at a safe distance away from the loading platform.

2.1.2 Dredging and Disposal of Spoil

To allow for an adequately-sized dredge pocket and to reduce the encroachment of the new LNG berth into the port manoeuvring area, localised dredging will be required as part of the proposed construction activities (Figure 3). Dredging would most likely be undertaken with a backhoe dredger that would load the dredged material directly into a series of sailing hopper barges, for transport to the disposal area (Figure 5). The dredge spoil will be disposed at an offshore site identified during the 2001 EIA for the Port of Ngqura (Figure 5). The site lies approximately 8 km offshore from the Coega River mouth at a depth of 29 m to 37 m. It is assumed that any further dredging (and disposal) activities required as part of the LNG terminal development would fall under the 2001 Port Expansion authorisation and that the same methodology and environmental management requirements would apply.

Preliminary calculations of anticipated dredge volumes indicate that dredged material would comprise primarily fill material and marine deposits, gravel lag deposits (cobbles and gravels) and medium to hard rock amounting to ~68,000 m^3. The identified dredge spoil site has sufficient capacity to receive the anticipated volume of dredge spoil from terminal excavations. Dedicated

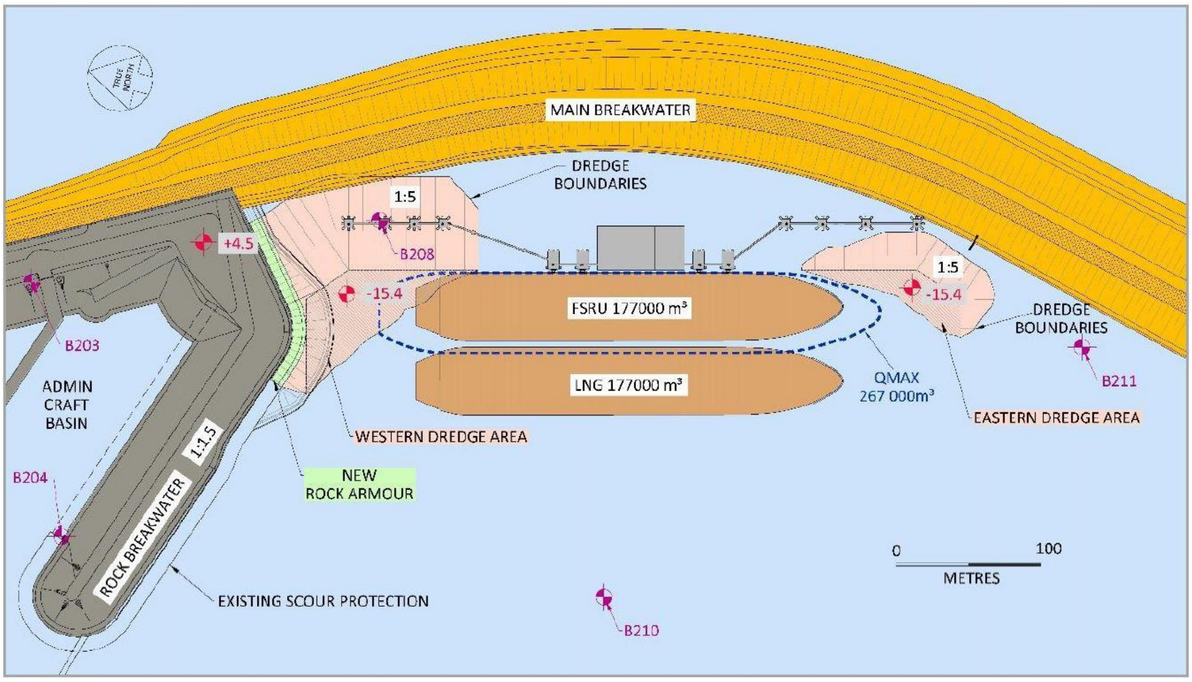

Figure 3: Location and extent of the western and eastern dredge areas (pink) at the proposed Ngqura LNG terminal (Source PRDW 2016).

Figure 4: Backhoe dredger loading dredged material into self-propelled split barges (Source PRDW 2016).

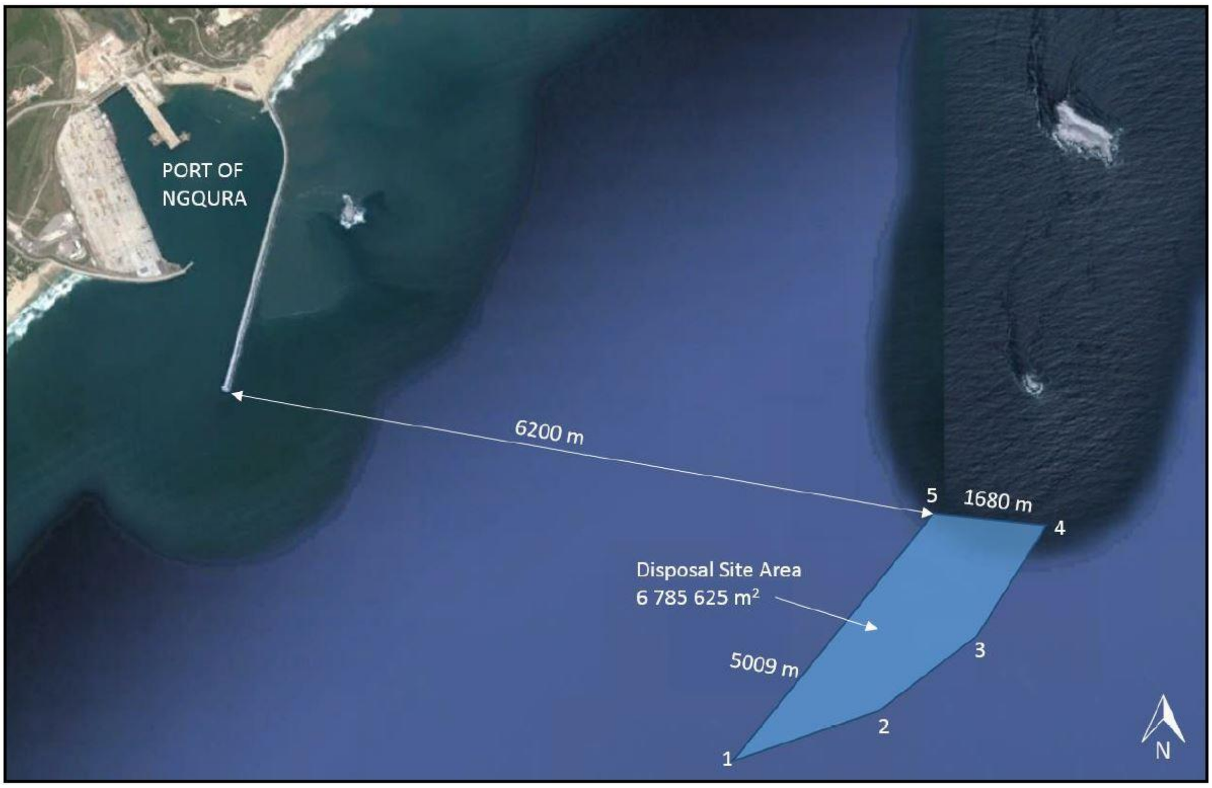

Figure 5: Location of proposed offshore dredge spoil disposal site (Source PRDW 2016).

disposal locations within the site will be confirmed, with attempts to locate the dump-site as close as possible to the dredging works. Environmental monitoring of turbidity and water quality would be required at dredging areas and dump sites. It is anticipated that dredging activities will take approximately 22 weeks to complete.

2.1.3 LNG Carrier (LNGC)

Liquefied Natural Gas Carriers (LNGC) are designed for the transportation of LNG in specially insulated tanks (to maintain temperatures below -162°C) inside the double hull of the ship to protect the cargo systems from damage or leaks. When delivering LNG to the Port of Ngqura the vessels would berth alongside the moored FSRU in a double banking (side-by-side) arrangement to enable direct ship-to-ship transfer of the LNG to the FSRU storage tanks. LNG will be offloaded from the LNGC to the FSRU *via* flexible cryogenic hoses. Typically six liquid hoses, each capable of transferring up to 1,000 m^3/h of LNG connect the LNGC to the FSRU, with the LNGC cargo transfer pumps utilised in transfer of the LNG. Typical flow rates are in the order of 3,000 to 4,500 m^3/h with the unloading process taking between 12 and 24 hours. As the LNGC offloads to the FSRU, seawater is taken into the vessel as ballast to maintain its position in the water.

Despite effective insulation, ambient heat will inevitably warm and vaporize the LNG, resulting in the generation of Boil-off Gas (BOG) (mainly methane). This is captured and returned to the LNGC's cargo system by separate vapour return lines to ensure that the pressure in both the FSRU and the LNGC storage tanks is maintained within their design operating parameters. The LNGC operator receiving vapour from the FSRU manages the BOG using gas burning[1] and/or re-liquefaction. Some

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[1] Primarily undertaken in early FSRUs; modern FSRUs recondense the BOG.

BOG would be used for electrical power generation and ship services and any surplus vapour is recondensed (Songhurst 2017). In early FSRUs the steam surplus to the requirements for heating and ship-board power generation was removed *via* steam “dump” valves to the atmosphere or as condensate to the sea.

Once land-based LNG storage facilities have been constructed and the FSRU has become redundant, LNG would be pumped directly from the LNGC to onshore storage tanks *via* cryogenic LNG unloading arms and a cryogenic pipeline. BOG would report back from the land-based storage tanks to the LNGC’s cargo system by separate vapour return line(s).

2.1.4 Floating Storage and Regasification Unit (FSRU)

Up to two FSRUs, each with a storage capacity of 170,000 m^3 would be required to meet the capacity of the gas-to-power plants, although land-based storage is likely to be implemented before the second FSRU becomes a requirement. The FSRU, and potentially the second FSRU, will be permanently berthed at the FSRU terminal.

The FSRU houses onboard LNG regasification facilities for the re-warming of the liquefied gas back to natural gas at ambient air temperature. FSRUs are typically capable of various modes of LNG vaporization:

- A closed-loop system requires steam from the FSRU’s steam boilers to heat either a fresh-water/glycol medium or propane circulated through the shell-tube vaporizers to regasify the LNG. Ambient seawater is pumped onboard as cooling water for the steam plant/propane condensers and the fresh-water cooling system, resulting in the discharge of heated water overboard from the FSRU. This system results in minimal use of seawater but uses a 2.5% of the send-out gas to heat the circulating water/glycol medium.
- An open-loop system makes use of ambient seawater as a heat source to pass through the shell of the vaporizers during the re-gasification process. The temperature of the seawater is lowered in this process and this cooler water is discharged overboard the FSRU. The energy used to pump the seawater through the heat exchanger consumes about 1.5% of the send out gas for power generation. This system is typically preferred as it uses considerably less fuel, resulting in lower operating costs and lower CO_2 emissions (Songhurst 2017).
- A combined system, which provides flexibility in the regasification process and allows the closed-loop system to be used initially to address any concerns about the potential impacts of thermal discharges to the marine environment and also, to enable the closed-loop method to be used in conjunction with the open-loop system to manage and mitigate any potential impacts during periods when there may be elevated levels of larvae and plankton present.

A FSRU is typically equipped with four seawater intakes each with a pipe diameter of up to 1.4 m and fitted with screens. These are all located near the stern of the FSRU. Two of the intakes provide suction to the ballast system, seawater cooling and vaporizers, while the other two provide cooling water to the main condenser and atmospheric condenser required for the cooling of the engines. While in operation, seawater is continuously sucked into the FSRU through two of these intakes, with the remainder being used only as a back-up or when the high-level intakes are being cleaned. The main intakes are located ~4.5 m above the baseline (keel) and thus relatively close to the surface of the sea (~7.5 m depth depending on ballasting).

For this project, an open-loop system is assumed. The estimated maximum quantity of seawater needed for heating LNG is 14,767 m^3/h (WSP 2020); discharged seawater would be 8°C cooler than the intake water (Carnegie Energie 2019). The heating water requirements for the FSRU have been modelled by WSP (2020), with two options being considered, namely:

- The FSRU vaporisers receive hot water from the power plant cooling water discharge pipeline/tunnel located to the east of the breakwater and discharge cold water downstream of the same discharge pipeline/tunnel. This option therefore has no heating water requirements from within the Port of Ngqura, and no thermal footprints within the Port.
- The FSRU vaporisers abstract heating water locally at the LNG berth (maximum of 14,767 m^3/h). The cold water discharged from the FSRU is piped to and discharged into the power plant cooling water pipeline/tunnel located to the east of the breakwater. This option therefore has heating water requirements but no thermal footprints within the Port of Ngqura.

Cooling water requirements for the FSRU and LNGC are expected to range from 1,250 m^3/h (30,000 m^3/day) when using supplemental power from onshore facilities to as high as 9,800 m^3/h (235,000 m^3/day) (FERC 2015). A further 1,140 m^3/day is required for onboard desalination.

Of the six discharge pipes typically occurring in a FSRU, four are located in the stern of the FSRU and two in the bow. Those in the stern discharge cooling water at a rate between 950 – 4,000 m^3/h and a temperature of ~6-7°C above ambient.

The vaporisation of LNG onboard the FSRU would utilize high-pressure LNG pumps configured for operational flexibility, and high-pressure vaporisers, using shell and tube heat exchangers. The LNG is therefore pressurised (75 – 104 barg) and heated indirectly to a pre-determined gas temperature and pressure. Working at full capacity, a 170,000 m^3 cargo could be regasified in about six days.

To maintain its draft, trim and stability during loading and regasification, the FSRU has a water ballast system. The FSRU will discharge ballast water while loading LNG from the carrier, and will take on ballast water to offset the vaporization and transfer of gas to the power plants. Intake rates for ballast water range from 2,600 to 3,900 m^3/h with as much as 65,100 to 280,900 m^3 of water required per vessel for ballast while LNG is offloaded at the terminal (FERC 2015), varying according to operational status and sea conditions. Ballast water intake rates as high as 7,600 m^3/h have been reported (FERC 2005).

The FSRU will also be required to provide an LNG supply for local truck loading operations within the LNG and gas hub for third-party offtake. Although the bulk of the delivery from the FSRU to the power plants will be *via* a Natural Gas pipeline, a smaller cryogenic pipeline will be required during the FSRU stage of the development. A Liquid LNG Unloading Arm System with LNG flow and BOG return lines would be required to provide safe unloading of the liquid LNG from the FSRU for onward conveyance to the LNG Truck Loading Facility.

While an FSRU may be economically more viable while the rate of gas consumption is relatively low, land-based storage and regasification would likely be developed once the demand for Natural Gas increases.

2.1.5 Gas Transmission Pipelines

Two types of gas pipelines are required to transfer both LNG and natural gas from the LNG terminal to the power plants and LNG and gas hub in Zone 10; a natural gas pipeline and cryogenic pipelines.

All gas transmission pipelines would be installed underground and would require servitude widths of 20 m for the double cryogenic pipeline (for LNG) and 10 m for the gas pipeline (for natural gas). The natural gas pipeline would be required during Phase 1 of the LNG terminal while the FSRU is operational. Cryogenic and return pipelines would be required both during Phase 1 to accommodate LNG distribution *via* the truck distribution centre in the LNG and gas hub and during Phase 2 of the proposed LNG terminal development to feed LNG from the LNG carrier to the land-based storage and regasification terminal located at the LNG and gas hub. The pipelines would be supported by a trestle structure running on the inside of the eastern breakwater as far as the admin craft basin (ACB). From the ACB they would be routed under and to the seaward side of the breakwater, following an inland routing parallel to the coast to the zone 10 power plants and LNG and gas hub.

3. DESCRIPTION OF THE BASELINE MARINE ENVIRONMENT

The project area, the Port of Ngqura itself, is in a severely modified state, largely due to land reclamation and port development. The area is subject to urban pollution *via* storm-water runoff, subtidal outfalls and operational hydrocarbon spills from vessels visiting the port. The benthic communities within the heavily modified environment are impoverished (Klages *et al*. 2006) and numerous alien species have been reported from within the Port (Laird *et al*. 2016).

For details on the physical oceanography, marine ecology and marine user groups in and around the Port of Ngqura and within Algoa Bay, the reader is referred to the comprehensive description of the baseline marine environment provided by Laird *et al*. (2016) as part of the Environmental Impact Assessment (EIA) for the Coega Marine Pipeline Servitude at the Coega Industrial Development Zone. A brief summary is provided below, with only salient aspects that have changed since the 2016 report was updated.

3.1. The Physical Environment

Algoa Bay lies in an area in which two large current systems (the Agulhas and Benguela) with different temperature regimes undergo mixing. The offshore movement of the Agulhas Current in the vicinity of East London creates shear edge eddies, which periodically circulate warm water inshore near Port Elizabeth resulting in rapid variation of water temperatures. During easterly wind conditions, periodic upwelling may occur near the rocky headlands, causing sharp drops in seawater temperature. Temperature and current dynamics are therefore complex and vary over small spatial scales within Algoa Bay.

Currents in Algoa Bay are highly variable in both direction and magnitude and show considerable variation depending on the area in which they are measured. Current speeds of less than 10 cm/s have been measured most frequently within the bay, although currents exceeding 20 cm/s are not uncommon. Off Port Elizabeth, currents flow in a predominately southerly direction out of the Bay.

The wave climate in Algoa Bay is predominantly from the south west with swells of less than 2 m occurring approximately 80% of the time, but with waves in excess of 3 m emanating from the south-west occurring for some of the time. Most of Algoa Bay is protected from these swells by the rocky headland at Cape Recife, although some degree of refraction does occur.

Marked seasonal differences in the temperature regime in Algoa Bay, with intense thermoclines in summer in the deeper sections of the Bay and isothermal conditions in winter. Temperature regimes within the Port of Ngqura are lacking.

Dissolved oxygen within the Port was 6-8 mg/ℓ in the upper 4 m of water, declining towards the bottom of the water column (generally <5 mg/ℓ). In winter, the water column was well mixed.

Within Algoa Bay, salinity remains relatively constant at 35.2 ‰, but in the vicinity of the Coega River, low salinity levels were measured in the upper two meters of the water column, with normal seawater below this depth.

The concentrations of nutrients (dissolved inorganic nitrogen, ammonia, nitrate, nitrite, orthophosphate, and silica) in surface waters in the Port are low, although typically higher than at the entrance channel.

During both summer and winter, turbidity levels in surface waters were mostly low (<10 NTU). In summer, however, near-bottom turbidity levels were elevated. Elevated levels outside of the Port are presumably caused by wave action, while high values within the Port are likely a result of propeller wash.

Concentrations of trace metals (arsenic, cadmium, copper, chromium, mercury, nickel, lead and zinc) and hydrocarbons (total petroleum hydrocarbons and polycyclic aromatic hydrocarbons) from the Port of Ngqura were mostly low or below detection limits, with the exception of mercury, zinc, arsenic, and copper, which were elevated at stations within the Port. Copper was the only trace metal that slightly exceeded guideline levels, while hydrocarbon concentrations were very low both inside and outside the Port.

3.2. The Ecological Environment

Algoa Bay falls within the warm temperate Agulhas ecoregion. The substratum in the bay is classified as Agulhas Bays (Figure 6), which is considered well protected (Figure 7) and has been assigned an ecosystem threat status of ‘Vulnerable’ (Figure 8) (Sink *et al*. 2019).

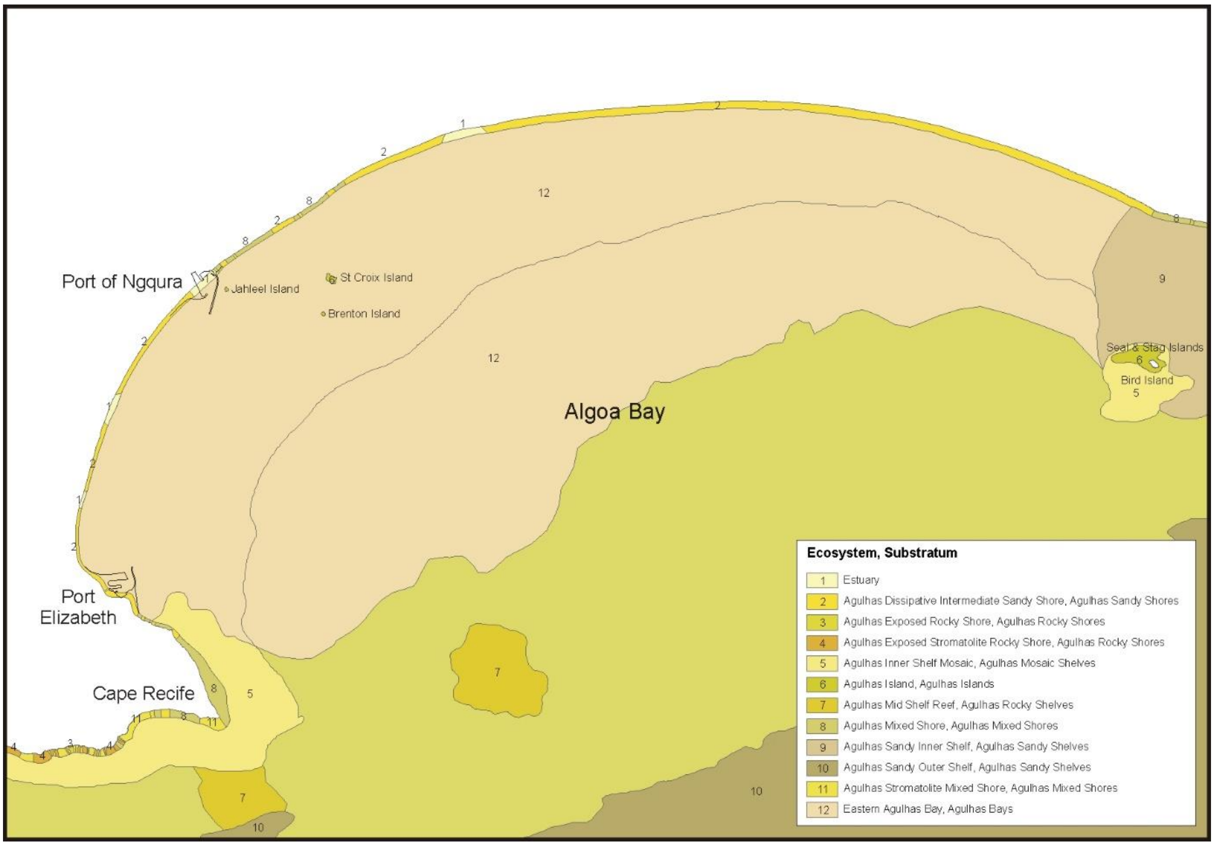

Figure 6: Ecosystem and substratum types within Algoa Bay (adapted from Sink *et al*. 2019).

Figure 7: The protection levels of marine ecosystem types in Algoa Bay as assessed by Sink *et al*. (2019).

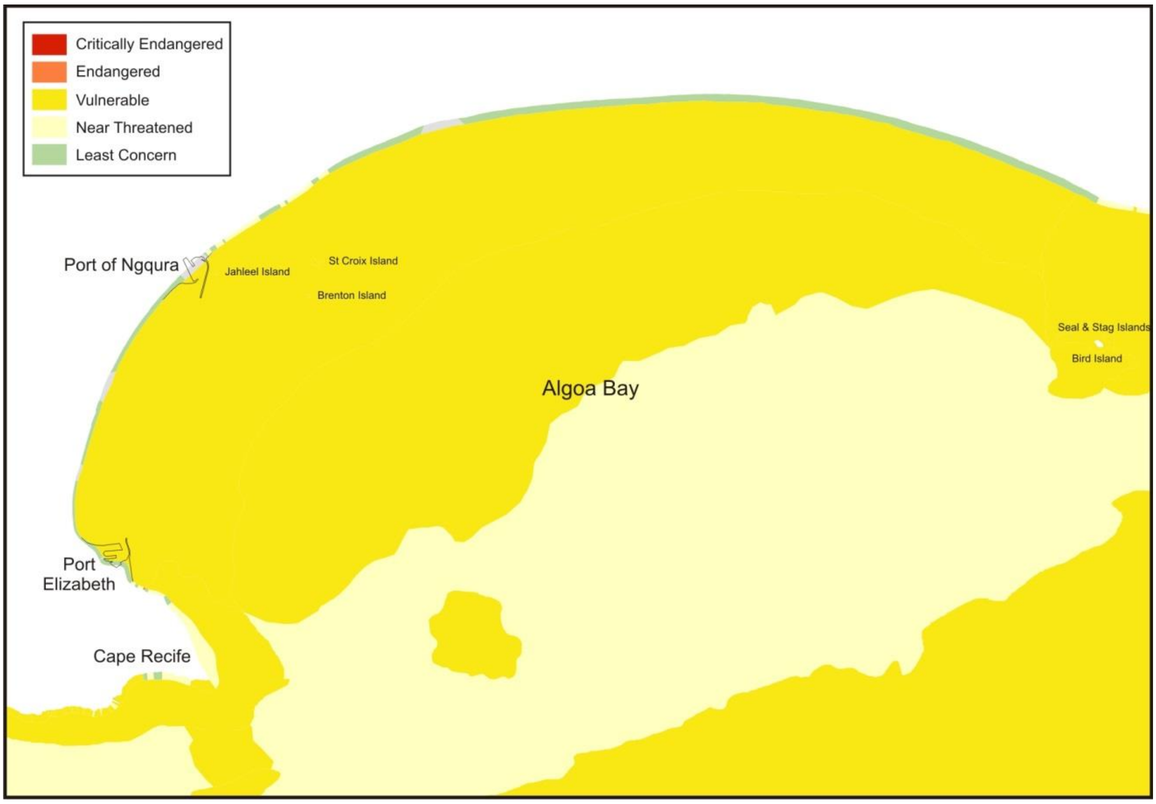

Figure 8: Ecosystem threat status for coastal and offshore benthic habitat types in Algoa Bay (adapted from Sink *et al*. 2019).

Algoa Bay is known to support a high biodiversity of marine life, particularly reef-associated invertebrates and fish, as well as several breeding colonies of 'critically endangered' (Damara tern), 'endangered' (African Penguin, Cape Cormorant, Cape Gannet, Roseate Tern) or vulnerable (Caspian Tern) seabirds.

