# ENVIRONMENTAL IMPACT ASSESSMENT IN SUPPORT OF THE AMENDMENT TO THE MINING RIGHT HELD BY WEST COAST RESOURCES (PTY) LTD OVER THE NAMAQUALAND MINES, NORTHERN CAPE PROVINCE

## Marine Specialist Assessment

Prepared for:

MYEZO ENVIRONMENTAL MANAGEMENT SERVICES
*Environmental Stewardship*

On behalf of:

West Coast Resources

January 2016

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## Marine Specialist Assessment

Prepared for

Myezo Environmental Management Services

On behalf of

West Coast Resources (Pty) Ltd

Prepared by

Andrea Pulfrich
Pisces Environmental Services (Pty) Ltd

August 2016

PISCES Environmental Services (Pty) Ltd

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## EXECUTIVE SUMMARY

West Coast Resources (WCR), a merger between Trans Hex Operations (Pty) Ltd, various companies and the Government Sector, intends to re-visit and mine a number of mines on the Namaqualand coast. Concession 6A is located north of Hondeklipbaai, including Koingnaas 475 and Samson's Bak 330, and Concession 7A is located south of Hondeklipbaai on Langklip 489 and Mitchells Bay 495. The acquisition of the existing mining rights in the South African Sea Concessions 8a and 9a, and prospecting rights in Concession 8b, formerly held by Namagroen Prospecting and Investments, are also underway. As the mining approach would involve the construction of coffer dams in the intertidal area or shoreline accretion to optimise the extraction of coastal diamond resources, an amendment of the current environmental authorisations over these mining rights areas is required.

To meet the requirements of the Mineral and Petroleum Resources Development Act and the National Environmental Management Act, an Environmental Impact Assessment (EIA) process is needed in order to obtain environmental authorisation for the proposed new activities. Myezo Environmental Management Services are undertaking the required EIA and in turn have approached Pisces Environmental Services (Pty) Ltd to provide marine specialist inputs as part of the EIA.

The project area encompasses a ~135 km stretch of the coastal and shallow marine habitats that fall within the central Benguela region. The Benguela region is dominated by wind-driven upwelling and swell events. Seasonal changes result in substantial differences between the typical summer and winter wind patterns in the region, and a cessation of upwelling in winter.

Most of the west coast of southern Africa is classified as exposed, experiencing strong wave action, rating between 13 - 17 on the 20 point exposure scale. South Atlantic Central Water (SACW) comprises the bulk of the seawater in the study area, either in its pure form in the deeper regions, or mixed with previously upwelled water of the same origin on the continental shelf. The continental shelf waters of the Benguela system are characterised by low oxygen concentrations, especially on the bottom.

During upwelling, the comparatively nutrient-poor surface waters are displaced by enriched deep water, supporting substantial seasonal primary phytoplankton production. High phytoplankton productivity in the upper layers again depletes the nutrients in these surface waters. This results in a wind-related cycle of plankton production, mortality, sinking of plankton detritus and eventual nutrient re-enrichment occurring below the thermocline as the phytoplankton decays. Biological decay of plankton blooms can in turn lead to "black tide" events.

An associated phenomenon ubiquitous to the Benguela system are red tides (dinoflagellate and/or ciliate blooms). Toxic dinoflagellate species can cause extensive mortalities of fish and shellfish through direct poisoning, while degradation of organic-rich material derived from both toxic and non-toxic blooms results in oxygen depletion of subsurface water.

The study area lies within the relatively uniform cool Namaqua marine biogeographic region. The major force driving the ecology of this region is coastal upwelling, predominantly occurring in the spring/summer period when the south-easterly is the prevailing wind. The upwelling process supplies inorganic nutrients to the euphotic zone supporting high biological productivity (see previous section). This coast is, however, characterized by low marine species richness and low endemicity.

The biota of nearshore marine habitats on the West Coast is relatively robust, being naturally adapted to an extremely dynamic environment where biophysical disturbances are commonplace. The benthic communities within this region are largely ubiquitous, particular only to substrate type (i.e. hard vs. soft bottom), exposure to wave action, or water depth. Habitats specific to the study area include:

- Sandy intertidal and subtidal substrates,
- Intertidal rocky shores and subtidal reefs, and
- The water body.

The biological communities consist of many hundreds of species, often displaying considerable temporal and spatial variability - even at small scales. No rare or endangered species have been recorded.

The West Coast rock lobster *Jasus lalandii* is a valuable resource of the South African West Coast and consequently an important income source for West Coast fishermen. The study area falls within Area 2 of the commercial rock lobster fishing zones that extends from Kleinzee to the mouth of the Brak River. Commercial catches of rock lobster in Area 2 are confined to shallower water (<30 m) with almost all the catch being taken in <15 m depth. Actual rock-lobster fishing, however, takes place only at discrete suitable reef areas along the shore within this broad depth zone. Lobster fishing is conducted from a fleet of small dinghies/bakkies.

The West Coast is divided into numerous seaweed concession areas. Permit holders collect beach casts of both *Ecklonia maxima* and *Laminaria pallida* from the driftline of beaches. The dried product is ground before being exported for production of alginic acid (alginate).

Commercial linefishing is conducted from a variety of vessels ranging from large deckboats to tiny rock lobster bakkies, most of which operate very close to the shore. The estimated annual inshore linefish catch along the Northern Cape coast amounts to <5 t/km/year. Recreational and subsistence fishing on the West Coast is small in scale when compared with the south and east coasts of South Africa. Recreational line-fishing is confined largely to rock and surf angling in places such as Brand-se-Baai and the more accessible coastal stretches in the regions. Recreational rock lobster catches are made primarily by diving or shore-based fishing using baitbags. Large numbers of rock lobsters are harvested in sheltered bays along the Namaqualand coastline by recreational divers who disregard bag-limits, size-limits or closed seasons. This potentially has serious consequences for the sustainability of the stock in the area.

Nearshore shallow-water diamond mining is typically conducted by divers using small-scale suction hoses operating either directly from the shore or from converted fishing vessels in small bays and out to ~30 m depth. Diver-assisted mining is largely exploratory and highly opportunistic in nature, being dependent on suitable, calm sea conditions. Vessel-based diver-mining contractors usually work in the depth range immediately seaward of that exploited by shore-based divers, targeting gullies and potholes in the sub-tidal area usually just behind the surf-zone.

The economy of the Namaqualand region is dominated by mining. However, with the decline in the mining industry and the closure of many of the coastal mines, the economy of the region is declining and jobs are being lost with potential devastating socio-economic impacts on the region. The Northern Cape provincial government has recognized the need to investigate alternative economic activities and concluded that fishing and specifically mariculture offer a significant opportunity for long term (10+ years) sustainable economic development along the Namaqualand coast. The major opportunities cited in these studies include hake and lobster fishing, seaweed harvesting and aquaculture of abalone, seaweeds, oysters and finfish.

'No-take' MPAs offering protection of the Namaqua biozones are currently absent northwards from Cape Columbine. Rocky shore and sandy beach habitats are generally not particularly sensitive to disturbance and natural recovery occurs within 2-5 years. However, much of the Namaqualand coastline has been subjected to decades of disturbance by shore-based diamond mining operations. These cumulative impacts and the lack of biodiversity protection have resulted in most of the coastal habitat types in Namaqualand being assigned a threat status of 'critically endangered'. Of those, 'critically endangered' Namaqua Sandy Inshore and Namaqua Sandy Rocky Coast occur in the concession but not the mining target areas, and 'endangered' Namaqua Mixed Shore occurs within the mining target areas.

A systematic biodiversity plan has been developed for the West Coast which identifies nine focus areas for protection on the West Coast between Cape Agulhas and the South African – Namibian border. Of principal importance in the project area is the proposed Namaqua MPA, which stretches between the Groen and Spoeg Rivers and adjacent to the Namaqua National Park. This area meets habitat targets for 14 habitat types including Critically Endangered habitat types such as Namaqua Inshore Reef, Namaqua Inshore Hard Grounds and Namaqua Sandy Inshore. The proposed Namaqua MPA inshore protected area overlaps with Concessions 8a, 9a and 8b. WCR has agreed to relinquish those areas within these concessions that overlap with the proposed Namaqua MPA.

For each impact, the SEVERITY, DURATION and EXTENT are described, a function of which was used to determine the CONSEQUENCE of the impact. The SIGNIFICANCE of an impact is then determined by multiplying the consequence of the impact by the probability of the impact occurring. In addition, the status of the impact, the degree of confidence in the assessment, the reversibility of the impact, degree of loss of resources and degree to which the impact can be mitigated were rated.

As part of the stakeholder engagement for this EMPr amendment meetings were held with the Department of Agriculture, Forestry and Fisheries, Department of Environment and Nature Conservation, and with the Department of Environmental Affairs – Oceans and Coast. The issues specifically associated with the marine environment raised by key stakeholders were :

- Overlap of proposed mining activities with proposed MPAs and with Operation Phakisa;
- Potential conflict with abalone ranching rights holders regarding water quality and habitat loss, particularly those companies that have already started seeding juveniles;
- Increased turbidity near mining site(s) may compromised water quality at the seawater intakes to land-based abalone farms.
- The impacts of suspended sediment plumes and elevated turbidity as a result of mining operations need to be assessed;
- Increased turbidity near mining site(s) may impact filter feeders;

- Requirements for discharge permits regarding discharges to the sea (particularly from diver-assisted shore units) is unclear.
- Blasting in the marine environment should be avoided and materials used for the construction of berms re-used as much as possible;
- Concern regarding the introduction of non-native material onto the beach during berm construction;
- Concern regarding the disturbance to marine habitats and associated biota through mining in subtidal areas; and
- The impacts associated with coffer dam construction vs. accretion need to be carefully considered.
- As seal colonies are unique habitats within the project area these should be mapped, and information available at DAFF and DEA should be used.
- Quantitative marine baseline studies focussing on the specific mining sites need to be undertaken;
- Provide DEA with information on the experimental design of baseline and monitoring studies prior to commencement of surveys;
- Give consideration to co-ordination of monitoring programmes with DEA and sharing of research information;
- Baseline and monitoring studies should focus both on rocky habitats (including an assessment on the impacts on reef structure) as well as sandy beach habitats;
- The recovery of these habitats following mining needs to be understood from the perspective of species recruitment and colonisation;
- Monitoring programmes should be co-ordinated to ensure an upfront understanding of sensitive habitats in the project area, with subsequent avoidance of these in the mine plans; and
- Give consideration to implementing a Strategic Environmental Assessment approach in partnership with other role players in the area so as to gain a broader understanding of the coastline rather than focusing on the project specific sites.
- Decommisioning and closure is required of old mining sites no longer used;
- As active rehabilitation below the low water mark is not practicable, there is concerns that wave action may not be sufficient to ensure natural rehabilitation of berms; and
- The viability of creating artificial habitats to offset habitat disturbance should be considered (e.g. leaving the rock armour of the berms in place to form islands as roosting habitats for seabirds);
- There is a need for the development of beach management plans for management of mining impacts;
- Strict house-keeping is required at beach mining sites (e.g. no refueling on the beach, and all equipment to be removed on cessation of operations); and
- An Environmental Control Officer should be appointed to ensure compliance with the Environmental Management Plan;

Issues relating to potential impacts on the marine environment identified by the marine specialist included:

- Damage to and destruction of intertidal and shallow subtidal communities as a result of shore-based diver-mining activities.

- Reduction in kelp bed habitats, potentially reducing suitable rock lobster recruitment habitats, and affecting the long-term sustainability of the resource.
- Blanketing of near-shore reefs and bedrock outcrops and their associated communities by discharged tailings.
- Burial of rocky shore and sandy beach benthos as a consequence of accretion and berm construction;
- Alteration of the physical characteristics of the beach through construction of coffer dams and aggressive shoreline accretion;
- Changes in macrofaunal community structure in response to physical changes of the beach;
- Generation of suspended sediment plumes;
- Disturbance and loss of intertidal and subtidal habitat and associated communities in the berm footprint and within the mining block; and
- Sedimentation of reef habitats adjacent to the mining site due to redistribution of sediments

Following a review and expert interpretation of all relevant, available local and international publications and information sources on the disturbances and risks associated with shore-based diver mining, seawall mining and beach accretion, all potential impacts resulting from the proposed mining operations that may influence the marine and coastal environment in the region were assessed. The significance of the impacts both before and after mitigation are summarised in the table below.

| Impact | Significance (before mitigation) | Significance (after mitigation) |
|---|---|---|
| **Impacts of shore-based divers** | | |
| Crushing and trampling | Low | Low |
| Kelp cutting | Low | Low |
| Degradation of nearshore reef habitats | Medium | Low |
| **Impacts of Beach and offshore channel mining** | | |
| Loss of benthic biota in construction and mining footprint | Medium - High | Medium - High |
| Burial of benthic biota | Medium - High | Medium - High |
| Changes in biophysical characteristics | Medium | Medium |
| Effects of suspended sediment plumes | Low | Low |
| Development of hypoxic sediments | Low | Low |
| Sedimentation of intertidal and subtidal reefs | Medium | Medium |
| Impacts on higher order consumers | Low | Low |

Environmental management actions should focus on the following aspects to be considered prior to, during and on cessation of mining activities in an area:

- Develop the mine plan to ensure that mining proceeds systematically and efficiently from one end of the target area to the next, and that the target area is mined to completion in as short a time as possible.
- To allow impacted communities to recover to a condition where they are functionally equivalent to the original condition, the beaches should not be re-mined for at least five years, if at all. Efficient, high intensity mining methods are thus preferable to repeated operations.

- To prevent degradation of the sensitive high-shore beach areas, all activities must be managed according to a strictly enforced Environmental Management Plan. High safety standards and good house-keeping must form an integral part of any operations on the shore from start-up, including, but not limited to:
  - drip trays and bunding under all vehicles and equipment on the shore where losses are likely to occur;
  - no vehicle maintenance or refuelling on shore;
  - accidental diesel and hydrocarbon spills to be cleaned up accordingly; and
  - collect and dispose polluted soil at appropriate bio-remediation sites.
- To avoid unnecessary disturbance of communities and destruction of habitats, heavy vehicle traffic in the high- and mid-shore must be limited to the minimum required, and must be restricted to clearly demarcated access routes and operational areas only. The operational footprint of the mining site should be minimised as far as practicable.
- Initiate restoration and rehabilitation as soon as mining is complete in an area. This should involve removal (and re-use) of as much of the rock armour off the berms as possible, levelling of seawalls above the low water mark to facilitate more rapid natural erosion by the sea, back-filling excavations using seawall material, tailings and discards and restoring the beach profile to that resembling the pre-mining situation. No accumulations of tailings should be left above the high water mark.
- Berms should be designed in such a way that they will erode naturally as rapidly as possible as soon as active maintenance ceases. Once mining has been completed in an area, as much of the berms as possible should be actively removed, leaving only those portions below the low water mark to be eroded naturally.
- On cessation of operations, all mining equipment, artificial constructions or beach modifications created during mining must be removed from above and within the intertidal zone.
- To quantify the full impact of the mining using berms on the beaches in the mining and prospecting licence areas, it is recommended that a structured Before-After/Control-Impact (BACI) monitoring programme be implemented. The experimental design and details of this programme should be compiled in collaboration with the DEA: Oceans & Coasts. Monitoring should commence before mining starts, be undertaken for at least as long as mining remains in operation, and thereafter to determine the rate of recovery. Monitoring should continue until communities in the impacted areas show evidence of having recovered to within 80% of levels at suitable ‘reference’ sites (bioequivalence tests) over a minimum of at least three successive years. However, following each survey the status of the beach should be re-assessed and the sampling programme revised to reflect both changes in the impacted communities as well as changes to the mining plan(s). The requirements for a monitoring programme and the proposed methodology are presented in Appendix I.
- In the case of diver-assisted shore-based mining operations, the following mitigation measures should be implemented:
  - No disposal of tailings above the high water mark;
  - Avoid re-mining of sites in the medium term;
  - Prohibit blasting and large-scale removal of rocks from subtidal gullies into the intertidal;
  - Designate and actively manage specific access, storage and operations areas;

  - Remove all equipment on completion of activities; and
  - Flatten all remaining tailings heaps on completion of operations.

If all environmental guidelines, and appropriate mitigation measures advanced in this report, and the EIA for the proposed project as a whole, are implemented, there is no reason why the coffer-dam mining operations proposed along the open coast should not proceed.  However, every effort should be made to avoid disturbance, even on a localised scale, of benthic habitats identified as ‘endangered’ or ‘critically endangered’ by Sink et al. (2012).  However, mining of Mitchell’s Bay, either by beach accretion or berm construction, is not recommended from a biodiversity and geomorphological perspective.

## ABBREVIATIONS & UNITS

| | |
|---|---|
| cm | centimetres |
| cm/s | centimetres per second |
| $C/m^2/day$ | Carbon per square metre per day |
| CSIR | Council for Scientific and Industrial Research |
| DAFF | Department of Aquaculture, Fisheries and Forestry |
| DEA | Department of Environmental Affairs |
| DMR | Department of Mineral Resources |
| E | East |
| EEZ | Exclusive Economic Zone |
| EIA | Environmental Impact Assessment |
| EMPr | Environmental Management Programme report |
| FAMDA | Fishing and Mariculture Development Association |
| h | hour |
| $g/m^2$ | grams per square metre |
| GIS | Global Information System |
| ha | hectare |
| HAB | Harmful Algal Blooms |
| HWM | High Water Mark |
| HWS | High Water Spring tide |
| km | kilometre |
| km/h | kilometre per hour |
| $km^2$ | square kilometre |
| M&CM | Marine & Coastal Management: Department of Environment Affairs |
| MPRDA | Mineral and Petroleum Resources Development Act |
| m | metres |
| $m^2$ | square metre |
| $m^2/yr$ | square metre per year |
| $m^3$ | cubic metre |
| mm | millimetres |
| m/s | metres per second |
| mg/l | milligrams per litre |
| MPA | Marine Protected Area |
| N | North |
| NEMA | National Environmental Management Act |
| NPR | Namaqualand Prospecting Right |
| PIM | Particulate Inorganic Matter |
| POM | Particulate Organic Matter |
| S | south |
| SACW | South Atlantic Central Water |
| SANBI | South African National Biodiversity Institute |
| SFRI | Sea Fisheries Research Institute (now DAFF) |
| sp. | species (singular) |
| spp. | species (plural) |
| tons/km/yr | tons per kilometre per year |

| | |
|---|---|
| tons/km$^2$ | tons per square kilometre |
| tons/y | tons per year |
| TAC | Total Allowable Catch |
| TSPM | Total Suspended Particulate Matter |
| WCR | West Coast Resources |
| µg/l | micrograms per litre |
| µM | micro Mol |
| µm | micrometre, micron |
| °C | degrees Centigrade |
| % | percent (parts per hundred) |
| ‰ | parts per thousand |
| ~ | approximately |
| < | less than |
| > | greater than |
| ≥ | greater than or equal to |

## GLOSSARY

| | |
|---|---|
| Anti-cyclonic | An extensive system of winds spiralling outward anti-clockwise (in Southern Hemisphere) from a high-pressure centre. |
| 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 mollusk 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. |
| Cyclonic | An atmospheric system characterized by the rapid inward circulation of air masses about a low-pressure centre; circulating clockwise in the Southern Hemisphere |
| Dissolved oxygen (DO) | Oxygen dissolved in a liquid, the solubility depending upon temperature, partial pressure and salinity, expressed in milligrams/litre or millilitres/litre. |
| Epifauna | Organisms, which live at or on the sediment surface being either attached (sessile) or capable of movement. |
| Ecosystem | A community of plants, animals and organisms interacting with each other and with the non-living (physical and chemical) components of their environment. |
| Euphotic/photic zone | the zone in the ocean that extends from the surface down to a depth where light intensity falls to one percent of that at the surface; i.e. there is to sufficient sunlight for photosynthesis to occur. |

| | |
|---|---|
| Habitat | The place where a population (e.g. animal, plant, micro-organism) lives and its surroundings, both living and non-living. |
| Hypoxic | Deficiency in oxygen. |
| Infauna | Animals of any size living within the sediment. They move freely through interstitial spaces between sedimentary particles or they build burrows or tubes. |
| Intertidal | The area of seashore which is covered at high tide and uncovered at low tide. |
| 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 environment | Marine environment includes estuaries, coastal marine and near-shore zones, and open-ocean-deep-sea regions. |
| Pelagic | of or pertaining to the open seas or oceans; living at or near the surface of ocean. |
| Population | Population is defined as the total number of individuals of the species or taxon. |
| 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 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. |
| Subtidal | The zone below the low-tide level, *i.e.* it is never exposed at low tide. |
| Supratidal | The zone above the high-tide level. |
| 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 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). |
| 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 relating to marine diamond mining and dredging, hydrocarbon exploration and thermal/hypersaline effluents, both along the southern African West Coast an elsewhere in southern Africa. She is a registered Environmental Assessment Practitioner and member of the South African Council for Natural Scientific Professions, South African Institute of Ecologists and Environmental Scientists, and International Association of Impact Assessment (South Africa).

This specialist report was compiled as a desktop study on behalf of Myezo Environmental Management Services, 645 Jacqueline Street, Unit 17, Garsfontein Office Park, Garsfontein, Pretoria, 0081, South Africa. The compilation followed a review process of published (peer reviewed) and unpublished literature.

This specialist report was compiled on behalf of Myezo Environmental Management Services for their use in preparing an Environnmental Impact Asessment for coastal diamond mining activities by West Coast Resources, in the existing mining licences for Koingnaas (SNC 522 MRC), Samson's Bak (SNC 525 MRC), and Concessions 8a and 9a, as well as the prospecting licence for 8b, off the West Coast of South Africa. I do hereby declare that Pisces Environmental Services (Pty) Ltd is financially and otherwise independent of the Applicant and Myezo Environmental Management Services.

Andrea Pulfrich

Dr Andrea Pulfrich

# 1. INTRODUCTION

## 1.1 Background

West Coast Resources (Pty) Ltd (WCR), a merger between Trans Hex Operations (Pty) Ltd, various companies and the Government Sector, intends to re-visit and mine a number of mines on the Namaqualand coast, particularly those in the existing mining licences for Koingnaas 475 and Samson's Bak 330 (Figure 1). The acquisition of the existing mining rights in the South African Sea Concessions 8a and 9a, and prospecting rights in Concession 8b, formerly held by Namagroen Prospecting and Investments, are also underway. As the mining approach would involve the construction of cofferdams in the intertidal area to optimise the extraction of coastal diamond resources, an amendment of the current environmental authorisations over these mining rights areas is required.

To meet the requirements of the Mineral and Petroleum Resources Development Act (MPRDA) and the National Environmental Management Act (NEMA), an Environmental Impact Assessment (EIA) process is needed in order to obtain environmental authorisation for the proposed new activities. Myezo Environmental Management Services are undertaking the required EIA and in turn have approached Pisces Environmental Services (Pty) Ltd to provide marine specialist inputs as part of the EIA.

## 1.2 Terms of Reference

The marine ecology specialist study for the EIA has been split into two phases. The initial report comprised a baseline description of the ecology of the area, which informed the Scoping Phase of the EIA and was incorporated into the Scoping Report. The Terms of Reference for the initial phase of the marine ecology specialist study were:

- Using a desktop approach, provide a marine ecological baseline of the intertidal and subtidal macrofaunal and floral communities in the project area.
- Based on information provided in the baseline description, identify and map key environmental constraints (e.g. sensitive marine receptors) that may impact the project design and/or site selection.

This report covers the second phase of the study, namely the marine specialist impact assessment as part of the EIA phase. The principal objectives of this marine ecology specialist assessment is to:

- Undertake an evaluation and assessment of the impacts of the proposed mining operations on the marine ecology in the project area. All identified marine and coastal impacts (direct, indirect and cumulative) will be summarised, categorised and ranked in appropriate EIA tables, to be incorporated in the overall EIA. The significance of the impacts will be rated according to the impact assessment methodology specified by the lead consultant for the EIA process, and will include an assessment of the no-go alternative. The assessment would be based on the results of the engineering design and coastal dynamic modelling studies undertaken by WSP Coastal Engineers.
- Propose mitigatory measures and management actions to avoid impacts or reduce their severity.
- Incorporate any further aspects identified during the Scoping Phase that may require further consideration.

- Recommend a defensible ecological monitoring programme that can quantitatively assess the impacts of the proposed mining operations on the marine environment and monitor the recovery of affected communities once mining ceases.

## 1.3 Approach and Methodology

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 on a review, collation and expert interpretation of existing information and data sources from available local and international publications and internal reports.

Although no site visit was conducted as part of the current study, the specialist is familiar with the stretch of coastline in question having undertaken a detailed site investigation during compilation of the EMPrs for Trans Hex Operations’ Concessions 5a, 6a and 7a, and for Namagroen Prospecting and Investments’ Concessions 8a and 9a, in 2003.

## 1.4 Limitations and Assumptions

The following are the assumptions and limitations of the study:

- The study is based on the project description made available to the specialist at the time of the commencement of the study.
- The ecological assessment is limited to a “desktop” approach and thus relies on existing information only; no new data were collected as part of the study.

## 1.5 Structure of the Report

This Marine Specialist Study Report describes the effects of the proposed cofferdam mining operations on the marine environment (i.e. the coastal zone below the high water mark), and its significance within the context of the receiving environment. The report is structured as follows:

**Section 1: General Introduction** - provides a general overview to the proposed project, and outlines the Scope of Work and objectives of the study and the report structure. Assumptions and limitations to the study are also given.

**Section 2: Project Description relative to the Marine Environment** - gives a brief overview of the proposed mining activities that will impact the marine environment.

**Section 3: Description of the affected Marine Environment** - describes the receiving marine biophysical environment that could be impacted by the mining activities. Existing impacts on the environment are discussed and sensitive and/or potentially threatened habitats or species are identified;

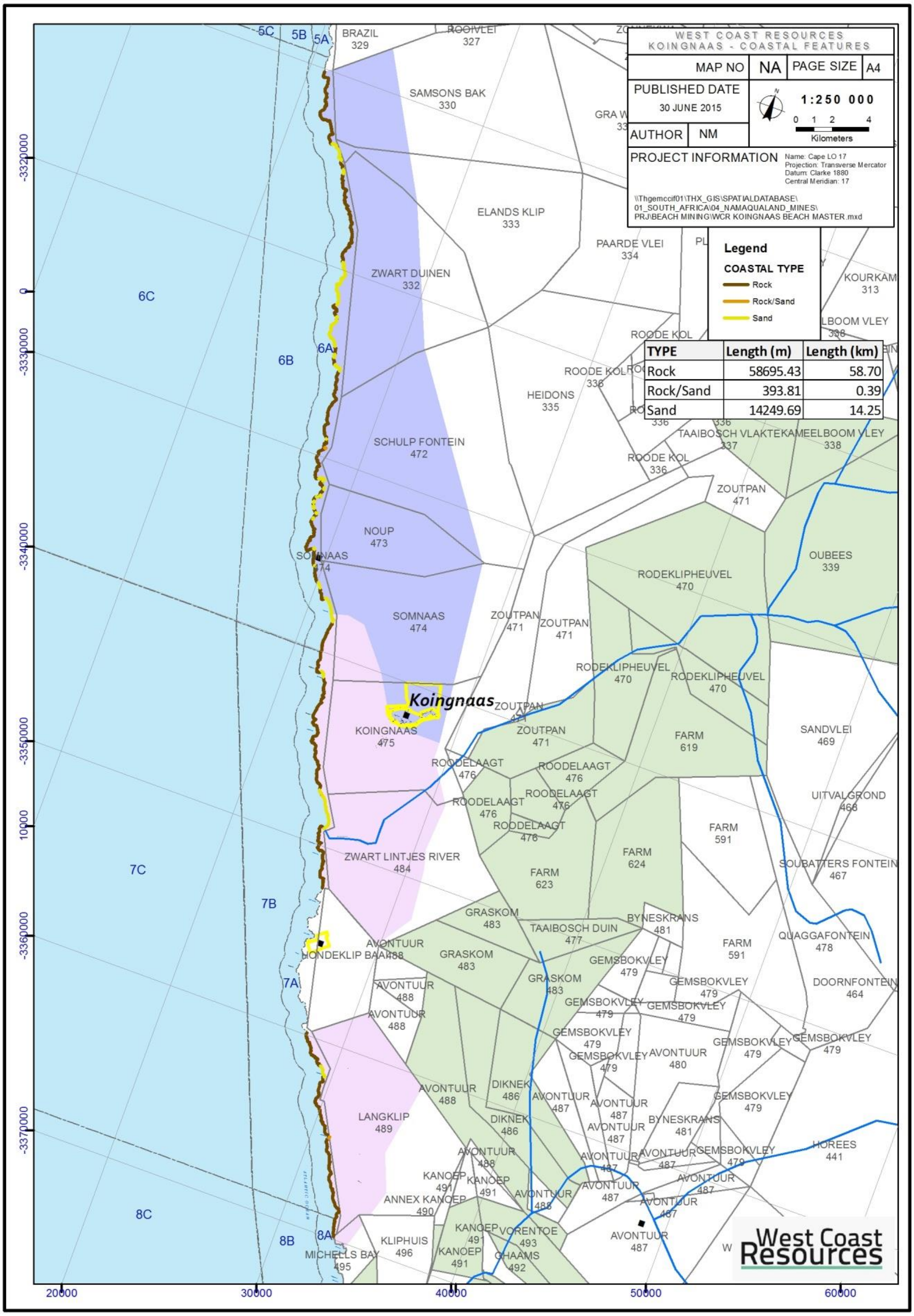
**Section 4: Impact Assessment Methodology** – provides details of the assessment methodology applied to the study.

**Section 5: Identification of Key Issues** - here key issues identified by the marine specialist and during stakeholder meetings are identified and listed.

**Section 6: Assessment of Environmental Impact -** the potential impacts to the marine communities in the project area are detailed and the significance of potential direct, indirect and cumulative environmental impacts of the proposed mining activities are assessed;

**Section 7: Recommendations and Conclusions -** the environmental acceptability of the proposed mining activities are discussed. A comparison between the “no development” alternative and the proposed development alternatives is also included. Mitigation measures and monitoring recommendations are presented.

**Section 8: References -** provides a full listing of all information sources and literature cited in this chapter.



| TYPE | Length (m) | Length (km) |
|---|---|---|
| Rock | 58695.43 | 58.70 |
| Rock/Sand | 393.81 | 0.39 |
| Sand | 14249.69 | 14.25 |

Figure 1: Detailed location map of Concessions 6a and 7a, indicating the Samson's Bak Complex (purple), Koingnaas Complex (pink) and their associated portions. The type and length of shoreline in the concessions is also indicated.

## 2. PROJECT DESCRIPTION

WCR holds existing mining and prospecting rights for a number of properties north and south of Hondeklipbaai on the west coast of the Northern Cape province, South Africa. The Mining/Prospecting Rights, and their portions comprise:

1. Koignaas – reference number SNC 522 MRC
    - Portion of remaining extent of the farm Somnaas No 474,
    - Portion of the farm Koignaas No 475,
    - Portion of the farm Zwart Lintjies River No 484,
    - Adjacent Sea Strips now described as unalienated state land, Portion of the Farm Langklip No 489,
    - Portion of the farm Mitchels Bay No 495 and adjacent Sea strips now described as state land.
2. Samson's bak - reference number SNC 525 MRC
    - Portion of the farm Elandsklip 333,
    - Portion of the Farm Koignaas 475
    - Portion of the farm Noup 473,
    - Portion of the farm Samson's bak 330,
    - Portion of the farm Schulpfontein 472,
    - Portion of the Remaining Extent and Portion 1 of the farm Somnaas 474
3. The Namaqualand Prospecting Right (NPR) - reference number SNC 672 PRC - incorporating farms:
    - Michell's Bay 495,
    - Langklip 489,
    - Farm No. 496 (known as Kliphuis),
    - Zwart Lintjes Rivier 484,
    - Samson's Bak 330,
    - Elands Klip 333,
    - Zwart Duinen 332,
    - Schulp Fontein 472,
    - Somnaas 474,
    - Koingnaas 475
4. Concession 8a - reference number NCS 30/5/1/2/2/555 MR
5. Concession 9a - reference number NCS 30/5/1/2/2/556 MR
6. Concession 8b - reference number 8bNCS 30/5/1/1/2/699 PR

Concession 6a is located north of Hondeklipbaai, in the Samson's Bak Complex, while Concession 7a spans the Koingnaas Complex and Hondeklipbaai. Concession 8a extends from Mitchell's Bay in the north to Skuit Bay, about 10 km south of the mouth of the Bitter River, whereas 9a extends from Skuit Bay to a position about 15 km south of Strandfontein Point. Each concession is approximately 30 km long (N-S), and extends from a line 31.49 m below the low water mark to a coast parallel line one kilometre seaward from the high water mark. Concession 8b lies seawards and adjacent to Concession 8a and extends from a coast-parallel line one kilometre seaward to about 5 km seaward of the high water mark. These concessions were formerly held by Namagroen Prospecting and Investments (Pty) Ltd.

For the purpose of this study, the project area thus encompasses a ~135 km stretch of the coastal and shallow marine habitats from approximately Swartklip in the north to south of Strandfontein Point (Figure 2a – 2c). WCR would commence with mining activities that are currently authorised under the existing mining right. Surf zone, beach and offshore channel mining activities would only commence once authorisation has been received as part of the Environmental Impact Assessment (EIA), which this marine specialist assessment forms part of. All marine mining operations would be conducted both by contractors and WCR. The proposed operations are described below.

## 2.1 Surf zone mining

Surf zone mining would be undertaken by diver-operated suction hoses, which feed the diamondiferous gravels to shore-based pumping units comprising a tractor modified to drive a centripetal pump and a rotary classifier. Operations would be confined to small bays at depths of <10 m. The classifier, which is positioned in the intertidal area, sorts the pumped material and extracts the size fraction of interest. The diamond-bearing gravel is bagged and transported on a daily basis to the nearest processing facility for diamond extraction. Over-sized tailings (+25 mm) are accumulated around the classifier and the fine tailings (-2 mm) are returned directly to the sea as a sediment slurry. The oversize tailing heaps which accumulate around the classifier are dispersed during the high tide, or mechanically redistributed over the beach at the end of mining operations. Care is taken to deposit oversized tailing below the High Water Mark (HWM) to allow natural redistribution by wave action. A shore-based operation typically consists of two to four divers, their assistants, and the necessary equipment.

To gain access to the water, the contractors attempt to locate their equipment as close to the sea as possible in the supratidal and intertidal regions. The topography of the bays targeted by shore contractors, enables the storage of classifiers and hoses on site above the HWM. The equipment storage areas are usually restricted to an area of <5 m$^2$ thereby limiting damage to sensitive strandveld vegetation.

## 2.2 Beach and offshore channel mining

WCR plan to extend mining activities seawards of the low water mark in order to access diamondiferous deposits in bedrock channels presently situated in the surf zone. As mineralisation along the shoreline of the project area is erratic and the technology to sample these zones in order to delineate and define ore reserves is as yet lacking, much of the beach and offshore channel mining operations to be undertaken by WCR and their contractors will be prospecting rather than full-scale mining operations.

Only once a bedrock feature yielding a viable reserve has been identified, would operations take on a larger, more permanent scale by sequentially mining the blocks following the feature. The *modus operandi* and scale of operation would therefore depends largely on whether prospecting or mining is taking place and on the depth of overburden that needs to be removed before the target gravels can be accessed.

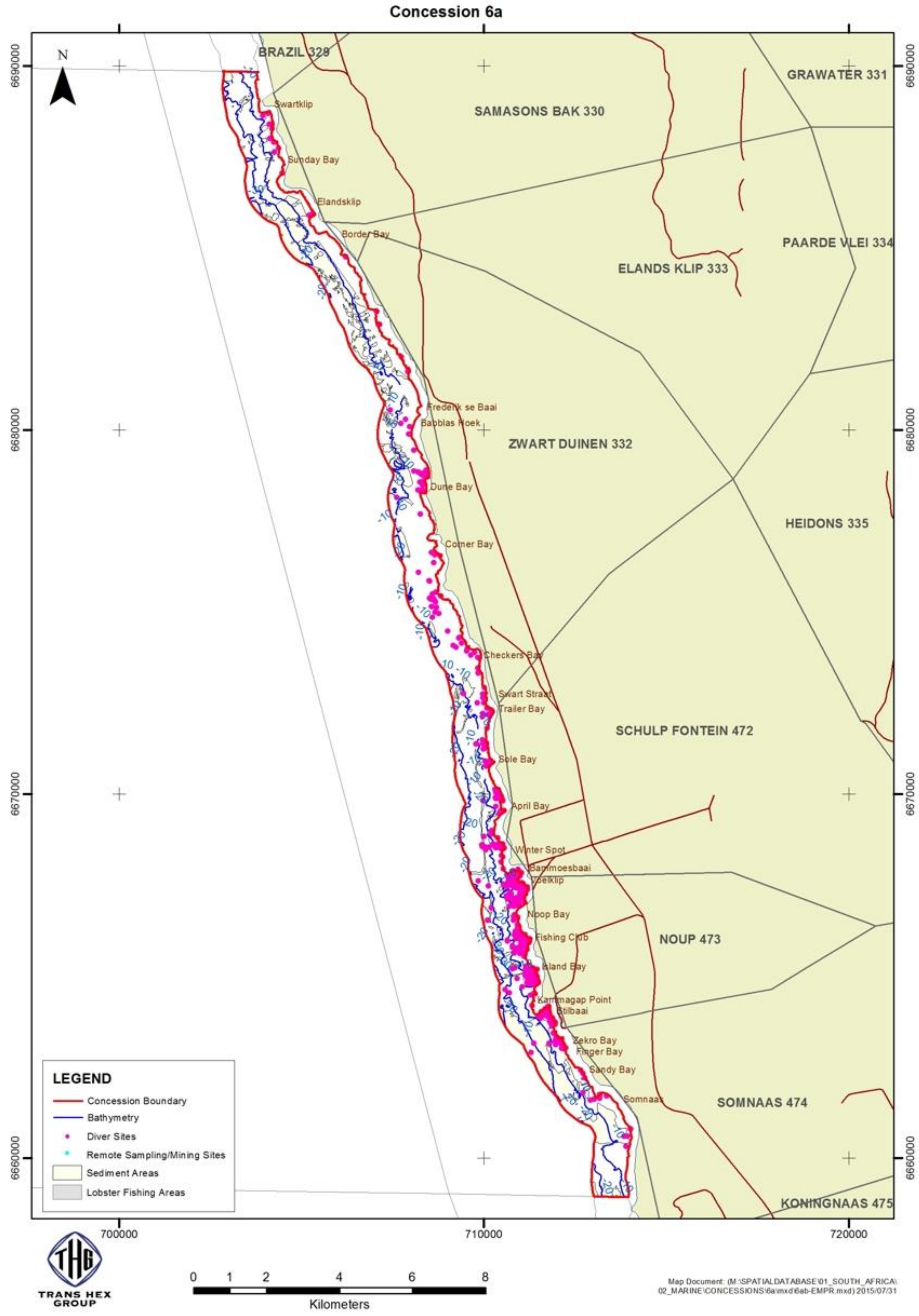
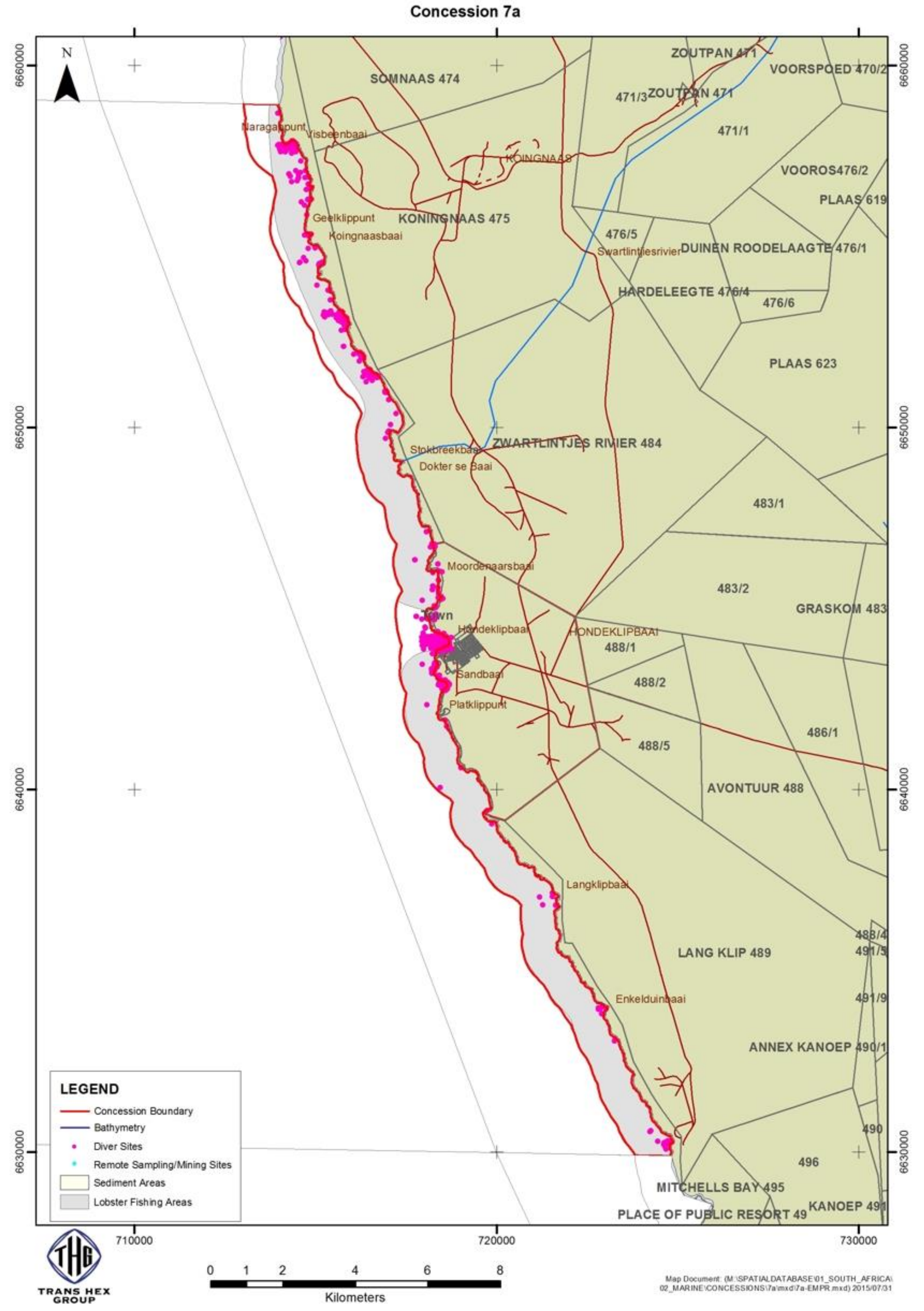


Figure 2a: Detailed location map of Concessions 6a.