The Port of Ngqura offers a relatively calm and sheltered environment in an otherwise high-energy coastline. Consequently, the harbour supports one of the most abundant and diverse fish populations along the South African coastline, functioning as an important habitat for both juvenile and adult fish, representing both estuarine and shore species (Dicken 2010). Of the most commonly occurring species, the Dusky kob (*Argyrosomus japonicas*) is considered 'Critically Endangered', whereas the elf (*Pomatomus saltatrix*), spotted grunter (*Pomadasys commersonnii*) and garrick (*Lichia amia*) are rated as nationally 'Vulnerable'. The Port also serves as an important summer habitat and core activity zone for neonate and juvenile dusky sharks (*Carcharinus obscurus*), and may serve as an important nursery area for the species (Dicken 2011). Although the national assessment identifies dusky sharks as being 'data deficient', its IUCN Conservation status is considered 'Vulnerable'. Other chondrichthyans reported from the harbour are the great white shark and giant manta, both of which are considered 'Vulnerable' by the IUCN, and the whale shark which is rated as 'Endangered'.

Dicken (2010) reported substantial differences in the fish assemblages associated with the different habitats provided by the Port (i.e. quay wall, sandy shore and dolosse). The dolosse habitat, in particular, supported the greatest abundance of fish. Almost twice as many fish species were recorded from the Dolosse (43) than either the Quay Wall (24) or Sandy Shore habitats (21). The relative abundance (recorded as total Catch-Per-Unit-Effort) of fish species at the Dolosse and Quay Wall habitats were more than double that of the Sandy Shore habitat, with the dominant species occurring at each habitat being different. Dusky cob and elf were dominant at the dolosse, whereas Garrick and dusky sharks where more prevalent at the sandy shore. Over 70% of the fish caught in the Port were juveniles indicating that although not an estuary, the harbour is functioning as an important nursery area for many species of linefish. It is thought that the harbour not only provides a sheltered environment from prevailing winds, to which juvenile fish can recruit but that they may also have greater access to food within the port due to hydrodynamic conditions within the port that promote the retention of planktonic larvae (Garcia-Charton & Perez-Ruzafa 2001; Floerl & Inglis 2003).

Since the study of Dicken (2010) there have been substantial developments in the Port, which will have influenced the abundance and diversity of ichthyofaunal communities. The former dolosse habitat in the southwest of the port has been replaced by quay wall with the expansion of the container terminal, and sandy shore habitats will have been much reduced through the construction of the Admin Craft Basin. Although no follow-up studies could be sourced, it is assumed that the port remains an important habitat and nursery area for a variety of fish species.

Six species of cetaceans are regularly seen in Algoa Bay; including southern right whales (*Eubalaena australis*), humpback whales (*Megaptera novaeangliae*), Bryde's whales (*Balaenoptera brydei*), Indo-Pacific bottlenose dolphins (*Tursiops aduncus*), Indian Ocean humpback dolphins (*Sousa chinensis*), and longbeaked common dolphins (*Delphinus capensis*). Of these, the Indo-Pacific bottlenose dolphin and Indian Ocean humpback dolphin is singled out for further discussion. The population of Indo-Pacific bottlenose dolphin inhabiting the South Coast has been estimated as between 16,000 and 41,000 based on data collected within Algoa Bay (Reisinger & Karczmarski 2010). The species tends to occur in large groups of 10s to 100s of individuals. The *aduncus* form, in general, is listed as 'Vulnerable' in the South African Red Data Book, while the migratory subpopulation is considered 'Endangered' (Peddemors & Oosthuizen 2004; Cockcroft *et al*. 2016).

The Indo-Pacific humpback dolphin is primarily a shallow-water species restricted to <50 m depth and are usually observed within 500 m from shore. Due to the recent recognition of the western Indian Ocean population as a separate species, their conservation status is regarded as as 'Endangered', and the species is accepted to be South Africa's most endangered resident cetacean (Child *et al*. 2016). Several lines of evidence suggest a decline in the population numbers and changes in behaviour (Peddemors *et al*. 2004; Plön *et al*. 2015; Vermeulen *et al*. 2017). Localised populations in the Plettenberg Bay - Algoa Bay region are concentrated around shallow reefs, predominantly within 10 km of river mouths (Melly 2011; Koper *et al*. 2016). This is similar to findings from the early 1990s, where 87% of sightings were observed within 400 m of land, and almost all the sightings were in waters less than 15 m deep (Karczmarski 1996; Karczmarski *et al*. 2000a). It appears that the species is more closely associated with estuaries and rivers than other shallow-water cetaceans. In Algoa Bay sightings rate and group size appears to increase between January and April, and again in September. The species also shows diurnal cycles within the bay (Karczmarski *et al*. 2000b). In Algoa Bay the population was estimated at 466 individuals of all age groups, with modelled population growth estimated to vary between -3% and 2% annually. This population was found to be separated from all other populations of the species, making them particularly vulnerable (Vermeulen *et al*. 2017). Recent studies in Plettenberg Bay and Algoa Bay indicated a decrease in sightings and group sizes in both locations by approximately 50% in the last decade and a reduction in mean group sizes from 7 to 4 individuals (Greenwood 2013; Koper *et al*. 2016). Several hypotheses have been suggested as likely reasons for the decline; a decrease in prey availability, prolonged disturbance from whale and dolphin watching tourism and other marine recreation, coastal development and sustained pollution that contaminates the prey on which this species depends.

3.3. Significance and Sensitivity

Since the comprehensive baseline description of Algoa Bay by Laird *et al*. (2016), there have been some substantial changes to the marine protected areas (MPAs) along the Eastern Cape Coastline as well as the establishment of Ecologically or Biologically Significant Areas (EBSAs). Using information from the marine protected areas website (https://www.marineprotectedareas.org.za/addo-elephant-national-park-mpa) and the EBSA Portal (https://cmr.mandela.ac.za/EBSA-Portal), these areas are described below.

Marine Protected Areas

The **Addo Elephant MPA**, which incorporates the Algoa Bay Islands was gazetted in May 2019. This 1,200 km^2 MPA expands on the original Bird Island MPA (comprising Bird, Seal, Stag and Black Rock Islands) to protect sandy beaches, rocky shores, reefs, an estuary and islands, and aid recovery of valuable fisheries resources such as abalone and kob, as well as great white sharks and whales (Bryde's, minke, humpback and right). The MPA protects important feeding areas for the 9,000 pairs of Endangered African penguins breeding at St Croix Island and the 60,000 pairs of Endangered Cape gannets breeding at Bird Island. These islands are the only important seabird islands along a 1,800 km stretch of coastline between Dyer Island near Hermanus in the Western Cape and Inhaca Island in Mozambique. Together with St Croix, Jahleel and Brenton Islands (also in Algoa Bay), they are classed as Important Bird Areas (IBAs) because they regularly support significant numbers of globally threatened bird species and hold large concentrations of seabirds. The islands form ecological distinct subtidal habitats, containing many endemic invertebrates, algae and linefish (e.g. santer and red roman). Black Rocks is an important seal breeding colony and serves as a great white shark feeding area. The MPA is also of particular importance to the threatened abalone as abalone poaching activities are strictly controlled.

Ecologically or Biologically Significant Areas (EBSAs)

As part of a regional Marine Spatial Management and Governance Programme (MARISMA 2014-2020), the Benguela Current Commission (BCC) and its member states have identified a number of Ecologically or Biologically Significant Areas (EBSAs) both spanning the border between Namibia and South Africa and along the South African West, South and East Coasts, with the intention of implementing improved conservation and protection measures within these sites. South Africa currently has 12 EBSAs solely within its national jurisdiction with a further three having been proposed. It also shares eight trans-boundary EBSAs with other countries (Namibia (3) and Mozambique (2)) and high seas (3). The principal objective of these EBSAs is the identification of features of higher ecological value that may require enhanced conservation and management measures.

The Port of Ngqura falls within the Algoa to Amathole EBSA, which spans the Eastern Cape shoreline between the Sardinia Bay MPA and the Amathole MPA/Kei River mouth. It extends from the dune base to approximately the continental shelf break/slope, thus spanning a depth range of approximately 0 - 2,000 m, but also encompasses the functional zone of several priority estuaries.

It is important for both benthic and pelagic features, comprising an offshore area of high habitat complexity, and containing a myriad of unique and interesting biodiversity features. Benthic features include a large shelf-intersecting canyon, and rare seabed ecosystem types (Sink *et al.* 2012). The pelagic environment is characterised by complex ocean circulation patterns because the EBSA includes the point where the Agulhas Current leaves the coast, following the shelf break. This results in the formation of cold-water eddies, intrusions of Agulhas water onto the shelf, large offshore meanders of the Agulhas Current, enhanced productivity through coastal upwelling, and relatively rare surf-diatom accumulations. Consequently, the area serves as spawning and/or nursery grounds for certain commercially-important demersal and pelagic fish species, squid, sharks, and whales; as transiting/foraging areas for seabirds, sharks, cetaceans, and turtles; and forms part of the migration routes of loggerhead and leatherback turtles, with hatchlings of both species passing through the area during their dispersal. Green turtles, killer whales and coelacanths have also been sighted in the area. Algoa Bay hosts the largest groups of bottlenose dolphins, the largest colony of endangered African Penguins and largest colony of Cape Gannets in the world.

This EBSA also includes priority estuaries, which serve as breeding sites of the Critically Endangered, and locally endemic pipefish: *Syngnathus watermeyeri*. These estuaries, together with the coastal areas, represent some critical ecological processes that support the important offshore features. These include key linkages among spawning, post-hatch and nursery areas of commercially important fish species that span the surf zone to nearshore and the shelf. Many of the fish in the area also use the estuaries for part of their life-histories. The EBSA encompasses the Algoa Bay Islands: Addo Elephant National Park, Swartkops Estuary - Redhouse and Chatty Saltpans Important Bird Areas (IBAs) and is adjacent to the Woody Cape Section: Addo Elephant National Park IBA.

Habitat diversity is also high within the EBSA, with 36 ecosystem types represented including stromatolites, canyons, steep shelf edge, deep reefs, outer shelf and shelf edge gravels, and reef-building cold-water corals ranging in depth between -100 and -1,000 m.

Although no specific management actions have as yet been formulated for the EBSAs, two biodiversity zones have recently been defined within each EBSA as part of the marine spatial planning process. The management objective in the zones marked for 'Conservation' is "*strict place-based biodiversity protection aimed at securing key biodiversity features in a natural or semi-natural state, or as near to this state as possible*". The management objective in the zones marked for 'Impact Management' is "*management of impacts on key biodiversity features in a mixed-use area to keep key biodiversity features in at least a functional state*" (https://cmr.mandela.ac.za/EBSA-Portal/South-Africa/SA-EBSA-Status-Assessment-Management). Future activities that may be prohibited in the conservation zone of this EBSA includes the exploration for Oil and Gas, although oil and gas activities may be consented to in the impact management zone (https://cmr.mandela.ac.za/EBSA-Portal/South-Africa/SA-EBSA-Status-Assessment-Management; accessed 22 April 2020).

Hope Spots

Hope Spots are defined by Mission Blue of the Sylvia Earle Alliance as special conservation areas that are critical to the health of the ocean. The first six Hope Spots were launched in South Africa in 2014 and include Aliwal Shoal in KwaZulu-Natal, Algoa Bay in the Eastern Cape, and Plettenberg Bay, Knysna, the Cape Whale Coast (Hermanus area) and False Bay in the Western Cape.

4. ASSESSMENT OF IMPACTS ON MARINE FAUNA

For this project, the identification and assessment of impacts relating specifically to the marine ecology cover the main activity phases (see Table 1 for an outline of the activities in these phases) of the proposed development of an LNG terminal, namely:

- Phase 1: Construction – dredging, construction of the access trestle, offloading platform and mooring and berthing dolphins, and installation of the pipelines;
- Phase 1: Operation – operation of the FSRU and transfer of product to the LNG and gas hub;
- Phase 2: Construction – modification of the LNG terminal once the FSRU has become redundant;
- Phase 2: Operation – operation of the LNG terminal and transfer of LNG to the land-based storage and regasification facility;
- Unplanned Activities.

4.1. Identification of Impacts

Interaction of these activities with the receiving environment gives rise to a number of environmental aspects, which in turn may result in a single or a number of impacts. The identified aspects and their potential impacts are summarised below.

Construction Phase

- Physical disturbance and removal of the seabed sediments during dredging and installation of pipelines and piles, changes in sediment structure through the placement of revetments
    - Disturbance and loss of seabed habitat and associated benthic macrofauna.
- Potential release of nutrients and heavy metals to the water column during dredging and spoil dumping
    - Toxicity and bioaccumulation effects on marine fauna.
    - Reduced physiological functioning of marine organisms due to the biochemical effects on the water column and seabed sediments.
- Increased water turbidity and reduced light penetration during dredging, spoils dumping, revetment construction, pile driving and pipeline installation
    - Reduced physiological functioning of plankton, fish, seabirds, cetaceans and other marine fauna.
- Increase in underwater noise and vibration levels during pile driving, general construction activities and operation of the LNGCs and FSRUs
    - Disturbance / behavioural changes of coastal and marine fauna.
    - Avoidance of key feeding areas.
    - Effects on key breeding areas (e.g. coastal birds, fish and cetaceans).
    - Abandonment of nests (birds) and young (birds and seals).
- Creation of artificial hard substrata by way of trestles, piles, and revetment material in an otherwise sand-dominated area;

  - Creation of alternative seabed habitats for colonisation of benthic fauna.
  - Increase in benthic and demersal biodiversity and biomass.
- Pollution in the marine environment through littering and operational spills during the construction of access trestle, offloading platform and mooring and berthing dolphins
  - Physical damage to habitats and/or damage to or mortality of species.

Operational Phase

- Intake and discharge of large volumes of seawater as heating for LNG vaporisation[2] or cooling of condensers in FSRUs and LNGCs
  - Impingement and entrainment of marine organisms.
  - Physiological effect on marine fauna of thermal discharge.
  - Physiological effect on marine fauna of biocides and co-pollutants in the discharge.
- Altered flows around the discharge structures of the FSRU
  - Scouring of the seabed and sediment resuspension through high velocity release of heating water.
  - Physiological effect on marine fauna of sediment resuspension and increased turbidity.
- Introduction of invasive alien species in the ballast water of the LNGCs or as fouling organisms on the hulls
  - Threats to Agulhas ecosystem biodiversity.
- Routine discharge of waste to the sea (e.g. deck and machinery space drainage, sewage and galley wastes) from vessels, or discharge of contaminated ballast water and local reduction in water quality
  - Reduced physiological functioning of marine organisms.
  - Increased food source for marine fauna.
  - Fish aggregation and increased predator-prey interactions.
  - Potential pollution of MPAs and EBSAs.
  - Potential risks to public health and safety.
- Increase in ambient lighting from dredger, LNGCs and FSRUs and offloading platform infrastructure
  - Disorientation and mortality of marine birds.
  - Physiological and behavioural effects on marine fauna.
  - Fish aggregation and increased predator-prey interactions.

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[2] The worst-case scenario of heating water being discharged directly from the FSRU into the Port of Ngqura has been assumed. i.e. heating water will NOT be piped to and discharged into the power plant cooling water pipeline/tunnel located to the east of the breakwater as modelled by WSP 2020.

Unplanned Events

- Collision of vessels with marine fauna
  - Ship strikes by dredger or LNGC during transit.
- Localised reduction in water quality due to accidental release of fuel into the sea, discharge of fuel during bunkering and discharge of hydraulic fluid due to pipe rupture
  - Toxic effects on marine biota and reduced faunal health.
- Uncontrolled release of fuel into the marine environment through vessel accidents or collisions
  - Toxic effects on marine biota and reduced faunal health.
  - Pollution and smothering of coastal habitats.
- Uncontrolled release of LNG into the marine environment through through upset conditions during unloading
  - Physiological effects on marine fauna and flora.
- Uncontrolled release of hypochlorite into the marine environment through upset conditions at the hypochlorite generation unit on the offloading platform
  - Physiological effects on marine fauna and flora.

Table 1: Aspects and Impacts Register for marine ecological impacts

Activity Phase	Activity	Aspect	Potential Impact
Phase 1: Construction	Dredging to reduce encroachment on port manoeuvring area	Removal of seabed sediments	Disturbance to seabed and benthos
		Sediment resuspension and associated increased water turbidity and reduced light penetration	Reduced physiological functioning of plankton, fish, seabirds, cetaceans and other marine fauna
		Potential release of contaminants and nutrients to water column	Toxicity and bioaccumulation or other physiological effects on marine fauna
			Reduced physiological functioning of marine organisms due to the biochemical effects on the water column
		Increase in underwater noise levels	Disturbance / behavioural changes to marine fauna
			Avoidance of key feeding/breeding areas
			Abandonment of nests and young
	Dumping of dredge spoil	Disturbance of seabed	Changes in sediment structure and smothering of benthic communities
		Sediment resuspension and associated increased water turbidity and reduced light penetration	Reduced physiological functioning of plankton, fish, seabirds, cetaceans and other marine fauna
		Potential release ofcontaminants and nutrients to water column	Toxicity and bioaccumulation or other physiological effects on marine fauna
			Reduced physiological functioning of marine organisms due to the biochemical effects on the water column and seabed sediments
	Transit of dredger/sailing hopper barges between dredging area and dump site	Underwater noise levels	Disturbance of behaviour and physiology of marine fauna
		Increase in ambient lighting	Disorientation and mortality of seabirds
			Physiological and behavioural effects on marine fauna
			Fish aggregation and increased predator-prey interactions

Activity Phase	Activity	Aspect	Potential Impact
Phase 1: Construction (cont.)		Routine discharges to sea (e.g. deck and machinery space drainage, sewage and galley wastes) and local reduction in water quality	Physiological effect on marine fauna
			Increased food source for marine fauna
			Increased predator - prey interactions
			Potential pollution to MPAs or sensitive marine areas (e.g. EBSAs)
			Potential risks to public health and safety
	Construction of revetments and scour protection to stabilise dredge slope and ACB causeway	Disturbance of seabed through placement of rock material	Disturbance to seabed and benthos
		Increased water turbidity and reduced light penetration	Reduced physiological functioning of plankton, fish, seabirds, cetaceans and other marine fauna
		Increased hard substrate on seafloor	Changes in sediment structure and creation of alternative habitat
	Construction of access trestle, offloading platform and mooring and berthing dolphins	Underwater noise and vibration levels during pile driving	Disturbance / behavioural changes to marine fauna
			Avoidance of key feeding/breeding areas
			Abandonment of nests and young
		Disturbance of seabed through placement of tubular steel piles	Crushing and smothering of benthos
		Increased water turbidity and reduced light penetration	Reduced physiological functioning of plankton, fish, seabirds, cetaceans and other marine fauna
		Increased hard substrate on seafloor	Creation of alternative habitat for colonisation by benthic fauna and increase in biodiversity
		Pollution in the marine environment through littering and operational spills	Physical damage to habitats and/or damage to or mortality of species

Activity Phase	Activity	Aspect	Potential Impact
Phase 1: Operation	Berthing and operation of FSRU	Intake and discharge of large volumes of seawater for heating of LNG (open-loop) and/or cooling of condensers (closed-loop) and cooling of the engines	Impingement and entrainment of marine organisms
			Physiological effect on marine fauna of thermal discharge
			Physiological effect on marine fauna of biocides and co-pollutants in discharge
		High velocity release of heating water	Seabed scouring
			Physiological effect on marine fauna of sediment resuspension and increased turbidity
		Routine discharges to sea (e.g. deck and machinery space drainage, sewage and galley wastes) and local reduction in water quality	Physiological effect on marine fauna
			Increased food source for marine fauna
			Increased predator - prey interactions
		Increased underwater noise levels	Disturbance of behaviour (foraging and anti-predator) and physiology of marine fauna
		Increase in ambient lighting	Disorientation and mortality of seabirds
			Physiological and behavioural effects on marine fauna
			Fish aggregation and increased predator-prey interactions
	Mooring and operation of LNGC	Intake and discharge of large volumes of seawater for cooling of condensers and engines,	Impingement and entrainment of marine organisms
			Physiological effect on marine fauna of thermal discharge
		Routine discharges to sea (e.g. deck and machinery space drainage, sewage and galley wastes) and local reduction in water quality	Physiological effect on marine fauna
			Increased food source for marine fauna
			Increased predator - prey interactions
		Increased underwater noise levels	Disturbance of behaviour (foraging and anti-predator) and physiology of marine fauna

Activity Phase	Activity	Aspect	Potential Impact
Phase 1: Operation (cont.)		Increase in ambient lighting	Disorientation and mortality of seabirds
			Physiological and behavioural effects on marine fauna
			Fish aggregation and increased predator-prey interactions
	Ballasting and de-ballasting during unloading and loading of LNG and unloading of gas	Introduction / spread of invasive alien species	Loss of biodiversity
		Discharge of contaminated water	Physiological effect on fish, plankton and other marine life
			Pollution of coastal and marine habitats and biota
Phase 2: Construction	Conversion of offloading platform to distribute cryogenic LNG	Underwater noise and vibration levels during pile driving	Disturbance / behavioural changes to marine fauna
			Avoidance of key feeding/breeding areas
			Abandonment of nests and young
		Disturbance of seabed through placement of tubular steel piles	Crushing ad smothering of benthos
		Increased water turbidity and reduced light penetration	Reduced physiological functioning of plankton, fish, seabirds, cetaceans and other marine fauna
		Increased hard substrate on seafloor	Creation of alternative habitat for colonisation of benthic fauna and increase in biodiversity
		Pollution in the marine environment through littering and operational spills	Physical damage to habitats and/or damage to or mortality of species
Phase 2: Operation	Mooring and operation of LNGC	Intake and discharge of large volumes of seawater for cooling of condensers and engines	Impingement and entrainment of marine organisms
			Physiological effect on marine fauna of thermal discharge
		Routine discharges to sea (e.g. deck and machinery space drainage, sewage and galley wastes) and local reduction in water quality	Physiological effect on marine fauna
			Increased food source for marine fauna
			Increased predator - prey interactions
		Underwater noise levels	Disturbance of behaviour (foraging and anti-predator) and physiology of marine fauna

Activity Phase	Activity	Aspect	Potential Impact
Phase 2: Operation (cont.)		Increase in ambient lighting	Disorientation and mortality of seabirds
			Physiological and behavioural effects on marine fauna
			Fish aggregation and increased predator-prey interactions
	Ballasting and de-ballasting during unloading and loading of LNG and unloading of gas	Introduction / spread of invasive alien species	Loss of biodiversity
Unplanned Activities	Vessel accident	Release of fuel into the sea and localised reduction in water quality	Effect on faunal health (e.g. respiratory damage) or mortality (e.g. suffocation and poisoning)
			Pollution and smothering of coastal habitats
	Hydrocarbon spills (minor) (e.g. bunkering, loss of hydraulic fluid)	Discharge of fuel into sea during bunkering and localised reduction in water quality Discharge of hydraulic fluid into sea due to pipe rupture and localised reduction in water quality	Effect on faunal health (e.g. respiratory damage) or mortality (e.g. suffocation and poisoning)
	Transit of dredger or LNGC	Marine mammal collisions	Injury or mortality of marine mammals or turtles
	Upset conditions during transfer of LNG	Accidental spills of LNG	Physiological effect on marine fauna and flora
	Upset conditions at hypochlorite generation unit	Accidental spills of hypochlorite into the marine environment	Physiological effect on marine fauna and flora

4.2. Assessment of Potential Impacts

4.2.1 Removal and Disturbance of Sediments

Source of Impact

The project activities and their associated aspects that will result in the removal and disturbance of seabed sediments are described below.

- The dredging of two small areas inside the eastern breakwater of the Port of Ngqura to a depth of -15.4 m below chart datum is required to reduce encroachment of the LNGCs on the port manoeuvring area. It is estimated that in total 68,000 m^3 of sediment, comprising primarily fine sandy marine deposits (~71%), with 24% comprising pebbles and cobbles and 5% medium to hard rock would be removed by cutter suction dredger or backhoe dredger. A hydraulic breaker may be required should rock outcrops be encountered.
- The dredge spoil would be loaded onto a series of sailing hopper barges that would sail to the dedicated disposal area and instantaneously release the spoil through bottom doors allowing the dredged material to drop into the sea. This bottom release method permits the rapid and controlled release of dredge spoil once the barge is on site.
- During construction of underwater revetments and rock armour to stabilise the dredge slope and protect the admin craft basin breakwater from scour by the LNGCs propeller wash, respectively, rock material with rock sizes of between 20 – 800 kg will be deposited onto the seabed.
- Construction of the access trestle, offloading platform and mooring and berthing dolphins would be undertaken by jack-up platform, which provides a construction platform for the installation of the piles. Construction of the piles would require driving steel tube casings into the sediment, excavating out the tubes, drilling holes for rock anchors and installing the pile.
- Heating and cooling water from the LNGC and FSRU would be discharged at velocities higher than background curents[3] and at the point of release from the vessels would form a discharge jet, which initially has the radius and orientation of the discharge port(s). Exit velocities can range from 0.7 – 3.0 m/s and are therefore considerably higher than background currents. On release, the jet would be deflected by the ambient currents at the terminal and by the positive (warm) or negative (cold) buoyancy of the discharge. Ambient seawater would become entrained in the jet resulting in dilution and changes in buoyancy, with the terminal level of the jet generally reached within a horizontal radius of 20 to 40 m from the discharge point (PRDW 2015). Depending on the discharge orientation, this would be the seabed (-90°), the water surface (0°) or a level where the jet is neutrally buoyant (-45°). Depending on the water depth below the vessels, significant scouring of the seabed and suspension of sediments could therefore occur if the high velocity jet is discharged vertically downwards (PRDW 2015).

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[3] Although no current measurements are available for the Port of Ngqura, currents within the port are largely tidal and/or wind-driven (PRDW 2016). Currents are likely to be in the order of 0.1 – 0.15 m/s.

Impact Description

Dredging of the unconsolidated sediments would result in the removal and destruction of the associated infaunal and epifaunal communities in the dredging area. Abundance and biomass of benthic organisms are normally more drastically reduced than species numbers. Research conducted over the last few decades on commercial aggregate dredging operations to sediment depths of 20 - 25 cm has shown that a 25 - 70% reduction of species diversity, 45 - 95% reduction in abundance, and a similar reduction in biomass (Newell *et al.* 1998; Herrmann *et al.* 1999) can be expected. Klages and Bornman (2005) similarly reported significant changes in species diversity and community structure of the macrofauna in the Port of Ngqura following the development of the harbour, with the impact persisting beyond the duration of dredging.