Concession 7a

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Figure 2b: Detailed location map of Concessions 7a.

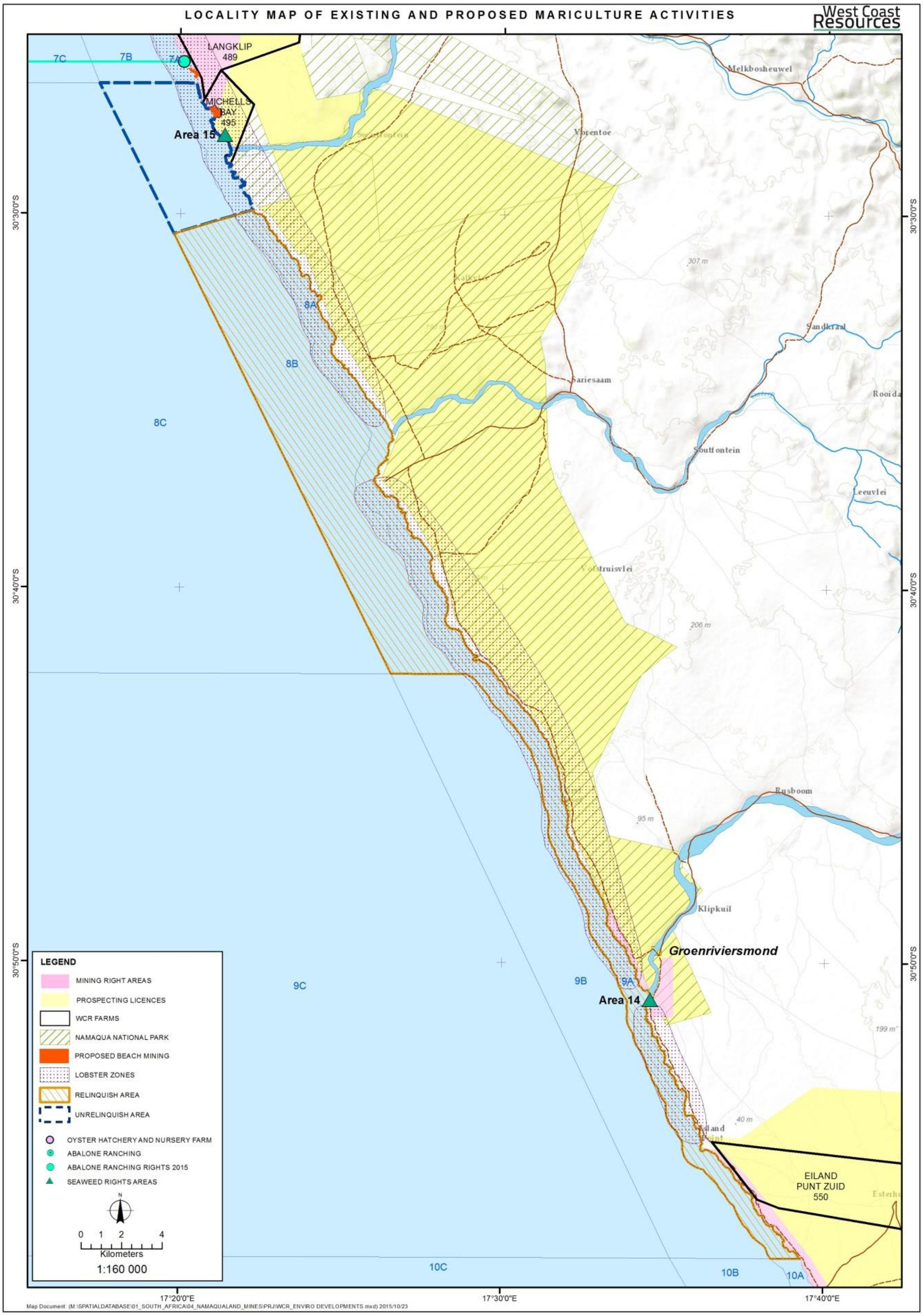


Figure 2c: Location map of Concessions 8a, 9a and 8b, illustrating area of mining interest and relinquished areas within the proposed Namaqua Marine Protected Area.

There are two alternative approaches to accessing diamond resources seaward of the low water mark, namely:

- temporary accretion of the beach in the immediate vicinity of the mining target using overburden material available on the beach or from adjacent onland mining sites; or
- the construction of a rock berm or coffer dam using non-native rocks and boulders sourced from rock stockpiles near Koingnaas. Both statistically stable and dynamically stable rock berms are being considered.

Up to six potential sites harbouring surf zone resources have been identified. However, the nature of the specific target area determines which of the alternative approaches is most suitable. For example, the exposed nature of the coastline and high longshore sediment transport rates, in combination with insufficient overburden sands available on the beach to maintain accretion under the resulting high erosion rates, negates the application of beach accretion using sand anywhere but in very sheltered bays.

Using information summarised from WSP (2015) and the Department of Mineral Resources (DMR) Application form, the alternative mining approaches are detailed below.

### 2.2.1 Coffer dams

Along the typically wave exposed coastline of the project area, rock berms or coffer dams are the only feasible alternative to effectively reclaiming a mining area located beyond the low water mark. The procedure for construction of a protective rock berm is described briefly below:

- On both the northern and southern side of the mining target area a rock berm is built by progressively end-tipping rock- and boulder core material from trucks perpendicular to the oncoming waves and shoreline. Dozers and excavators subsequently shape the profile and dress the slope with a suitable armour layer of larger rocks;
- The berms extend from above the storm high water mark into the surf zone until the seaward extent of the mining block is reached and a shore-parallel berm is constructed linking the two shore-perpendicular berms;
- Once the berm is in place and the mining block is enclosed overburden stripping and gravel extraction can be undertaken using conventional open-cast mining approaches;
- Once the area has been mined out, the rock berm would be progressively extended offshore to enclose the next mining block, potentially enabling mining up to 300 m seawards of the low water mark.

The material used to construct such breakwaters typically consists of an underlying core of quarried material, which gets progressively coarser towards the outside and is covered by an outer layer of large armour rock. Geotextile sandbags commonly used for coastal protection works may also be used in areas of low wave energy, as temporary emergency measures or above the high water mark on the wall itself. The seaward extent of the berm and prevailing wave conditions determine the size/mass of the rock required for the armour layer. Berm can be extended in phases as far offshore as conditions allow. Although four phases have been assumed for this project (Figure 3), the material requirements for Stages 3 and 4 would necessitate the use of very large armour rocks that would be difficult to produce, transport and place, thereby reducing the feasibility of these structures. Possible alternatives for Stage 4 include the use of concrete armour units on the seaward face of the berm, or constructing the berm as a dynamically reshaping profile using smaller rocks (see later). However, this would involve prohibitively high construction and rehabilitation costs and high erosion rates, possibly exceeding material placement rates, respectively. The Stage 4 berm is thus not considered feasible.

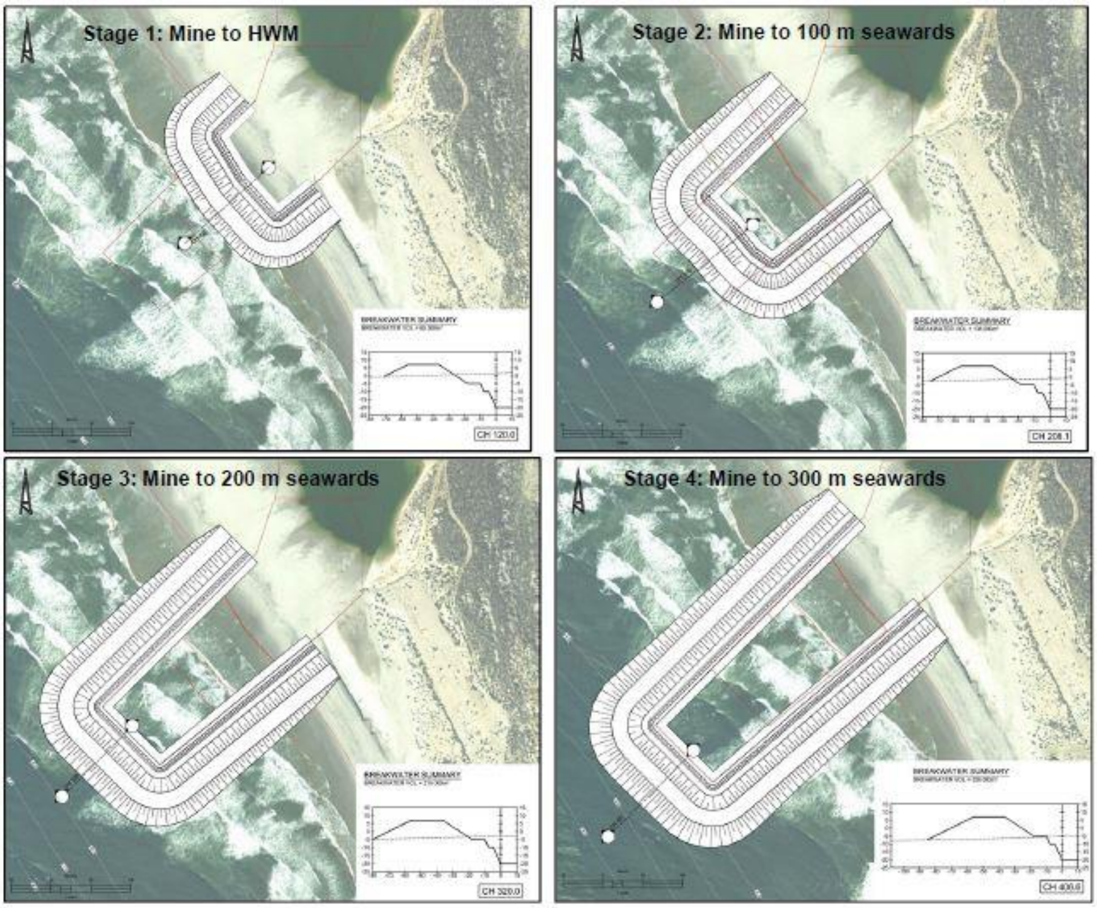


Figure 3: Proposed phased rock berm construction at Koingnaas 68/69, Somnaas and Langklip Central (Source: WSP 2015).

Despite the comparatively high volumes of material required for berm construction (Table 1), the design-life of such berms is typically 1-2 years and they can thus be considered temporary structures.

Table 1: Estimated rock volumes required for the various construction phases

| **Construction Phase** | **Material requirements (m$^3$)** |
|---|---|
| Stage 1 | 65,000 |
| Stage 2 | 135,000 |
| Stage 3 | 216,000 |
| Stage 4 | 356,000 |

Similar beach mining operations have previously been successfully undertaken near the Olifant's River and along the coastline near Alexander Bay. For the current project, WCR is intending to implement this mining approach at the sandy beach target sites known as Koingnaas 68/69, Somnaas and Langklip Central. The estimated area to be disturbed at each of these sites amounts to ~118,000 m$^2$.

### 2.2.2 Accretion of Mitchell's Bay

Mitchell's Bay (Rooiwal Bay) is a small protected bay located north of the Spoeg River in Concession 8a. The mouth of the bay is some 700 m across. The bay hosts a narrow sandy beach backed by steep soil cliff and a shallow reef in the mouth. The seabed is mainly rock – bedrock, boulders, cobble and gravel, although there is limited sand cover at the beach in the eastern side of the bay and at the palaeochannel in the north of the bay. An irregular, deep, channel reaching at least 20 m depth is present in the northern part of the bay, with a second depression occurring in the southern part of the bay.

One of the proposed mining approaches implemented to access the diamond deposits on the seabed and adjacent beaches within Mitchell's Bay, involves using fine overburden sands stripped from a potential mining site in an adjacent on-land dune field to accrete the shoreline of the bay. Mining of the accreted area would liberate further material that can be dumped into the sea to gain additional accretion. Three stages of beach accretion are being considered, with the shoreline moving seawards by 150 m during each successive stage (Figure 4). Sand volumes required for each stage comprised 1.3 million, 2.5 million and 5.9 million cubic metres, respectively for 150 m, 300 m and 450 m accretion. However, as the beach is accreted and the shoreline maintains equilibrium with the wave-driven currents, sand placed on the beach would be redistributed by currents and transported southwards and westwards out of the bay, where it would redeposit on the seabed and adjacent shoreline.

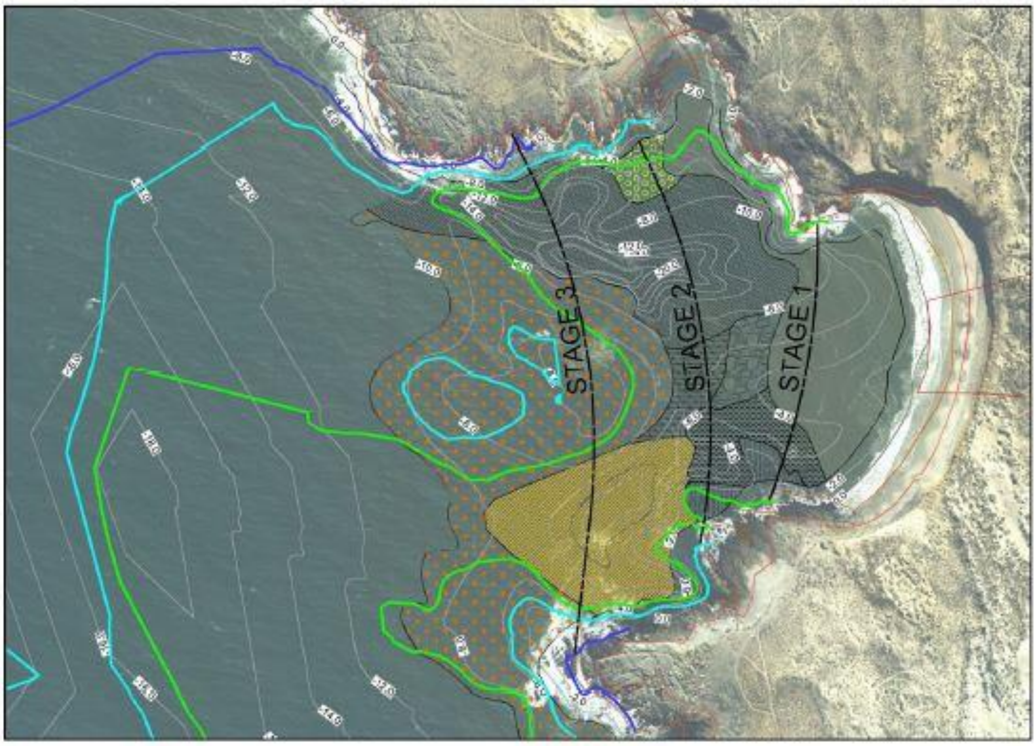


Figure 4: Three phases of proposed shoreline accretion within Mitchell's Bay. The associated deposition of sand for Stage 1 is shown in green, Stage 2 in cyan and Stage 3 in blue (Source: WSP 2015).

While this alternative for Mitchell's Bay is considered feasible from an engineering perspective, it is dependent on the mining of the inland deposits for a source of the accretion material. The estimated area to be disturbed using this approach would be 541,755 m$^2$, excluding indirect effects due to redistribution of eroded sediments.

### 2.2.3 Closure of Mitchell's Bay with a Dynamically Stable Rock Berm

The alternative approach proposed for Mitchell's Bay is the construction of a dynamically stable rock berm across the mouth of the bay and perpendicular to the predominant wave action (Figure 5). To avoid erosion of the berm profile during storms, it needs to be relatively wide and therefore requires large volumes of material for construction and covers a larger footprint than a conventional rock berm.