The ecological recovery of the disturbed seafloor is generally defined as the establishment of a successional community of species, which progresses towards a community that is similar in species composition, population density and biomass to that previously present (Ellis 1996). The rate of recolonization depends largely on the type of community that inhabits the deposits in the dredged area, the extent to which the community is naturally adapted to high levels of sediment disturbances, the sediment structure (grain size) and physical factors such as depth and exposure (waves, currents) (Newell *et al.* 1998; Herrmann *et al.* 1999). Recolonization typically takes place by passive translocation of animals during storms or sediment infill from nearby unaffected areas, active immigration of mobile species, and immigration and settlement of pelagic larvae and juveniles (Hall 1994; Kenny & Rees 1994, 1996; Herrmann *et al.* 1999; Ellis 2000). Areas of undisturbed deposits adjacent to dredged furrows may also provide an important source of colonizing species that enable a faster recovery than might occur solely by larval settlement and growth (van Moorsel 1993, 1994).

In general, communities of short-lived species and/or species with a high reproduction rate (opportunists) recover more rapidly than communities of slow growing, long-lived species. Opportunists are usually small, mobile, highly reproductive and fast growing species and are the early colonizers. Fine mobile deposits, such as occur in estuaries (and in this case dominate the sediments in the Port of Ngqura) and which are subjected to frequent disturbances, are typically inhabited by such opportunistic species. More stable habitats characterised by coarser sediments on the other hand, are typified by large, often burrowing, slow growing and long-lived species (Newell *et al.* 1998).

Recolonization starts rapidly after cessation of dredging, and species numbers may recover within short periods (weeks). Opportunistic species may already attain increased densities within months after sediment removal. However, long-lived species such as like molluscs and echinoderms need longer to re-establish the natural age and size structure of the population. Biomass therefore often remains reduced for several years (Kenny & Rees 1994, 1996).

Ellis (1996) provided typical recovery rates for different grained deposits based on several sources (

Table **2**). These average time scales conform to those from other studies (see Newell *et al.* 1998). From this it can be assumed that a period of 1-3 years is a realistic estimate for the time required for recovery of benthic communities in medium-grained deposits such as those at the proposed dredge site.

Table 2: Timing for recovery of seabed habitats after dredging (after Ellis 1996).

Sediment type	Recovery time
Fine-grained deposits: muds, silts, clays, which can contain some rocks and boulders	1 year
Medium-grained deposits: sand, which can contain some silts, clay and gravel	1-3 years
Coarse-grained deposits: gravels, which can contain some finer fraction and some rock and boulders	5 years
Coarse-grained deposits: gravels with many rocks and boulders	>5 years

The main impacts associated with the disposal of dredge spoil at the dedicated offshore dump site would be smothering of sessile benthic fauna and physical alteration of the benthic habitat (changes in sediment properties). The effects of smothering on the receiving benthic macrofauna are determined by 1) the depth of burial; 2) the nature of the depositing sediments; and 3) the tolerance of species (life habitats, escape potential, tolerance to hypoxia etc.) and 4) the presence of contaminants in the depositing solids (Kranz 1974; Maurer *et al*. 1981a, 1981b, 1982, 1986; Bijkerk 1988; Hall 1994; Baan *et al*. 1998; Harvey *et al*. 1998; Essink 1999; Schratzberger *et al*. 2000b; Baptist *et al*. 2009).

In areas where sedimentation is naturally high (e.g. wave-disturbed shallow waters) the ability of taxa to migrate through layers of deposited sediment is typically well developed (Roberts *et al*. 1998). Many benthic infaunal species are able to burrow or move through the sediment matrix, and some infaunal species are able to actively migrate vertically through overlying deposited sediment thereby significantly affecting the recolonisation and subsequent recovery of impacted areas (Maurer *et al*. 1979, 1981a, 1981b, 1982, 1986; Ellis 2000; Schratzberger *et al*. 2000a; but see Harvey *et al*. 1998; Blanchard & Feder 2003). Maurer *et al*. (1979) reported that some animals are capable of migrating upwards through 30 cm of deposited sediment. In contrast, consistent faunal declines were noted during deposition of mine tailings from a copper mine in British Columbia when the thickness of tailings exceeded 15-20 cm (Burd 2002), and Schaffner (1993) recorded a major reduction in benthic macrofaunal densities, biomass, and species richness in shallow areas in lower Chesapeake Bay subjected to heavy disposal (>15 cm) of dredged sediments. Similarly, Roberts *et al*. (1998) and Smith and Rule (2001) found differences in species composition detectable only if the layer of instantaneously applied overburden exceeded 15 cm (see also Bakke *et al*. 1986; Trannum *et al*. 2011). In general, mortality tends to increase with increasing depth of deposited sediments, and with speed and frequency of burial.

The survival potential of benthic infauna, however, also depends on the nature of the deposited non-native sediments (Turk & Risk 1981; Chandrasekara & Frid 1998; Schratzberger *et al*. 2000a). Although there is considerable variability in species response to specific sediment characteristics (Smit *et al*. 2006), higher mortalities were typically recorded when the deposited sediments have a different grain-size composition from that of the receiving environment (Cantelmo *et al*. 1979; Maurer *et al*. 1981a, 1981b, 1982, 1986; Smit *et al*. 2006; Smit *et al*. 2008). Migration ability and survival rates of organisms are generally lower in silty sediments than in coarser sediments (Hylleberg *et al*. 1985; Ellis & Heim 1985; Maurer *et al*. 1986; Romey & Leiseboer 1989, cited in Schratzberger *et al*. 2000a; Schratzberger *et al*. 2000b). Some studies indicate that changes to the geomorphology and sediment characteristics may in fact have a greater influence on the recovery rate of invertebrates than direct burial or mortality (USDOI/FWS 2000). The availability of food in the depositional sediment is, however, also influential.

The duration of burial would also determine the effects on the benthos. Here a distinction must be made between incidental deposition, where species are buried by deposited material within a short period of time (as would occur during dumping of dredge spoils), and continuous deposition, where species are exposed to an elevated sedimentation rate over a long period of time (e.g. in the vicinity of river mouths). Provided the sedimentation rate of incidental deposition is not higher than the velocity at which the organisms can move or grow upwards, such deposition need not necessarily have negative effects. The sensitivity to short-term incidental deposition is species dependent and also dependent on the sediment type, with deposition of silt being more lethal than a deposition of sand.

The nature of the receiving community is also of importance. In areas where sedimentation is naturally high (e.g. wave-disturbed shallow waters) the ability of taxa to migrate through layers of deposited sediment is likely to be well developed (Roberts *et al.* 1998). The life-strategies of organisms are a further aspect influencing the susceptibility of the fauna to mortality. Benthic and demersal species that spawn, lay eggs or have juvenile life stages dependent on the seafloor habitat may be negatively affected by the smothering effects of dredge spoil. Studies on the burrowing habits of 30 species of bivalves showed that mucous-tube feeders and labial palp deposit-feeders were most susceptible to sediment deposition, followed by epifaunal suspension feeders, boring species and deep-burrowing siphonate suspension-feeders, none of which could cope with more than 1 cm of sediment overburden. Infaunal non-siphonate suspension feeders were able to escape 5 cm of burial by their native sediment, but normally no more than 10 cm (Kranz 1972, cited in Hall 1994). The most resistant species were deep-burrowing siphonate suspension-feeders, which could escape from up to 50 cm of overburden. Meiofaunal species appear to be less susceptible to burial than macrofauna (Menn 2002).

Where rock material is deposited on the seabed following dredging to stabilise sediments and prevent scour, most of the epifauna or infauna inhabiting the sediments would be smothered and crushed. Similarly, biota in the pile footprints would be disturbed and destroyed, and those in the footprint of the jack-up platform legs would be crushed. This would constitute a permanent loss as the unconsolidated sediments would be replaced by hard substrata, which in turn would offer alternative habitats for colonisation by a different suite of species (see section 4.2.5).

If the orientation of the higher velocity discharges of both cooling and heating water are directed vertically downwards, biota in the sediments below the LNGC and FSRU and in the direct footprint of the discharged water jet would be displaced and/or mechanically destroyed, and those in the surrounding area may be disturbed and smothered during redeposition of the displaced sediments.

Sensitivity of Receptors

Soft bottom habitats between Mossel Bay and Cape Padrone support a high diversity of polychaetes (56 species of bristle worms), gastropods (53 species of snails), ophiuroids (9 species of brittle star) and mysids (4 species of shrimps) (Wallace *et al.* 1984). Benthic macrofauna collected off Cape Recife included three species of amphipod (*Griffithsius latipes*, *Urothoe pinnata* and *Colomastigidae pusilla*), four species of isopod (all belonging to the genus *Cirolana*), two species of polychaete (*Ophelia* sp. and *Pectiniaria* sp.), as well as a species of sea cucumber and a species of brittle star (*Amphipholis squata*) (Laird *et al.* 2016). These species are ubiquitous to unconsolidated sediments in the area, however, and no rare or endangered species have been reported. The dredge disposal site was also reported to have a comparatively low abundance and diversity (CES 2001).

In 2006, macrofauna in the harbour sediments were relatively impoverished (Klages *et al* 2006) but not taxonomically different from adjacent biological communities. Abundance and diversity were low relative to sites some distance from the harbour and dominated by opportunists (polychaetes, amphipods and isopods) with a fast turn-over rate, and suspension-feeders tolerant of elevated turbidity levels. Similarly, the dredge spoil site has been used for disposal of dredged sediments in two significant construction projects within the Ngqura Port, and the benthic communities there have therefore also been previously disturbed. Although no post spoil disposal monitoring of macrofauna has been undertaken, dumped dredge spoil has had a significant increase in topographic features at the dump site, with a large proportion of the seabed being elevated by 1.5 m or more (CSIR 2007). Concomitant changes in macrofaunal community structure can thus be expected. As the harbour sediments have previously been disturbed by port construction, capital and maintenance dredging, and harbour expansions such as the admin craft basin, the macrofaunal communities are not pristine and are likely to be severely impoverished, particularly on completion of the required dredging works at the LNG terminal basin. Subsequent reports on the Port of Ngqura Biomonitoring Programme (Klages *et al*. 2006; Du Preez & Campbell 2007; Campbell & Du Preez 2008) are confidential documents and although requested from the Ports Authorities could not be sourced.

Impact Significance

The elimination of marine benthic communities in the dredging area and structural footprint of the LNG Terminal is an unavoidable consequence of the proposed development, and no direct mitigation measures, other than the no-project alternative, are possible. In the case of the heating and cooling water discharges from the LNGC and FSRU, structural adaptations can be implemented to the vessels outlets thereby avoiding impacts to the sediments below the vessels. The initial negative impacts are deemed of low intensity within the immediate vicinity of the LNG terminal and dredge disposal site. Furthermore, the negative impacts persist over the short-term only recolonization of unconsolidated sediments will be rapid and as the new structures and rock armouring will offer a new settling ground for hard bottom species and will be rapidly colonised. The impact is therefore assessed to be of **VERY LOW** significance both without and with mitigation.

Impact: Elimination of benthic communities through disturbance and loss of substratum

<table>
<tr><th></th><th><i>Extent</i></th><th><i>Intensity</i></th><th><i>Duration</i></th><th><i>Consequence</i></th><th><i>Probability</i></th><th><i>Significance</i></th><th><i>Status</i></th><th><i>Confidence</i></th></tr>
<tr><td>Without mitigation</td><td>Local
1</td><td>Low
1</td><td>Short-term
1</td><td>Very Low
3</td><td>Definite</td><td>VERY LOW</td><td>- ve/
+ ve</td><td>High</td></tr>
<tr><td colspan="9">Essential mitigation measures:
• No direct mitigation possible other than the no-project alternative.

Best practice mitigation measures:
• Fit deflector plates to discharges directed vertically downwards to modify the discharge to 45°.</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Low
1</td><td>Short-term
1</td><td>Very Low
3</td><td>Probable</td><td>VERY LOW</td><td>- ve/
+ ve</td><td>High</td></tr>
</table>

Potential for Cumulative Effects

Any disturbance of sediments within the Port of Ngqura, be it as a result of dredging or the construction of quays, breakwaters, underwater revetments, jetties and mooring and berthing dolphins or placement of mooring legs, will have cumulative impacts on the marine communities associated with those sediments. Over the lifetime of the port, these impacts are likely to be of medium significance.

4.2.2 Sediment Resuspension and Increased Turbidity

Source of Impact

The project activities and their associated aspects that will generate suspended sediment plumes and an increase in turbidity are described below.

- The dredging of two small areas inside the eastern breakwater of the Port of Ngqura is required, with an estimated 68,000 m^3 of sediment, comprising primarily fine sandy marine deposits with slightly clayey lumps and shell fragments (~71%), with 24% comprising pebbles and cobbles and 5% medium to hard rock needing to be removed by cutter suction dredger or backhoe dredger. During dredging, suspended sediments can be generated near the seabed by the cutter suction head or backhoe bucket and at the surface arising from the overflow of material from hoppers during loading.
- Once at the sacrificial dump site, the spoil is released through bottom doors in the sailing hopper allowing the dredged material to drop into the sea. This bottom release method permits the rapid and controlled release of dredge spoil. The spoils discharged from the initially behave like a density current, with particles being held together by cohesion during the early phase of the sedimentation process, reducing the spread of the sediments considerably (Gajewski & Uscinowicz 1993; Whiteside *et al*. 1995). During this convective descent entrainment of the receiving waters reduces turbidity in the upper water column as the jet mixed with the ambient seawater. The jet eventually either reaches the seabed or a level of neutral buoyancy above the bottom, spreading dynamically in a horizontal plane in the water column. The coarser particles settle out first with the finer sediments remaining in suspension for longer. The dispersion pattern and depositional footprint depends on water depth, current strength and the frequency of storm surges (Buchanan *et al*. 2003).
- During construction of underwater revetments and rock armour, rock material will be deposited onto the seabed, where the impact with the unconsolidated sediments can generate a near-bottom plume. If the receiving sediments are fine to medium-sized sands the suspended sediments will redeposit rapidly, whereas silts, muds and clays (<63 µm) will remain in suspension for longer. The rock material may also carry dust and fine sediment with it from the quarrying process.
- Installation and anchoring of the piles for the access trestle, offloading platform and mooring and berthing dolphins displace sediments on the seabed and could resuspend sediments into the water column thereby generating near-bottom plumes. The placement of the steel jackets on the seafloor and subsequent pile installation would cause most of the sediment disturbance. The insertion of the piles into the seafloor would directly displace a corresponding volume of substrate and the vibrations caused by a vibratory or impact hammer could dislodge and cause resuspension of surrounding material. If the receiving sediments are fine to medium-sized

sands the suspended sediments will redeposit rapidly, whereas muds and clays will remain in suspension for longer.

- Heating and cooling water discharged vertically downwards from the LNGC and FSRU can cause significant scouring of the seabed and suspension of sediments.
- Resuspension of sediments by turbulence generated by the LNGCs propeller wash when underway and/or manoeuvring into the offloading facility.

Impact Description

It is important to distinguish between elevated suspended sediments and elevated turbidity, as the latter is not necessarily linearly related to the former. For example, an increase in suspended sediment concentration by a given amount will result in a greater increase in turbidity if the sediment is silt rather than sand (Posford Duvivier Environment 2001). Turbidity is usually measured as light scatter in nephelometric turbidity units (NTU), which is an appropriate measure regarding light attenuation. With respect to the impact on aquatic organisms, the parameter of most concern is, however, the amount of suspended material in mg/ℓ.

Sediment resuspension during dredging and construction is mainly dependant on the properties of the sediments, with plumes decreasing in size as the sediments become coarser. The size fractions of greatest relevance are the silts, muds and clays (<63 µm) as these create the highest level of turbidity. Near-bottom dredge plumes usually decrease rapidly with distance from the dredger (Posford Duvivier Environment 2001), reaching ambient levels within 100 m of the cutter head (Kirby & Land 1991). As the sediment at the proposed dredge site is dominated by fine to medium-sized material (>90 µm) with rapid settlement rates, resuspended sediment should disperse only over short distances and quickly settle out of the water column. This is further supported by the low near-bottom current velocities predicted in Ngqura Port.

Greater amounts of suspended sediments are usually generated by the overflow of material from the hoppers during dredging (Newell *et al*. 1998; Herrmann *et al*. 1999; Posford Duvivier Environment 2001), with spill percentages ranging between 2 and 10%, and 0.5 and 25%, depending on the aggregate type and dredging technology (Nielsen 1997, cited in Herrmann *et al*. 1999). Generally, the extent and area over which overspill plumes disperse are dependent on the strength and direction of the prevailing currents and winds, and the particle size of the material in question. Where dredged sediments are dominated by sands suspended sediment at concentrations likely to cause a detrimental effect do not persist for more than 150 m downstream of the dredger (Gibb Environmental Sciences 1992).

The effects that elevated suspended sediment concentrations have on organisms are related to the concentration of the suspended material and the duration of exposure to it. Along the South African coastline marine organisms are naturally exposed to elevated suspended-sediment levels from storms, tidal flows, currents and river discharges, and therefore have behavioural and physiological mechanisms for dealing with this feature of their habitat. Dredging-related suspended-sediment plumes may differ in scope, timing, duration and intensity from those natural conditions, thus potentially causing conditions not normally experienced by the organisms. Effects of suspended sediment are highly species-specific and can vary greatly. Although published data on suspended sediments effects on fish and bivalves are typically for species occurring elsewhere, they are summarised below.

Suspended sediments also load the water with inorganic particles, which may affect the biological responses such as feeding rate, hatching success, larval survival and foraging success of higher-order consumers (reviewed by Clarke & Wilber 2000). For fish, critical exposure levels can range from

~500 mg/ℓ for 24 hours to no effects at concentrations of >10,000 mg/ℓ over 7 days (Clarke & Wilber 2000). Direct long-term impacts for fish are, however, unlikely to occur as they are mobile and can actively avoid any area affected by increased sediment loadings. Short-term impacts may occur by reducing the ability to find prey by visual feeders (Hecht & van der Lingen 1992). On the other hand, fish may be attracted by the 'odour stream' of crushed benthic organisms during dredging activities (Herrmann *et al.* 1999). Fish eggs and larvae are generally more susceptible to elevated concentrations of suspended sediments; hatching can be delayed and feeding of larvae may be impaired. The adhesion of particles to eggs may cause loss of buoyancy resulting in the eggs sinking to the bottom (ICES ACME 1997). Benthic and demersal species that spawn, lay eggs or have juvenile life stages dependent on the seafloor habitat (e.g. hake, squid) could therefore be negatively affected by the smothering effects of redepositing sediments.

Filter-feeders are generally more sensitive to suspended solids than deposit-feeders, since heavy sedimentation may clog the gills. However, research has shown that filter-feeders (particularly bivalves) living in coastal waters are highly adaptable, and can maintain their feeding activity over a wide range of inorganic particulate loads (Iglesias *et al.* 1996; Navarro *et al.* 1996). Suspended sediment effects on juvenile and adult bivalves occur mainly at the sub-lethal level with the predominant response being reduced filter-feeding efficiencies occurring generally at concentrations of about 100 mg/ℓ. Lethal effects are seen at much higher concentrations (>7,000 mg/ℓ) and at long-term (3 weeks) exposures (Clarke & Wilber 2000). For bivalve egg stages, critical suspended sediment concentration range from 188 mg/ℓ for oysters to 1,000 mg/ℓ for burrowing clams (Clarke & Wilber 2000) and larval stages show no effects at suspended sediment concentrations <750 mg/ℓ (Clarke & Wilber 2000).

Crustaceans appear similarly resistant to lethal effects with 25% mortality rate reported at 10,000 mg/ℓ for >240 h exposures (Clarke & Wilber 2000).

Increases in suspended material in the water column will diminish the light penetration with potential adverse effects on the photosynthetic capability of phytoplankton and other aquatic plants, or reduced feeding in zooplankton (Kirk 1985; Parsons *et al.* 1986a, 1986b). On the other hand, resuspended nutrients may stimulate phytoplankton productivity (ICES 1992).

The presence of surface and sub-surface plumes has the potential to reduce the ability of visually-feeding marine mammals (e.g. seals and dolphins) and diving seabirds (e.g. Damara terns, Cape Cormorants, African Penguins) to locate their prey, thereby diminishing their feeding success and potentially negatively affecting reproductive success. However, most animals are likely to move away from areas of elevated suspended sediment concentrations. Considering the ranges over which marine mammals and seabirds feed, and that prey abundance is likely to be lower in areas affected by plumes, the feeding ability or efficiency of pelagic mammals and seabirds is unlikely to be adversely affected by the highly localised dredging plumes and sediments resuspended during construction activities (Posford Duvivier Environment 2001).

CSIR (2007) report that turbidity measurements in Algoa Bay prior to dredging and dredge spoil disposal fell into the overall range of 0.5-10 NTU in surface waters and 3-20 NTU in bottom waters. During and after dredging (September 2004, January and September 2005) upper water column turbidity remained in the 5-10 NTU range, but bottom waters had turbidity levels at 30 – >150 NTU, with elevated turbidity levels persisting for at least six months after cessation of dredging (Klages & Bornman 2005b). The persistent high turbidities were attributed to the fact that the finer particles in the dumped dredge spoil had not yet been consolidated into the seabed sediments and were readily resuspended by wave action. However, as Algoa Bay is periodically influenced by highly turbid nepheloid layer water (Dorfler

2002), the elevated turbidities observed by Klages and Bornman (2005b) in September 2005 cannot be unequivocally attributed to dredge spoil disposal.

Capital dredging works in the Port of Ngqura, however, involved the removal of ~15,000,000 m^3 of dredge spoil, whereas the dredging required for the LNG terminal would remove only an estimated 68,000 m^3 of sediment. As the target sediments are primarily fine to medium sands, it is likely that elevated suspended sediment levels and turbidity plumes generated during dredging would remain confined to the vicinity of the point of extraction in the port and would not escape through the port entrance or persist for more than a few days (see for example Evans 1994; Whiteside *et al.* 1995).

An issue of concern, however, is the total duration of the dredging work (estimated at 22 weeks; PRDW 2016) and the continuity of the operation (the hopper barges will operate in series thereby allowing for uninterrupted dredging during daylight hours), potentially resulting in higher levels of suspended sediment concentrations due to additive processes. In such cases, this may result in deleterious environmental impacts because of increased concentrations. Due to similar hydrographic conditions over the proposed dredge area and its sheltered location in the lee of the breakwater, sediment plumes are likely to have similar characteristics as regards the broad direction of dispersal. However, even where repeated extraction takes place from the same site, the path of sediment dispersal is unlikely to be the same each time (Posford Duvivier Environment 2001). The timing of any dredging activity may also control the potential for additive processes due to localised differences in hydrographical circulation patterns. In some areas, for example, tidal conditions at the time of extraction were found to strongly influence the spatial characteristics of plumes (Posford Duvivier Environment 2001). Consequently suspended sediment plume generation will be continuous, at least during daylight hours.

The research on biological responses to potential effects of suspended sediments generated by coastal dredging has been synthesised by Clarke & Wilber (2000). These authors found that, despite a significant body of research, potential biological responses or effects at suspended sediment concentrations typical of plumes generated by dredging are not yet well defined. This was attributed to most of the observational research being based on biological reactions to suspended sediment concentrations higher (>100 mg/ℓ) than those generally produced by dredging, or to longer exposure periods (>2 days) than typical life spans of suspended sediment plumes.

Sensitivity of Receptors

Offering a relatively calm and sheltered environment in an otherwise high-energy coastline, the Port of Ngqura supports one of the most abundant and diverse fish populations along the South African coastline, functioning as an important habitat for both juvenile and adult fish, representing both estuarine and shore species (Dicken 2010). Of the most commonly occurring species, the Dusky kob (*Argyrosomus japonicas*) is considered ‘Critically Endangered’, whereas the elf (*Pomatomus saltatrix*), spotted grunter (*Pomadasys commersonnii*) and garrick (*Lichia amia*) are rated as nationally ‘Vulnerable’. The Port also serves as an important summer habitat and core activity zone for neonate and juvenile dusky sharks (*Carcharinus obscurus*), and may serve as an important nursery area for the species (Dicken 2011). Although the national assessment identifies dusky sharks as being ‘data deficient’, its IUCN Conservation status is considered ‘Vulnerable’. Other chondrichthyans reported from the harbour are the great white shark and giant manta, both of which are considered ‘Vulnerable’ by the IUCN, and the whale shark which is rated as ‘Endangered’.

The dolosse habitat, in particular, supported the greatest abundance of fish. The dredging and construction area lies immediately adjacent to the dolosse area at the base of the breakwater.

The bulk of the South African population of 'Critically Endangered' Damara terns nest near the proposed zone 10 power plant site (Whittington *et al*. 2015) and feeds in the port. The African Penguin that breeds on St Croix Islands and feeds on small pelagic shoaling species within 20-30 km of their breeding sites (Crawford *et al*. 1999, Pichegru *et al*. 2009) is listed as 'Endangered'. Similarly, the Cape Gannet, which breeds on Bird Island is considered 'Endangered'

The Port also falls within the conservation zone of the Algoa to Amathole EBSA, whereas the dredge spoil disposal site now falls within the Addo Elephant MPA, which protects important feeding areas for the 9,000 pairs of African Penguins and the 60,000 pairs of Cape Gannets.

Considering that as Algoa Bay is periodically influenced by highly turbid nepheloid layer water it can be assumed that the benthic fauna and demersal species at least are naturally adapted to periodic elevated turbidity and suspended sediment concentrations.

Impact Significance

Elevated suspended sediment concentrations and increased turbidity in the Port due to dredging and construction activities, and in the vicinity of the dredge disposal site during dredge spoil disposal is deemed of low intensity within the immediate vicinity of the dredging and construction sites, with impacts persisting over the short-term only. As dredging and construction activities relating to the offloading facilities will be confined to within the Port area, impacts on the adjacent Addo Elephant MPA and Algoa to Amathole EBSA are unlikely. Suspended sediment plumes generated during dumping of dredge spoil and installation of the gas and cryogenic pipelines would, however, overlap with the MPA and EBSA, but as impacts would be highly localised and ephemeral, the impact is assessed to be of **VERY LOW** significance both without and with mitigation. Similarly, regular movement of maritime traffic already occurs along the existing approach channel to, and within the Port of Ngqura. Although additional sediment resuspension by turbulence generated propeller wash from LNGCs can be considered a cumulative effect, the impact can be considered insignificant. Although elevated suspended sediment concentrations are an unavoidable consequence of dredging and construction activities, impacts can be kept to a minimum through responsible dredging and construction practices.

Impact: Reduced physiological functioning of marine organisms due to increased suspended sediment concentrations or turbidity

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Low 1	Short-term 1	**Very Low** 3	Definite	**VERY LOW**	**- ve**	High

Essential mitigation measures:

- All dredging activities and associated environmental monitoring must be conducted in accordance with the conditions stipulated under the port expansion authorisation.
- All contractors must have an approved Environmental Management Plan in place that ensures that environmental impacts are minimised as far as practicable possible.