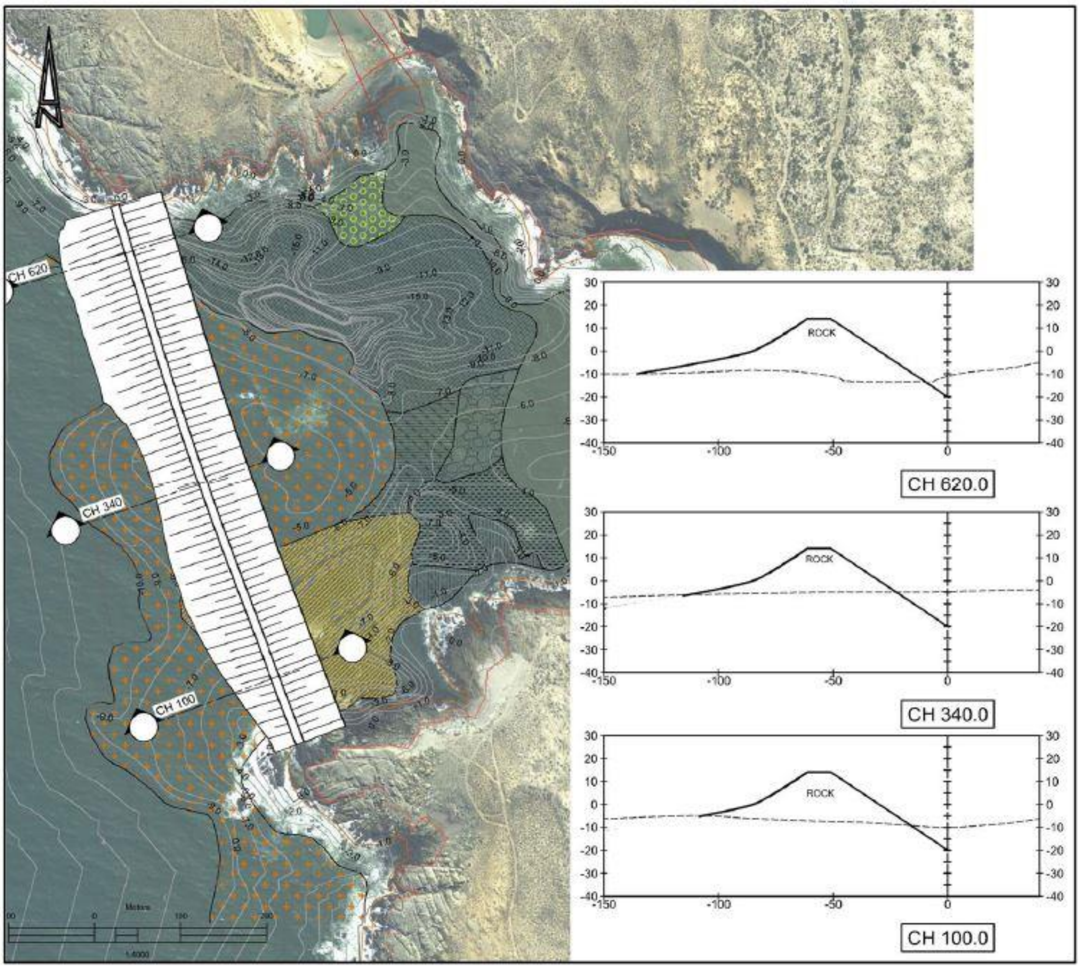


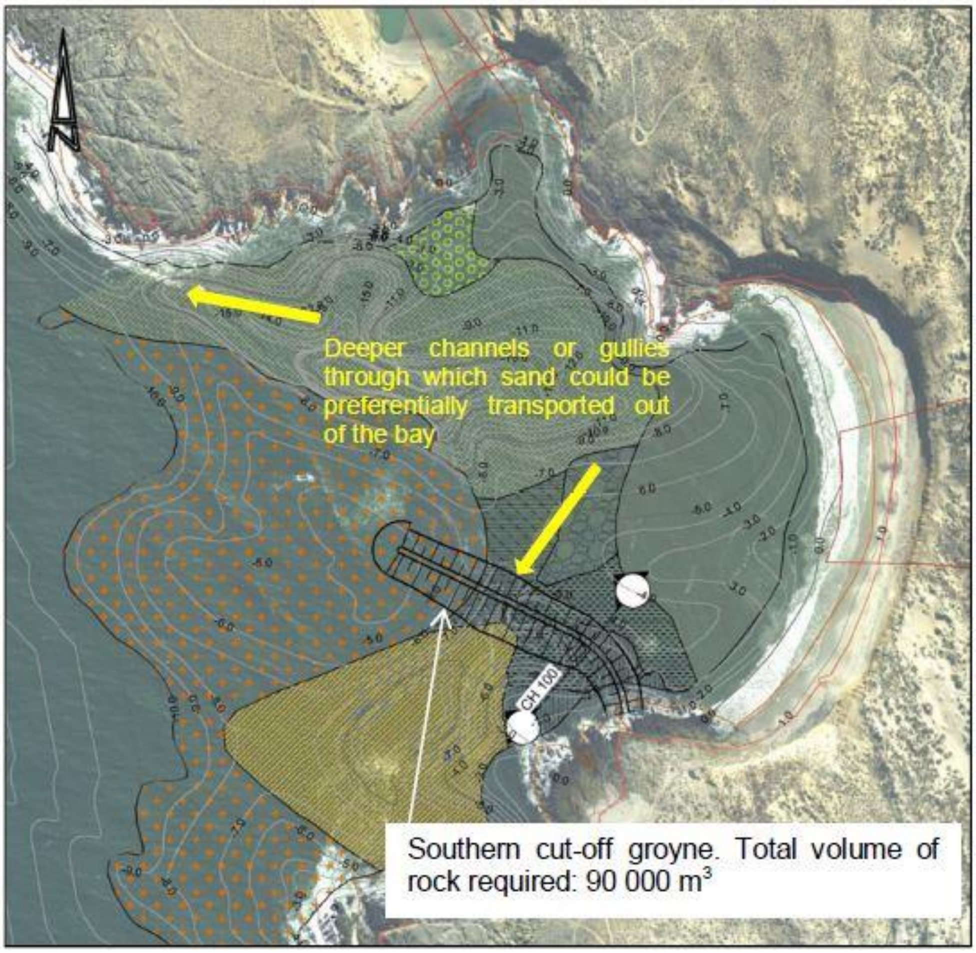
Figure 5: Layout and sections for a proposed dynamically stable rock berm for the closure of Mitchell's Bay (Source: WSP 2015).

To implement this approach in Mitchell's Bay, a berm crest of 14 m in height would be required to protect the mining area from extreme wave conditions. With a berm width of 10 m at the crest and as much as 140 m at the base, at minimum 660,000 m$^3$ of large cobbles/small boulders would be required. This volume does not cater for wastage through erosion of material during the construction phase, or for ongoing replenishment of eroded material during the life of the structure. While considered technically feasible, this alternative has high costs associated with it and the high loss rate of material off the partly completed berm during construction may result in the structure being impossible to build. The estimated area to be disturbed using this approach would be 541,755 m$^2$, excluding indirect effects due to loss of construction material.

Closure of Mitchell’s Bay with a statisticall stable rock berm is not considered feasible due to the need for either very large armour rocks or concrete armour units on the seaward side of the berm facing the oncoming waves.

### 2.2.4 Partial Closure of Mitchell’s Bay with a Rock Groyne

A further option considered was to partially close the southern portion of Mitchell’s Bay through the construction of a rocky groyne, which would extend some 275 m in a north-westerly direction to the reef in the centre of the bay (Figure 6). The groyne would be positioned over the natural underwater ridge occurring in the south of the bay and would reduce the wave heights inside the bay. The water depth at the tip of the groyne would be approximately 4 m. The volume of rock required for construction amounts to ~90 000 m$^3$.



Deeper channels or gullies through which sand could be preferentially transported out of the bay

Southern cut-off groyne. Total volume of rock required: 90 000 m$^3$

Figure 6: Layout for a proposed rock groyne for the partial closure of Mitchell’s Bay (Source: WSP 2016).

### 2.2.5 Generic Protection Design

A more generic design involving either statistically stable rock berms, or these in combination with dynamically stable berms, is being considered for other potential mining sites characterised by either a rocky shoreline or a shoreline of mixed sand and rock. The generic design is proposed for the Noup, Visbeen, Koingnaas, Langklip Central and Langklip target areas.

The generic designs assume an initial mining area of 200 x 200 m, with sequential extension into adjacent blocks as mining progresses and the resource in a block is mined out. The type of design applied is determined largely by the depth of the seabed at the seaward extreme of the shore parallel berm. Two alternative generic designs are being considered, namely:

*1) Statistically stable rock berm*

In areas of seabed depth up to 2.5 m below mean sea level at the seaward edge of the mining target, a conventional, statistically stable rock berm comprising a core of finer material and an armour layer of larger rocks facing the prevailing waves would be constructed. For protection of the Stage 1 mining block, these berms would comprise a shore-parallel and shore-perpendicular component (grey shading in Figure 7). Extension of operations into subsequent mining blocks would require the construction of a further shore-parallel berm to protect the adjacent area (lighter shading in Figure 7).

*2) Alternative combination berm*

In areas of seabed depth up to 4 m below mean sea level at the seaward edge of the mining target, a conventional, statistically stable groyne would be built perpendicular to the shore to the required depth. Large armouring would be required at the seaward edge of this groyne to prevent erosion. To protect the Stage 1 mining block, the seaward end of the groyne would connect to a shore-parallel dynamic re-shaping berm (grey shading in Figure 8). An further shore-parallel dynamic re-shaping berm would then be added for the protection of the Stage 2 mining block (lighter shading in Figure 8).

For each site, the most economically and technically viable concept/s will be selected bearing in mind the temporary nature of the mining, the quantity and characteristics of available construction materials (rock, sand and clay), possible phasing of the mining to facilitate recovery of diamonds at an early stage, the need to minimise seepage into the mining area and the costs of protective measures. The potential areas to be disturbed by these proposed operations are provided in Table 2.

Table 2: Potential areas to be disturbed in the mining areas targeted for beach and offshore channel mining.

| Mining Zone | Total Area ($m^2$) | Disturbed Area (%) | Disturbed Area ($m^2$) |
|---|---|---|---|
| Noup | 1 589 380 | 25% | 397 345 |
| Visbeen | 448 457 | 75% | 336 343 |
| Koingnaas | 1 340 284 | 50% | 670 142 |
| Langklip Central | 391 679 | 50% | 195 839 |
| Langklip | 165 443 | 25% | 41 361 |

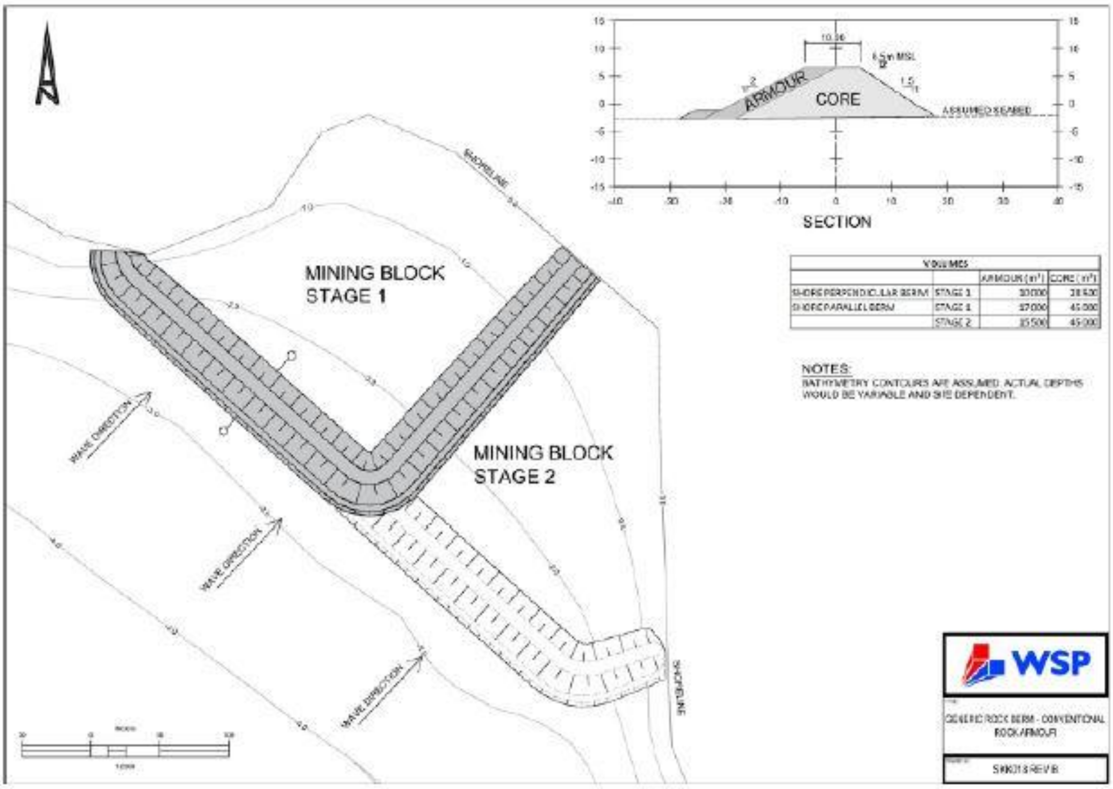


Figure 7: Layout of a generic rock berm with a conventional statistically stable armour slope (Source: WSP 2015).

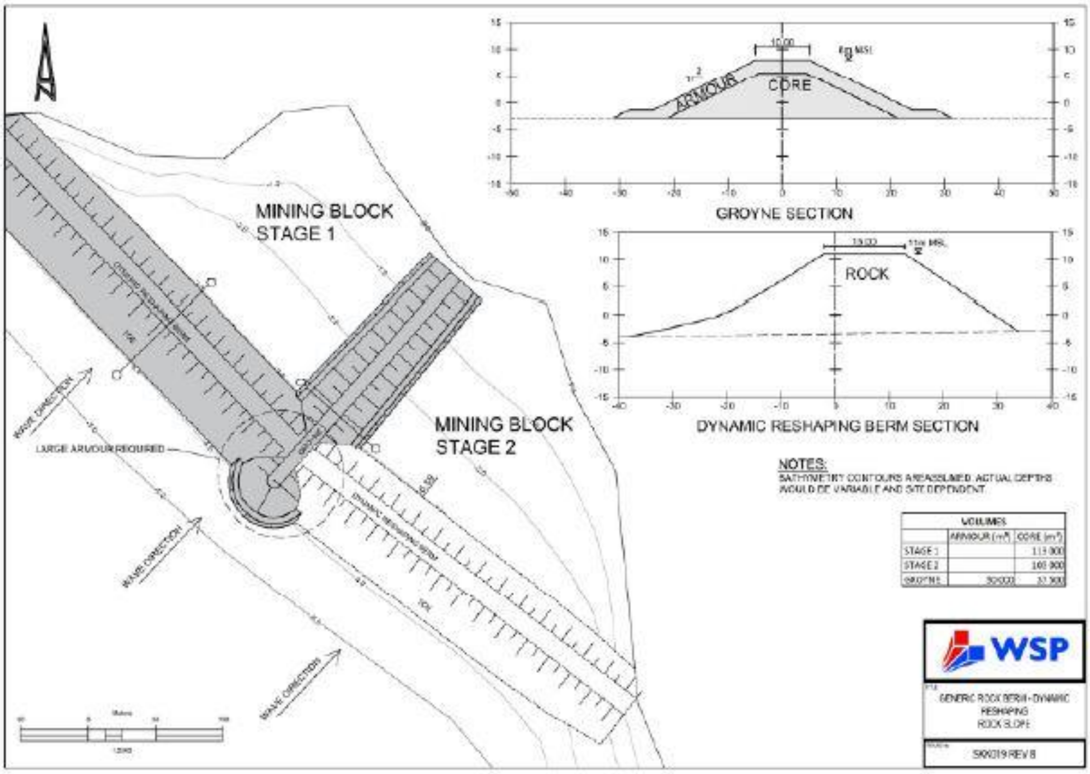


Figure 8: Layout of an alternative generic design using a conventional statistically stable groyne in combination with a dynamic re-shaping shore-parallel berm (Source: WSP 2015).

# 3. DESCRIPTION OF THE AFFECTED MARINE ENVIRONMENT

## 3.1 Physical Environment

### 3.1.1 Sea Surface Temperature, Currents and Circulation Patterns

An overview of the water masses, and major coastal and oceanic current and circulation patterns along the South African west coast was presented by Shannon & Nelson (1996). The cool temperate Benguela region (average sea surface temperature 10 - 14°C) is located between two warm current features, namely the Angola Current in the north and the Agulhas current in the south. The southward flowing Angola Current originates from the circular gyre on the Angola Dome, which is a prominent oceanographic feature off the coast of Angola. At the opposite end of the Benguela system, the strong Agulhas Current flows down the eastern South African shelf edge, along the Agulhas Bank past Cape Agulhas, and periodically generates massive, warm 'Agulhas Rings', resulting in substantial heat flux into the central South Atlantic ocean. The Agulhas Current is also capable of rounding Cape Point and generating an episodic, northward-flowing current, which splits near Cape Columbine (33°S) into the offshore Cape Canyon jet, and a northward longshore flow (Figure 9). The surface water of the Agulhas Current is generally >21 C, and its influence west of Cape Agulhas results in average sea surface temperatures in the southern Benguela of 16 – 20°C (Shannon 1985).

The Benguela region, in contrast, is dominated more by wind-driven upwelling and swell events than by consistent current flows. Currents tend to follow major topographic features, with typical current speeds in the region ranging from 10 - 50 cm/s. Over the southern Benguela region (south of Cape Columbine), there is a southward flow of cold water close inshore near the surface, which occurs during periods of barotropic reversals, and during the winter non-upwelling period (Nelson & Hutchings 1983). There is also a significant southerly poleward flow of sub-thermocline water on the continental shelf and at the shelf break, forming a poleward undercurrent, which becomes more consistent to the south (Nelson 1989; Boyd & Oberholster 1994; Shannon & Nelson 1996) (Figure 9).

The project area falls within the nearshore central Benguela region (Cape Columbine to Lüderitz), which is primarily characterised by variable, northward flowing, longshore surface currents, generated by consistent, strong winds and swells from the south and southwest (Shillington et al. 1990; Shannon & Nelson 1996). These nearshore surface currents remain closely aligned with the coastline and the winds, generally flowing in a northerly direction, although periodic reversals can occur. Winds are the main physical driver of the nearshore region, and physical processes are characterised by the average seasonal wind patterns. Substantial episodic changes in these wind patterns can consequently have strong effects on the entire Benguela region.

The prevailing winds along the southern African West Coast are controlled by the South Atlantic subtropical anticyclone, the eastward moving mid-latitude cyclones south of southern Africa, and the seasonal atmospheric pressure field over the subcontinent. The south Atlantic anticyclone is a perennial feature that forms part of a discontinuous belt of high-pressure systems, which encircle the subtropical southern hemisphere. This undergoes seasonal variations, being strongest in the austral summer, when it also attains its southernmost extension, lying south west and south of the subcontinent. In winter, the south Atlantic anticyclone weakens and migrates north-westwards.

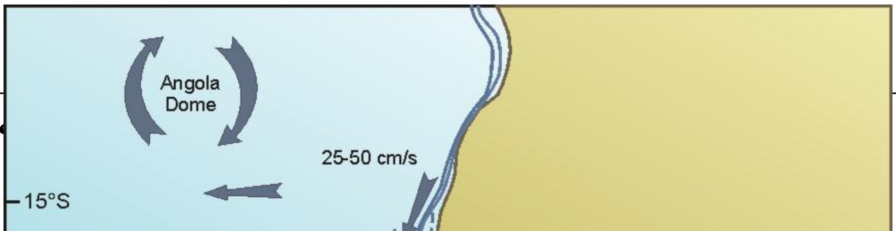


Figure 9: Major features of the predominant circulation patterns and volume flows in the Benguela System, along the southern Namibian and South African west coasts (re-drawn from Shannon & Nelson 1996), in relation to the project area (red polygon).

These seasonal changes result in substantial differences between the typical summer and winter wind patterns in the region, as the southern hemisphere anti-cyclonic high-pressure systems, and the associated series of cold fronts, moves northwards in winter, and southwards in summer (Figure 10). The strongest winds occur in summer, during which winds blow 99% of the time, and gales (winds exceeding 63 km/h or 18 m/s) are frequent. In summer, winds are dominated by southerlies, which occur over 40% of the time, averaging 37 – 55 km/h (10 – 15 m/s) and reaching speeds in excess of 100 km/h. South-easterlies are almost as common, blowing about one-third of the time, and also averaging 37 – 55 km/h. The combination of these southerly/south-easterly winds drives the massive offshore movements of surface water, and the resultant strong upwelling of nutrient-rich bottom waters, which characterise this region in summer.