Best practice mitigation measures:

- Manage suspended sediment plumes generated during dredging and construction of the LNG Terminal by the installation of silt curtains.

With mitigation	Local 1	Low 1	Short-term 1	**Very Low** **3**	Probable	**VERY LOW**	**- ve**	High

Potential for Cumulative Effects

Although increased suspended sediment concentrations associated with construction activities are ephemeral, when taken in combination with capital and maintenance dredging operations, cumulative impacts on water quality of medium significance can be expected over the medium to long term.

4.2.3 Release of Contaminants, Altered Dissolved Oxygen Distributions and Increases in Nutrients

Source of Impact

The project activities and their associated aspects that may result in the release of contaminants, increased nutrient concentrations and potential alteration of dissolved oxygen levels are described below.

- During dredging, the resuspension of sediments can result in contaminants associated with the dredged sediment being released and entering the dissolved and reactive phase. Inorganic nutrients may also be introduced to the water column and oxygen concentrations depressed if the dredge area sediments contain significant quantities of organic matter.
- Once at the sacrificial dump-site, the spoil is released through bottom doors in the sailing hopper allowing the dredged material to drop into the sea. Contaminants and nutrients associated with the dredged sediments could be introduced to the water column and sediments at the dredge disposal site. Nutrients may also be introduced to the water column and sediments at the dump-site and oxygen concentrations depressed if the dumped material contains significant quantities of organic matter.
- Installation and anchoring of the piles for the access trestle may similarly resuspend contaminants and nutrients associated with the harbour sediments at the construction site.

Impact Description

Trace metal uptake by organisms may occur through direct absorption from solution, by uptake of suspended matter and/or *via* their food source. Toxic effects on organisms may be exerted over the short term (acute toxicity), or through accumulation. In addition, feeding on contaminated food may produce bio-magnification, whereby top predators accumulate toxic levels of contaminants. In a pelagic environment where both the plume containing contaminants and susceptible organisms are non-stationary, acute effects are proposed to be of greater concern than bio-accumulation. In the case of benthic communities, however, the risk of bio-accumulation is greater.

The toxicity of trace metals to organisms is complex and depends on the partitioning of metals between dissolved and particulate phases and the speciation of the dissolved phase into bound (inorganic or organic complexes) or free forms. The most bio-available forms that are potentially toxic to aquatic life are free metals, as well as some weak inorganic complexes. Metals that make up the total concentration are thus not always bio-available and potentially toxic. Frequently, these bio-available metals constitute only a fraction of the total.

Previous studies have identified that contaminant (trace metal, chlorinated hydrocarbon and PCB) concentrations in the Port of Ngqura sediments were all low with the exception of arsenic (CSIR 1999 in CES 2001b) and well within sediment quality guideline values (DEAT 1998; BCLME 2004). After the completion of the initial dredging programme, contaminant concentrations in the sediments adjacent to the port (Klages *et al* 2006) and within the port (CSIR 2007) have remained low, falling within the limits of special care set for RSA dredging and dredge spoil dumping activities (DEAT 1998, BCLME 2004). Arsenic and chromium were exceptions to this at two sites within the harbour. Further, four of the samples in the harbour and 23 of the vibro-core samples exceeded the special care limits for combined London Convention Annex 2 trace metal concentrations. However, most of the trace metals were strongly associated with clay minerals (i.e. lithogenic origin) and therefore relatively unavailable to uptake by marine organisms.

Depletion of water column oxygen concentration through the bacterial decomposition of organic matter associated with the resuspension of sediments during dredging may occur. In bottom waters, which may already be oxygen-depleted, this effect is considered deleterious (Herrmann *et al*. 1999). As the organic content of sediments in the Ngqura port area were low (Newman 2001), the risks of eutrophication due to introductions of nutrients to the water column during dredging are considered to be low.

The unloading of the dredge spoils at the sacrificial dump-site can result in the release of contaminants associated with the dredged material. Also, nutrients may be introduced to the water column and oxygen concentrations depressed if the dumped material contains significant quantities of organic matter. Sediment samples were taken from the dump site in July 2006 (CSIR 2007) identified that trace metal concentrations were mainly low and, similar to the sediments in the port, below the special care level (DEAT 1998; BCLME 2004). Most of the sediment classified as sand.

Sensitivity of Receptors

Contaminants resuspended in sediments can be released and enter the dissolved reactive phase, whereafter uptake by organisms may occur through direct absorption from solution, by uptake of suspended matter and/or *via* their food source. Such toxic effects on organisms and food chains may be exerted over the short term (acute toxicity), or through bio-accumulation thereby potentially affecting all benthic and pelagic species.

Impact Significance

As contaminant concentrations in the sediments are low, and if resuspended should dilute rapidly to background levels, the remobilisation of contaminants and nutrients in the dredge area and spoils disposal site is deemed of low intensity within the immediate vicinity of the dredging and construction sites, with impacts persisting over the short-term only. As dredging and construction activities relating to the offloading facilities will be confined to within the Port area, impacts on the adjacent Addo Elephant MPA and Algoa to Amathole EBSA are highly unlikely. Suspended sediment plumes generated during dumping of dredge spoil and installation of the gas and cryogenic pipelines east of the breakwater could, however, overlap with the MPA and EBSA, but as impacts would be highly localised and ephemeral, the impact is assessed to be **INSIGNIFICANT** both without and with mitigation. Although elevated suspended sediment concentrations are an unavoidable consequence of dredging and construction activities, impacts can be kept to a minimum through responsible dredging and construction practices.

Impact: Toxic effects of remobilised contaminants and nutrients in the dredge and construction area on marine organisms

<table>
<tr><th></th><th><i>Extent</i></th><th><i>Intensity</i></th><th><i>Duration</i></th><th><i>Consequence</i></th><th><i>Probability</i></th><th><i>Significance</i></th><th><i>Status</i></th><th><i>Confidence</i></th></tr>
<tr><td>Without mitigation</td><td>Local
1</td><td>Low
1</td><td>Short-term
1</td><td>Very Low
3</td><td>Improbable</td><td>INSIGNIFI-CANT</td><td>- ve</td><td>High</td></tr>
<tr><td colspan="9">Essential mitigation measures:
• All dredging activities and associated environmental monitoring must be conducted in accordance with the conditions stipulated under the port expansion authorisation.
Best practice mitigation measures:
• Manage suspended sediment plumes generated during dredging and construction of the LNG Terminal by the installation of silt curtains.</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Low
1</td><td>Short-term
1</td><td>Very Low
3</td><td>Improbable</td><td>INSIGNIFI-CANT</td><td>- ve</td><td>High</td></tr>
</table>

Potential for Cumulative Effects

Although contaminant concentrations in the sediments are currently low, compromised sediment quality within the port over the long-term due to cumulative impacts resulting from port developments and other anthropogenic sources in the Coega SEZ can be expected. Over the lifetime of the port, these impacts are likely to be of medium to high significance.

4.2.4 Underwater Noise and Vibrations Levels

Source of Impact

The project activities and their associated aspects that will generate underwater noise are described below.

- Dredging of sediments by cutter suction dredger or backhoe dredge, loading of spoil onto sailing hopper barges for transport of spoil to the sacrificial dump site, and discard of dredge spoil will generate underwater noise. Should rock outcrops be encountered, a hydraulic breaker may be required to remove these; this would generate both noise and vibrations near the seabed.
- The dredge spoil would be loaded onto a series of sailing hopper barges that would sail to the dedicated disposal area and instantaneously release the spoil through bottom doors allowing the dredged material to drop into the sea. This bottom release method permits the rapid and controlled release of dredge spoil once the dredger is on site.
- Deposition of rock material onto the seabed during the construction of underwater revetments and rock armour would generate noise from the barge carrying the rocks to the construction site, the crane used to place the rocks and the deposition of the rocks themselves. Larger quarried rocks (~800 kg) would be used for the toe of the revetment, decreasing in size (>20 kg) further up the slope of the scour protection.

- Construction of the access trestle, offloading platform and mooring and berthing dolphins will require pile driving, rock drilling and other construction noise from marine plant and machinery. Steel casings will be transported to site and stockpiled on flat-decked barges. For the setting of each pile, the casing is picked up and pitched by a crane[4] before being vibrated through the unconsolidated seabed sediments until it reaches bedrock. The casing is then hammered open-ended some distance into the bedrock to seat the pile and/or seal it for socketing, and cleaned out using a grab hammer or by flushing or airlifting out the loose material. The removed material is stockpiled on a barge for subsequent disposal at the sacrificial dump-site. A drill is inserted down the centre of the casing and a hole is drilled into the bedrock. Drill bits are typically attached to a rotating kellybar operated from a diesel-powered drill-unit mounted on a frame or the leads of a crane. Drill cuttings are airlifted to the surface through the kellybar and the material stockpiled onto a barge. A steel pipe pile is then run down the hole a certain distance into the rock and the balance of the hole is filled with a cast-in-place reinforced concrete core, which acts as an extension of the steel pile into the rock thereby providing anchorage. Once anchored the remainder of the steel pipe pile is filled with concrete. A combination of a precast and *in-situ* concrete deck is then placed on the piles to complete the trestle and platform.
- Most of the audible noise coming from the operational FSRU and LNGC would be from power generation turbines. The pumping of heating and cooling water by the LNGC and FSRU, the flow of water through heat exchangers and the transfer and vapourisation of LNG will result in elevated noise levels around the vessels and at the LNG terminal. The FSRU is designed to minimise the impact of noise, including for the crew that stays on board the vessel.

Impact Description

Of all human-generated sound sources, the most persistent in the ocean is the noise of shipping. The noise generated by large vessels is predominantly from cavitation bubbles at the tips of the propellers, as a result of a static pressure drop below ambient water pressure (Hildebrand 2009). Noise is, however, also generated by both the machinery onboard and hydraulic flow over the hull (Hildebrand 2005). Depending on size and speed, the sound levels radiating from vessels range from 160 to 220 dB re 1 μPa at 1 m (NRC 2003). Especially at low frequencies between 5 to 100 Hz, vessel traffic is a major contributor to noise in the world's oceans, and under the right conditions, these sounds can propagate 100s of kilometres thereby affecting very large geographic areas (Coley 1994, 1995; NRC 2003; Pidcock *et al*. 2003).

As the proposed LNG terminal is located within a port, the shipping noise component of the ambient noise environment is expected to be significant within and around the construction site. Given the significant local shipping traffic and relatively strong metocean conditions specific to the area, ambient noise levels are expected to be 90–120 dB re 1 μPa for the frequency range 10 Hz – 10 kHz (SLR Consulting Australia 2020). The noise generated by the vessels, barges and underwater construction in general required for the development of the LNG terminal, falls within the hearing range of most fish and marine mammals, and would be audible for considerable ranges before attenuating to below threshold levels. The received level of noise (and risk of physiological injury or behavioural changes) would depend on the animal's proximity to the sound source. However, unlike the noise generated by pile driving (see below), underwater noise from vessels is not considered to be of sufficient amplitude

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[4] the crane is typically mounted on a barge or a jack-up platform.

to cause direct physical injury to marine life, even at close range (SLR Consulting Australia 2019). The risk of temporary threshold shifts (TTS) close to continuous shipping sounds is generally low. The underwater noise from dredging, LNGC and FSRU vessels and general construction activities may, however, induce localised behavioural changes or masking of biologically relevant sounds in some marine fauna, but there is no evidence of significant behavioural changes that may impact on the wider ecosystem (Perry 2005).

The noise generated during pile-driving varies with the size of the pile being installed, the pile material, the pile-driving method used, as well as the blow energy of the hammer, pulse duration and environmental factors such as water depth and substrate (Popper *et al.* 2006; Robinson *et al.* 2007; Nehls *et al.* 2007; Wyatt 2008). The most common pile driving methods likely to be used during the installation of the access trestle and offloading platform include impact pile-driving and vibro-driving. These are discussed briefly below (Parnum 2009; Reinhall & Dahl 2011; DPTI 2012; Lippert & von Estorff 2014; Glanfield 2015):

- Impact piling – a hydraulic ram is used to hammer the pile into the ground. The noise generated is impulsive and characterised by a rapid build-up to a peak followed by decay, with multiple pulses occurring at blow rates in the order of 30 to 60 impacts per minute. Typical sound exposure levels (SEL) 170–225 dB re 1 $\mu Pa^2 \cdot s$ for a single pulse, sound pressure levels (SPL) of 180–235 dB re 1 µPa, and peak levels of 190–245 dB re 1 µPa. Most of the sound energy usually occurs at lower frequencies between 100 Hz and 2 kHz but there can be substantial energy up to 10 kHz (Bailey *et al.* 2010). Factors that influence the source level include the size, shape, length and material of the pile, the weight and drop height of the hammer, and the seabed material and depth.
- Vibro-driving – rotating eccentric weights create an alternating force on the pile, vibrating it into the ground. The noise generated is continuous or intermittent and may only last a few seconds but is characterised by a build-up to a level that is maintained for a considerable number of cycles. Consequently, sound levels are usually of a much lower level than impact piling with a reduction of about 15 – 20 dB over an impact hammer (Elmer *et al.* 2007; Matuschek & Betke 2009). Typical source levels range from sound pressure levels (SPL) of 160–200 dB re 1 µPa, with most of the sound energy occurring between 100 Hz and 2 kHz. Strong tones at the driving frequency and associated harmonics may occur with the driving frequency typically ranging between 10 and 60 Hz. Sound propagation at such low frequencies is often poor in shallow water environments, such that the tones may not be noticeable at greater distances from the source.

A number of different mechanisms for producing the sound come in to play during pile driving (Duncan *et al.* 2010). Firstly, there is the direct radiation from the impacted portion of the pile in the water column and there is also the mechanical vibrations and sudden displacement of the pile in the seabed. This motion and vibration of the pile also contribute to the overall sound produced; the harder the composition of the seabed, the more difficult it is to drive the pile and the larger the hammer energy required. Sound can also be transferred by the substrate and then emerge within the water column at some distance from the source (Hawkins 2009). At Ngqura, this has potential impacts on the adjacent MPA and EBSA, as the noise generated by pile driving may not be confined to the port.

Exposure to high sound levels can result in physiological injury to marine fauna through a number of avenues, including shifts of hearing thresholds (as either permanent (PTS) or temporary threshold shifts (TTS)), tissue damage, acoustically induced decompression sickness, and non-auditory physiological effects. Both PTS and TTS represent actual changes in the ability of an animal to hear, usually at a particular frequency, whereby it is less sensitive at one or more frequencies as a result of exposure to sound. In assessing injury from noise, a dual criterion is adopted based on the peak sound pressure level (SPL) and sound exposure level (SEL) (a measure of injury that incorporates the sound pressure level and duration), with the one that is exceeded first used as the operative injury criterion. PTS-onset and TTS-onset thresholds differ between impulsive and non-impulsive noise, with ranges for marine mammals summarised in Table 3. The assessment criterion for the onset of behavioural disruption in marine mammals of all hearing groups is root-mean-square (RMS) SPL of 160 dB re 1μPa for impulsive noise and 120 dB re 1μPa for non-impulsive noise (NMFS 2013).

The high sound and vibration levels associated with hydraulic rock breaking and pile-driving can therefore cause permanent or temporary damage to the acoustics systems of at least some marine species, with marine mammals and fish known to be particularly susceptible (Anderson 1990; Reyff 2004; Carstensen *et al*. 2006; David 2006; Carlson & Weiland 2007). Most studies have focused on the impacts of impact pile driving (but see Graham *et al*. 2017) and have concluded that pile-driving sound could kill or injure fish in the close vicinity of the construction site, with temporary hearing loss likely at slightly farther ranges, depending on whether the fish move away in response to the sound (see OSPAR 2009; Popper & Hastings 2009). Responses to piling noise in fish include impaired startle response (Everley *et al*. 2016), freezing response (Mueller-Blenkle *et al*. 2010), to no response at all (Nedwell *et al*. 2006; Ruggerone *et al*. 2008). Fish species strongly associated with structures such as jetties and breakwaters or that form resting schools may be less likely to leave the area and therefore be more prone to physiological injury from piling noise (Iafrate *et al*. 2016).

Behavioural changes in fish can occur at greater distances from the source and therefore may affect a larger portion of a population, by causing movement of fish away from feeding or breeding grounds or changes in migratory behaviour. For example, it was estimated that cod and herring could perceive pile-driving sounds over distances of at least 80 km from the source or within the zone of audibility (Thomsen *et al*.2006; Tougaard *et al*. 2009; Mueller-Blenkle *et al*. 2010; Ellison *et al*. 2012)). Such behavioural responses could potentially prevent fish from reaching breeding or spawning sites if migratory corridors (e.g. river mouths) are affected. In species subject to national or international conservation efforts and/or of commercial interest, such potential long-term effects on reproduction and survival could have significant ecological consequences. Additionally, consequences could be more severe if pile driving occurs within critical habitat of endangered species.

For marine mammals, PTS onset has been reported within 5 m of piling operations for cetaceans and within 20 m for pinnepeds, with TTS exceeded within 10 m and 40 m, respectively. Behavioural effects in marine mammals can occur within 20 km of the noise source, extending to 50 km and 40 km for bottlenose dolphins and minke whales (David 2006; Bailey *et al*. 2010; Brandt *et al*. 2011; Russell *et al*. 2016). These authors determined that the noise of impact pile driving capable of masking vocalisations in dolphins over significant distances.

Table 3: PTS- and TTS-onset threshold levels for marine mammals exposed to impulsive and non-impulsive noise (Southall *et al*. 2019).

Marine mammal hearing group	PTS and TTS threshold levels impulsive noise				PTS and TTS threshold levels non-impulsive noise	
	Injury (PTS) onset		TTS onset		Injury (PTS) onset	TTS onset
	Pk SPL, dB re 1μPa (unweighted)	SEL$_{24hr}$, dB re 1μPa^2·S (weighted)	Pk SPL, dB re 1μPa (unweighted)	SEL$_{24hr}$, dB re 1μPa^2·S (weighted)	SEL$_{24hr}$, dB re 1μPa^2·S (weighted)	SEL$_{24hr}$, dB re 1μPa^2·S (weighted)
Low-frequency cetaceans	219	183	213	168	199	179
High-frequency cetaceans	230	185	224	170	198	178
Very high-frequency cetaceans	202	155	196	140	173	153
Sirenians	226	203	220	175	206	186
Phocid carnivores in water	218	185	212	170	201	181
Other marine carnivores in water	232	203	226	188	219	199

Sensitivity of Receptors

Vessel noise would primarily take place in the harbour area behind the breakwater, on the way to the dredge disposal site, and during transit of the LNGCs. The possible noise effects of the pile-driving operations on marine fauna in the port area will depend on the method used to install the piles and sensitivity of the species present. Any mobile marine fauna particularly sensitive to noise (e.g. seals, dolphins, penguins and finfish species) are expected to avoid the construction area once piling activities commence, thereby moving away from the sound source before trauma could occur. The maximum radius over which the noise of pile driving may influence is also comparatively small relative to the population distribution ranges of the potentially sensitive species.

The taxa most vulnerable to disturbance by underwater noise are fish, turtles, diving seabirds and marine mammals. Some of of the species potentially occurring in the project area, are considered regionally or globally 'Critically Endangered' (e.g. leatherback turtles, Damara terns), 'Endangered' (e.g. African Penguin, whale shark, Indian Ocean humpback dolphin, fin and sei whales), 'vulnerable' (e.g. loggerhead turtles, dusky shark, great white shark, Bryde's and humpback whales) or 'near threatened' (e.g. Indo-Pacific bottlenose dolphin). Although not all of these have been reported from within the Port of Ngqura, they are likely to occur in Algoa Bay and may be affected by the underwater noise in the far-field.

The responses of cetaceans to noise sources are often also dependent on the perceived motion of the sound source as well as the nature of the sound itself. Many whales, for example, are more likely to tolerate a stationary source than they are one that is approaching them (Watkins 1986; Leung-Ng & Leung 2003), or are more likely to respond to a stimulus with a sudden onset than to one that is continuously present (Malme *et al.* 1985).

Impact Significance

The underwater noise generated by construction barges, dredgers and general construction noise is deemed to be of medium intensity but would remain localised to the port or just beyond and would persist over the short-term only. As disturbance effects due to construction noise will definitely occur, the significance of dredging and general construction noise is deemed to be of **VERY LOW** significance.

The underwater noise generated by the LNGC and FSRU is deemed to be of low intensity, remaining localised to the port or just beyond but persisting over the long-term. As the noise will be a stationary source with likely habituation by affected groups, the behavioural disturbance is considered possible. The significance of noise from the LNGC and FSRU is thus deemed to be of **VERY LOW** significance.

In the case of pile driving, the intensity of the impact is considered high, and impacts may extend considerable distances beyond the construction site are therefore of regional extent, but persist over the short-term only. Due to the sound levels involved, noise impacts on fish and marine mammals are definite and consequently the impact is considered of **MEDIUM** significance without mitigation.

Impact: Disturbance, behavioural changes and avoidance of feeding and/or breeding areas in fish, seabirds, seals, turtles and cetaceans due to underwater noise generated by dredging and general construction

<table>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Local
1</td><td>Medium
2</td><td>Short-term
1</td><td>Very Low
4</td><td>Definite</td><td>VERY LOW</td><td>- ve</td><td>High</td></tr>
<tr><td colspan="9">Essential mitigation measures:
• Restrict construction noise and vibration-generating activities to the absolute minimum required.
Best practice mitigation measures:
• Have good house-keeping practices in place during construction.</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Low
1</td><td>Short-term
1</td><td>Very Low
3</td><td>Probable</td><td>VERY LOW</td><td>- ve</td><td>High</td></tr>
</table>

Impact: Disturbance, behavioural changes and avoidance of feeding and/or breeding areas in fish, seabirds, seals, turtles and cetaceans due to underwater noise from the LNGCs and FSRU

<table>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Local
1</td><td>Low
1</td><td>Long-term
3</td><td>Low
5</td><td>Possible</td><td>VERY LOW</td><td>- ve</td><td>Medium</td></tr>
<tr><td colspan="9">Essential mitigation measures:
• No mitigation possible other than the no-go option.
Best practice mitigation measures:
• Have good house-keeping practices in place on the vessels to reduce noise effects.</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Low
1</td><td>Long-term
3</td><td>Low
5</td><td>Possible</td><td>VERY LOW</td><td>- ve</td><td>High</td></tr>
</table>

Impact: Disturbance, behavioural changes and avoidance of feeding and/or breeding areas in fish seabirds, seals, turtles and cetaceans due to pile driving, underwater drilling and hydraulic rock breaking

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Regional 2	High 3	Short-term 1	**Medium** 6	Definite	**MEDIUM**	**- ve**	Medium

Essential mitigation measures:

- Ensure that all pile driving is undertaken in accordance with international protocols (e.g. JNCC 2010; DPTI 2012), which stipulate:
  - Avoid conducting piling activities during times when marine mammals are likely to be breeding, calving, feeding, or resting in biologically important habitats. In Algoa Bay, African Penguins breeding is extended, but nesting usually peaks from March to May; nesting of Cape Gannets extends from August to April. Humpback whales pass through the area around April, continuing through to September/October when the southern migration begins and continues through to December; cow-calf pairs are usually the last to leave and may use Algoa Bay as a resting site on their way south. Southern right whales typically arrive in coastal waters between June and November each year, although animals may be sighted as early as April and as late as January. Southern rights are found in groups of 1-10 individuals, with cow-calf pairs predominating in inshore nursery areas. From July to October, animals aggregate and become involved in surface-active groups, which can persist for several hours. Piling operations should therefore take place between January and March.
  - Use low noise piling methods, such as vibro-driving, instead of impact piling methods where possible.
  - Piling activities should be monitored by Marine Mammal Observers (MMO) and Passive Acoustic Monitoring (PAM) operatives to detect marine mammals and to potentially recommend a delay in the commencement of piling activity if any marine mammals are detected;
  - Establish a 500 m radius mitigation zone around the pile driving activity (measured from the pile location);
  - Prior to the commencement of pile driving operations, the mitigation zone must be monitored visually by MMO and acoustically by PAM for a period of at least 30 minutes;
  - Piling should not be commenced if marine mammals are detected within the mitigation zone or until 20 minutes after the last visual or acoustic detection;
  - Implement a 'soft-start' procedure of at least 10 minutes at the start of piling operations. This involves the gradual ramp-up of piling power allowing marine mammals and fish to move away from the noise source;
  - Piling should not commence in the dark or during periods of low visibility;
  - If a marine mammal enters the mitigation zone during the soft-start then, whenever possible, the piling operation should cease, or at the least, the power should not be further increased until the marine mammal exits the mitigation zone, and there is no further detection for 20 minutes.
  - When piling at full power, there is no requirement to cease piling or reduce the power if a marine mammal is detected in the mitigation zone. The marine mammal should, however, be continuously monitored by MMO;
  - If there is a pause in the piling operations for a period of greater than 10 minutes, then the pre-piling search and soft-start procedure should be repeated before piling recommences. If a watch has been kept during the piling operation, the MMO or PAM operative should be able to confirm the presence or absence of marine mammals, and it may be possible to commence the soft-start immediately.

    However, if there has been no watch, the complete pre-piling search and soft-start procedure should be undertaken;
    - The MMO and PAM reports compiled in accordance with JNCC guidelines should be sent to the relevant conservation agency after the end of the piling activity.
- Include the standard management and mitigation procedures, and any in the contract documentation of the construction contractor;
- Consider the use of a bubble curtain. As the noise from pile driving is transmitted through the sediment into the water, bubble screens do not eliminate all behavioural responses to the piling noise, but reported noise reductions range from 3 to 20 dB (Würsig *et al.* 2000; DPTI 2012).

Best practice mitigation measures:

- Demonstrate that the BATNEEC (Best Available Technique Not Entailing Excessive Cost) approach has been applied to proposed pile driving operations.
- Avoid pile driving in the early morning and evening when penguins and gannets are leaving for offshore feeding areas, or returning to their nesting sites.
- Consider the use of Acoustic Deterrent Devices in conjunction with visual and/or acoustic monitoring to exclude animals from the piling area;
- To improve the confidence rating in the assessment of significance, consider engaging an acoustic consultant to undertake a site specific underwater noise assessment before the start of construction of the access trestle and dolphin berths. At a minimum this should address:
    - Determine the existing ambient noise environment based on measurements.
    - Establish the likely hearing sensitivity and bandwidth for the considered sensitive marine mammal species, and determine noise exposure criteria for behavioural and physiological impacts.
    - Determine the expected source levels for the piling/construction activity, and predict received levels versus distance from the piling activity using a suitable noise propagation modelling method.
    - Estimate the size of the zone of audibility, responsiveness, and hearing injury based on the above information, and determine suitable sizes for the safety zones.

With mitigation	Local 1	Medium 2	Short-term 1	**Very Low** **4**	Definite	**VERY LOW**	**- ve**	High

Potential for Cumulative Effects

Although noise and vibrations associated with construction activities are ephemeral, the cumulative impact of increased background anthropogenic noise levels in the oceans has been recognised as an ongoing and widespread issue of concern (Koper & Plön 2012). The long term cumulative impacts of noise on marine organisms in the port are therefore predicted to be of medium significance.

4.2.5 Creation of Artificial Hard Substrata

Source of Impact

The project activities and their associated aspects that will result in the habitat alteration and the creation of hard substrata are described below.

- Deposition of rock material onto the seabed during the construction of underwater revetments and rock armour would transform the unconsolidated sediments in the dredged area into a high-profile artificial reef.
- Installation of piles to support the access trestle and for the mooring and berthing dolphins would provide additional vertical/near vertical hard surfaces for colonisation by biofouling communities

Impact Description

The construction of underwater revetments, and rock armouring, and the installation of piles will result in the physical destruction of subtidal soft-sediment habitats. Although the construction of these hard structures will result in a permanent net loss of soft-sediment habitat, this negative impact will be temporary only through the replacement by hard substrata offering alternative habitats for colonisation.

The composition of the fouling community on artificial structures depends on the age (length of time immersed in water) and the composition of the substratum, and usually differs from the communities of nearby natural rocky reefs (Connell & Glasby 1999; Connell 2001). Colonization of hard substratum goes through successional stages (Connell & Slayter 1977). Early successional communities are characterized by opportunistic algae (e.g. *Ulva* sp., *Enteromorpha* sp.). These are eventually displaced by slower growing, long-lived species such as mussels, sponges and/or coralline algae, and mobile organisms, such as urchins and lobsters, which feed on the fouling community. With time, a consistent increase in biomass, cover and number of species can usually be observed (Bombace *et al*. 1994; Relini *et al*. 1994; Connell & Glasby 1999). Depending on the supply of larvae and the success of recruitment, the colonization process can take up to several years. For example, a community colonising concrete blocks in the Mediterranean was found to still be changing after five years with large algae and sponges, in particular, increasing in abundance (Relini *et al*. 1994). Other artificial reef communities, on the other hand, were reported to reach similar numbers of species (but not densities and biomass) to those at nearby artificial reefs within eight months (Hueckel *et al*. 1989).

Sensitivity of Receptors

The area proposed for the LNG terminal lies within an enclosed water body that has been created on a previously open shoreline, and the entire port comprises artificial hard structures that have been placed on what was previously a linear sandy shore. The adjacent dolosse of the main eastern breakwater and the recently constructed ACB breakwater all represent introduced artificial substrata and their succession communities will be in different stages of development and not necessarily representative of nearby natural rocky intertidal and subtidal habitats. Klages *et al* (2006) reported that the intertidal zone of the harbour structures supported brown mussel *Perna perna* and rock oyster *Striostrea margaritacea,* as well as attached epiphytic and filamentous algae, barnacles (*Tetraclita, Chthamalus*) etc., species that can be considered as being typical of the region. It appears therefore that the development of biofouling communities can be rapid in this particular location.

Impact Significance

Although artificial structures will provide a new settling habitat for reef dwellers, the biofouling community that will establish itself on the new artificial structures over the short-term will be different from that characterising the original unconsolidated sediments. The creation of artificial hard substrata through the placement of revetments and rock armour, and the installation of piles is thus deemed to be of low intensity. The impact can be considered positive as the developing successional biofouling communities would serve as a food source for reef-associated fish and invertebrate species thereby potentially enhancing the biodiversity and abundance in the port. The effect will be highly localised and limited to the area of the artificial structures themselves. The impact is assessed to be of **VERY LOW** significance. No mitigation is possible other than the no-project alternative.

Impact: Creation of Artificial Hard Substrata

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Medium 2	Short-term 1	**Very Low** 4	Definite	**VERY LOW**	**+ ve**	High
Essential mitigation measures: • No direct mitigation possible other than the no-project alternative.								
With mitigation	Local 1	Medium 2	Short-term 1	**Very Low** **4**	Definite	**VERY LOW**	**+ ve**	High

Potential for Cumulative Effects

Any developments within the port that require the installation of hard structures will have a cumulative impact on the availability of hard substrata for colonisation by marine organisms. The long term cumulative impacts are, however, expected to be of low significance.

4.2.6 Intake of Large Volumes of Seawater from the Port

Source of Impact

The project activities and their associated aspects that will result in the intake of large volumes of seawater are described below.

- The FSRU is typically equipped with four seawater intakes, each with a pipe diameter of 1.4 m and located within ~30 m of one another near the stern of the vessel. While in operation, seawater will be continuously sucked into the FSRU through two of these intakes, with the remainder being used only as a back-up or when the high level intakes are being cleaned. Maximum flow rates of 14,767 m^3/h (~354,400 m^3/day) (WSP 2020) are expected for the vapourisers alone, with cooling water requirements ranging from 1,250 m^3/h (30,000 m^3/day) when using supplemental power from onshore facilities to as high as

9,800 m^3/h (235,000 m^3/day) (FERC 2015). A further 120 m^3/day is required for onboard desalination (Note: this is production capacity and the full volume is unlikely to be realised). During normal water use capacity, the presence of screens on the intakes ensure that the through-screen velocity of water entering the sea chests is in the order of 0.14 m/s and therefore below the threshold of 0.15 m/s recommended as best practice to minimise impingment and entrainment (IFC 2007; EPA 2011).

- Water requirements for the LNGCs engine cooling systems would represent the main water intake during operation and unloading. Flow rates would be similar to the FSRU (i.e. 1,250 – 9,800 m^3/h).
- Both LNGC and FSRU vessels have a ballast control system, which permits simultaneous ballasting during cargo transfer thereby maintaining draft, trim and stability of the vessels. The FSRU in turn discharges ballast water while loading LNG from the carrier, and takes on ballast water to offset the vaporization and transfer of gas to the power plants. Intake rates for ballast water range from 2,600 to 3,900 m^3/h with as much as 65,100 to 280,900 m^3 of water required per vessel for ballast while LNG is offloaded at the terminal (FERC 2015), varying according to operational status and sea conditions. Ballast water intake rates as high as 7,600 m^3/h have been reported (FERC 2005).
- During LNG transfer or regasification it is common practice for most LNG vessels to maintain a constant flow of water, referred to as a “water curtain,” over the deck and hull of the vessel. In the event of a LNG leak during these operations, the presence of the water curtain helps protect the metal hull from any potential cracking or stress. The FSRU would use seawater drawn through the sea chests, pumped onto the deck at a flow rate of ~2,270 m^3/day, and then discharged over the port and starboard sides of the vessel as runoff.

Impact Description

The intake of large volumes of water directly from the ocean through the submerged intakes of the LNGC and FSRU has the potential to entrain and impinge large numbers of marine species, particularly eggs and larvae (see for example Sadler 1980; California Energy Commission 2005; Poorima *et al.* 2006; Newbold & Iovanna 2007; Chuang *et al.* 2009). Impingement refers to injury or mortality of larger organisms (e.g. fish, jellyfish, turtles) that collide with and are trapped by intake screens, whereas entrainment refers to smaller organisms that slip through the screens and are taken into the vessels with the cooling/heating water or ballast water. Impingement mortality is typically due to suffocation, starvation, or exhaustion due to being pinned up against the intake screens. The significance of impingement is related primarily to the location of the intakes and is a function of intake velocity.

While using screens reduce the impingement caused by seawater intakes, entrainment effects are likely to remain, as most of the entrained organisms are too small to be screened out without significantly reducing the intake water volume. Entrained material includes holoplanktic organisms (permanent members of the plankton, such as copepods, diatoms and bacteria) and meroplanktic organisms (temporary members of the plankton, such as juvenile shrimps and the planktonic eggs and larvae of invertebrates and fish). Fish and invertebrates entrained into industrial water intake structures experience nearly 100% mortality from the combined stresses associated with altered temperatures, toxic effects of biocides added specifically to eliminate and kill entrained biota, and mechanical and pressure-related injuries (Enright 1977; Hanson *et al*. 1977; Moazzam & Rizvi 1980; Barker *et al*. 1981; Richkus & McLean 2000). The significance of entrainment is related both to the location of the intake, as well as the overall volume of water required.

Depending upon the size of the FSRU and LNGCs, thousands of litres of water and its associated marine life can be transferred to the ballast tanks at a rate of tens of thousands of litres per minute. Ballast water requirements range from 52,000 m^3 (138,000 m^3 vessel) to 75,000 m^3 (200,000 m^3 vessel) at intake rates of up to 7,600 m^3/h (FERC 2005). With cooling water requirements, water for onboard desalination, the safety water curtain and heating water for regasification, the total water requirements for potentially two FSRUs and a LNGC would amount to in the order of 81,900 m^3/h (Table 4). The use of seawater at these volumes and rates, particularly from a confined water body such as a port, would have the potential to affect the productivity of coastal ecosystems (particularly that in the harbour area), but effects are difficult to quantify (see for example UNEP 2008; WHO 2007).

Table 4: Worst-case scenario seawater flow rates for a LNG carrier and potentially two FSRUs.

	LNGC1 Flow rate (m^3/hr)	FSRU1 Flow rate (m^3/hr)	FSRU2 Flow rate (m^3/hr)
Ballast	7,600	7,600	7,600
Cooling	9,800	9,800	9,800
Desalination	5	5	5
Water curtain	--	95	95
Vapourisation	--	14,767	14,767
TOTAL	17,405	32,267	32,267

Although planktonic organisms show temporal and spatial variations in species abundance, diversity and productivity, it can be assumed that the common native species will be prevalent in coastal surface waters and may be present in the port. Furthermore, as planktonic species typically have rapid reproductive cycles, it seems unlikely that the operation of a FSRU facility will have a substantial negative effect on the ability of plankton organisms to sustain their populations within Algoa Bay. Localised effects within the Port of Ngqura can, however, be expected. The entrainment of the eggs and larvae of invertebrate and fish species occurring in the Ngqura Harbour may, however, adversely affect the ability of these species to maintain populations within the port, and may have negative implications for the continued use of the port as a nursery area and summer habitat for a number of teleost and chondrythian species.

Water intake structures, such as power plants and industrial facilities, have been identified as a source of mortality for managed-fishery species and play a role as one of the factors driving changes in species abundance over time (Richkus & McLean 2000). In a case study conducted for a proposed offshore open-loop LNG degasification facility in the USA, the estimated annual mortality of eggs and larvae from vessel ballast and cooling water amounted to 8.5 million, 7.8 million, 411,000, and 569,000 for Atlantic mackerel (*Scomber scombrus*), pollock (*Pollachius virens*), yellowtail flounder (*Limanda ferruginea*), and Atlantic cod (*Gadus morhua*), respectively (US CG 2006). In contrast, entrainment studies undertaken for Seawater Reverse Osmosis Plants, where the intake volumes are considerably higher than those considered for the FSRU, showed that the estimated effects of fish larvae entrainment were minimal and indicated little potential for population-level effects (Tenera Environmental 2007). It was argued that the entrainment of eggs and larvae of common invertebrate and fish species is unlikely to adversely affect the ability of these species to successfully reproduce, as their reproduction strategy involves production of a large number of eggs and larvae, of which only a small percentage reaches maturity due to natural mortality (such as starvation of larvae or failure to settle in a suitable location).

The proximity of intakes to estuary mouths potentially increases the significance of entrainment. Estuaries are important nurseries for many marine-spawned fishes and crustaceans, and larvae and juveniles of these species are likely to be concentrated in the vicinity of estuary mouths during critical recruitment periods.

The question is whether entrainment causes a significant additional source of mortality, which may have a substantial negative effect on the ability of a species to sustain its population, i.e. cumulative effects such as the existence of other nearby seawater intakes (Cerebos and Zone 10 power plants and Engie FSU). While it is relatively simple to quantify the levels of entrainment for a specific project, it is difficult and complex to estimate the actual ecosystem impacts, especially when cumulative effects with other projects (e.g. desalination plants, aquaculture farms and/or power plants) may occur. Cumulative impacts of entrainment and entrapment are usually only an issue in cases where multiple feedwater intake systems are developed in bays or inlets where water exchange is somewhat reduced. On an open coastline, cumulative impacts are generally unlikely; however, given the absence of information on entrainment and entrapment rates of the existing industries, actual ecosystem effects remain difficult to estimate.

An issue of potential concern in large-volume intakes is the removal of particulate matter from the water column, where it is a significant source of food for surf zone and nearshore communities (UNEP 2008; WHO 2007). Although the effects are difficult to quantify, this is unlikely to be of significance in the port area. Algoa Bay itself, and the adjacent surf zone in particular is particularly productive and particulate organic matter frequently accumulates on the beach as foam and scum.

In their review of the impacts of non-fishing activities on marine fisheries habitat, Johnson *et al.* (2008) concluded that both entrainment and impingement of fish and invertebrates in large-volume intakes may potentially have immediate as well as long-term impacts on marine ecosystems, both directly through removal of fish and invertebrate biomass from the system, and indirectly through cascade effects on higher order consumers (see for example Rago 1984). Such effects would be difficult to quantify, however.

Sensitivity of Receptors

The Port of Ngqura supports one of the most abundant and diverse fish populations along the South African coastline, functioning as an important habitat for both juvenile and adult fish, representing both estuarine and shore species (Dicken 2010). Of the most commonly occurring species, the Dusky kob (*Argyrosomus japonicas*) is considered 'Critically Endangered', wheras the elf (*Pomatomus saltatrix*), spotted grunter (*Pomadasys commersonnii*) and garrick (*Lichia amia*) are rated as nationally 'Vulnerable'. The Port also serves as an important summer habitat and core activity zone for neonate and juvenile dusky sharks (*Carcharinus obscurus*), and may serve as an important nursery area for the species (Dicken 2011). Many of the teleost species occurring in the port are commonly found in the diet of juvenile dusky sharks, and this abundance of prey may be a significant factor in attracting sharks to the port (Dicken 2011). Although the national assessment identifies dusky sharks as being 'data deficient', its IUCN Conservation status is considered 'Vulnerable'. Other chondrichthyans reported from the harbour are the great white shark and giant manta, both of which are considered 'Vulnerable' by the IUCN, and the whale shark which is rated as 'Endangered'.

The dolosse habitat in particular supported the greatest abundance of fish. The propsed LNG offloading terminal would be located immediately adjacent to the dolosse area at the base of the breakwater.

The bulk of the South African population of 'Critically Endangered' Damara terns nest near the proposed zone 10 power plant site (Whittington *et al.* 2015) and feeds in the port. The African Penguin that breeds on St Croix Islands and feeds on small pelagic shoaling species within 20-30 km of their breeding sites (Crawford *et al.* 1999, Pichegru *et al.* 2009) is listed as 'Endangered'. Similarly, the Cape Gannet, which breeds on Bird Island is considered 'Endangered'

The Port also falls within the conservation zone of the Algoa to Amathole EBSA, whereas the dredge spoil disposal site now falls within the Addo Elephant MPA, which protects important feeding areas for the 9,000 pairs of African Penguins and the 60,000 pairs of Cape Gannets.

Impact Significance

The impingement and entrainment of marine organisms through the intake of large volumes of seawater by the LNGC and FSRU for ballasting and heating and cooling of onboard processes is deemed to potentially be of medium intensity. The effect will be highly localised but would continue over the medium- (FSRU and LNGC) to long-term (LNGC only) and is assessed to be of **MEDIUM** significance.

Impact: Intake of large volumes of seawater from the port

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Medium 2	Long-term 3	**Medium** 6	Definite	**MEDIUM**	**- ve**	Low

Essential mitigation measures:

- Design intakes to minimise entrainment or impingement by reducing the average intake velocity to about 0.1 to 0.15 m/s. This is comparable to background currents in the oceans, and will allow mobile organisms to swim away from the intake under these flow conditions (UNEP 2008).
- Optimise operating modes in the open-loop system as far as possible to reduce impacts, or use closed-loop systems in recruitment areas or during periods when abundances of eggs and larvae are seasonally high.
- Undertake an entrainment study to more accurately determine the potential impacts of impingement and entrainment on communities within the Port of Ngqura.

Best practice mitigation measures:

As per IFC (2007) and World Bank (2017) guidelines for FSRUs

- Consider water conservation opportunities for LNG facility cooling systems (e.g. air cooled heat exchangers in place of water cooled heat exchangers and opportunities for the integration of cold water discharges with other proximate industrial or power plant facilities). The selection of the preferred system should balance environmental benefits and safety implications of the proposed choice.

• Discharge cooling or cold water to surface waters in a location that will allow maximum mixing and dulition of the thermal plume to ensure that the temperature is within 3 °C of ambient temperature at the edge of the mixing zone or within 100 meters of the discharge point.								
With mitigation	Local 1	Low 1	Long-term 3	**Low** **5**	Definite	**LOW**	**- ve**	High

Potential for Cumulative Effects

With the development of multiple gas-to-power projects within the port and in the Coega CDC large volumes of seawater will be required for both cooling and regasification. Any impingement and entrainment effects will therefore be cumulative, potentially extending over the long term. Without the results of an entrainment study to more accurately determine the potential impacts of impingement and entrainment on communities within the Port of Ngqura, the cumulative impacts of the extraction of large volumes of seawater from the harbour is difficult to predict with confidence. In a comparatively confined space such as the Port of Ngqura, cumulative impacts could be of medium to high significance.

4.2.7 Introduction and/or Spread of Invasive Alien Species

Source of Impact

The project activities and their associated aspects that may result in the introduction and / or spread of invasive alien species are described below.

- To maintain draft, trim and stability during unloading of LNG from the carrier and regasification on the FSRU, both vessels have a ballast control system. The LNGC takes on ballast water as it unloads LNG to the FSRU. The FSRU, in turn, discharges ballast water while loading LNG from the carrier, and takes on ballast water to offset the vaporization and transfer of gas to the power plants.
- LNGCs calling at the port may have bio-fouling organisms on their hulls from other parts of the ocean and that therefore constitute non-native species.

Impact Description

Vessel hulls serve as a substrate for a wide variety of larvae, cysts, eggs and adult marine organisms. The transportation of LNG from one part of the ocean to another would therefore also facilitate the transfer of the associated marine organisms. LNGCs are used and relocated all around the world. Similarly, the ballasting and de-ballasting of vessels may lead to the introduction of exotic species and harmful aquatic pathogens to the marine ecosystems (Bax *et al*. 2003). Ballast water discharges, occurring when ships take on additional cargo while at a port, are one of the largest pathways for the introduction and spread of marine invasive alien species. Many aquatic nuisance species are transported and released in ballast in their larval stages, become bottom-dwelling as adults, and can have wide-reaching impacts to the marine ecosystem, the economy, and human health.

The marine invertebrates that colonize the surface of vessels can easily be introduced to a new region, where they may become invasive by out-competing and displacing native species and can potentially alter nutrient cycling and energy flow leading to cascading and unpredictable ecological effects (Carlton 2001). Marine invasive species are considered primary drivers of ecological change in that they create and modify habitat, consume and out-compete native fauna, cause the loss of native genotypes, act as disease agents or vectors, affect food web properties and ecosystem processes and threaten biodiversity, impede the provision of ecosystem services, impact human health and cause substantial economic losses (Katsanevakis *et al.* 2014). Once established, an invasive species is likely to remain in perpetuity (Bax *et al.* 2003).

The most important pathways in the transfer of marine alien species have always been related to shipping (Hewitt *et al.* 1999; Ruiz *et al.* 2000; Ruiz & Carlton 2003), with primary introduction events arising mainly from ships moving between major international ports and secondary local spread occurring *via* regional vessels (Wasson *et al.* 2001; Lacoursière-Roussel *et al.* 2012).

The principal vectors responsible for the transfer of alien invasive species are ballast water and external hull fouling (Carlton 1987, 1999; Hewitt *et al.* 2009). Following the prohibition of harmful organotins, such as tributyltin (TBT), in anti-fouling paints (IMO 2001), hull fouling remains responsible for a large proportion of current alien introductions. More than half of the recognised marine alien species in the United Kingdom have been associated with shipping, with the main vector being fouling (Eno 1996), with Australia demonstrating a similar pattern (Thresher 1999).

In South Africa, the first review of marine alien species was published in 1992 and listed 15 introduced species (Griffiths *et al.* 1992). This number has grown rapidly since then, with the National Biodiversity Assessment (Sink *et al.* 2019) reporting 96 introduced marine species including 55 that are considered to be invasive. Invasive species were more prevalent on rocky shores than in other broad ecosystem groups and in the Southern Benguela than in other ecoregions. Shipping activity has been responsible for 86% of these marine introductions, 48% of which are due to fouling and 38% to ballast water. Of the introductions, 53% were concentrated within harbour areas (Mead *et al.* 2011).

The LNGC will more than likely have spent time outside of South Africa's EEZ prior to offloading the LNG at Ngqura. This exposure to foreign water bodies and possible loading of ballast water increases the risk of introducing invasive or non-indigenous species into South African waters. The risk of this impact is, however, significantly reduced due to the implementation of ballast water management measures in accordance with the International Maritime Oranisation (IMO) guidelines. The risk is further reduced due to the LNGCs being laden on arrival, with de-ballasting only occurring once they return to their home-port to load more LNG. They might, therefore, introduce non-native marine organisms into waters at their home ports. Ballasting and de-ballasting of the FSRU will occur only within the Port and will thus not pose an additional risk to the introduction of invasive species.

As the port hosts international cargo vessels, the introduction of invasive species into South African waters due to hull fouling of LNGCs is unlikely to add to the current risk that exists due to the numerous vessels that call at the port on a daily basis.

Sensitivity of Receptors

The ballasting and de-ballasting of the LNGCs and FSRU would primarily take place in the Port of Ngqura. A survey conducted in the Port in 2013 (Anchor Environmental 2013) identified that of the invertebrate species collected, 18% were alien to South Africa, 9% were endemic to South Africa, and 40% were widespread or cosmopolitan species. The alien introductions included the barnacle *Balanus glandula*, the isopod *Dynamene bidentata* and the ascidian *Styela plicata*. Whether these occur outside of the port is not know.

The Port falls within the conservation zone of the Algoa to Amathole EBSA, and lies close to the western boundary of the Addo Elephant MPA, which protects the Algoa Bay Islands. The islands form ecological distinct subtidal habitats, containing many endemic invertebrates, algae and linefish, and as such would be most sensitive to the introduction of non-native species.

Impact Significance

The introduction and spread of non-native species through hull fouling or ballast water discharge by the LNGC and FSRU is deemed to potentially be of medium intensity. If alien species become established they could spread regionally and persist in perpetuity. As the LNGCs would, however, not be de-ballasting in the Port, it is improbable that non-native species would be introduced through ballast water, although they may still be introduced through hull fouling. The impact is thus assessed to be of **MEDIUM** significance without mitigation.

This potential impact cannot be eliminated due to the necessity of bringing LNGC vessels into the port from other parts of the world, and the need for de-ballasting these once the vessel returns to its base.

Impact: Introduction and spread of non-native species

<table>
<tr><th></th><th><i>Extent</i></th><th><i>Intensity</i></th><th><i>Duration</i></th><th><i>Consequence</i></th><th><i>Probability</i></th><th><i>Significance</i></th><th><i>Status</i></th><th><i>Confidence</i></th></tr>
<tr><td>Without mitigation</td><td>Regional
2</td><td>Medium
2</td><td>Long-term
3</td><td>High
7</td><td>Possible</td><td>MEDIUM</td><td>- ve</td><td>High</td></tr>
<tr><td colspan="9">Essential mitigation measures:
• The LNGCs must have a Ballast Water Management Plan in place.
• Ballast water exchange must be done at least 200 nautical miles from the nearest land in waters of at least 200 m deep; the absolute minimum being 50 nautical miles from the nearest land.
• Ensure that routine cleaning of ballast tanks to remove sediments is carried out, where practicable, in mid-ocean or under controlled arrangements in port or dry dock, in accordance with the provisions of the ship's Ballast Water Management Plan.
• Use filtration procedures during loading of ballast in order to avoid the uptake of potentially harmful aquatic organisms, pathogens and sediment that may contain such organisms.

Best practice mitigation measures:
• Ensure that hulls are regularly cleaned in controlled environments at ports certified to undertake such operations.</td></tr>
<tr><td>With mitigation</td><td>Regional
2</td><td>Low
1</td><td>Long-term
3</td><td>Medium
6</td><td>Improbable</td><td>LOW</td><td>- ve</td><td>High</td></tr>
</table>

Potential for Cumulative Effects

Any further port developments that result in an increase in vessel traffic to and from the port will result in an increased risk in the introduction of non-native marine organisms. The long term cumulative impacts of the introduction and spread of alien species are difficult to predict with confidence, but could be of medium to high significance (depending on the species involved and its invasive abilities). The implementation of an invasive species monitoring programme by the Port authorities should provide valuable information on this.

4.2.8 Discharge of high volumes of Thermal Effluent

Source of Impact

The project activities and their associated aspects that will result in the discharge of high volumes of water with elevated or depressed temperatures are described below.

- When operating in open-loop mode, the vapourising process uses ambient seawater as a heat source to passes through the shell of the vaporizers. The temperature of the seawater is lowered in this process and this cooler water is discharged overboard. The FSRU is fitted with six discharge outlets of which four are typically used during regular vapourising operations. Two of the discharges are situated near the stern and two near the bow. The discharges are located between 6-10 m below the sea surface. On discharge, this water would be 8°C cooler than the ambient seawater.

- When operating in closed-loop mode, steam from the FSRU's steam boilers is used to heat either a fresh-water/glycol medium or propane circulated through the shell-tube vaporizers to regasify the LNG. Ambient seawater is used as cooling water for the steam plant condensers and the fresh-water/propane cooling system, resulting in the discharge of heated water overboard from the FSRU through two discharges in the stern of the vessel. On discharge the water would be ~6-7°C above ambient.

- Cooling of the engines of both the LNGC and FSRU is undertaken by a refrigeration system typically consisting of shell-and-tube heat exchangers that uses seawater as the cooling medium. The engines generate electrical power for the offloading pumps and other onboard systems such as regulation of ballast water, provision of a safety water curtain during LNG transfer and regasification, maintenance of a desalination system to provide freshwater onboard the vessels and maintenance of the marine growth preventative system. On discharge the water would be ~3°C above ambient.