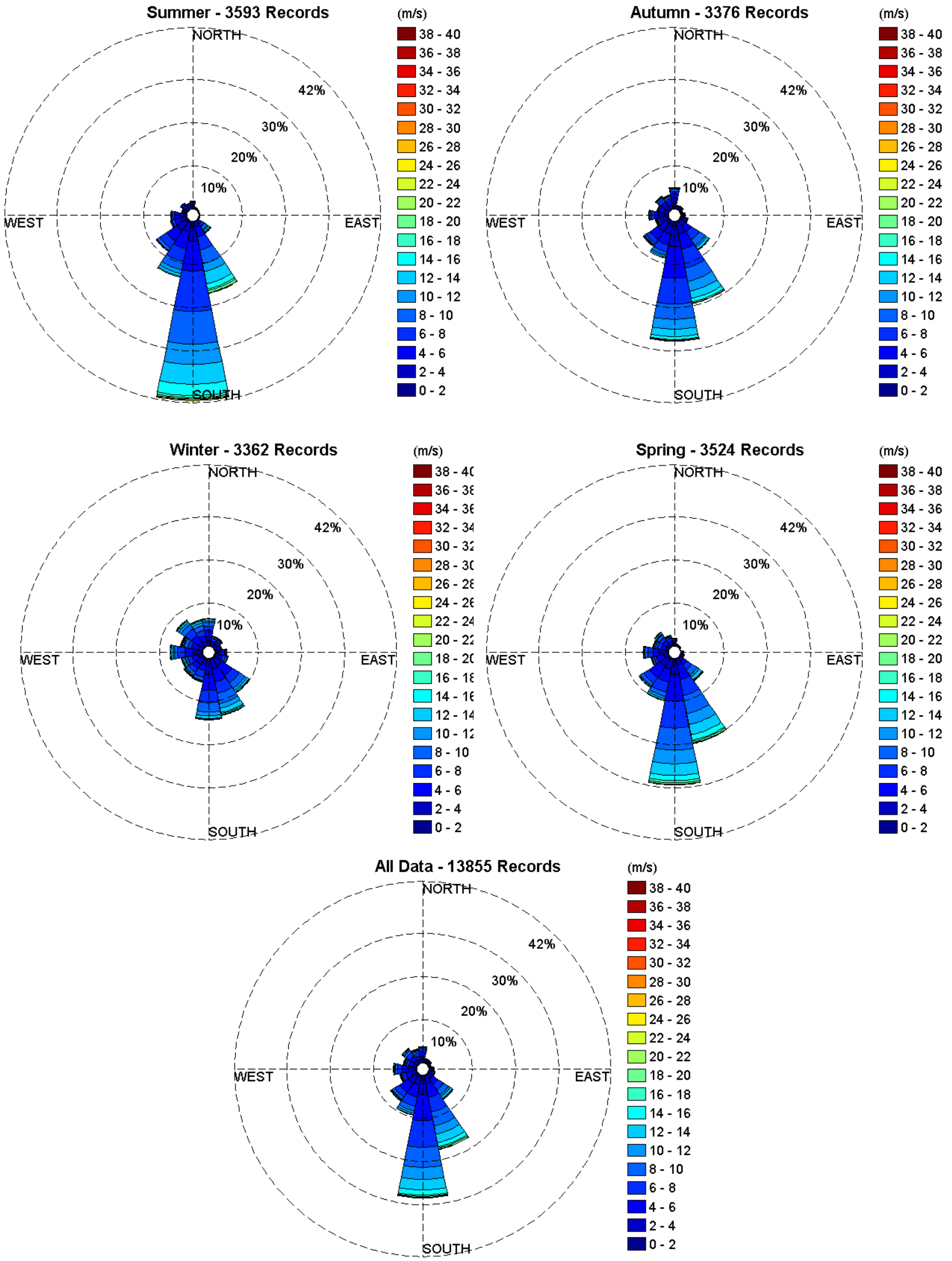


Figure 10: VOS Wind Speed vs. Wind Direction data for the Cape Columbine area 32.0 to 32.9 S and 17.0 to 17.9 E (1903-11-01 to 2011-05-24; 13,855 records) (from CSIR).

Southerly to south-southeasterly winds continue to dominate the wind pattern during winter, but the closer proximity of the winter cold-front systems also results in a significant south-westerly to north-westerly component (Figure 10). This 'reversal' from the summer condition results in cessation of upwelling, movement of warmer mid-Atlantic water shorewards and breakdown of the strong thermoclines, which typically develop during summer. There are also more calms in winter, occurring about 3% of the time, and wind speeds generally do not reach the maximum speeds of summer. The westerly winds blowing in synchrony with the prevailing south-westerly swell direction in winter, however, usually result in far heavier swell conditions.

### 3.1.2 Waves and Tides

Most of the west coast of southern Africa is classified as exposed, experiencing strong wave action, rating between 13 - 17 on the 20 point exposure scale (McLachlan 1980). West- to north-facing embayments are limited and most of the coastline is therefore impacted by heavy south-westerly swells generated in the roaring forties, as well as significant sea waves generated locally by the prevailing moderate to strong southerly winds characteristic of the region. The Namaqualand coastline is particularly exposed, being rated as "exposed" and "extremely exposed" (Steffani 2001).

The wave regime along the southern African west coast shows only moderate seasonal variation in direction, with virtually all swells throughout the year coming from the southwesterly to southerly direction (Figure 11). Winter swells are strongly dominated by those from the southwest to south-southwest, which occur almost 80% of the time, and typically exceeding 2 m in height, averaging about 3 m, and often attaining over 5 m. With wind speeds capable of reaching 100 km/h (during heavy winter south-westerly storms, winter swell heights can exceed 10 m). The dominant peak energy period for waves is ~12 seconds, although longer period swells occur about 30% of the time.

Summer swells tend to be smaller on average, typically around 2 m with a more pronounced southerly swell component. These southerly swells tend to be wind-induced, with shorter wave periods (~8 seconds), and are generally steeper than swell waves. The wind-induced southerly waves are relatively local and work together with the strong summer southerly winds to cause the northward-flowing nearshore surface currents, which results in substantial nearshore sediment mobilisation and northwards transport. In common with the rest of the southern African coast, tides along the Namaqualand coast and in the project area are semi-diurnal, with a total range of some 1.5 m at spring tide, but only 0.6 m during neap tide periods.

### 3.1.3 Water

South Atlantic Central Water (SACW) comprises the bulk of the seawater in the study area, either in its pure form in the deeper regions, or mixed with previously upwelled water of the same origin on the continental shelf (Nelson & Hutchings 1983). Salinities range between 34.5 ‰ and 35.5 ‰ (Shannon 1985).

Seawater temperatures on the continental shelf of the central Benguela typically vary between 6°C and 16°C. Well-developed thermal fronts exist, demarcating the seaward boundary of the upwelled water. Upwelling filaments are characteristic of these offshore thermal fronts, occurring as surface streamers of cold water, typically 50 km wide and extending beyond the normal offshore

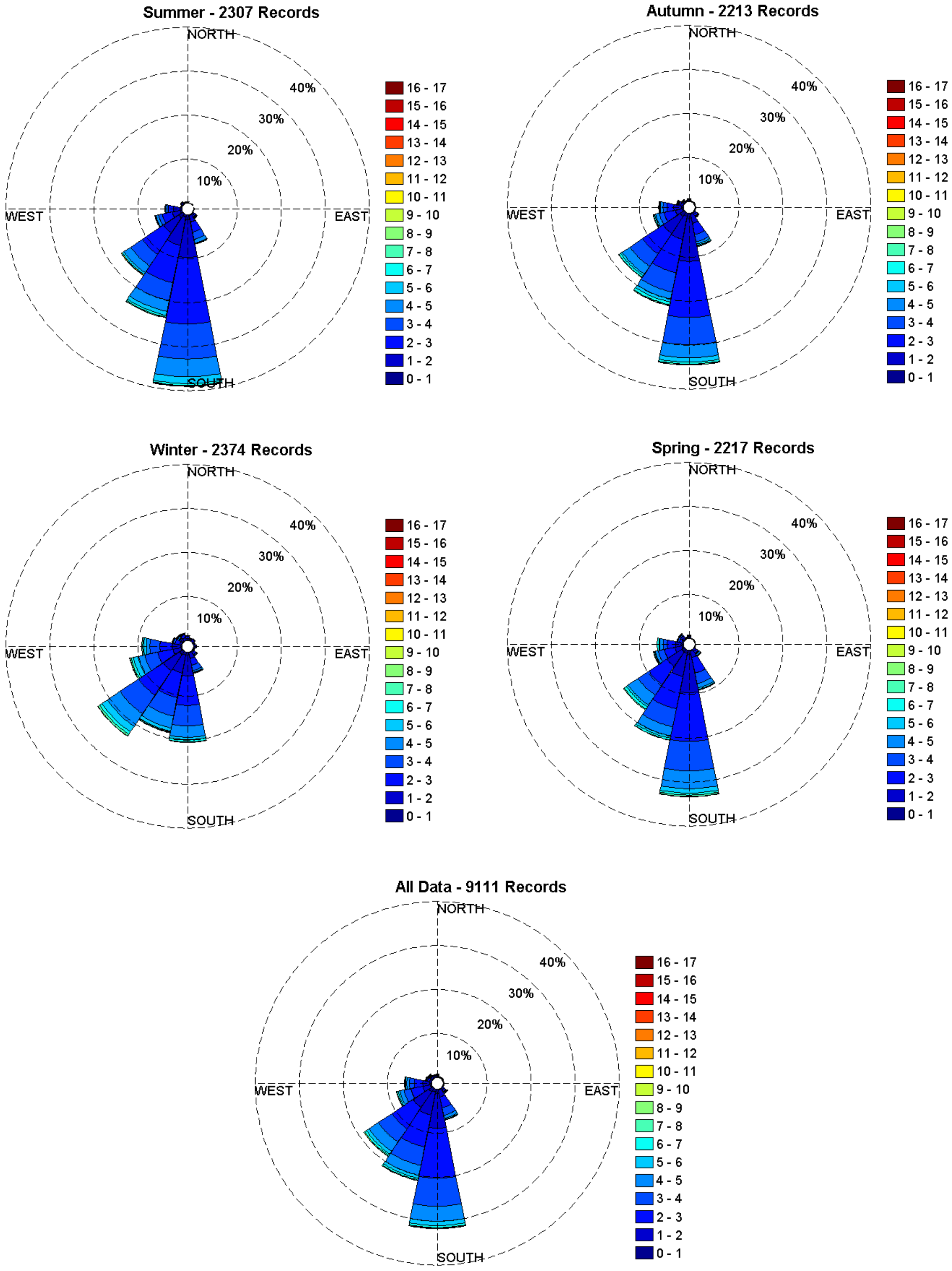


Figure 11: VOS Wave Height vs. Wave Direction data for the Cape Columbine area 32.0 to 32.9 S and 17.0 to 17.9 E (1903-11-01 to 2011-05-24; 9,111 records) (from CSIR).

extent of the upwelling cell. Such fronts typically have a lifespan of a few days to a few weeks, with the filamentous mixing area extending up to 625 km offshore.

The continental shelf waters of the Benguela system are characterised by low oxygen concentrations, especially on the bottom. SACW itself has depressed oxygen concentrations (~80% saturation value), but lower oxygen concentrations (<40% saturation) frequently occur (Bailey *et al*. 1985; Chapman & Shannon 1985).

### 3.1.4 Upwelling and Plankton Production

Coastal, wind-induced upwelling is the principal physical process that shapes the marine ecology of the Benguela region. The prevailing longshore, equatorward winds move nearshore surface water northwards and offshore. To balance the displaced water, cold, deeper water wells up inshore.

During upwelling the comparatively nutrient-poor surface waters are displaced by enriched deep water, supporting substantial seasonal primary phytoplankton production. The cold, upwelled water is rich in inorganic nutrients, the major contributors being various forms of nitrates, phosphates and silicates (Chapman & Shannon 1985). Nutrient concentrations of upwelled water of the Benguela system attain 20 μM nitrate-nitrogen, 1.5 μM phosphate and 15-20 μM silicate, indicating nutrient enrichment (Chapman & Shannon 1985). This is mediated by nutrient regeneration from biogenic material in the sediments (Bailey *et al*. 1985). Modification of these peak concentrations depends upon phytoplankton uptake which varies according to phytoplankton biomass and production rate. The range of nutrient concentrations can thus be large but, in general, concentrations are high.

High phytoplankton productivity in the upper layers again depletes the nutrients in these surface waters. This results in a wind-related cycle of plankton production, mortality, sinking of plankton detritus and eventual nutrient re-enrichment occurring below the thermocline as the phytoplankton decays. Biological decay of plankton blooms can in turn lead to “black tide” events, as the available dissolved oxygen is stripped from the water during the decomposition process (see below). Subsequent anoxic decomposition by sulphur reducing bacteria can result in the formation and release of hydrogen sulphide (Pitcher & Calder 2000).

Although the rate and intensity of upwelling fluctuates with seasonal variations in wind patterns, the most intense upwelling tends to occur where the shelf is narrowest and the wind strongest. The largest and most intense upwelling cell is in the vicinity of Lüderitz, and upwelling can occur there throughout the year (Shannon & O’Toole 1998; Shillington 2003). Several secondary upwelling cells occur, of which the Namaqua cell is centred around Hondeklip Bay (30°S), and the Cape Columbine (33°S) and Cape Point (34°S) upwelling cells are located further south (Figure 12). Upwelling in these secondary cells is seasonal, with maximum upwelling occurring between September and March. The project area is located within the Hondeklip Bay cell, and is thus likely to be periodically influenced by upwelling-related processes (Figure 12). During the winter months westerly winds result in relaxation of upwelling and often warmer surface water temperatures (Lutjeharms & Meeuwis 1987).

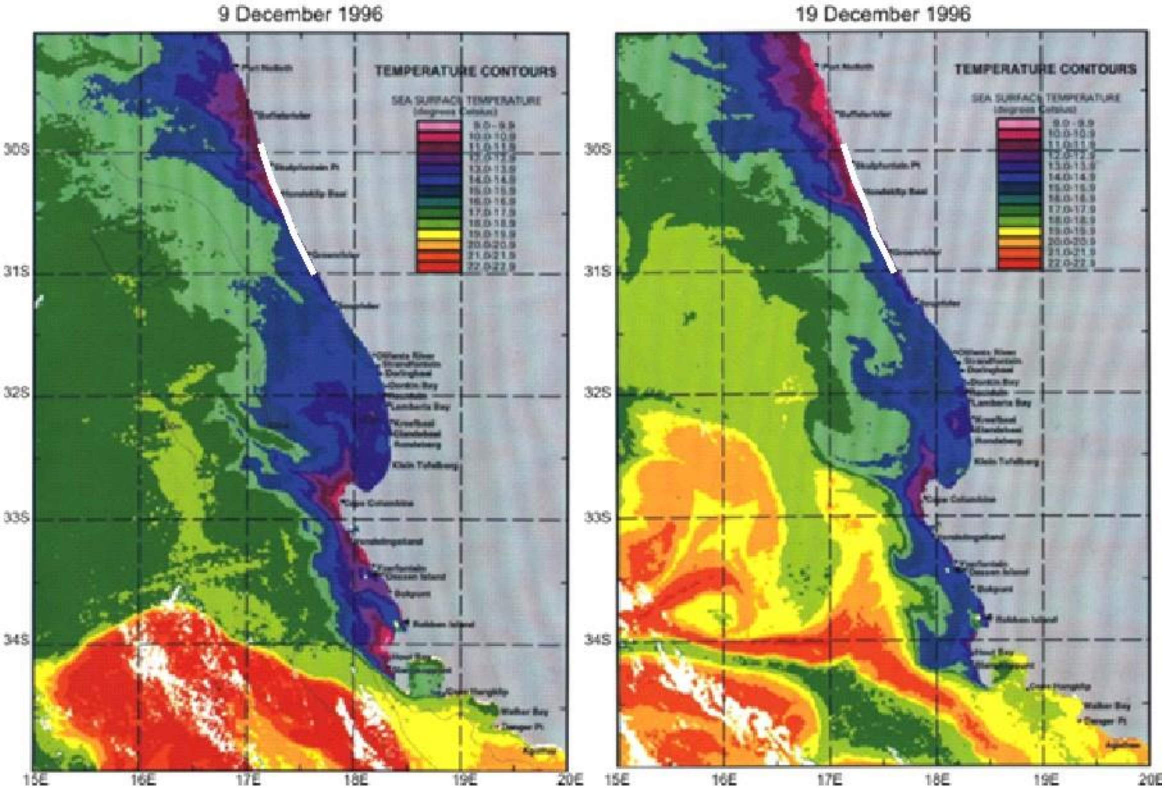


Figure 12: Satellite sea-surface temperature images showing upwelling intensity along the South African west coast and the influence of the Agulhas current on temperatures on the southwest coast (from Lane & Carter 1999). The white line denotes the project area.

### 3.1.5 Organic Inputs

The Benguela upwelling region is an area of particularly high natural productivity, with extremely high seasonal production of phytoplankton and zooplankton. These plankton blooms in turn serve as the basis for a rich food chain up through pelagic baitfish (anchovy, pilchard, round-herring and others), to predatory fish (snoek), mammals (primarily seals and dolphins) and seabirds (jackass penguins, cormorants, pelicans, terns and others). All of these species are subject to natural mortality, and a proportion of the annual production of all these trophic levels, particularly the plankton communities, die naturally and sink to the seabed.Balanced multispecies ecosystem models have estimated that during the 1990s the Benguela region supported biomasses of 76.9 tons/km$^2$ of phytoplankton and 31.5 tons/km$^2$ of zooplankton alone (Shannon *et al*. 2003). Thirty six percent of the phytoplankton and 5% of the zooplankton are estimated to be lost to the seabed annually. This natural annual input of millions of tons of organic material onto the seabed off the southern African West Coast has a substantial effect on the ecosystems of the Benguela region. It provides most of the food requirements of the particulate and filter-feeding benthic communities that inhabit the sandy-muds of this area, and results in the high organic content of the muds in the region. As most of the organic detritus is not directly consumed, it enters the seabed decomposition cycle, resulting in subsequent depletion of oxygen in deeper waters.

### 3.1.6 Low Oxygen Events

An associated phenomenon ubiquitous to the Benguela system are red tides (dinoflagellate and/or ciliate blooms) (see Shannon & Pillar 1985; Pitcher 1998). Also referred to as Harmful Algal Blooms (HABs), these red tides can reach very large proportions, extending over several square kilometres of ocean (Figure 13, left). Toxic dinoflagellate species can cause extensive mortalities of fish and shellfish through direct poisoning, while degradation of organic-rich material derived from both toxic and non-toxic blooms results in oxygen depletion of subsurface water (Figure 13, right).

Figure 13: Red tides can reach very large proportions (left,Photo: www.e-education.psu.edu) and can lead to mass stranding, or ‘walk-out’ of rock lobsters, such as occurred at Elands Bay in February 2002 (Photo: www.waterencyclopedia.com).

The continental shelf waters of the Benguela system are characterised by low oxygen concentrations with <40% saturation occurring frequently (e.g. Visser 1969; Bailey *et al*. 1985). The low oxygen concentrations are attributed to nutrient remineralisation in the bottom waters of the system (Chapman & Shannon 1985). The absolute rate of this is dependent upon the net organic material build-up in the sediments, with the carbon rich mud deposits playing an important role. As the mud on the shelf is distributed in discrete patches (see Figure 14), there are corresponding preferential areas for the formation of oxygen-poor water. The two main areas of low-oxygen water formation in the central Benguela region are in the Orange River Bight and St Helena Bay (Chapman & Shannon 1985; Bailey 1991; Shannon & O’Toole 1998; Bailey 1999; Fossing *et al*. 2000). The spatial distribution of oxygen-poor water in each of the areas is subject to short- and medium-term variability in the volume of hypoxic water that develops. De Decker (1970) showed that the occurrence of low oxygen water off Lambert’s Bay is seasonal, with highest development in summer/autumn. Bailey & Chapman (1991), on the other hand, demonstrated that in the St Helena Bay area daily variability exists as a result of downward flux of oxygen through thermoclines and short-term variations in upwelling intensity. Subsequent upwelling processes can move this low-oxygen water up onto the inner shelf, and into nearshore waters, often with devastating effects on marine communities.

Periodic low oxygen events in the nearshore region can have catastrophic effects on the marine communities leading to large-scale stranding of rock lobsters, and mass mortalities of marine biota and fish (Newman & Pollock 1974; Matthews & Pitcher 1996; Pitcher 1998; Cockcroft *et al*. 2000) (see Figure 13, right). The development of anoxic conditions as a result of the decomposition of huge amounts of organic matter generated by phytoplankton blooms is the main cause for these

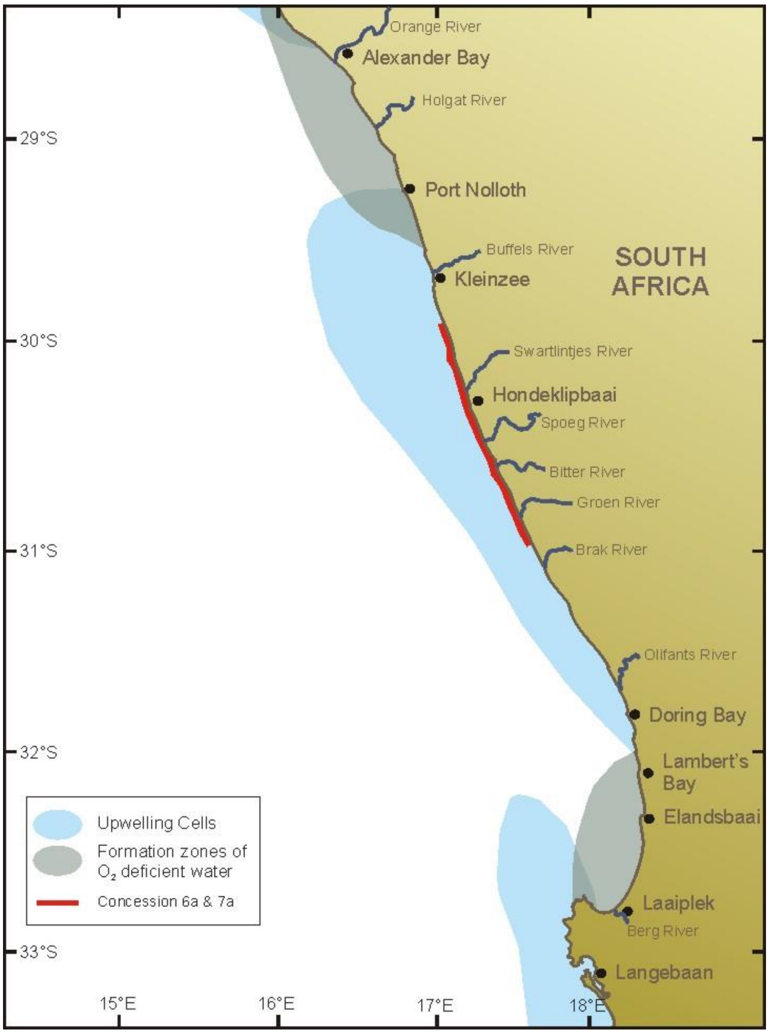


Figure 14: Upwelling centres and formation zones of oxygen deficient water on the West Coast in relation to the project area (red line).

mortalities and walkouts. The blooms develop over a period of unusually calm wind conditions when sea surface temperatures where high. Algal blooms usually occur during summer-autumn (February to April) but can also develop in winter during the ‘berg’ wind periods, when similar warm windless conditions occur for extended periods. Low-oxygen events have, however, not been reported from the region in which the project area is located.

### 3.1.7 Turbidity

Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particulate matter. Total Suspended Particulate Matter (TSPM) can be divided into Particulate Organic Matter (POM) and Particulate Inorganic Matter (PIM), the ratios between them varying considerably. The POM usually consists of detritus, bacteria, phytoplankton and zooplankton, and serves as a source of food for filter-feeders. Seasonal microphyte production associated with upwelling events will play an important role in determining the concentrations of POM in coastal waters. PIM, on the other hand, is primarily of geological origin consisting of fine sands, silts and clays. Off Namaqualand, the PIM loading in nearshore waters is strongly related to natural inputs from the Orange River or from 'berg' wind events. Although highly variable, annual discharge rates of sediments by the Orange River is estimated to vary from 8 - 26 million tons/yr (Rogers 1979). 'Berg' wind events can potentially contribute the same order of magnitude of sediment input as the annual estimated input of sediment by the Orange River (Shannon & Anderson 1982; Zoutendyk 1992, 1995; Shannon & O'Toole 1998; Lane & Carter 1999). For example, a 'berg' wind event in May 1979 described by Shannon and Anderson (1982) was estimated to have transported in the order of 50 million tons of sand out to sea, affecting an area of 20,000 km$^2$.

Concentrations of suspended particulate matter in shallow coastal waters can vary both spatially and temporally, typically ranging from a few mg/ℓ to several tens of mg/ℓ (Bricelj & Malouf 1984; Berg & Newell 1986; Fegley *et al.* 1992). Field measurements of TSPM and PIM concentrations in the Benguela current system have indicated that outside of major flood events, background concentrations of coastal and continental shelf suspended sediments are generally <12 mg/ℓ, showing significant long-shore variation (Zoutendyk 1995). Considerably higher concentrations of PIM have, however, been reported from southern African West Coast waters under stronger wave conditions associated with high tides and storms, or under flood conditions. During storm events, concentrations near the seabed may even reach up to 10,000 mg/ℓ (Miller & Sternberg 1988). In the vicinity of the Orange River mouth, where river outflow strongly influences the turbidity of coastal waters, measured concentrations ranged from 14.3 mg/ℓ at Alexander Bay just south of the mouth (Zoutendyk 1995) to peak values of 7,400 mg/ℓ immediately upstream of the river mouth during the 1988 Orange River flood (Bremner *et al.* 1990).

The major source of turbidity in the swell-influenced nearshore areas off the West Coast is the redistribution of fine inner shelf sediments by long-period Southern Ocean swells. The current velocities typical of the Benguela (10-30 cm/s) are capable of resuspending and transporting considerable quantities of sediment equatorwards. Under relatively calm wind conditions, however, much of the suspended fraction (silt and clay) that remains in suspension for longer periods becomes entrained in the slow poleward undercurrent (Shillington *et al.* 1990; Rogers & Bremner 1991).

Superimposed on the suspended fine fraction, is the northward littoral drift of coarser bedload sediments, parallel to the coastline. This northward, nearshore transport is generated by the predominantly south-westerly swell and wind-induced waves. Longshore sediment transport varies considerably in the shore-perpendicular dimension, being substantially higher in the surf-zone than at depth, due to high turbulence and convective flows associated with breaking waves, which suspend and mobilise sediment (Smith & Mocke 2002).

On the inner and middle continental shelf, the ambient currents are insufficient to transport coarse sediments typical of those depths, and re-suspension and shoreward movement of these by wave-induced currents occur primarily under storm conditions. Data from a Waverider buoy at Port Nolloth have indicated that 2-m waves are capable of re-suspending medium sands (200 µm diameter) at ~10 m depth, whilst 6-m waves achieve this at ~42 m depth. Low-amplitude, long-period waves will, however, penetrate even deeper. Most of the sediment shallower than 90 m can therefore be subject to re-suspension and transport by heavy swells (Lane & Carter 1999).

## 3.2 Biological Environment

The study area lies within the relatively uniform cool Namaqua marine biogeographic region, which extends from Cape Point to Lüderitz in Namibia (Emanuel *et al*. 1992; Lombard *et al*. 2004) (Figure 15). The major force driving the ecology of this region is coastal upwelling, predominantly occurring in the spring/summer period when the south-easterly is the prevailing wind. The upwelling process supplies inorganic nutrients to the euphotic zone supporting high biological productivity (see previous section). This coast is, however, characterized by low marine species richness and low endemicity (Awad *et al*. 2002).

The biota of nearshore marine habitats on the West Coast is relatively robust, being naturally adapted to an extremely dynamic environment where biophysical disturbances are commonplace. The benthic communities within this region are largely ubiquitous, particular only to substrate type (i.e. hard vs. soft bottom), exposure to wave action, or water depth. Habitats specific to the study area include:

- Sandy intertidal and subtidal substrates,
- Intertidal rocky shores and subtidal reefs, and
- The water body.

The biological communities consist of many hundreds of species, often displaying considerable temporal and spatial variability - even at small scales. No rare or endangered species have been recorded (Awad *et al*. 2002). Consequently, this review describes ‘typical’ biological communities, focussing on dominant, commercially important and conspicuous species only.

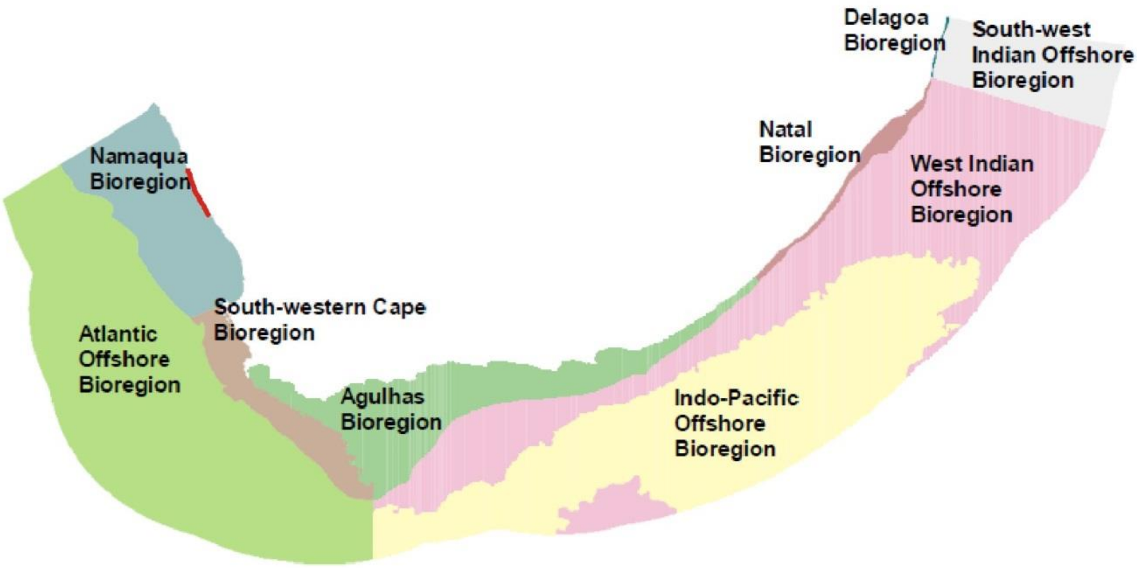


Figure 15: The South African inshore and offshore bioregions in relation to the concession areas (red line) (adapted from Lombard et al. 2004).

### 3.2.1 Sandy Substrate Habitats and Biota

Sandy substrates comprise approximately 14.25 km of the coast of concession 6a and 7a (Figure 1). Similar spatial data are unfortunately not available for concessions 8a and 9a. The benthic biota of soft bottom substrates constitutes invertebrates that live on, or burrow within, the sediments, and are generally divided into megafauna (>10 cm), macrofauna (animals >1 mm) and meiofauna (<1 mm).

*Intertidal Sandy Beaches*

Although the coastline of the study area is highly dominated by rocky shores, there are some isolated pocket beaches between the rocky outcrops. Sandy beaches are one of the most dynamic coastal environments. The composition of their faunal communities is largely dependent on the interaction of wave energy, beach slope and sand particle size, which is termed beach morphodynamics. Three morphodynamic beach types are described: dissipative, reflective and intermediate beaches (McLachlan *et al.* 1993):

**Dissipative beaches** are generally relatively wide and flat with fine sands and high wave energy. Waves start to break far from the shore in a series of spilling breakers that 'dissipate' their energy along a broad surf zone. This generates slow swashes with long periods, resulting in less turbulent conditions on the gently sloping beach face. These beaches usually harbour the richest intertidal faunal communities.

**Reflective beaches** have low wave energy, and are coarse grained (>500 µm sand) with narrow and steep intertidal beach faces. The relative absence of a surf-zone causes the waves to break directly on the shore causing a high turnover of sand. The result is depauperate faunal communities.

**Intermediate beach** conditions exist between these extremes and have a very variable species composition (McLachlan et al. 1993, Jaramillo et al. 1995, Soares 2003). This variability is mainly attributable to the amount and quality of food available.

Beaches with a high input of e.g. kelp wrack have a rich and diverse drift-line fauna, which is sparse or absent on beaches lacking a drift-line (Branch & Griffiths 1988). As a result of the combination of typical beach characteristics, and the special adaptations of beach fauna to these, beaches act as filters and energy recyclers in the nearshore environment (Brown & McLachlan 1990). Due to the exposed nature of the coastline in the study area, most beaches are of the intermediate to reflective type.

Numerous methods of classifying beach zonation have been proposed, based either on physical or biological criteria. The general scheme proposed by Branch & Griffiths (1988) is used below (Figure 16), supplemented by data from various publications on West Coast sandy beach biota (e.g. Bally 1987; Brown *et al.* 1989; Soares *et al.* 1996, 1997; Nel 2001; Nel *et al.* 2003; Soares 2003; Branch *et al.* 2010; Harris 2012). The macrofaunal communities of sandy beaches are generally ubiquitous throughout the southern African West Coast region, being particular only to substratum type, wave exposure and/or depth zone.

The supralittoral zone is situated above the high water spring (HWS) tide level, and receives water input only from large waves at spring high tides or through sea spray. This zone is characterised by a mixture of air-breathing terrestrial and semi-terrestrial fauna, often associated with and feeding on kelp deposited near or on the driftline. Terrestrial species include a diverse array of beetles and arachnids and some oligochaetes, while semi-terrestrial fauna include the oniscid isopod *Tylos granulatus*, and amphipods of the genus *Talorchestia* and *Africorchestia.*

The intertidal or mid-littoral zone has a vertical range of about 2 m. This mid-shore region is characterised by the cirolanid isopods *Pontogeloides latipes*, *Eurydice* (*longicornis*=) *kensleyi*, and

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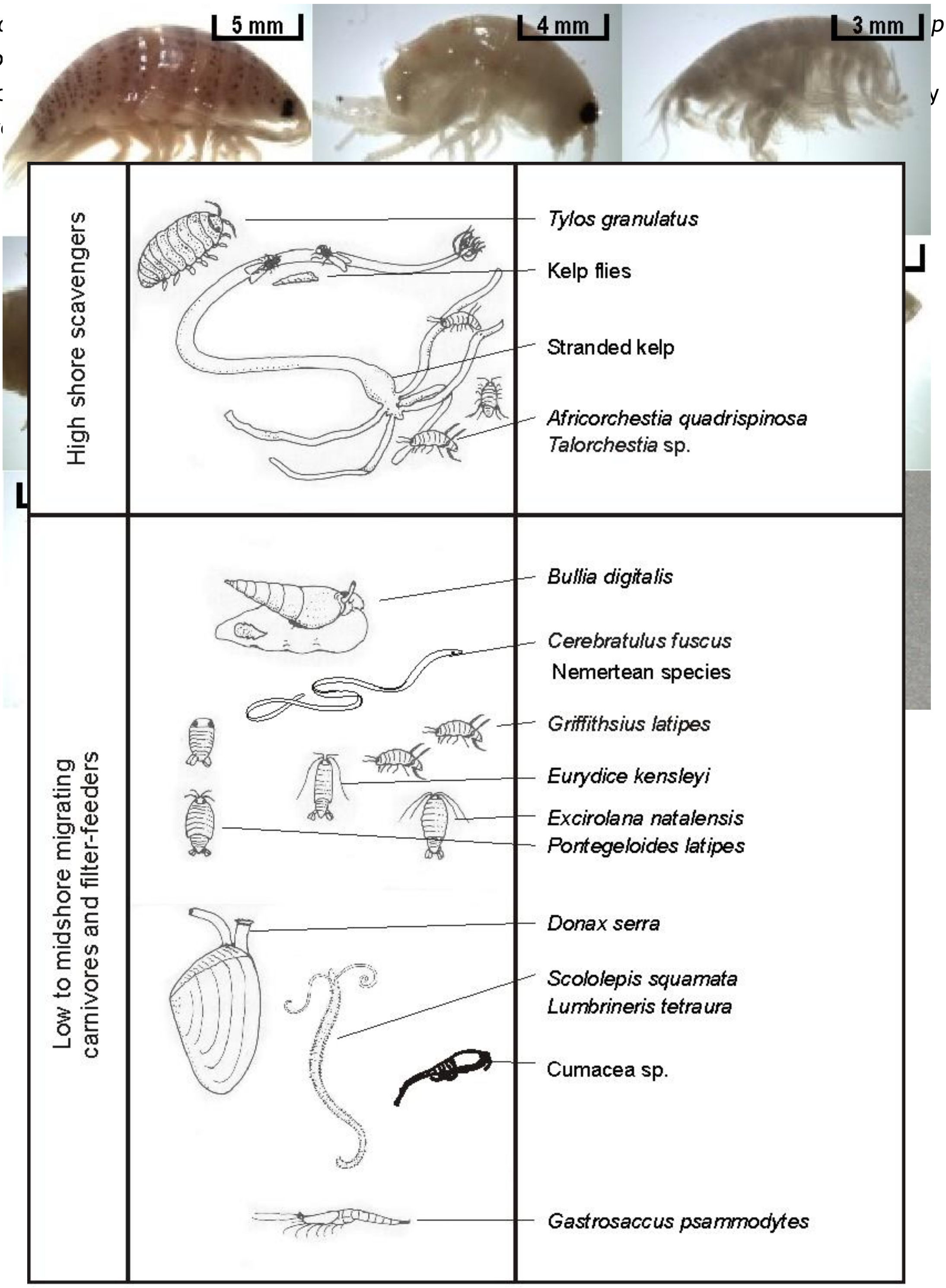

Figure 16: Schematic representation of the West Coast intertidal beach zonation (adapted from Branch & Branch 1981). Species commonly occurring on the Namaqualand beaches are listed.

Figure 17: Common beach macrofaunal species occurring on exposed West Coast beaches.

The inner turbulent zone extends from the Low Water Spring mark to about -2 m depth. The mysid *Gastrosaccus psammodytes* (Mysidacea, Crustacea), the ribbon worm *Cerebratulus fuscus* (Nemertea), the cumacean *Cumopsis robusta* (Cumacea) and a variety of polychaetes including *Scolelepis squamata* and *Lumbrineris tetraura*, are typical of this zone, although they generally extend partially into the midlittoral above. In areas where a suitable swash climate exists, the gastropod *Bullia digitalis* (Gastropoda, Mollusca) may also be present in considerable numbers, surfing up and down the beach in search of carrion.

The transition zone spans approximately 2 - 5 m depth beyond the inner turbulent zone. Extreme turbulence is experienced in this zone, and as a consequence this zone typically harbours the lowest diversity on sandy beaches. Typical fauna include amphipods such as *Cunicus profundus* and burrowing polychaetes such as *Cirriformia tentaculata* and *Lumbrineris tetraura.*

The outer turbulent zone extends below 5 m depth, where turbulence is significantly decreased and species diversity is again much higher. In addition to the polychaetes found in the transition zone, other polychaetes in this zone include *Pectinaria capensis*, and *Sabellides ludertizii*. The sea pen V*irgularia schultzi* (Pennatulacea, Cnidaria) is also common as is a host of amphipod species and the three spot swimming crab *Ovalipes punctatus* (Brachyura, Crustacea).

### *Nearshore and Offshore unconsolidated habitats*

Numerous studies have been conducted on southern African West Coast continental shelf benthos, mostly focused on mining, pollution or demersal trawling impacts (Christie & Moldan 1977; Moldan 1978; Jackson & McGibbon 1991; Environmental Evaluation Unit 1996; Parkins & Field 1997; 1998; Pulfrich & Penney 1999; Goosen *et al*. 2000; Savage *et al*. 2001; Steffani & Pulfrich 2004a, 2004b; 2007; Steffani 2007a; 2007b; Steffani 2009, 2010; Atkinson *et al*. 2011; Steffani 2012). The description below is drawn from recent surveys by Karenyi (unpublished data), De Beers Marine Ltd surveys in 2008 and 2010 (unpublished data), and Atkinson *et al*. (2011).

Three macro-infauna communities have been identified on the inner- (0-30 m depth) and mid-shelf (30-150 m depth, Karenyi unpublished data) off the Namaqualand coast. The inner-shelf community, which is affected by wave action, is characterised by various mobile predators (e.g. the gastropod *Bullia laevissima* and polychaete *Nereis* sp.), sedentary polychaetes and isopods. The mid-shelf community inhabits the mudbelt and is characterised by the mud prawns *Callianassa* sp. and *Calocaris barnardi*. A second mid-shelf sandy community occurring in sandy sediments, is characterised by various polychaetes including deposit-feeding *Spiophanes soederstromi* and *Paraprionospio pinnata*. Polychaetes, crustaceans and molluscs make up the largest proportion of individuals, biomass and species on the west coast (Figure 18). The distribution of species within these communities are inherently patchy reflecting the high natural spatial and temporal variability associated with macro-infauna of unconsolidated sediments (e.g. Kenny *et al*. 1998; Kendall & Widdicombe 1999; van Dalfsen *et al*. 2000; Zajac *et al*. 2000; Parry *et al*. 2003), with evidence of mass mortalities and substantial recruitments recorded on the South African West Coast (Steffani & Pulfrich 2004).