Impact Description

Internationally, a large number of studies have investigated the effects of point source discharge of thermal effluents on open coasts. These studies have, however, focussed primarily on cooling water releases from power plants, where the temperature of the discharge is elevated **above** ambient. Research into the ecological effects of effluents with depressed temperatures is limited mainly to cold water pollution of rivers following release of cold bottom waters from dams (e.g. Astles *et al.* 2003; Preece 2004; Lugg & Copeland 2014; Parisi *et al.* 2020). In the case of Ocean Thermal Energy

Conversion (OTEC)[5] technologies, the effects of cold water discharges below the photic zone have not yet been adequately investigated (Boehlert & Gill 2010; Comfort & Vega 2011; Vega 2012).

Bamber (1995) defined four categories for direct effects of thermal discharges on marine organisms:

- Increases/decreases in mean temperature;
- Increases/decreases in absolute temperature;
- High short term fluctuations in temperature; and
- Thermal barriers.

Increased/decreased mean temperature

Changes in water temperature can have a substantial impact on aquatic organisms and ecosystems, with the effects being separated into three groups:

- Influences on the physiology of the biota (e.g. growth and metabolism, reproduction timing and success, mobility and migration patterns, and production);
- Localised changes in the behaviour of marine species by changes to the chemical and physical attributes of both the water column and the habitat in the vicinity of the outfall, and
- Influences on ecosystem functioning (e.g. through altered oxygen solubility).

Alteration of temperature regimes can have both lethal and sublethal impacts on the physiology of the marine biota. A sudden change in ambient temperature can cause thermal shock and mortality of sessile or slow-moving species. Sublethal effects include debilitation and consequently increased susceptibility to predation (Pilati 1976). Temperature also plays an important role in determining the survival and fitness of fish, particularly coldwater species, and can affect the normal growth and development of eggs and fry by either retarding or accelerating egg and larval development and time of hatching (Blaxter 1969; Cook, 1978; Spence *et al.* 1996; Sandstrom *et al.* 1997; Luksiene *et al.* 2000). Fish subjected to abnormally cold or hot temperatures from water discharges have beenreported to either leave the affected area or acclimate to the change if it is within the species' thermal tolerance zone (Pilati 1976).

Behavioural effects include attractions to the increase in flow velocity and altered temperature regimes around the discharge point and changes in predator/prey interactions. Changes in temperature regimes can artificially attract species and alter their normal seasonal migration behaviour. During facility shutdown, when the flow of the thermal discharge ceases, this can result in cold/heat shock and mortality of fish when ambient temperatures become colder or warmer over the short term (Pilati 1976). Numerous studies have also reported the congregation of endangered species (e.g. Florida manatees (*Trichechus manatus latirostris*), loggerhead turtles (*Caretta caretta*), green turtles (*Chelonia mydas*)) at warm-water effluent channels of power plants, especially during winter months, and in some cases, these warm water sources have been deemed essential for species survival and population maintenance (Turner-Tomaszewicz & Seminoff 2012 and references therein). In such cases, decommissioning of the power plants result in regime shifts in the affected marine environment and potential elimination of some ecosystem inhabitants as a

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[5] Ocean Thermal Energy Conversion (OTEC) technologies use the temperature difference between warm surface water, and cold seawater abstracted at depth to produce electricity

result of the temperature-range shifts. This needs to be kept in mind when the FSRU becomes redundant and vapourisation is undertaken only at the land-based gas hub facility.

In southern Africa, the impacts of increased temperature have been reviewed in a number of studies along the West Coast (e.g. Luger *et al.* 1997; van Ballegooyen & Luger 1999; van Ballegooyen *et al.* 2004, 2005). A synthesis of these findings is given below.

Most reports on adverse effects of changes in seawater temperature on Southern African West Coast species are for intertidal (e.g. the white mussel *Donax serra*) or rocky bottom species (e.g. abalone *Haliotis midae*, kelp *Laminaria pallida*, mytilid mussels, and Cape rock lobster *Jasus lalandii*). Cook (1978) specifically studied the effect of thermal pollution on the commercially important rock lobster *Jasus lalandii*, and found that adult rock lobsters appeared reasonably tolerant of increased temperature of +6°C and even showed an increase in growth rate. The effect on the reproductive cycle of the adult lobster female was, however, more serious as the egg incubation period shortened and considerably fewer larvae survived through the various developmental stages at +6°C above ambient temperature. Zoutendyk (1989) also reported a reduction in respiration rate of adult *J. lalandii* at elevated temperatures.

Other reported effects include an increase in biomass of shallow water hake *Merluccious capensis* and West Coast sole *Austroglossus microlepis* at 18°C (MacPherson & Gordoa 1992) but no influence of temperatures of <17.5°C on chub-mackerel *Scomber japonicus* (Villacastin-Herroro *et al.* 1992). In contrast, 18°C is the lower lethal limit reported for larvae and eggs of galjoen *Distichius capensis* (Van der Lingen 1994).

Although both physiological and behavioural effects have been demonstrated, most studies investigating the effects of cooling water discharges from coastal power stations on open coasts have concluded that at elevated temperatures of <5°C above ambient seawater temperature, little or no effect on species abundances and distribution patterns were discernible (van Ballegooyen *et al.* 2005). However, where the thermal discharge is located in a confined area such as the Port of Ngqura it may result in a rise or drop of temperature of a few degrees and an associated reduction in temperature variability. Ultimately, such a long-term thermal discharge may lead to a changed and thermally adapted community, which could be vulnerable to any change in habitat due to a reduction/increase in seawater temperatures should the thermal discharge be interrupted (e.g. when the SFRU becomes redundant) (CSIR 2004).

The South African Water Quality Guidelines recommend that the maximum acceptable variation in ambient temperature should not exceed 1°C (DWAF 1995), which is an extremely conservative value in view of the negligible effects of thermal plumes on benthic assemblages reported elsewhere for a ΔT of +5°C or less. In contrast, the International Finance Corporation (IFC) water quality guidelines require that the effluent should result in a temperature increase (or decrease) of no more than 3°C at the edge of the 100 m mixing and dilution zone.

Increased/Decreased absolute temperature

Temperatures in Algoa Bay range from ~14 °C to ~22 °C, but in extreme events can rise to ~27 °C during summer. In shallow waters, strong wind events are likely to mix the water column to such an extent that the bottom waters usually have similar water temperatures to the surface waters. The discharged cooling water will not be heated above this naturally occurring maximum temperature and therefore an increase in absolute temperature is not expected. Similarly, due to the rapid initial dilutions of the released heating water, a decrease in absolute temperature is not expected. Changes in absolute temperature are thus not further assessed here.

Short term fluctuations in temperature and thermal barriers

Temperature fluctuations are typically caused by variability in the flow or circulation driven by frequently reversing winds or tidal streams. For example, Bamber (1995) described faunal impoverishment in a tidal canal receiving hot water effluent where the temperature variability was ~12 °C over each tidal cycle.

For thermal barriers to be effective in limiting or altering marine organism migration paths they need to be persistent over time and cover a large cross-sectional area of the water body. Being 7 °C colder than the ambient seawater, the plume of water released through the discharge ports from the FSRU during re-gasification is more than 1 kg/m^3 denser than the receiving seawater. The plume will descend to the seabed, diluting and mixing with the surrounding water on the way due to shear forces, with the amount of dilution depending on the strength of the prevailing near-bottom tidal currents and the angle of the discharge port below horizontal (CEE 2018b). The amount of dilution is also affected by water depth below the FSRU discharge ports with dilution increasing with increasing depth. Dilution is also affected by discharge rate, increasing as the discharge rate decreases. On reaching the seabed, the coldwater plume will spread to form a cold water layer over the seabed, pooling into the manoeuvring basin and along the dredged approach channel (see also CSIR 2004). In the absence of strong tidal currents, the pool of cold water will move with tidal flows, thinning outwards as it spreads. In a modelling study undertaken for FSRU discharges in Walvis Bay (PRDW 2015), the maximum plume footprint for the worst-case scenario of a 1 °C decrease in temperature extended over an area of seabed roughly ~2 km^2 although this acute impact occurred <1 % of the time. The size and position of the footprint will vary with changes in tidal current speed and direction, with the only location(s) constantly exposed to cold seawater being the water column and seabed within the fall line of the descending cold plume. Depending on the position of the discharge port relative to adjacent piles from the offloading platform, or the hull of the LNGC lying alongside, the fall line may be slightly deflected. Although localised, the thermal footprint marginally exceeded the IFC guideline of 3°C at 100 m from the FSRU. Similarly, CEE (2018b) determined that temperature difference were undetectable 300 – 900 m downstream of an FSRU in Victoria, Australia. This footprint was reduced with an increase in the number of operational discharge ports.

In contrast, water 6-7°C above ambient would be buoyant and depending on the discharge depth and angle would tend to either remain trapped at mid-depth (during periods of water column stratification) or rise to the surface from the point of discharge. Dilution would be achieved primarily by wind-driven surface flows. The Walvis Bay FSRU modelling study (PRDW 2015), predicted that the maximum plume footprint for the worst-case scenario of a 1 °C increase in temperature extended over an area of ~0.2 km^2, although such acute impacts would occur <1 % of the time. The increase in seawater temperature due to the release of cooling water from the FSRU reached a maximum of 1.6 °C at 100 m from the FSRU on the side of the discharge port. In areas where currents are minimal, the maximum temperature may be reached even closer to the discharge ports (see for example FERC 2015). The thermal footprint was thus highly localised and well within the IFC guideline of 3 °C at the edge of the zone where initial mixing and dilution take place, or within 100 m from point of discharge (IFC 2007a).

The mean temperature changes relating to chronic impacts would be significantly lower. Although the thermal plumes released from the FSRU may be relatively consistent, the area affected would be localised and, for 99% of the time, temperature elevations/depressions would comply with IFC requirements within 100 m of the FSRU. The discharges could thus not be considered to represent thermal barriers.

The cumulative impacts of the thermal effluents from the FSRU and those from the on-land re-gasification facility and power-plants need to be considered. A modelling study undertaken by PRDW (2020) for anticipated thermal discharges in the Coega marine pipeline servitude ascertained that water quality guideline targets with respect to temperature were met within 300 m of the proposed discharge location to the east of the breakwater. There would therefore be no overlap of the thermal plumes from the FSRU moored at the LNG terminal within the Port, with the thermal discharges from the power-plant outfalls to the east of the breakwater and within the Addo Elephant MPA and Algoa Bay to Amathole EBSA.

Sensitivity of Receptors

In nearshore regions coastal winds and swell typically ensure thorough mixing of the water column ensuring that the bottom waters usually have similar water temperatures to the surface waters. In Algoa Bay, however, marked seasonal differences in the temperature regime have been reported, with intense thermoclines in summer in the deeper sections of the Bay and isothermal conditions in winter (Goschen & Schumann 2011). In winter, the minimum water temperature in Algoa Bay is 14°C, while the maximum reaches 22°C (Beckley 1983; 1988, Schumann *et al.* 2005). In summer, the water temperature can reach 27°C (Beckley 1983; 1988). Due to the sheltered nature of the port, particularly in the proposed location of the LNG terminal, a thermocline can be expected during summer. This will have implications for the discharge of an effluent that has a temperature up to 7°C below ambient.

All marine species have preferred temperature ranges and it is reasonable to expect that benthic species closest to their upper or lower limits would be negatively affected by an increase or decrease in mean temperature, respectively. The sessile biota in Algoa Bay is, however, naturally exposed to wide temperature ranges due to surface heating and rapid vertical mixing of the water column and intrusions of cold bottom shelf water into the system. It can thus be assumed that the biota in these waters is relatively robust and well-adapted to substantial natural variations in temperature.

Impact Significance

Based on the results of modelling studies from elsewhere, the discharge of thermal effluents from the FSRU moored at the proposed LNG terminal in the Port of Ngqura would be of low intensity and remain localised to within 100 m of the vessel and to within the port. The negative impacts would, however, persist over the medium-term (assuming the FSRU operations are replaced by land-based LNG storage and re-gasification facilities within 15 years). Although various engineering designs are being developed internationally to reduce the need for high volumes of seawater for heating/cooling, this is an unavoidable impact associated with the operation of FSRUs. The impact is therefore assessed to be of **VERY LOW** significance both without and with mitigation.

Other than the ‘no-go’ option, no mitigation can be implemented for the effects of the thermal discharges from the FSRU.

Impact: Discharge of high volumes of water with depressed or elevated temperatures

<table>
<tr><th></th><th><i>Extent</i></th><th><i>Intensity</i></th><th><i>Duration</i></th><th><i>Consequence</i></th><th><i>Probability</i></th><th><i>Significance</i></th><th><i>Status</i></th><th><i>Confidence</i></th></tr>
<tr><td>Without mitigation</td><td>Local
1</td><td>Low
1</td><td>Medium-term
2</td><td>Very Low
4</td><td>Probable</td><td>VERY LOW</td><td>- ve</td><td>High</td></tr>
<tr><td colspan="9">Essential mitigation measures:
• Optimise operating modes in the open-loop system as far as possible to reduce impacts, or use closed-loop systems whenever practicable.
• Use multi-port discharges and adjust discharge rate to facilitate enhanced mixing with the receiving water body.
• Ports should discharge horizontally or within -45° of horizontal to maximise dilution and avoid erosion of the sediments where the jet hits the seabed.

Best practice mitigation measures:
As per IFC (2007) and World Bank (2017) guidelines for FSRUs
• Consider water conservation opportunities for LNG facility cooling systems (e.g. air cooled heat exchangers in place of water cooled heat exchangers and opportunities for the integration of cold water discharges with other proximate industrial or power plant facilities). The selection of the preferred system should balance environmental benefits and safety implications of the proposed choice.
• Discharge cooling or cold water to surface waters in a location that will allow maximum mixing and dilution of the thermal plume to ensure that the temperature is within 3 °C of ambient temperature at the edge of the mixing zone or within 100 meters of the discharge point.</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Low
1</td><td>Medium-term
2</td><td>Very Low
4</td><td>Probable</td><td>VERY LOW</td><td>- ve</td><td>High</td></tr>
</table>

Potential for Cumulative Effects

The cumulative impacts of the thermal effluents from the FSRU, the proposed Engie FSU, and those from the on-land re-gasification facility and power-plants need to be considered. A modelling study undertaken by PRDW (2020) for anticipated thermal discharges in the Coega marine pipeline servitude ascertained that water quality guideline targets with respect to temperature were met within 300 m of the proposed discharge location to the east of the breakwater. There would therefore be no overlap of the thermal plumes from the FSRU moored at the LNG terminal within the Port, with the thermal discharges from the power-plant outfalls to the east of the breakwater and within the Addo Elephant MPA and Algoa Bay to Amathole EBSA. If the thermal plumes are limited to within 100 m of the discharge point, there will also unlikely be cumulative impacts between the thermal discharges from the FSRU and proposed Engie FSU to be situated a few 100 m south along the breakwater. Cumulative impacts of thermal discharges are thus not expected.

4.2.9 Co-pollutants in the Thermal Effluent

Source of Impact

The project activities and their associated aspects that may result in the release of co-pollutants into the receiving environment with the thermal effluent are described below.

- To prevent biofouling in the heat exchange system hypochlorite is typically used to disinfect pipe and plant system. Hypochlorite is produced by running an electric current through the seawater at the intakes, to produce residual chlorine and hypochlorite; a process known as electro-chlorination. It is assumed that this chlorination process is continuous rather than pulsed. The seawater discharged from the FSRU heat exchange process would therefore contain short-lived residual chlorine at a concentration of ~0.1 mg/ℓ at the point of exit and prior to any blending with the receiving water or decay and recombine to NaCl and H_2O.

- Designs for the offloading platform indicate a hypochlorite generation unit. It is assumed the product would be used as a biocide in either the FSRU, or in the seawater intake to the on-land regasification at the admin craft basin, or both.

- Other available marine growth prevention systems include onboard paired copper-aluminum anodes mounted in-line with the seawater intake system that receive a direct electrical current thereby effecting a controlled release of copper and aluminium ions that coat the FSRU's seawater piping. The system prevents settlement of fouling organisms and inhibits corrosion. On average, 2 of copper ions are released at the beginning of the system, with lower levels released at the outfall due to the copper ions coating the linings of the FSRU piping. This is below the target level of 5 µg/ℓ as specified by the South African Water Quality Guidelines (1995, 2012).

- Both the LNGC and FSRU have onboard desalination plants to provide in the order of 115 m^3/day of potable water for drinking and sanitary purposes, feed water for the main and auxiliary boilers, and make-up water. About 1,020 m^3/day of brine is generated, which is discharged overboard.

Impact Description

Biocides

The seawater intakes of the FSRU would be located at ~7 m depth thereby reducing the intake of unicellular algae, floating debris, grease and oil. Chlorination of the intake water would nonetheless need to be undertaken to ensure that the pumping systems (e.g. intake pipe and sea chests) are maintained free of biofouling organisms. For example, larvae of sessile organisms (e.g. mussels, barnacles) can grow in the intake pipe and impede the flow of the cooling/heating water.

Sodium hypochlorite (NaOCl) is an oxidising biocide, non-selective with respect to the organisms it kills. Values listed in DWAF (1995) show that 1.5 mg/ℓ chlorine is lethal to some phytoplankton species; 0.2 mg/ℓ reduces sea urchin fertilisation rates and 0.3 mg/ℓ impacts deleteriously on sand mussel with concentrations of 0.6 to 1.2 mg/ℓ killing the sand mussel *Donax serra* if exposure periods are ≥ 14 days (Stenton-Dozey & Brown 1994b). As marine organisms are extremely sensitive to residual chlorine, it is vital to ensure that the residual chlorine concentration in the discharge is at all times reduced to a level below that which may have lethal or sublethal effects on the biota, particularly the larval stages. Reducing the concentration of biocide in the discharge prior to release into the marine environment is usually achieved by neutralising the residual chlorine with sodium metabisulfite (SMBS) (Lattemann & Höpner 2003).

A summary of chlorine chemistry and its potential effects on the receiving environment is provided in Appendix A.1. A major disadvantage of chlorination is the formation of organohalogen compounds. However, as only a few percent of the total added chlorine is recovered as halogenated by-products, and as by-product diversity is high, the environmental concentration of each substance can be expected to be relatively low. Dechlorination reduces the potential for by-product formation considerably. Nonetheless, there is some evidence that chlorinated-dechlorinated seawater increased mortality of test species and chronic effects of dechlorinated seawater were observed, which were assumed to be as a result of the presence of halogenated organics formed during chlorination (see UNEP 2008 for references).

Although the World Bank (World Bank 2017) and International Finance Corporation (IFC 2007a) permit a 0.2 mg/ℓ limit at the point of discharge, this is two orders of magnitude higher than the 3 µg/ℓ limit specified by ANZECC (2000) and <2 µg/ℓ limit suggested by the South African Water Quality Guidelines. Considering the location of the FSRU within the shelter of Ngqura Harbour, the importance of the harbour as a spawning and recruitment area, and the proximity of sensitive receptors (e.g. MPAs and EBSAs), the more conservative guideline of <2 µg/ℓ should be implemented for any discharges from the FSRU. Although NaOH and chlorine would degrade and transform rapidly, should the exceedance of the recommended guideline (<2 µg/ℓ) be a more persistent or recurrent event, there could be serious implications for marine biota in the vicinity of the FSRU. Should the NaOCl be neutralised, residual chlorine concentrations would be very low to non-detectable in the effluent and compliance with the more conservative guidelines is thus expected.

Metals

The discharge will also contain trace amounts of Aluminium (0.5 µg/ℓ) and Copper (2 µg/ℓ). The following discussion of these metals and their potential ecological effects is summarised from EMBECON (2004).

Aluminium is the most abundant metallic element in the lithosphere and it has a complex, yet poorly understood biogeochemical cycle. In seawater, insoluble $Al(OH)_3$ is the predominant species, and as a consequence, dissolved aluminium concentrations in seawater are low (ca. 1 µg/ℓ). The presence of organic or inorganic complexes generally ameliorates toxicity as the concentration of the other aluminium species believed to be responsible for toxic response, is reduced (ANZECC 2000). Australia is the only country that has provided a marine guideline value for aluminium, albeit a low-reliability interim value.

Copper exhibits oxidation states of +2, the most common, and +1. Although an essential dietary element, high concentrations in water can be toxic to aquatic organisms especially algae, crustaceans, annelids, cyprinids and salmonids. Organisms have different mechanisms by which they cope with and process copper. Generally, copper is actively regulated in fish, decapod crustaceans, and algae and stored in bivalves, barnacles, and aquatic insects (Guardiola *et al.* 2012). Phytoplankton species have different sensitivities to copper toxicity: resistant (diatoms), intermediate sensitivity (Coccolithophorids and dinoflagellates), and most sensitive (cyanobacteria; Guardiola *et al.* 2012). Some effects levels are provided in (Table 5).

Copper is an effective biocide used to eliminate biofouling organisms and is listed by the EPA as one of the 129 priority pollutants (Irwin *et al.* 1997). The toxicity of copper in water is greatly affected by the chemical form and to what degree it is bound to various ions or molecules present in the water, making the copper unavailable to organisms (Guardiola *et al.* 2012). The bioavailability and bioaccumulation of copper in organisms is influenced by water chemistry; copper oxide enters the water as a free copper ion (Cu+) it immediately oxidizes to cupric ion (Cu2+), which can form complexes with inorganic and organic ions or molecules. Copper bound to organic matter and particulate material in the marine environment is thought to be non-bioavailable and, therefore, non-toxic (Guardiola *et al.* 2012).

Metal bioavailability and ecotoxicology is determined primarily by speciation in the dissolved phase, and by partitioning between the dissolved and particulate phases (Paulson & Amy 1993; Rainbow 1995; Galvin 1996). Although the dissolved forms are regarded as the most bioavailable to aquatic organisms, some suspension feeders can respond to metal sources in both the particulate and dissolved phases (Rainbow 1995).

Although many heavy metals are needed in trace amounts, they become toxic to plants and animals at high concentrations. Presented here are examples of toxicity data for a number of organisms using, where possible, a reasonable spectrum of different groups ranging from phytoplankton to marine fish (Table 5). Young life stages have been emphasised as, in the marine environment at least, they are consistently more sensitive than adults (Mance 1987) and of more obvious relevance to the pelagic environment. An exception may be bivalve molluscs for which the larvae often display a comparable sensitivity to the adults. It should be remembered that young life stages are essentially transient, thus the results from toxicity studies with these tend to overestimate the long-term “safe” concentration. The short-term (96-hour) LC_{50} tests have been focussed upon for conformity, though such an experimental duration will underestimate “instantaneously” lethal levels.

Salinity

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 being stenohaline.

Salinity changes may affect aquatic organisms in two ways:

- direct toxicity through physiological changes (particularly osmoregulation), and
- indirectly by modifying the species distribution.

In marine ecosystems, adverse effects or changes in species distribution are anticipated more from a reduction rather than an increase in salinity (ANZECC 2000), and most studies undertaken to date have investigated effects of a decline in salinity due to an influx of freshwater, or salinity fluctuations in estuarine environments, where most of the fauna are of the euryhaline type. Elevated salinity has a toxic effect on numerous organisms dependant on specific sensitivities (Mabrook 1994; Eniev *et al.* 2002), and by upsetting the osmotic balance, can lead to the dehydration of cells (Kirst 1989; Ruso *et al.* 2007).

Increased salinity can reduce the production of plankton, particularly of invertebrate and fish larvae (Miri & Chouikhi 2005), lead to reductions in fish populations, die-offs of coral (Mabrook 1994), and

Table 5: Results of toxicity studies for various metals.

Concentration (µg/l)	Effect	Common name	Scientific name	Reference
ALUMINIUM				
97	LC_{50}	annelid	*Ctenodrilus serratus*	ANZECC (2000)
240	LC_{50} (72-96h)	barnacle	*Balanus eburneus*	ANZECC (2000)
405	LC_{50}	annelid	*Capitella capitata*	ANZECC (2000)
500 – 2 000	LC_{50} (96h)	polychaetes	*Capitella capitata* *Ctenodrilus serratus* *Neanthes arenaceodentata*	Petrich & Reisch (1979)
1 000	No observed effect concentration (NOEC) for mortality	crab	*Cancer anthonyi*	ANZECC (2000)
10 000	LC_{50}	crustacean	*Nitocra spinipes*	ANZECC (2000)
COPPER				
9.9	LC_{50} (5 days)	green alga	*Enteromorpha* sp.	EPA (1997), cited in Irwin *et al.* (1997)
18	Inhibited sporophyte production	kelp	*Macrocystis pyrifera*	Anderson *et al.* (1994)
50 (larvae) 100 (adults)	LC_{50} (96 h)	American lobster	*Homarus americanus*	McLeese (1974)
41.1 & 32.9	EC_{50} (48 h) for larval embryogenesis and growth, respectively	sea urchin	*Paracentrotus lividus*	Lorenzo *et al.* (2002)
64 (nauplius) 88 (adult)	LC_{50} (96 h)	copepod	*Tisbe battaglia*	Hutchinson *et al.* (1994)
65	LC_{50} for adults	red abalone	*Haliotus rufescens*	Martin *et al.* (1977)
66 – 126	Asphyxial hypoxia at acute exposure (8 h) of young	young red abalone	*Haliotus rufescens*	Viant *et al.* (2002)
100 (growth) 500 (photosynthesis)	50 % reduction in growth and photosynthesis	diatom	*Phaeodactylum tricornutum*	Cid *et al.* (1995)
180	LC_{50} (96 h)	mysid	*Mysidopsis bahia*	Lussier *et al.* (1985)
109 – 1 400	LC_{50} (48-96 h) for early life stages	marine fish		Taylor *et al.* (1985) Anderson *et al.* (1994) Hutchinson *et al.* (1994)
160 - 4760	LC_{50} (48 h) for larvae	shrimp	*Metapnaeus ensis*	Wong *et al.* (1993)

to mortalities in mangroves, seagrasses and marine angiosperms (Vries *et al.* 1997; Latorre 2005). Salinity increases near the outfall of a seawater Reverse Osmosis (SWRO) plant were reported to be responsible for a decline of macroalgae forests and disappearance of echinoderms (Argyrou 1999 cited in UNEP 2008). 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 by marine organisms. Some evidence exists for an increase in uptake of certain trace metals with an increase in salinity (Roast *et al.* 2002; Rainbow & Black 2002). Sub-lethal effects of changed salinity regimes (or salinity stress) can include modification of metabolic rate, change in activity patterns, slowing of development and alteration of growth rates (McLusky 1981; Moullac *et al.* 1998), lowering of immune function (Matozzo *el al.* 2007) and increased mortality rates (Fagundez & Robaina 1992) in marine invertebrates and fish.