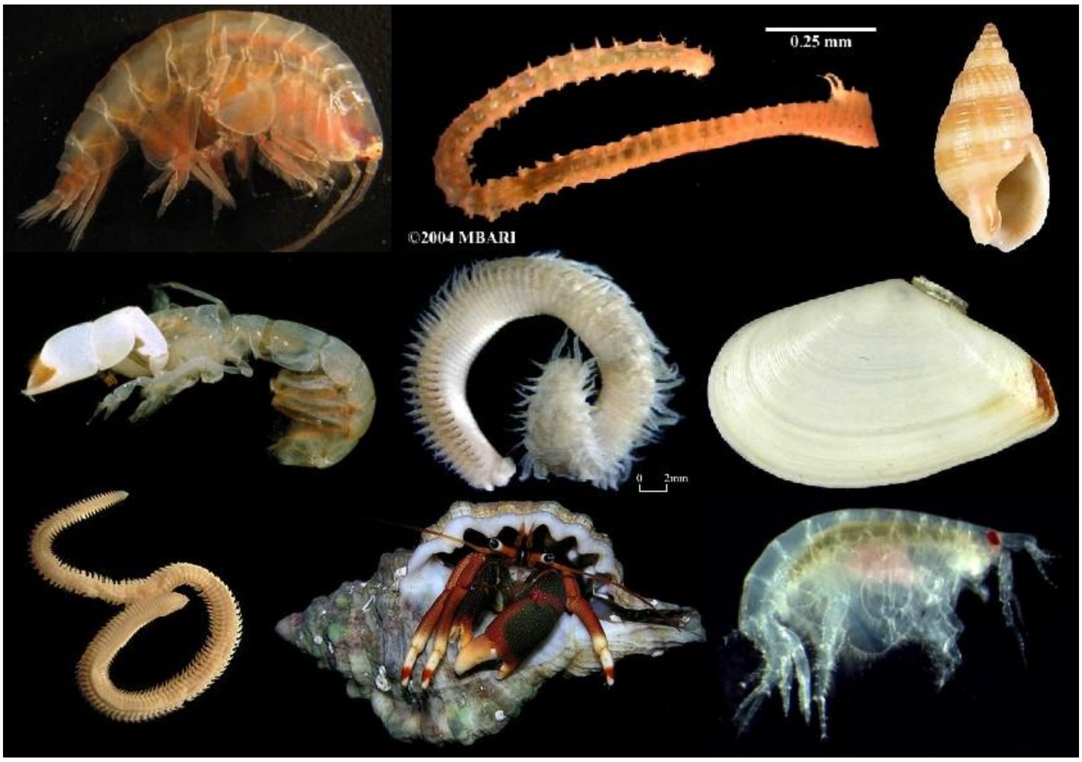

Figure 18: Benthic macrofaunal genera commonly found in nearshore sediments include: (top: left to right) *Ampelisca*, *Prionospio*, *Nassarius*; (middle: left to right) *Callianassa*, *Orbinia*, *Tellina*; (bottom: left to right) *Nephtys*, hermit crab, *Bathyporeia*.

Generally species richness increases from the inner shelf across the mid shelf and is influenced by sediment type (Karenyi unpublished data). The highest total abundance and species diversity was measured in sandy sediments of the mid-shelf. Biomass is highest in the inshore (± 50 g/m$^2$ wet weight) and decreases across the mid-shelf averaging around 30 g/m$^2$ wet weight. This is contrary to Christie (1974) who found that biomass was greatest in the mudbelt at 80 m depth off Lamberts Bay, where the sediment characteristics and the impact of environmental stressors (such as low oxygen events) are likely to differ from those further offshore.

Benthic communities are structured by the complex interplay of a large array of environmental factors. Water depth and sediment grain size are considered the two major factors that determine benthic community structure and distribution on the South African west coast (Christie 1974, 1976; Steffani & Pulfrich 2004a, 2004b; 2007; Steffani 2007a; 2007b) and elsewhere in the world (e.g. Gray 1981; Ellingsen 2002; Bergen *et al.* 2001; Post *et al.* 2006). However, studies have shown that shear bed stress - a measure of the impact of current velocity on sediment – oxygen concentration (Post *et al.* 2006; Currie *et al.* 2009; Zettler *et al.* 2009), productivity (Escaravage *et al.* 2009), organic carbon and seafloor temperature (Day *et al.* 1971) may also strongly influence the structure of benthic communities. There are clearly other natural processes operating in the deepwater shelf areas of the West Coast that can over-ride the suitability of sediments in determining benthic community structure, and it is likely that periodic intrusion of low oxygen water masses is a major cause of this variability (Monteiro & van der Plas 2006; Pulfrich *et al.* 2006). In areas of frequent oxygen deficiency, benthic communities will be characterised either by species able to survive chronic low oxygen conditions, or colonising and fast-growing species able to rapidly recruit into areas that have suffered oxygen depletion. The combination of local, episodic hydrodynamic conditions and patchy settlement of larvae will tend to generate the observed small-scale variability in benthic community structure.

The invertebrate macrofauna are important in the marine benthic environment as they influence major ecological processes (e.g. remineralisation and flux of organic matter deposited on the sea floor, pollutant metabolism, sediment stability) and serve as important food source for commercially valuable fish species and other higher order consumers. As a result of their comparatively limited mobility and permanence over seasons, these animals provide an indication of historical environmental conditions and provide useful indices with which to measure environmental impacts (Gray 1974; Warwick 1993; Salas *et al.* 2006).

Also associated with soft-bottom substrates are demersal communities that comprise epifauna and bottom-dwelling vertebrate species, many of which are dependent on the invertebrate benthic macrofauna as a food source. According to Lange (2012) the continental shelf on the West Coast between depths of 100 m and 250 m, contained a single epifaunal community characterised by the hermit crabs *Sympagurus dimorphus* and *Parapaguris pilosimanus*, the prawn *Funchalia woodwardi* and the sea urchin *Brisaster capensis*. Atkinson (2009) also reported numerous species of urchins and burrowing anemones beyond 300 m depth off the West Coast.

### 3.2.2 Rocky Substrate Habitats and Biota

Rocky and mixed sand and rock substrates comprise approximately 59.1 km of the concession 6a and 7a coastline (Figure 1). Similar spatial data are unfortunately not available for concessions 8a and 9a. The following general description of the intertidal and subtidal habitats for the West Coast is based on Field *et al.* (1980), Branch & Branch (1981), Branch & Griffiths (1988) and Field & Griffiths (1991). It is supplemented by the descriptions of Steffani (2001), Blamey (2003), Pulfrich *et al.* (2003a), and Steffani & Branch (2003a, b, 2005), from the Groen River coastline just south of the project area. The biological communities of rocky intertidal and subtidal reefs are generally ubiquitous throughout the southern African West Coast region, being particular only to wave exposure, turbulence and/or depth zone.

***Intertidal Rocky Shores***

Several studies on the west coast of southern Africa have documented the important effects of wave action on the intertidal rocky-shore community. Specifically, wave action enhances filter-feeders by increasing the concentration and turnover of particulate food, leading to an elevation of overall biomass despite low species diversity (McQuaid & Branch 1985, Bustamante & Branch 1995a, 1996a, Bustamante *et al*. 1997). Conversely, sheltered shores are diverse with a relatively low biomass, and only in relatively sheltered embayments does drift kelp accumulate and provide a vital support for very high densities of kelp trapping limpets, such as *Cymbula granatina* that occur exclusively there (Bustamante *et al*. 1995b). In the subtidal, these differences diminish as wave exposure is moderated with depth.

West Coast rocky intertidal shores can be divided into five zones on the basis of their characteristic biological communities: The Littorina, Upper Balanoid, Lower Balanoid, Cochlear/Argenvillei and the Infratidal Zones. These biological zones correspond roughly to zones based on tidal heights (Figure 19 and Figure 20). Tolerance to the physical stresses associated with life on the intertidal, as well as biological interactions such as herbivory, competition and predation interact to produce these five zones.

*Supralittoral fringe or Littorina zone* - The uppermost part of the shore is the supralittoral fringe, which is the part of the shore that is most exposed to air, perhaps having more in common with the terrestrial environment. The supralittoral is characterised by low species diversity, with the tiny periwinkle *Afrolittorina knysnaensis*, and the red alga *Porphyra capensis* constituting the most common macroscopic life.

*Upper Mid-littoral or Upper Balanoid zone* - The upper mid-littoral is characterised by the limpet *Scutellastra granularis*, which is present on all shores. The gastropods *Oxystele variegata*, *Nucella dubia*, and *Helcion pectunculus* are variably present, as are low densities of the barnacles *Tetraclita serrata*, *Octomeris angulosa* and *Chthalamus dentatus*. Flora is best represented by the green algae *Ulva* spp.

*Lower Mid-littoral or Lower Balanoid zone* - Toward the lower shore, biological communities are determined by exposure to wave action. On sheltered and moderately exposed shores, a diversity of algae abounds with a variable representation of: green algae – *Ulva* spp, *Codium* spp.; brown algae – *Splachnidium rugosum*; and red algae – *Aeodes orbitosa*, *Mazzaella (=Iridaea) capensis*, *Gigartina polycarpa* (=*radula*), *Sarcothalia* (=*Gigartina*) *stiriata*, and with increasing wave exposure

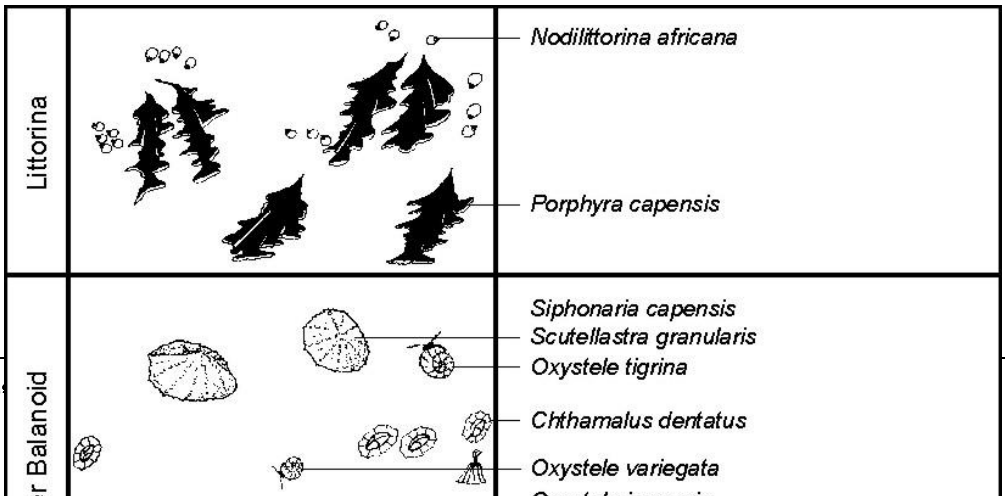

Figure 19: Schematic representation of the West Coast intertidal zonation. Species commonly occurring north of the Olifants River mouth are listed (adapted from Branch & Branch 1981).

*Plocamium rigidum* and *P. cornutum*, and *Champia lumbricalis*. The gastropods *Cymbula granatina* and *Burnupena* spp. are also common, as is the reef building polychaete *Gunnarea capensis*, and the small cushion starfish *Patiriella exigua*. On more exposed shores, almost all of the primary space can be occupied by the dominant alien invasive mussel *Mytilus galloprovincialis*. First recorded in 1979 (although it is likely to have arrived in the late 1960's), it is now the most abundant and widespread invasive marine species spreading along the entire West Coast and parts of the South Coast (Robinson *et al*. 2005). *M. galloprovincialis* has partially displaced the local mussels *Choromytilus meridionalis* and *Aulacomya ater* (Hockey & Van Erkom Schurink 1992), and competes with several indigenous limpet species (Griffiths *et al*. 1992; Steffani & Branch 2003a, b). Recently, another alien invasive has been recorded, the acorn barnacle *Balanus glandula*, which is native to the west coast of North America where it is the most common intertidal barnacle. The presence of *B. glandula* in South Africa was only noticed a few years ago as it had always been confused with the native barnacle *Cthamalus dentatus* (Simon-Blecher *et al*. 2008). There is, however, evidence that it has been in South Africa since at least 1992 (Laird & Griffith 2008). At the time of its discovery, the barnacle was recorded from 400 km of coastline from Elands Bay to Misty Cliffs near Cape Point (Laird & Griffith 2008). As it has been reported on rocky shores south of Lüderitz in Namibia (Pulfrich 2013), it is likely that it occurs in the study area. When present, the barnacle is typically abundant at the mid zones of semi-exposed shores.

Figure 20: Typical rocky intertidal zonation on the southern African west coast.

*Sublittoral fringe or Argenvillei zone* - Along the sublittoral fringe, the large kelp-trapping limpet *Scutellastra argenvillei* dominates forming dense, almost monospecific stands achieving densities of up to 200/m$^2$ (Bustamante *et al*. 1995). Similarly, *C. granatina* is the dominant grazer on more sheltered shores, also reaching extremely high densities (Bustamante *et al*. 1995). On more exposed shores *M. galloprovincialis* dominates. There is evidence that the arrival of the alien *M. galloprovincialis* has led to strong competitive interaction with *S. argenvillei* (Steffani & Branch 2003a, b, 2005). The abundance of the mussel changes with wave exposure, and at wave-exposed locations, the mussel can cover almost the entire primary substratum, whereas in semi-exposed situations it is never abundant. As the cover of *M. galloprovincialis* increases, the abundance and size of *S. argenvillei* on rock declines and it becomes confined to patches within a matrix of mussel bed. As a result exposed sites, once dominated by dense populations of the limpet, are now largely covered by the alien mussel. Semi-exposed shores do, however, offer a refuge preventing global extinction of the limpet. In addition to the mussel and limpets, there is variable representation of the flora and fauna described for the lower mid-littoral above, as well as the anemone *Aulactinia reynaudi*, numerous whelk species and the sea urchin *Parechinus angulosus*. Some of these species extend into the subtidal below.

Very recently, the invasion of west coast rocky shores by another mytilid, the small *Semimytilus algosus*, was noted (de Greef *et al*. 2013). It is hypothesized that this species has established itself fairly recently, probably only in the last ten years. Its current range extends from the Groen River mouth in the north to Bloubergstrand in the south. Where present, it occupies the lower intertidal zone, where they completely dominate primary rock space, while *M. galloprovincialis* dominates higher up the shore. Many shores on the West Coast have thus now been effectively partitioned by the three introduced species, with *B. glandula* colonizing the upper intertidal, *M. galloprovincialis* dominating the mid-shore, and now *S. algosus* smothering the low-shore (de Greef *et al*. 2013).

***Rocky Subtidal Habitat and Kelp Beds***

Biological communities of the rocky sublittoral can be broadly grouped into an inshore zone from the sublittoral fringe to a depth of about 10 m dominated by flora, and an offshore zone below 10 m depth dominated by fauna. This shift in communities is not knife-edge, and rather represents a continuum of species distributions, merely with changing abundances.

From the sublittoral fringe to a depth of between 5 and 10 m, the benthos is largely dominated by algae, in particular two species of kelp. The canopy forming kelp *Ecklonia maxima* extends seawards to a depth of about 10 m. The smaller *Laminaria pallida* forms a sub-canopy to a height of about 2 m underneath *Ecklonia*, but continues its seaward extent to about 30 m depth, although further north up the west coast increasing turbidity limits growth to shallower waters (10-20 m) (Velimirov *et al*. 1977; Jarman & Carter 1981, Branch 2008). *Ecklonia maxima* is the dominant species in the south forming extensive beds from west of Cape Agulhas to north of Cape Columbine, but decreasing in abundance northwards. *Laminaria* becomes the dominant kelp north of Cape Columbine and thus in the project area, extending from Danger Point east of Cape Agulhas to Rocky Point in northern Namibia (Stegenga *et al*. 1997; Rand 2006).

Kelp beds absorb and dissipate much of the typically high wave energy reaching the shore, thereby providing important partially-sheltered habitats for a high diversity of marine flora and fauna, resulting in diverse and typical kelp-forest communities being established (Figure 21). Through a combination of shelter and provision of food, kelp beds support recruitment and complex trophic food webs of numerous species, including commercially important rock lobster stocks (Branch 2008). Growing beneath the kelp canopy, and epiphytically on the kelps themselves, are a diversity of understorey algae, which provide both food and shelter for predators, grazers and filter-feeders associated with the kelp bed ecosystem. Representative under-storey algae include *Botryocarpa prolifera*, *Neuroglossum binderianum*, *Botryoglossum platycarpum*, *Hymenena venosa* and *Rhodymenia* (=*Epymenia*) *obtusa*, various coralline algae, as well as subtidal extensions of some algae occurring primarily in the intertidal zones (Bolton 1986). Epiphytic species include *Polysiphonia virgata*, *Gelidium vittatum (=Suhria vittata)* and *Carpoblepharis flaccida*. In particular, encrusting coralline algae are important in the under-storey flora as they are known as settlement attractors for a diversity of invertebrate species. The presence of coralline crusts is thought to be a key factor in supporting a rich shallow-water community by providing substrate, refuge, and food to a wide variety of infaunal and epifaunal invertebrates (Chenelot *et al.* 2008).

Figure 21: The canopy-forming kelp *Ecklonia maxima* provides an important habitat for a diversity of marine biota (Photo: Geoff Spiby).

The sublittoral invertebrate fauna is dominated by suspension and filter-feeders, such as the mussels *Aulacomya ater* and *Choromytilus meriodonalis*, and the Cape reef worm *Gunnarea capensis*, and a variety of sponges and sea cucumbers. Grazers are less common, with most herbivory being restricted to grazing of juvenile algae or debris-feeding on detached macrophytes. The dominant herbivore is the sea urchin *Parechinus angulosus*, with lesser grazing pressure from limpets, the isopod *Paridotea reticulata* and the amphipod *Ampithoe humeralis*. The abalone *Haliotis midae*, an important commercial species present in kelp beds is naturally absent north of Cape Columbine.

Key predators in the sub-littoral include the commercially important West Coast rock lobster *Jasus lalandii* and the octopus *Octopus vulgaris*. The rock lobster acts as a keystone species as it influences community structure via predation on a wide range of benthic organisms (Mayfield *et al.* 2000). Relatively abundant rock lobsters can lead to a reduction in density, or even elimination, of black mussel *Choromytilus meriodonalis*, the preferred prey of the species, and alter the size structure of populations of ribbed mussels *Aulacomya ater*, reducing the proportion of selected size-classes (Griffiths & Seiderer 1980). Their role as predator can thus reshape benthic communities, resulting in large reductions in taxa such as black mussels, urchins, whelks and barnacles, and in the dominance of algae (Barkai & Branch 1988; Mayfield 1998).

Of lesser importance as predators, although numerically significant, are various starfish, feather and brittle stars, and gastropods, including the whelks *Nucella* spp. and *Burnupena* spp. Fish species commonly found in kelp beds off the West Coast include hottentot *Pachymetopon blochii*, two tone finger fin *Chirodactylus brachydactylus*, red fingers *Cheilodactylus fasciatus*, galjoen *Dichistius capensis*, rock suckers *Chorisochismus dentex* and the catshark *Haploblepharus pictus* (Branch *et al.* 2010).

There is substantial spatial and temporal variability in the density and biomass of kelp beds, as storms can remove large numbers of plants and recruitment appears to be stochastic and unpredictable (Levitt *et al.* 2002; Rothman *et al.* 2006). Some kelp beds are dense, whilst others are less so due to differences in seabed topography, and the presence or absence of sand and grazers. Due to their importance as recruitment, nursery, and feeding grounds for numerous species, including the commercially important rock lobster *J. lalandii*, kelp beds are considered a medium sensitivity habitat.

### 3.2.3 The Water Body

The study area is located in the central Benguela ecosystem and, as there are few barriers to water exchange, pelagic communities are typical of those of the region. The pelagic communities are typically divided into plankton, fish, and marine mammals (seals, dolphins and whales).

#### *Plankton*

Plankton is particularly abundant in the shelf waters off the West Coast, being associated with the upwelling characteristic of the area. Plankton range from single-celled bacteria to jellyfish of 2-m diameter, and includes bacterio-plankton, phytoplankton, zooplankton, and ichthyoplankton (Figure 22).

Phytoplankton are the principle primary producers with mean productivity ranging from 2.5 - 3.5 g C/m$^2$/day for the midshelf region and decreasing to 1 g C/m$^2$/day inshore of 130 m (Shannon & Field 1985; Mitchell-Innes & Walker 1991; Walker & Peterson 1991). The phytoplankton is dominated by large-celled organisms, which are adapted to the turbulent sea conditions. The most common diatom genera are *Chaetoceros*, *Nitschia*, *Thalassiosira*, *Skeletonema*, *Rhizosolenia*, *Coscinodiscus* and *Asterionella* (Shannon & Pillar 1985). Diatom blooms occur after upwelling events, whereas dinoflagellates (e.g. *Prorocentrum*, *Ceratium* and *Peridinium*) are more common in blooms that occur during quiescent periods, since they can grow rapidly at low nutrient concentrations. In the surf zone, diatoms and dinoflagellates are nearly equally important members of the phytoplankton, and some silicoflagellates are also present.