Abalone (*Haliotis diversicolor supertexta*) experience significant mortality at salinities greater than 38 psu (Cheng & Chen 2000), with that salinity stress affects their immune system, making them more vulnerable to bacterial infection (Cheng *et al.* 2004). Similarly, the immune capabilities in bivalve molluscs (Matozzo *et al.* 2007) and crustaceans (Chen & Chen 2000; Verghese *et al.* 2007) were affected by elevated salinities.

The small volumes of brine produced by the LNGC and FSRU (~115 m^3/day) would be rapidly diluted with the other discharges and the footprints around the outlet are expected to be insignificant.

Sensitivity of Receptors

Contaminants discharged with the heating/cooling water from the FSRU and LNGC would be rapidly diluted in the receiving environment. The biota in the Port of Ngqura most sensitive to residual chlorine, metals and elevated salinity would be the pelagic and benthic invertebrates at the LNG terminal (i.e. plankton, invertebrate biofouling community on the piles and dolosse and macrofaunal communities in the unconsolidated sediments in the terminal basin).

Impact Significance

The release of trace amounts of chlorine, aluminium and copper in the thermal discharges, and the discharge of small volumes of brine from the onboard desalination plant is considered to be of low intensity and remain highly localised to within a few 10s of metres of the vessel and to within the port. Any impacts would, however, persist over the long-term. The impact is therefore assessed to be of **VERY LOW** significance both without and with mitigation.

Other than the 'no-go' option, no mitigation can be implemented for the effects of the thermal discharges from the FSRU.

As lethal and sublethal effects occur only at concentrations well in excess of those expected in the effluent, the impact of these metals on marine biota is assessed as being insignificant.

Impact: Discharge of Co-pollutants

<table>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Local
1</td><td>Low
1</td><td>Long-term
3</td><td>Low
5</td><td>Improbable</td><td>VERY LOW</td><td>- ve</td><td>High</td></tr>
<tr><td colspan="9">Essential mitigation measures:
• Neutralise NaOCl with SMBS prior to discharge to ensure that the most conservative international guideline value (<2 µg/ℓ) for residual chlorine at the point of discharge is met.
• Blend the brine with the cooling/heating water prior to release.

Best practice mitigation measures:
• Implement closed-loop systems whenever practicable.
• Implement the principle of mechanical cleaning of the entire system as part of regular annual maintenance of the FSRU in preference to the use of a biocide.</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Low
1</td><td>Long-term
3</td><td>Low
5</td><td>Improbable</td><td>VERY LOW</td><td>- ve</td><td>High</td></tr>
</table>

Potential for Cumulative Effects

No long term cumulative impacts on marine organisms are expected as effluents will comply with water quality guidelines.

4.2.10 Impact of Survey Vessel Lighting on Pelagic Fauna

Source of Impact

The project activities that will result in an increase in ambient nighttime lighting on marine fauna are:

- Operational vessel lighting on the LNGC and FSRU can be a significant source of artificial light in the nearshore environment increasing the ambient lighting in marine and coastal areas.
- Operational lighting on the offloading platform and access trestle would similarly be a significant source of artificial light in the coastal environment

Impact Description

The strong operational lighting used to illuminate the LNGC and FSRU vessel at night may disturb and disorientate pelagic seabirds feeding in the area or attract turtles, marine mammals and fish. The response of marine organisms to artificial lights can vary depending on a number of factors such as the species, life stage and the intensity of the light. Strong lights could cause artificially induced biological aggregations. Operational lights may also result in physiological and behavioural effects of fish and cephalopods as these may be drawn to the lights at night where they may be more easily preyed upon by other fish and seabirds. Although some species may change their feeding habits based on these aggregations, the impacts on marine species are generally expected to be minor as the LNG terminal will be located in a port where artificial lighting will be of comparatively high intensity. It is expected, therefore, that seabirds and marine mammals in the area would become accustomed to the presence of the vessels within a few days.

Sensitivity of Receptors

The taxa most vulnerable to ambient lighting are pelagic seabirds, although turtles, shoaling pelagic fish, and both migratory and resident cetaceans transiting through the area may also be attracted by the lights. Some of of the species potentially occurring in the project area, are considered regionally or globally 'Critically Endangered' (e.g. leatherback turtles, Damara terns), 'Endangered' (e.g. African Penguin, whale shark, Indian Ocean humpback dolphin, fin and sei whales), 'vulnerable' (e.g. loggerhead turtles, dusky shark, great white shark, Bryde's and humpback whales) or 'near threatened' (e.g. Indo-Pacific bottlenose dolphin). Although not all of these have been reported from within the Port of Ngqura, they are likely to occur in Algoa Bay and may be affected by the increase in ambient lighting generated by the LNG terminal.

Impact Significance

The intensity of the impact of an increase in ambient lighting at the LNG terminal is considered low, with effects remaining localise. The impact would, however, endure over the life-time of the terminal. The impact of increased lighting is deemed to be of **VERY LOW** significance, both without and with mitigation. The use of lighting on the LNG vessels and at the terminal cannot be eliminated due to safety, navigational and operational requirements.

Impact: Increase in ambient lighting

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Low 1	Long-term 3	**Low** 5	Improbable	**VERY LOW**	**- ve**	High
Essential mitigation measures: • Reduce lighting in non-essential areas. • Use of guards to direct lights to areas requiring lighting • Avoid direct light in water, exept during safety inspections • Low light mounting where possible • Use of long wavelength lights that are less intense for nocturnal animals. **Best practice mitigation measures:** • Compile a lighting plan that identifies specific measures that could be implemented to minimize or avoid impacts associated with operational nighttime lighting on avian species, fish species, and marine mammals.								
With mitigation	Local 1	Low 1	Long-term 3	**Low** **5**	Improbable	**VERY LOW**	**- ve**	High

Potential for Cumulative Effects

No long term cumulative impacts on marine organisms are expected relative to the ambient light levels in the Coega SEZ.

4.2.11 Impacts of Waste Discharges to Sea

Source of Impact

The project activities that will result in a reduction of water quality from routine discharges to the sea from vessels are listed below.

- Operation of the dredger during dredging and transit of sailing hoppers to the sacrificial dump site.
- Construction activities on the breakwater and in the harbour during the installation of the access trestle, offloading platforms, berthing and mooring dolphins and installation of cryogenic, gas and return pipelines.
- Operation of the LNGC and FSRU at the LNG terminal.

The aspects associated with these activities are described further below:

- **Deck drainage**: all deck drainage from work-spaces is collected and piped into a sump tank on board the seismic vessel to ensure MARPOL compliance (15 ppm oil in water). The fluid would be analysed and any hydrocarbons skimmed off the top prior to discharge. The oily substances would be added to the waste (oil) lubricants and disposed of at a suitable facility onshore.
- **Grey Water and Sewage**: sewage discharges will be comminuted and disinfected. In accordance with MARPOL Annex IV, the effluent must not produce visible floating solids in, nor causes discolouration of, the surrounding water. The treatment system must provide primary settling, chlorination and de-chlorination before the treated effluent can be discharged into the sea.
- **Vessel machinery spaces, mud pit wash residue and ballast water**: the concentration of oil in discharge water from vessel machinery space or ballast tanks may not exceed 15 ppm oil in water (MARPOL Annex I). If the vessel intends to discharge bilge or ballast water at sea, this is achieved through use of an oily-water separation system. Oily waste substances must be shipped to land for treatment and disposal.
- **Food (galley) wastes**: food wastes may be discharged after they have been passed through a comminuter or grinder, and when the seismic vessel is located more than 3 nautical miles from land. Discharge of food wastes not comminuted is permitted beyond 12 nautical miles. The ground wastes must be capable of passing through a screen with openings <25 mm.
- **Cooling Water and drinking water surplus:** The cooling water and surplus generated by the drinking water supply system are likely to contain a residual concentration of chlorine (generally less than 0.5 mg/ℓ for drinking water supply systems. Such water would be tested prior to discharge and would comply with relevant Water Quality Guidelines.
- **Litter and construction wastes:** construction activities can lead to operational spills of diesel and hydraulic fluid into the marine environment from machinery and plant used in

the harbour. Construction activities can also result in concrete spills and the discard of litter into the marine environment.

Impact Description

The discharge of wastes to sea could create local reductions in water quality, both during transit to and from the dredge spoil site and within the port. Deck and machinery space drainage may result in small volumes of oils, detergents, lubricants and grease, the toxicity of which varies depending on their composition, being introduced into the marine environment. Sewage and gallery waste will place a small organic and bacterial loading on the marine environment, resulting in an increased biological oxygen demand. For vessels permanently moored at the terminal, all such wastes should be taken ashore and disposed of accordingly. Discharges to sea will result in a local reduction in water quality, which could impact marine fauna in a number of different ways:

- Physiological effects: Ingestion of hydrocarbons, detergents and other waste could have adverse effects on marine fauna, which could ultimately result in mortality.
- Increased food source: The discharge of galley waste and sewage will result in an additional food source for opportunistic feeders, speciality pelagic fish species.
- Increased predator-prey interactions: Predatory species, such as sharks and pelagic seabirds, may be attracted to the aggregation of pelagic fish attracted by the increased food source.

Sensitivity of Receptors

The operational waste discharges from the activities described above would primarily take place in the harbour or during transit to the dredge disposal site. The project area lies adjacent to the Addo Elephant MPA and Addo to Amathole EBSA and therefore in close proximity to sensitive coastal receptors (e.g. key faunal breeding/feeding areas, bird or seal colonies and nursery areas for commercial fish stocks).

The taxa most vulnerable to waste discharges are pelagic seabirds, turtles, and marine mammals. Some of of the species potentially occurring in the project area, are considered regionally or globally ‘Critically Endangered’ (e.g. leatherback turtles, Damara terns), ‘Endangered’ (e.g. African Penguin, whale shark, Indian Ocean humpback dolphin, fin and sei whales), ‘vulnerable’ (e.g. loggerhead turtles, dusky shark, great white shark, Bryde’s and humpback whales) or ‘near threatened’ (e.g. Indo-Pacific bottlenose dolphin). Although not all of these have been reported from within the Port of Ngqura, they are likely to occur in Algoa Bay and may be affected by operational discharges from the LNG terminal.

Impact Significance

The impacts associated with normal waste discharges from construction activities, the LNG vessels and the LNG terminal are deemed to be of low intensity and would remain localised. The impacts would, however, persist over the long-term and, based on the relatively small discharge volumes and compliance with MARPOL 73/78 standards, are considered of **LOW** significance.

Impact: Waste Discharges to Sea

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Low 1	Long-term 3	**Low** 5	Probable	**LOW**	**- ve**	High
Essential mitigation measures: • Implement a waste management system that addresses all wastes generated at the various sites, shore-based and marine. This should include: – Separation of wastes at source; – Recycling and re-use of wastes where possible; – Treatment of wastes at source (maceration of food wastes, compaction, incineration, treatment of sewage and oily water separation). • Implement leak detection and repair programmes for valves, flanges, fittings, seals, etc. • Use a low-toxicity biodegradable detergent for the cleaning of all deck spillages. **Best practice mitigation measures:** • All construction activities in the coastal zone must be managed according to a strictly enforced Environmental Management Plan. • Good house-keeping must form an integral part of any marine construction operations from start-up.								
With mitigation	Local 1	Low 1	Long-term 3	**Low** **5**	Probable	**LOW**	**- ve**	High

Potential for Cumulative Effects

Although pollutant levels in the waters of the Port of Ngqura are currently low, compromised water quality within the port over the long-term due to cumulative impacts resulting from port developments, vessel discharges and other anthropogenic sources in the Coega SEZ can be expected. Over the lifetime of the port, these impacts are likely to be of medium significance.

4.3. Unplanned events

4.3.1 LNG spill

Source of Impact

The project activities that may result in an accidental spill of LNG are listed below.

- During the connection and disconnection process between the LNGC and FSRU;
- During the connection and disconnection process between the FSRU and the on-shore unloading arms;
- Leakage from swivel joints, emergency disconnection of unloading arms, or a rupture in the cargo ship's containment system; and
- The unlikely event of a LNGC vessel casualty or collision.

Impact Description

LNG cargo is a clear, colourless and odourless liquid with a very low temperature. When spilled on the ocean, LNG would disperse faster than if spilled on land as water spills provide very limited opportunity for containment. As seawater provides an effective heat source, LNG spilled at a fast rate would quickly and completely evaporate leaving no footprint behind. Such a sudden phase change (known as a Rapid Phase Transition (RPT)) releases a large amount of energy and can cause a physical explosion with no combustion or chemical reaction. The hazard potential of rapid phase transitions can be severe but generally remains localized within the spill area. Any aquatic life that comes into direct contact with the LNG will experience a sudden cold shock; depending in what context the contact occurs, the exposure could be lethal. Most motile underwater organisms would detect the temperature change and avoid the area. The likely duration of such exposure would, however, be short.

The history of LNG shipping has been free of major incidents, and none have resulted in significant quantities of LNG being released (FERC 2006). The events most likely to cause a significant release of LNG are a ship casualty such as a collision with another vessel. Any event causing a release of LNG would need to involve sufficient impact to breach the LNGC's double hull and cargo tanks. Over 45,000 voyages have been completed since the inception of LNG maritime transportation, with only ten substantial incidents involving LNGCs, and none of those resulted in spills due to rupturing of the cargo tanks (FERC 2006). Based on the extensive operational experience of LNG shipping, the structural design of an LNG vessel, and the operational controls imposed by the local pilots, the possibility of a LNG spill from a vessel casualty in Algoa Bay is highly unlikely.

Sensitivity of Receptors

The biota in the Port of Ngqura most sensitive to LNG spills would be the pelagic and benthic invertebrates at the LNG terminal (i.e. plankton, invertebrate biofouling community on the piles and dolosse and macrofaunal communities in the unconsolidated sediments in the terminal basin). Any fish present in the immediate footprint of the spill may also be affected. Of the most commonly occurring species, the Dusky kob (*Argyrosomus japonicas*) is considered 'Critically Endangered', whereas the elf (*Pomatomus saltatrix*), spotted grunter (*Pomadasys commersonnii*) and garrick (*Lichia amia*) are rated as nationally 'Vulnerable'. The Port also serves as an important summer habitat and core activity zone for neonate and juvenile dusky sharks (*Carcharinus obscurus*), and may serve as an important nursery area for the species (Dicken 2011). Although the national assessment identifies dusky sharks as being 'data deficient', its IUCN Conservation status is considered 'Vulnerable'. Other chondrichthyans reported from the harbour are the great white shark and giant manta, both of which are considered 'Vulnerable' by the IUCN, and the whale shark which is rated as 'Endangered'.

As the effects of a LNG spill would remain highly localised, the adjacent Addo Elephant MPA and Algoa to Amathole EBSA are unlikely to be affected in any way.

Impact Significance

The impacts associated accidental spills of LNG at the offloading terminal are deemed to be of low intensity and would remain localised. The impacts would persist over the short-term only as the LNG would rapidly evaporate. Due to the low likelihood of a spill, the potential impacts associated with a spill are considered to be **INSIGNIFICANT**.

Impact: Accidental Spills if LNG

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Medium 2	Short-term 1	**Very Low** 4	Improbable	**INSIGNIFI-CANT**	**- ve**	High
Essential mitigation measures: As per IFC (2007) and World Bank (2017) guidelines for FSRUs • Prepare an emergency response plan covering recommended measures to prevent and respond to LNG spills.								
With mitigation	Local 1	Low 1	Short-term 1	**Very Low** **3**	Improbable	**INSIGNIFI-CANT**	**- ve**	High

4.3.2 Hypochlorite Spill

Source of Impact

The project activities and their associated aspects that may result in the accidental spill of hypochlorite on the offloading platform are described below.

- A hypochlorite generation unit has been proposed for the offloading platform. Sodium hypochlorite can be produced by dissolving salt in softened water, resulting in a concentrated brine, which then electrolyzed to form a sodium hypochlorite solution containing 150 grams of active chlorine per litre. During this reaction, hydrogen gas is also formed. Sodium hypochloriteis commonly used as a disinfectant and for the control of marine biofouling in seawater intakes.

Impact Description

Sodium hypochlorite (NaOCl) is an oxidising biocide, non-selective with respect to the organisms it kills. Marine organisms are extremely sensitive to residual chlorine, making it a prime choice as a biocide to prevent the fouling of marine water intakes. Many of the chlorinated and halogenated by-products that are formed during seawater chlorination (see Appendix A.1) are also carcinogenic or otherwise harmful to aquatic life (Einav *et al*. 2002; Lattemann & Höpner 2003). Values listed in the South African Marine Water Quality Guideline (DWAF 1995) show that 1,500 µg/ℓ is lethal to some phytoplankton species, 0.3 mg/ℓ impacts deleteriously on sand mussel with concentrations of 0.6 to 1.2 mg/ℓ killing the sand mussel *Donax serra* if exposure periods are ≥ 14 days (Stenton-Dozey & Brown 1994). Concentrations of 820 µg/ℓ induced 50% mortality for a copepod and 50% mortality rates are observed for some fish and crustacean species at values exceeding 100 µg/ℓ (see also ANZECC 2000). The lowest values at which lethal effects are reported are 10 – 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 <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 dinoflaggelate *Gymnodinium catenatum* by 50% whereas there was no discernable effect at 10 µg/ℓ. This indicated that particularly 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 (e.g. sea urchin) eggs is reduced by approximately 50% after 5-minute exposures.

As marine organisms are extremely sensitive to residual chlorine, a spill of concentrated hypochlorite solution into the marine environment at the generation unit would likely have lethal or sublethal effects on the biota in the area affected by the spill.

Sensitivity of Receptors

The biota in the Port of Ngqura most sensitive to hypochlorite spills would be the pelagic and benthic invertebrates at the LNG terminal (i.e. plankton, invertebrate biofouling community on the piles and dolosse and macrofaunal communities in the unconsolidated sediments in the terminal basin). Any fish present in the immediate footprint of the spill may also be affected. Of the most commonly occurring species, the Dusky kob (*Argyrosomus japonicas*) is considered 'Critically Endangered', whereas the elf (*Pomatomus saltatrix*), spotted grunter (*Pomadasys commersonnii*) and garrick (*Lichia amia*) are rated as nationally 'Vulnerable'. The Port also serves as an important summer habitat and core activity zone for neonate and juvenile dusky sharks (*Carcharinus obscurus*), and may serve as an important nursery area for the species (Dicken 2011). Although the national assessment identifies dusky sharks as being 'data deficient', its IUCN Conservation status is considered 'Vulnerable'. Other chondrichthyans reported from the harbour are the great white shark and giant manta, both of which are considered 'Vulnerable' by the IUCN, and the whale shark which is rated as 'Endangered'.

As the effects of a hypochlorite spill would remain highly localised, the adjacent Addo Elephant MPA and Algoa to Amathole EBSA are unlikely to be affected in any way.

Impact Significance

The impacts associated accidental spills of hypochlorite at the offloading terminal are deemed to be of medium intensity and would remain localised. The impacts would persist over the short-term only as the residual chlorine would rapidly degrade. Due to the low likelihood of a spill, the potential impacts associated with a spill are considered to be **INSIGNIFICANT**.

Impact: Accidental Spills of Hypochlorite

<table>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Local
1</td><td>Medium
2</td><td>Short-term
1</td><td>Very Low
4</td><td>Improbable</td><td>INSIGNIFI-CANT</td><td>- ve</td><td>High</td></tr>
<tr><td colspan="9">Essential mitigation measures:
• The hypochlorite generation unit must be suitably bunded to prevent and spills from the plant entering the marine environment.</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Low
1</td><td>Short-term
1</td><td>Very Low
3</td><td>Improbable</td><td>INSIGNIFI-CANT</td><td>- ve</td><td>High</td></tr>
</table>

4.3.3 Faunal Strikes with LNGCs and Dredgers

Source of Impact

The project activities that will result in potential collision impacts with marine fauna are listed below.

- Transit of dredger/sailing hopper barges between dredging area and dump site.
- Arrival and departure of the LNGC to and from the Port of Ngqura and the LNG terminal.

Impact Description

Vessel traffic can affect large cartilaginous fish species, turtles and marine mammals by direct collisions or propeller injuries. The potential effects of vessel presence on turtles and cetaceans include behavioural disturbance, physiological injury or mortality.

Collisions between cetaceans and vessels are not limited to LNGCs. In areas of heavy ship traffic, whales and dolphins can experience propeller or collision injuries, with most of these injuries caused by fast-moving vessels. Injuries and deaths resulting from direct ship collisions represent a significant threat to several whale populations (Laist *et al.* 2001; Jensen & Silber 2003). All types and sizes of vessels hit whales, but most lethal and serious injuries are caused by larger vessels and most vessel strikes occur on the continental shelf and when vessels were doing in excess of 10 knots (Laist *et al.* 2001). LNGC, which have a maximum transiting speed of 19 knots in the open ocean, could therefore result in the severe injury or mortality to a whale if struck. However, when transiting to and from the port and through sensitive areas the vessel speeds would be reduced to around 3 knots when within 2 nautical miles of the port and further reduced to less than 1 knot as the vessel nears the port. Ship strikes whilst entering and within Algoa Bay are thus unlikely but may occur once in the offshore shipping lanes.

Increased vessel traffic during dredging and spoils dumping activities and from arrival or departure of LNGCs could potentially increase the risk of collision between, or disturb of whales, particularly mother-and-calf pairs travelling through the Algoa Bay area and resting near the surface. Sailing hopper barges moving between the port and the sacrificial dump-site would have sailing speeds of <10 knots, and ship strikes are therefore not expected.

Ship strikes have been reported to result in medium-term effects such as evasive behaviour by animals experiencing stress, or longer-term effects such as decreased fitness or habitual avoidance of areas where disturbance is common and in the worst case death (see for example Constantine 2001; Hastie *et al*. 2003; Lusseau 2004, 2005; Bejder *et al*. 2006; Lusseau *et al*. 2009). Ship strikes have been documented from many regions and for numerous species of whales (Panigada *et al*. 2006; Douglas *et al*. 2008; Elvin & Taggart 2008) and dolphins (Bloom & Jager 1994; Elwen & Leeney 2010), with large baleen whales being particularly susceptible to collision.

Sensitivity of Receptors

The taxa most vulnerable to vessel strikes are large, slow-moving chondrichthyans (e.g. manta ray, whale shark), turtles and marine mammals. Some of of the species potentially occurring in the project area, are considered regionally or globally 'Critically Endangered' (e.g. leatherback turtles,), 'Endangered' (e.g. whale shark, Indian Ocean humpback dolphin, fin and sei whales), 'vulnerable' (e.g. loggerhead turtles, Bryde's and humpback whales) or 'near threatened' (e.g. Indo-Pacific bottlenose dolphin). Although not all of these have been reported from within the Port of Ngqura, they are likely to occur in Algoa Bay and may be affected by the transit of project-associated vessels from and to the port.

Impact Significance

The potential for strikes and collisions with large cartilaginous fish, turtles and cetaceans is highly dependent on the abundance and behaviour of these animals in the project area at the time. Due to their extensive distributions and feeding ranges, the number of large cetaceans encountered during the dredging activities or by LNGCs arriving at or departing from the port is expected to be low. As project-associated vessels will be travelling at low speeds the likelihood of a vessel strike is very low (improbable). However, should strikes occur, the impacts would be of high intensity for individuals but of LOW intensity for the population as a whole. Furthermore, as the duration of the impact would be limited to the short-term and be restricted to the survey area (LOCAL), the impact is considered to be **INSIGNIFICANT**.

Impact: Faunal strikes with LNGCs and Dredgers

	Extent	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Without mitigation	Local 1	Low 1	Short-term 1	**Very Low** 3	Improbable	**INSIGNIFICANT**	**- ve**	High
Essential mitigation measures: • Ensure that vessel speed is kept below 10 knots when underway in Algoa Bay. • The vessel operators should keep a constant watch for slow-swimming large pelagic fish, marine mammals and turtles in the path of the vessel.								
With mitigation	Local 1	Low 1	Short-term 1	**Very Low** **3**	Improbable	**INSIGNIFICANT**	**- ve**	High

4.3.4 Release of diesel to sea during bunkering or due to vessel accident

Source of Impact

The project activities that may result in the accidental release of diesel/oil are listed below.

- Instantaneous spills of marine diesel at the surface of the sea can potentially occur during operation of the dredger and hopper barges, and marine construction equipment. Such spills are usually of a low volume.
- Refuelling of project-associated vessels within the port or during offshore bunkering.
- Larger volume spills of marine diesel would occur in the event of a vessel collision or vessel accident.

Impact Description

Most LNGCs and FSRUs are powered by dual fuel engines that use natural gas and bunker fuel to convert chemical energy in to mechanical energy. Initially, most LNGCs were powered by steam turbines that utilized the BOG, but within the past decade, dual-fuel diesel-electric systems have become the propulsion solution of choice due to improved fuel efficiency and reduced emissions. In some of the more modern carriers, the engines are able to burn heavy fuel oil as well as natural gas and marine diesel.

Various factors determine the impacts of oil released into the marine environment. The physical properties and chemical composition of the oil, local weather and sea state conditions and currents greatly influence the transport and fate of the released product. The physical properties that affect the behaviour and persistence of oil spilled at sea are specific gravity, distillation characteristics, viscosity and pour point, all of which are dependent on the oils chemical composition (e.g. the amount of asphaltenes, resins and waxes). Spilled oil undergoes physical and chemical changes (collectively termed ‘weathering’), which in combination with its physical transport, determine the spatial extent of oil contamination and the degree to which the environment will be exposed to the toxic constituents of the released product.

As soon as oil is spilled, various weathering processes come into play. Although the individual processes may act simultaneously, their relative importance varies with time. Whereas spreading, evaporation, dispersion, emulsification and dissolution are most important during the early stages of a spill, the ultimate fate of oil is determined by the longer-term processes of oxidation, sedimentation and biodegradation.

As a general rule, oils with a volatile nature, low specific gravity and low viscosity (e.g. marine diesel) are less persistent and tend to disappear rapidly from the sea surface. In contrast, high viscosity oils containing bituminous, waxy or asphaltenic residues, dissipate more slowly and are more persistent, usually requiring a clean-up response.

Heavy fuel oil or marine diesel spilled in the marine environment will have an immediate detrimental effect on water quality, with the toxic effects potentially resulting in mortality (e.g. suffocation and poisoning) of marine fauna or affecting faunal health (e.g. respiratory damage). Any release of liquid hydrocarbons thus has the potential for direct, indirect and cumulative effects on the marine environment. These effects include physical oiling and toxicity impacts to marine fauna and flora, localised mortality of plankton (particularly copepods), pelagic eggs and fish larvae, and habitat loss or contamination (Perry 2005). If the spill reaches the coast, it can result in the smothering of sensitive coastal habitats.

The consequences and effects of small (2 000 – 20 000 litres) diesel fuel spills into the marine environment are summarised below (NOAA 1998). Diesel is a light oil that, when spilled on water, spreads very quickly to a thin film and evaporates or naturally disperses within a few days or less, even in cold water. Diesel oil can be physically mixed into the water column by wave action, where it adheres to fine-grained suspended sediments, which can subsequently settle out on the seafloor. As it is not very sticky or viscous, diesel tends to penetrate porous sediments quickly, but also to be washed off quickly by waves and tidal flushing. In the case of a coastal spill, shoreline cleanup is thus usually not needed. Diesel oil is degraded by naturally occurring microbes within one to two months. Nonetheless, in terms of toxicity to marine organisms, diesel is considered to be one of the most acutely toxic oil types. Many of the compounds in petroleum products are known to smother organisms, lower fertility and cause disease. Intertidal invertebrates and seaweed that come in direct contact with a diesel spill may be killed. Fish kills, however, have never been reported for small spills in open water as the diesel dilutes so rapidly. Due to differential uptake and elimination rates, filter-feeders (particularly mussels) can bio-accumulate hydrocarbon contaminants. Crabs and shellfish can be tainted from small diesel spills in shallow, nearshore areas.

Chronic and acute oil pollution is a significant threat to both pelagic and inshore seabirds. Diving sea birds that spend most of their time on the surface of the water are particularly likely to encounter floating oil and will die as a result of even moderate oiling which damages plumage and eyes. The majority of associated deaths are as a result of the properties of the oil and damage to the water repellent properties of the birds' plumage. This allows water to penetrate the plumage, decreasing buoyancy and leading to sinking and drowning. In addition, thermal insulation capacity is reduced requiring greater use of energy to combat cold.

Impacts of oil spills on turtles are thought to primarily affect hatchling survival (CSIR & CIME 2011). Turtles encountered in the project area would mainly be migrating adults and vagrants. Similarly, little work has been done on the effect of an oil spill on fur seals.

The effects of oil pollution on marine mammals are poorly understood (White *et al.* 2001), with the most likely immediate impact of an oil spill on cetaceans being the risk of inhalation of volatile, toxic benzene fractions when the oil slick is fresh and unweathered (Geraci & St Aubin 1990, cited in Scholz *et al*. 1992). Common effects attributable to the inhalation of such compounds include absorption into the circulatory system and mild irritation to permanent damage to sensitive tissues such as membranes of eyes, mouth and respiratory tract. Direct oiling of cetaceans is not considered a serious risk to the thermoregulatory capabilities, as cetacean skin is thought to contain a resistant dermal shield that acts as a barrier to the toxic substances in oil. Baleen whales may experience fouling of the baleen plates, resulting in temporary obstruction of the flow of water between the plates and, consequently, reduce feeding efficiency. Field observations record few, if any, adverse effects among cetaceans from direct contact with oil, and some species have been recorded swimming, feeding and surfacing amongst heavy concentrations of oil (Scholz *et al.* 1992) with no apparent effects.

Sensitivity of Receptors

Accidental spills and loss of marine diesel during bunkering or in the event of a vessel collision could take place offshore in the shipping lanes or within Algoa Bay. Diesel spills or accidents within Algoa

Bay could result in fuel loss closer to shore, thereby potentially having an environmental effect on the sensitive coastal environments, the Addo Elephant MPA and the Algoa to Amathole EBSA.

The taxa most vulnerable to hydrocarbon spills are coastal and pelagic seabirds. Some of the species potentially occurring in the survey area, are considered regionally or globally 'Critically Endangered' (e.g. Damara Tern), 'Endangered' (e.g. African Penguin, Cape Gannet, Cape Cormorant) or 'vulnerable' (e.g. Caspian Tern). As species listed as 'Critically Endangered' or 'Endangered' occur on the Algoa Bay Islands their numbers in the project area will be high and any hydrocarbon spill could therefore have catastrophic consequences to the populations of these species.

Impact Significance

In the unlikely event of an operational spill or vessel collision, the magnitude of the impact would depend on whether the spill occurred in offshore waters where encounters with pelagic seabirds, turtles and marine mammals would be low due to their extensive distribution ranges, or whether the spill occurred closer to the shore where encounters with sensitive receptors will be higher. In the case of a spill or collision within Algoa Bay and *en route* to the Port, the spill may extend into the Addo Elephant MPA and would affect the Algoa to Amathole EBSA, and would likely reach the shore affecting intertidal and shallow subtidal benthos and sensitive coastal bird species. The intensity of a heavy oil spill within Algoa Bay can be considered of high intensity, potentially extending regionally, and with impacts potentially persisting over the medium- to long-term. A heavy oil spill would consequently be of **HIGH** significance. In the case of marine diesel, which evaporates relatively quickly, the impact would only persist over the short-term and would likely remain localised but would be of medium intensity. A precautionary approach is adopted and the worst-case scenario of a heavy fuel oil spill outside of the port boundary is assumed in the assessment below. It must be pointed out that the probability of a spill or collision is highly unlikely.

Impact: Release of marine diesel or heavy fuel oil into the marine environment

	Extent	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Without mitigation	Regional 2	High 3	Long-term 3	**Very High** **8**	Improbable	**HIGH**	**- ve**	High
Essential mitigation measures[6]: • Ensure that all project-associated vessels have an oil spill contingency plan in place. • As far as possible, and whenever the sea state permits, attempt to control and contain the spill at sea with suitable recovery techniques to reduce the spatial and temporal impact of the spill. • Ensure adequate resources are provided to collect and transport oiled birds to a cleaning station. • Refueling is to take place only under controlled conditions within the port.								
With mitigation	Local 1	Medium 2	Short-term 1	**Very Low** **4**	Improbable	**INSIGNIFI-CANT**	**- ve**	High

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[6] These measures are most likely already in place as part of Port operations but are included here for the sake of completeness

5. MITIGATION MEASURES AND MONITORING REQUIREMENTS

5.1. Mitigation Measures

The essential mitigation measures for the development of the LNG terminal are:

- All dredging activities and associated environmental monitoring must be conducted in accordance with the conditions stipulated under the port expansion authorisation.
- All contractors must have an approved Environmental Management Plan (EMP) in place that ensures that environmental impacts are minimised as far as practicably possible.
- Ensure that all pile driving is undertaken in accordance with international protocols (e.g. JNCC 2010; DPTI 2012), which stipulate:
  - Avoid conducting piling activities during times when marine mammals are likely to be breeding, calving, feeding, or resting in biologically important habitats. In Algoa Bay, African Penguins breeding is extended, but nesting usually peaks from March to May; nesting of Cape Gannets extends from August to April. Humpback whales pass through the area around April, continuing through to September/October when the southern migration begins and continues through to December; cow-calf pairs are usually the last to leave and may use Algoa Bay as a resting site on their way south. Southern right whales typically arrive in coastal waters between June and November each year, although animals may be sighted as early as April and as late as January. Southern rights are found in groups of 1-10 individuals, with cow-calf pairs predominating in inshore nursery areas. From July to October, animals aggregate and become involved in surface-active groups, which can persist for several hours. Piling operations should therefore take place between January and March.
  - Use low noise piling methods, such as vibro-driving, instead of impact piling methods where possible.
  - Piling activities should be monitored by Marine Mammal Observers (MMO) and Passive Acoustic Monitoring (PAM) operatives to detect marine mammals and to potentially recommend a delay in the commencement of piling activity if any marine mammals are detected;
  - Establish a 500 m radius mitigation zone around the pile driving activity (measured from the pile location);
  - Prior to the commencement of pile driving operations, the mitigation zone must be monitored visually by MMO and acoustically by PAM for a period of at least 30 minutes;
  - Piling should not be commenced if marine mammals are detected within the mitigation zone or until 20 minutes after the last visual or acoustic detection;
  - Implement a ‘soft-start’ procedure of at least 10 minutes at the start of piling operations. This involves the gradual ramp-up of piling power allowing marine mammals and fish to move away from the noise source;
  - Piling should not commence in the dark or during periods of low visibility;
  - If a marine mammal enters the mitigation zone during the soft-start then, whenever possible, the piling operation should cease, or at least the power should not be further increased until the marine mammal exits the mitigation zone, and there is no further detection for 20 minutes.

  - When piling at full power, there is no requirement to cease piling or reduce the power if a marine mammal is detected in the mitigation zone. The marine mammal should, however, be continuously monitored by MMO;
  - If there is a pause in the piling operations for a period of greater than 10 minutes, then the pre-piling search and soft-start procedure should be repeated before piling recommences. If a watch has been kept during the piling operation, the MMO or PAM operative should be able to confirm the presence or absence of marine mammals, and it may be possible to commence the soft-start immediately. However, if there has been no watch, the complete pre-piling search and soft-start procedure should be undertaken;
  - The MMO and PAM reports compiled in accordance with JNCC guidelines should be sent to the relevant conservation agency after the end of the piling activity.
- Include the standard management and mitigation procedures, and any in the contract documentation of the construction contractor;
- Consider the use of a bubble curtain. As the noise from pile driving is transmitted through the sediment into the water, bubble screens do not eliminate all behavioural responses to the piling noise, but reported noise reductions range from 3 to 20 dB (Würsig *et al.* 2000; DPTI 2012).
- Design intakes to minimise entrainment or impingement by reducing the average intake velocity to about 0.1 to 0.15 m/s. This is comparable to background currents in the oceans, and will allow mobile organisms to swim away from the intake under these flow conditions (UNEP 2008).
- Optimise operating modes in the open-loop system as far as possible to reduce impacts, or use closed-loop systems in recruitment areas or during periods when abundances of eggs and larvae are seasonally high.
- Use multi-port discharges and adjust the discharge rate to facilitate enhanced mixing with the receiving water body.
- Ports should discharge horizontally or within -45° of horizontal to maximise dilution and avoid erosion of the sediments where the jet hits the seabed.
- The LNGCs must have a Ballast Water Management Plan in place.
- Ballast water exchange must be done at least 200 nautical miles from the nearest land in waters of at least 200 m deep; the absolute minimum being 50 nautical miles from the nearest land.
- Ensure that routine cleaning of ballast tanks to remove sediments is carried out, where practicable, in mid-ocean or under controlled arrangements in port or dry dock, in accordance with the provisions of the ship's Ballast Water Management Plan.
- Use filtration procedures during loading of ballast in order to avoid the uptake of potentially harmful aquatic organisms, pathogens and sediment that may contain such organisms.
- Neutralise NaOCl with SMBS prior to discharge to ensure that the most conservative international guideline value (<2 µg/ℓ) for residual chlorine at the point of discharge is met.
- Blend the brine from the onboard desalination plant with the cooling/heating water prior to release.

- Reduce lighting in non-essential areas.
- Use of guards to direct lights to areas requiring lighting
- Avoid direct light in water, exept during safety inspections
- Low light mounting where possible
- Use of long-wavelength lights that are less intense for nocturnal animals.
- Implement a waste management system that addresses all wastes generated at the various sites, shore-based and marine. This should include:
  - Separation of wastes at source;
  - Recycling and re-use of wastes where possible;
  - Treatment of wastes at source (maceration of food wastes, compaction, incineration, treatment of sewage and oily water separation).
- Implement leak detection and repair programmes for valves, flanges, fittings, seals, etc.
- Use a low-toxicity biodegradable detergent for the cleaning of all deck spillages.
- As per IFC (2007) and World Bank (2017) guidelines for FSRUs prepare an emergency response plan covering recommended measures to prevent and respond to LNG spills.
- The hypochlorite generation unit on the offloading platform must be suitably bunded to prevent and spills from the plant entering the marine environment.
- Ensure that vessel speed is kept below 10 knots when underway in Algoa Bay.
- The vessel operators should keep a constant watch for slow-swimming large pelagic fish, marine mammals and turtles in the path of the vessel.
- Ensure that all project-associated vessels have an oil spill contingency plan in place.
- As far as possible, and whenever the sea state permits, attempt to control and contain the spill at sea with suitable recovery techniques to reduce the spatial and temporal impact of the spill.
- Ensure adequate resources are provided to collect and transport oiled birds to a cleaning station.
- Refueling is to take place only under controlled conditions within the port.

The best practice mitigation measures for the development and operation of the LNG terminal are:

- Implement closed-loop systems whenever practicable.
- Implement the principle of mechanical cleaning of the entire system as part of regular annual maintenance of the FSRU in preference to the use of a biocide.
- Fit deflector plates to discharges directed vertically downwards to modify the discharge to 45°.
- Manage suspended sediment plumes generated during dredging and construction of the LNG Terminal by the installation of silt curtains.

- Demonstrate that the BATNEEC (Best Available Technique Not Entailing Excessive Cost) approach has been applied to proposed pile driving operations.
- Avoid pile driving in the early morning and evening when seabirds are leaving for offshore feeding areas or returning to their nesting sites.
- Consider the use of Acoustic Deterrent Devices in conjunction with visual and/or acoustic monitoring to exclude animals from the piling area;
- As per IFC (2007) and World Bank (2017) guidelines for FSRUs
  - Consider water conservation opportunities for LNG facility cooling systems (e.g. air-cooled heat exchangers in place of water-cooled heat exchangers and opportunities for the integration of cold-water discharges with other proximate industrial or power plant facilities). The selection of the preferred system should balance environmental benefits and safety implications of the proposed choice.
  - Discharge cooling or cold water to surface waters in a location that will allow maximum mixing and dilution of the thermal plume to ensure that the temperature is within 3 °C of ambient temperature at the edge of the mixing zone or within 100 m of the discharge point.
- Ensure that hulls are regularly cleaned in controlled environments at ports certified to undertake such operations.
- Compile a lighting plan that identifies specific measures that could be implemented to minimize or avoid impacts associated with operational nighttime lighting on avian species, fish species, and marine mammals.
- All construction activities in the coastal zone must be managed according to a strictly enforced Environmental Management Plan.
- Good house-keeping must form an integral part of any marine construction operations from start-up

5.2. Monitoring Recommendations

- During pile-driving operations monitoring by Marine Mammal Observers (MMO) and Passive Acoustic Monitoring (PAM) operatives to detect marine mammals must be undertaken;
- Engage an acoustic consultant to undertake a site-specific underwater noise assessment. At a minimum this should:
  - Determine the existing ambient noise environment based on measurements.
  - Establish the likely hearing sensitivity and bandwidth for the considered sensitive marine mammal species, and determine noise exposure criteria for behavioural and physiological impacts.
  - Determine the expected source levels for the piling/construction activity, and predict received levels versus distance from the piling activity using a suitable noise propagation modelling method.
  - Estimate the size of the zone of audibility, responsiveness, and hearing injury based on the above information, and determine suitable sizes for the safety zones.
- Undertake an entrainment study to more accurately determine the potential impacts of impingement and entrainment on communities within the Port of Ngqura.

- Implement an invasive species monitoring programme both in the harbour and on the St Croix Island Group.

6. CONCLUSIONS

6.1. Impact Summary

The impact assessment identified that the marine environment will be impacted to some degree during the construction and operational phases of the proposed Coega LNG terminal. With the exception of the creation of artificial hard substrata, which can be considered a positive impact, all other impacts were rated as negative.

A summary of impacts is provided below.

Impact	Significance (before mitigation)	Significance (after mitigation)
Elimination of benthic communities through disturbance and loss of substratum	Very Low	Very Low
Reduced physiological functioning of marine organisms due to increased suspended sediment concentrations or turbidity	Very Low	Very Low
Toxic effects of remobilised contaminants and nutrients in the dredge and construction area on marine organisms	Insignificant	Insignificant
Disturbance, behavioural changes and avoidance of feeding and/or breeding areas in fish, seabirds, seals, turtles and cetaceans due to underwater noise generated by dredging and general construction	Very Low	Very Low
Disturbance, behavioural changes and avoidance of feeding and/or breeding areas in fish, seabirds, seals, turtles and cetaceans due to underwater noise from the LNGCs and FSRU	Very Low	Very Low
Disturbance, behavioural changes and avoidance of feeding and/or breeding areas in fish seabirds, seals, turtles and cetaceans due to pile driving, underwater drilling and hydraulic rock breaking	Medium	Very Low
Creation of Artificial Hard Substrata	Very Low	Very Low
Intake of large volumes of seawater from the port	Medium	Low
Introduction and spread of non-native species	Medium	Low
Discharge of high volumes of water with depressed or elevated temperatures	Very Low	Very Low
Discharge of co-pollutants (biocide, metals and salinity)	Very Low	Very Low
Increase in ambient lighting	Very Low	Very Low
Waste Discharges to Sea	Low	Low
Accidental Spills if LNG	Insignificant	Insignificant
Accidental Spills if Hypochlorite	Insignificant	Insignificant
Faunal strikes with LNGCs and Dredgers	Insignificant	Insignificant
Release of diesel to sea during bunkering or due to vessel accident	High	Insignificant

6.2. Cumulative Impacts and Climate Change

Anthropogenic activities in the coastal zone can result in complex immediate and indirect effects on the natural environment. Effects from disparate activities can combine and interact with each other in time and space to cause incremental or cumulative effects. Cumulative effects can also be defined as the total impact that a series of developments (both disparate and similar), 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).

To define the level of cumulative impact in the intertidal and subtidal environment within the Port of Ngqura, it is therefore necessary to look beyond the environmental impacts of the current project and consider also the influence of other past, current or future developments in the area, relating both to further port developments as well as other gas-to-power developments within and around the Port of Ngqura as part of the Risk Mitigation Independent Power Producer Procurement Programme (RMIPPPP). From a marine perspective this requires consideration of a further two projects, namely:

- The development by **Engie Southern Africa (Pty) Ltd** of a dedicated mooring for a Floating Storage Unit (FSU) along the eastern breakwater[7] within the Port of Ngqura for unloading of LNG from an LNG Carrier (LNGC), with subsequent transfer to road tankers that will be ferried across the port on a floating truck carrier to a Roll-on/Roll-off berth; and
- The development by **Karpowership SA (Pty) Ltd** of two floating, mobile powerships moored within the Port of Ngqura receiving piped gas from a FSRU moored along the eastern breakwater[8]. The FSRU will periodically receive gas from a LNGC calling at the port.

Cumulative impacts would relate specifically to:

- Changes in habitat due to construction of quays, breakwaters, underwater revetments, jetties and mooring and berthing dolphins or placement of mooring legs;
- Compromised water quality due to capital and maintenance dredging, operational discharges from ships within the port and waste water discharges into the port *via* the Coega River;
- Physiological effects on marine fauna of thermal discharges;
- Increased background anthropogenic noise levels;
- Compromised sediment quality within the port in response to increased port development and other anthropogenic sources in the Coega Special Economic Zone;
- Increased introductions of non-native species on vessel hulls and in ballast water; and
- Impingement and entrainment effects of multiple seawater intakes within the port.

Cumulative effects on the marine ecology in response to the proposed development are thus highly likely.

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[7] The proposed mooring dolphins are located further along the breakwater and to the south of the berthing dolphins and access trestle planned for the current project. Cumulative impacts could thus occur consecutively as well as concomitantly.

[8] The preferred position for mooring of the FSRU conflicts with the location of the access trestle and berthing dolphins proposed for the current project. This suggests that cumulative impacts would only occur consecutively rather than concomitantly.

The Climate Change Impact Assessment (Promethium 2020) identified that the Gas Distribution Infrastructure was anticipated to experience various climate-related changes including increased atmospheric temperatures, decreased annual rainfall events but increased flood occurrences, and increased storm and wind severity. Although the Port of Ngqura has already taken impacts such as sea level rise and increased storm surge into account during its design, the climate change study recommended that the potential impact of extreme weather events such as severe storms/storm surge be taken into accound in the design of infrastructure (including the LNG terminal). Associated climate change effects such as ocean warming would ultimately contribute cumulatively to changes in biodiversity of marine organisms and range-related community shifts.

6.3. Conclusions

Other than the unplanned event of a vessel accident or the release of large volumes of diesel into the marine environment, the impacts of MEDIUM significance relate primarily to short-term construction impacts, the introduction and spread of non-native marine species and impingement and entrainment effects resulting from the intake of large volumes of seawater from the Port for the purposes of re-gasification, cooling and ballasting. Whereas the introduction of non-native marine species is a cosmopolitan problem in all ports, the intake of large volumes of water from a relatively confined and sheltered waterbody such as a port warrants further consideration, especially when the port has been identified as supporting one of the most abundant and diverse fish populations along the South African coastline, and functioning as an important habitat for both juvenile and adult fish many of which are considered ‘vulnerable’, ‘endangered’ and ‘critically endangered’.

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A.1. Seawater Chlorine Chemistry and Associated Potential Impacts

The chemistry associated with seawater chlorination when using chlorine-based products is complex and only a few of the reactions are given below, summarised from ANZECC (2000), Lattemann and Höpner (2003) and UNEP (2008). Chlorine does not persist for extended periods in water but is very reactive. Its by-products, however, can persist for longer. The addition of sodium hypochlorite to seawater results in the formation of hypochlorous acid:

$NaOCl + H_2O \rightarrow HOCl + Na^+ + OH^-$

Hypochlorous acid is a weak acid, and will undergo partial dissociation as follows:

$HOCl \rightarrow H^+ + OCl^-$

In waters of pH between 6 and 9, both hypochlorous acid and hypochlorite ions will be present; the proportion of each species depending on the pH and temperature of the water. Hypochlorous acid is significantly more effective as a biocide than the hypochlorite ion.

In the presence of bromide (Br-), which like chloride is a natural component of seawater (average bromide concentration in seawater is 67 mg/ℓ), chlorine instantaneously oxidises bromide to form hypobromous acid and hypobromite (HOBr):

$HOCl + Br^- \rightarrow HOBr + Cl^{--}$

Hypobromous acid is also an effective biocide. It is worth noting that, for a given pH value, the proportion of hypobromous acid relative to hypobromite is significantly greater than the corresponding values for the hypochlorous acid - hypochlorite system. Thus, for example, at pH 8 (the pH of seawater), hypobromous acid represents 83% of the bromine species present, compared with hypochlorous acid at 28%. Hypobromous acid can also disproportionate into bromide and bromated, which is accelerated by sunlight.

In natural waters, chlorine can undergo a range of reactions in addition to those discussed above, leading to the formation of a range of by-products. The reaction of chlorine with organic constituents in aqueous solution can be grouped into several types:

(a) Oxidation,
where chlorine is reduced to chloride ion, e.g. $RCHO + HOCl \rightarrow RCOOH + H^+ + Cl^-$

(b) Addition,
to unsaturated double bonds, e.g. $RC = CR' + HOCl \rightarrow RCOHCClR'$

(c) Substitution,
to form N-chlorinated compounds, e.g. $RNH_2 + HOCl \rightarrow RNHCl + H_2O$
or C-chlorinated compounds, e.g. $RCOCH_3 + 3HOCl \rightarrow RCOOH + CHCl_3 + 2H_2O$

Chlorine substitution reactions can lead to the formation of organohalogen compounds, such as chloroform, and, where HOBr is present, mixed halogenated and brominated organic compounds. The number of by-products can hardly be determined due to many possible side reactions. A major component, however, are the trihalomethanes (THMs) such as bromoform. Concentrations of other halogenated organics are considerably lower and usually in the nanogram per liter range. Substances of anthropogenic origin in coastal waters, especially mineral oil or diesel fuels, may give rise to compounds like chlorophenols (some of which can taint fish flesh at concentrations as low as 0.001 mg/ℓ (DWAF 1995)) or chlorobenzenes. However, THMs such as bromoform account for most of the compounds.

A number of other source water characteristics are likely to have an impact on the concentrations of organic by-products present in brine water discharges: natural organic matter in water is the major precursor of halogenated organic by-products, and hence the organic content of the source water (often measured as total organic carbon, TOC) may affect the concentration of by-products formed. In general, the higher the organic content of the source water, the higher the potential for by-product formation. The ammonia concentration is likely to affect the extent of by-product formation, through reaction with chlorine to form chloramines. Although seawater generally contains low concentrations of ammonia than freshwater, under certain conditions (dependent on chlorine dose: ammonia nitrogen concentration) it can compete with bromide for the available chlorine to form monochloramine. In addition, hypobromous acid can react with ammonia to form bromamines. Although the sequence of reactions is complex, it is likely that the reaction of either hypochlorous or hypobromous acid with ammonia to form halamines will reduce organic by-product formation during the chlorination of seawater. Chlorine can also react with nitrogen-containing organic compounds, such as amino acids to form organic chloramines. The pH of the incoming feed water water could also affect the nature of the by-products formed. In general, while variations in pH are likely to affect the concentrations of individual by-products, the overall quantity formed is likely to remain relatively constant. Little is known about the biocidal properties of these compounds.

Paradoxically, chlorine chemistry thus establishes that no free chlorine is found in chlorinated seawater where bromide oxidation is instantaneous and quantitative. However, the chlorinated compounds, which 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).

A.2 References for Appendices

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Specialist Company Name:	Pisces Environmental Services (Pty) Ltd			
B-BBEE	Contribution level (indicate 1 to 8 or non-compliant)	EME Level 4	Percentage Procurement recognition	
Specialist name:	Andrea Pulfrich			
Specialist Qualifications:	PhD			
Professional affiliation/registration:	South African Council for Natural Scientific Professions (Pr.Sci.Nat. No: 400327/06) South African Institute of Ecologists and Environmental Scientists International Association of Impact Assessment (South Africa)			
Physical address:	20 Plein Street, McGregor			
Postal address:	PO Box 302, McGregor			
Postal code:	6708	Cell:	082 7818152	
Telephone:	021 7829553	Fax:	n/a	
E-mail:	apulfrich@pisces.co.za			

2. DECLARATION BY THE SPECIALIST

I, _____Andrea Pulfrich____________, declare that –

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, Regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- all the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of regulation 48 and is punishable in terms of section 24F of the Act.

Andrea Pulfrich

Signature of the Specialist

Pisces Environmental Services (Pty) Ltd

Name of Company:

19 January 2021

Date

3. UNDERTAKING UNDER OATH/ AFFIRMATION

I, ____Andrea Pulfrich______, swear under oath / affirm that all the information submitted or to be submitted for the purposes of this application is true and correct.

Andrea Pulfrich

Signature of the Specialist

Pisces Environmental Services (Pty) Ltd

Name of Company

19 January 2021

Date

7206994-5

Signature of the Commissioner of Oaths

2021. 01. 20

Date

SOUTH-AFRICAN POLICE SERVICE
STATION COMMANDER MCGREGOR
20 JAN 2021
STASIE BEVELVOERDER MCGREGOR
SUID-AFRIKAANSE POLISIE DIENS