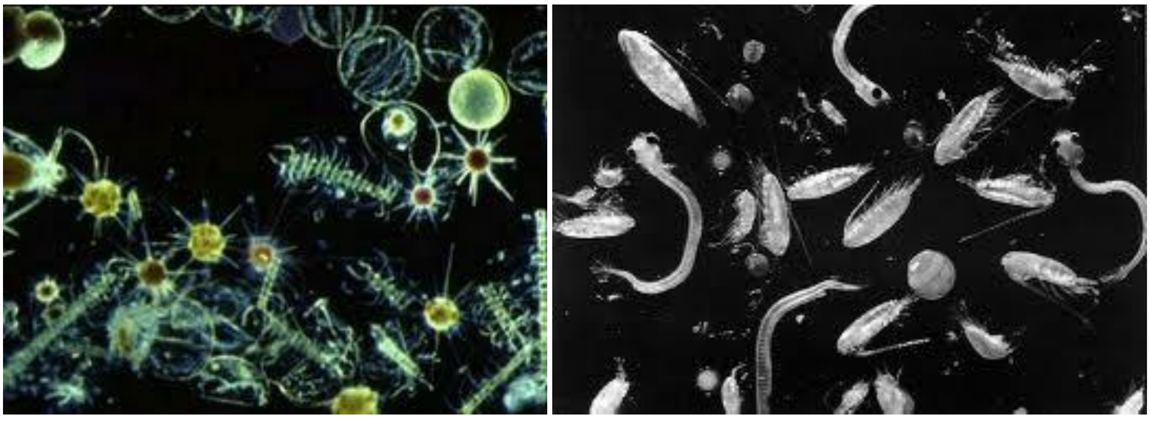

Figure 22: Phytoplankton (left, photo: hymagazine.com) and zooplankton (right, photo: mysciencebox.org) is associated with upwelling cells.

The phytoplankton includes diatoms, dinoflagellates, coccolithophorids and microflagellates. Phytoplankton biomass in the southern Benguela is generally high in summer during the upwelling season, but also quite extensive in the autumn and spring, with diatoms generally dominating inshore and small flagellates offshore (Barlow *et al.* 2005). Maximum diatom concentrations are found in the upper 10 m and thereafter decrease with an increase in depth. Common and widely distributed diatom species include *Asterionella glacialis*, *Leptocylindrus danicus*, *Minidiscus trioculatus*, *Skeletonema costatum*, *Thalassionema nitzschioides* and a number of *Navicula*, *Nitzschia* and *Thalassiosira* species. The most common member of the microflagelattes is a species of *Pyramimonas*. Dinoflagellates are represented by several members of the genus *Gyrodinium*, *Ceratium*, *Protoperidilium* amongst others. Also present in the area are toxic dinoflagellate species such as *Alexandrium catenella* and various members of the genus *Dinophysis*, which can cause mass mortalities of fish, shellfish, marine mammals, seabirds and other animals (Pitcher & Calder 2000).

Zooplankton is characterised by pelagic crustaceans (e.g. copepods, cumaceans, hyperiid amphipods, chaetognaths, mysids, euphausiids), invertebrate larvae (e.g. bivalve, polychaete, *etc.*), pelagic cnidarians, and ichthyoplankton. Crustacean zooplankters often contribute greatest to the total zooplankton with copepods (e.g. *Calanus* spp., *Centropages* spp., *Metridia* spp.) being the most common organisms in the zooplankton (Verheye & Richardson 1998, Hutchings *et al.* 2006). Ichthyoplankton constitutes the eggs and larvae of fish. Long-term changes in the southern Benguela include a significant increase in zooplankton over the past five decades, with a decline since 1995 linked to a concomitant increase in pelagic fish biomass as the main predators on zooplankton (Hutchings *et al.* 2006).

Red-tides are ubiquitous features of the Benguela system (see Shannon & Pillar 1986). The most common species associated with red tides (dinoflagellate and/or ciliate blooms) are *Noctiluca scintillans*, *Gonyaulax tamarensis*, *G. polygramma* and the ciliate *Mesodinium rubrum*. *Gonyaulax* and *Mesodinium* have been linked with toxic red tides. Most of these red-tide events occur quite close inshore although Hutchings *et al.* (1983) have recorded red-tides 30 km offshore.

The mesozooplankton (≥200 µm) is dominated by copepods, which are overall the most dominant and diverse group in southern African zooplankton. Important species are *Centropages brachiatus*, *Calanoides carinatus*, *Metridia lucens*, *Nannocalanus minor*, *Clausocalanus arcuicornis*, *Paracalanus parvus*, *P. crassirostris* and *Ctenocalanus vanus*. All of the above species typically occur in the phytoplankton rich upper mixed layer of the water column, with the exception of *M. lucens* which undertakes considerable vertical migration.

The macrozooplankton (≥1,600 µm) are dominated by euphausiids of which 18 species occur in the area. The dominant species occurring in the nearshore are *Euphausia lucens* and *Nyctiphanes capensis*, although neither species appears to survive well in waters seaward of oceanic fronts over the continental shelf (Pillar *et al.* 1991).

Standing stock estimates of mesozooplankton for the southern Benguela area range from 0.2 - 2.0 g C/m$^2$, with maximum values recorded during upwelling periods. Macrozooplankton biomass ranges from 0.1-1.0 g C/m$^2$, with production increasing north of Cape Columbine (Pillar 1986). Although it shows no appreciable onshore-offshore gradients, standing stock is highest over the shelf, with accumulation of some mobile zooplanktors (euphausiids) known to occur at oceanographic fronts. Beyond the continental slope biomass decreases markedly. Localised peaks in biomass may, however, occur in the vicinity of Child's Bank and Tripp seamount in response to topographically steered upwelling around such seabed features.

Zooplankton biomass varies with phytoplankton abundance and, accordingly, seasonal minima will exist during non-upwelling periods when primary production is lower (Brown 1984; Brown & Henry 1985), and during winter when predation by recruiting anchovy is high. More intense variation will occur in relation to the upwelling cycle; newly upwelled water supporting low zooplankton biomass due to paucity of food, whilst high biomasses develop in aged upwelled water subsequent to significant development of phytoplankton. Irregular pulsing of the upwelling system, combined with seasonal recruitment of pelagic fish species into West Coast shelf waters during winter, thus results in a highly variable and dynamic balance between plankton replenishment and food availability for pelagic fish species.

Although ichthyoplankton (fish eggs and larvae) comprise a minor component of the overall plankton, it remains significant due to the commercial importance of the overall fishery in the region. Various pelagic and demersal fish species are known to spawn in the inshore regions of the southern Benguela, (including pilchard, round herring, chub mackerel lanternfish and hakes (Crawford *et al*. 1987), and their eggs and larvae form an important contribution to the ichthyoplankton in the region. Ichthyoplankton abundance within the project area is thus expected to be high.

### *Fish*

The structure of the nearshore and surf zone fish community varies greatly with the degree of wave exposure. Species richness and abundance is generally high in sheltered and semi-exposed areas but typically very low off the more exposed beaches (Clark 1997a, 1997b).

The surf-zone and outer turbulent zone habitats of sandy beaches are considered to be important nursery habitats for marine fishes (Modde 1980, Lasiak 1981, Kinoshita & Fujita 1988, Clark *et al*. 1994). However, the composition and abundance of the individual assemblages seems to be heavily dependent on wave exposure (Blaber & Blaber 1980; Potter *et al*. 1990; Clark 1997a, b). Surf-zone fish communities off the South African West Coast have relatively high biomass, but low species diversity. Typical surf-zone fish include harders (*Liza richardsonii*), white stumpnose (*Rhabdosargus globiceps*) (Figure 23), Cape sole (*Heteromycteris capensis*), Cape gurnard (*Chelidonichthys capensis*), False Bay klipfish (*Clinus latipennis*), sandsharks (*Rhinobatos annulatus*), eagle ray (*Myliobatis aquila*), and smooth-hound (*Mustelus mustelus*) (Clark 1997b).

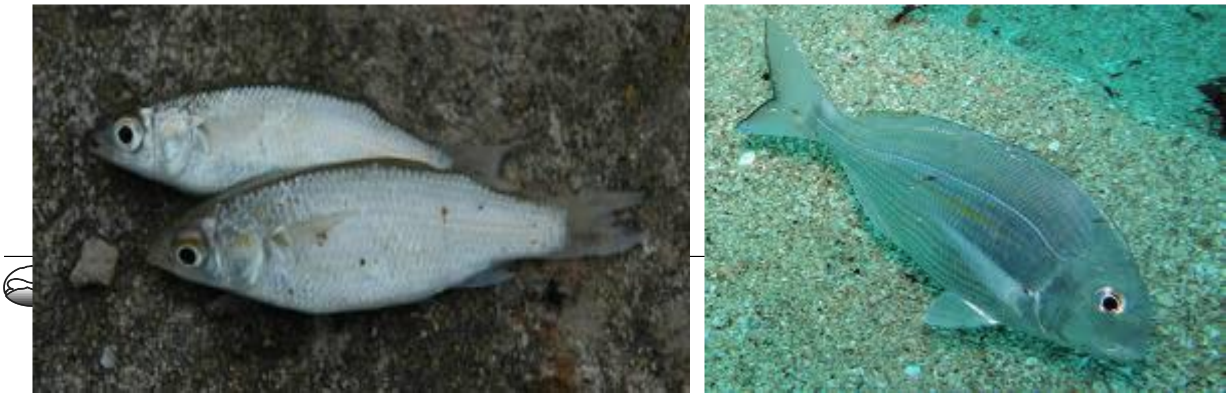

Figure 23: Common surf-zone fish include the harder (left, photo: aquariophil.org) and the white stumpnose (right, photo: easterncapescubadiving.co.za).

Fish species commonly found in kelp beds off the West Coast include hottentot *Pachymetopon blochii*, twotone fingerfin *Chirodactylus brachydactylus* (Figure 24), red fingers *Cheilodactylus fasciatus*, galjoen *Dichistius capensis*, rock suckers *Chorisochismus dentex*, maned blennies *Scartella emarginata* and the catshark *Haploblepharus pictus* (Sauer *et al*. 1997; Brouwer *et al*. 1997; Branch *et al*. 2010). Several additional species of fish are also commonly caught in gill-nets set over rocky reef areas between the Orange River and Cape Columbine. Species of importance include harder *Liza richardsonii*, pilchard *Sardinops sagax*, strepie *Sarpa salpa*, houndsharks *Mustelus mustelus* and cowsharks *Notorynchus cepedianus* (K. Hutchings, UCT, pers. comm.).

Figure 24: Common fish found in kelp beds include the Hottentot fish (left, photo: commons. wikimedia.org) and the twotone fingerfin (right, photo: www.parrphotographic.com).

Small pelagic species that occur in the area include the sardine (*Sardinops sagax*), anchovy (*Engraulis encrasicolus*), juvenile Cape horse mackerel (*Trachurus trachurus capensis*), and round herring (*Etrumeus whiteheadi*). Although these species generally occur within the 200 m contour, they may often be found very close inshore (Pecquerie *et al*. 2004). Demersal fish include deep water (*Merluccius paradoxus*), shallow water hake (*M. capensis*) and kingklip (*Genypterus capensis*), and St Joseph shark (*Callorhinchus capensis*) in shallow inshore waters. Linefish species include (juvenile) snoek (*Thyrsites atun*), silver kob (*Argyrosomus inodorus*), white steenbras (*Lithognathus lithognathus*), blacktail (*Diplodus sargus*), white stumpnose (*Rhabdosargus globiceps*), Hottentot (*Pachymetopon blochii*), geelbek (*Atractoscion aequidens*) and galjoen (*Dichistius capensis*).

***Seabirds***

Large numbers of pelagic seabirds exploit the pelagic fish stocks of the Benguela system. Of the 49 species of seabirds that occur in the Benguela region, 14 are defined as resident, 10 are visitors from the northern hemisphere and 25 are migrants from the southern Ocean. The area between Cape Point and the Orange River supports 38% and 33% of the overall population of pelagic seabirds in winter and summer, respectively. 14 species of seabirds breed in southern Africa; Cape Gannet, African Penguin, four species of Cormorant, White Pelican, three Gull and four Tern species. The breeding areas are distributed around the coast with islands being especially important. The number of successfully breeding birds at the particular breeding sites varies with food abundance.

Birds endemic to the region and liable to occur most frequently in the project area include Cape Gannets, Kelp Gulls, African Penguins, African Black Oystercatcher (Figure 25, left), Bank, Cape and Crowned Cormorants (Figure 25, right), and Hartlaub's Gull. Of these the Black Oystercatcher and Bank Cormorant are rare. The breeding success of African Black Oystercatcher is particularly susceptible to disturbance from off-road vehicles as they nest and breed on beaches between the Eastern Cape and southern Namibia. Caspian and Damara terns are likewise rare and breed in the study area, especially in the wetland and saltpan areas associated with the Olifants River estuary.
Most of the breeding seabird species forage at sea with most birds being found relatively close inshore (10 - 30 km), although African Penguins and Cape Gannets are known to forage up to 60 km and 140 km offshore, respectively.

Figure 25: The African Black Oystercatcher (Left, photo: patrickspilsbury.blogspot.com) and Crowned Cormorant (right, photo: savoels.za.net).

***Marine Mammals***

The marine mammal fauna of the West Coast comprises between 28 and 31 species of cetaceans (whales and dolphins) and four species of seals. The Cape fur seal *Arctocephalus pusillus* (Figure 26) is the only species of seal resident along the west coast of Africa, occurring at numerous breeding and non-breeding sites on the mainland and on nearshore islands and reefs. Vagrant records from four other species of seal more usually associated with the subantarctic environment have also been recorded: southern elephant seal (*Mirounga leoninas),* subantarctic fur seal (*Arctocephalus tropicalis),* crabeater *(Lobodon carcinophagus)* and leopard seals (*Hydrurga leptonyx)* (David 1989). There are three Cape fur seal breeding colonies within the broader study area: at Kleinzee (incorporating Robeiland), and at Bucchu Twins near Alexander Bay. The colony at Kleinzee has the highest seal population and produces the highest seal pup numbers on the South African Coast (Wickens 1994). The colony at Bucchu Twins, formerly a non-breeding colony, has also attained breeding status (M. Meyer, SFRI, pers. comm.). Non-breeding colonies occur at Strandfontein Point

(~5 km north or the Groen River mouth) and on Bird Island at Lamberts Bay. All have important conservation value since they are largely undisturbed at present.

Dusky dolphin (*Lagenorhynchus obscurus*) (Figure 27, right) and Heaviside's dolphin (*Cephalorhynchus heavisidii*) (Figure 27, left) are resident year round throughout the Benguela ecosystem coastal waters (Findlay *et al*. 1992; Elwen 2008; Elwen *et al*. 2010). In water <500 m deep, Dusky Dolphins are likely to be the most frequently encountered small cetacean. The species is very boat friendly and will often approach boats to bowride. This species is resident year round throughout the Benguela ecosystem in waters from the coast to at least 500 m deep, but may occur as far offshore as 2 000 m depth (Findlay *et al*. 1992). Although no information is available on the size of the population, they are regularly encountered in near shore waters between Cape Town and Lamberts Bay, but further north they are usually found further from shore in slightly deeper waters (Elwen *et al*. 2010a; NDP unpubl data). Abundances estimates are being calculated but currently suggest a relatively large population of several thousand at least. Group sizes up to 800 have been reported in southern African waters (Findlay *et al*. 1992). Dusky Dolphins are resident year round in the Benguela, although a hiatus in sightings (or low density area) is reported between ~27°S and 30°S, associated with the Lüderitz upwelling cell (Findlay *et al*. 1992).

Figure 26: Colony of Cape fur seals *Arctocephalus pusillus pusillus* (Photo: Dirk Heinrich).

Heaviside's Dolphins are relatively abundant in the Benguela ecosystem (Elwen *et al*. 2009). Individuals show high site fidelity to small home ranges, 50-80 km along shore (Elwen *et al*. 2006) and may thus be more vulnerable to threats within their home range. This species occupies waters from the coast to at least 200 m depth, (Elwen *et al*. 2006; Best 2007). They may show a diurnal onshore-offshore movement pattern (Elwen *et al*. 2010b), but this varies throughout the species range. Heaviside's dolphins are resident year round.

Whale species that may be sighted in the area include Southern Right Whale (*Balaena glacialis*), Humpback Whale (*Megaptera novaeangliae*), and Killer Whale (*Orcinus orca*), along with Antarctic Minke (*Balaenoptera acutorostrata*) and Bryde's (*B. brydei*) whales (Best 2007). Whales occurring in the nearshore region in the project area will largely be transitory.

All whales and dolphins are given protection under the South African Law. The Marine Living Resources Act, 1998 (No. 18 of 1998) states that no whales or dolphins may be harassed, killed or fished. No vessel or aircraft may, without a permit or exemption, approach closer than 300 m to any whale and a vessel should move to a minimum distance of 300 m from any whales if a whale surfaces closer than 300 m from a vessel or aircraft.

Figure 27: The endemic Heaviside's Dolphin *Cephalorhynchus heavisidii* (left) (Photo: De Beers Marine Namibia), and Dusky dolphin *Lagenorhynchus obscurus* (right) (Photo: scottelowitzphotography.com).

### 3.2.4 Other Uses of the Area

***Rock Lobster Fishery***

The West Coast rock lobster *Jasus lalandii* is a valuable resource of the South African West Coast and consequently an important income source for West Coast fishermen. Following the collapse of the rock-lobster resource in the 1970s, fishing has been controlled by a Total Allowable Catch (TAC), a minimum size, restricted gear, a closed season and closed areas (Crawford *et al*. 1987; Melville-Smith & Van Sittert 2005). The West Coast rock lobster fishery is seasonally restricted to the period 15 November to the last day in May. Management of the resource is geographically specific, with the TAC annually allocated by Area. The study area falls within Area 2 of the commercial rock lobster fishing zones that extends from Kleinzee to the mouth of the Brak River. The TAC for the season 2013/14 has been set at 2167.06 tons.

Commercial catches of rock lobster in Area 2 are confined to shallower water (<30 m) with almost all the catch being taken in <15 m depth. Actual rock-lobster fishing, however, takes place only at discrete suitable reef areas along the shore within this broad depth zone. Lobster fishing is conducted from a fleet of small dinghies/bakkies. The majority of these works directly from the shore within a few nautical miles of the harbours, with only 30% of the total numbers of bakkies partaking in the fishery being deployed from larger deck boats. As a result, lobster fishing tends to be concentrated close to the shore within a few nautical miles of Port Nolloth and Hondeklip Bay.

Rock lobster landings for the fishing season 2008/09 to 2012/13 for the sub-areas 1 and 2 of Area 2 are provided in Table 3.

Table 3: Actual rock lobster catch (kg) for subareas 1 and 2 of Area 2 for the 2008/09 to 2012/2013 fishing seasons (Data source: Rock Lobster Section, DAFF).

| Area/subarea | Actual Catch 2008/09 | Actual Catch 2009/10 | Actual Catch 2010/11 | Actual Catch 2011/12 | Actual Catch 2012/13 |
|---|---|---|---|---|---|
| 2/1 | 937 | 1,286 | 2,246 | 1,683 | -- |
| 2/2 | -- | -- | -- | -- | -- |

### ***Kelp Collecting***

The West Coast is divided into numerous seaweed concession areas (Figure 28). Access to a seaweed concession is granted by means of a permit from the Fisheries Branch of the Department of Agriculture, Forestry and Fisheries to a single party for a period of five years. The seaweed industry was initially based on sun dried beach-cast seaweed, with harvesting of fresh seaweed occurring in small quantities only (Anderson *et al*. 1989). The actual level of beach-cast kelp collection varies substantially through the year, being dependent on storm action to loosen kelp from subtidal reefs.

Permit holders collect beach casts of both *Ecklonia maxima* and *Laminaria pallida* from the driftline of beaches (Table 4). The kelp is initially dried just above the high water mark before being transported to drying beds in the foreland dune area. The dried product is ground before being exported for production of alginic acid (alginate).

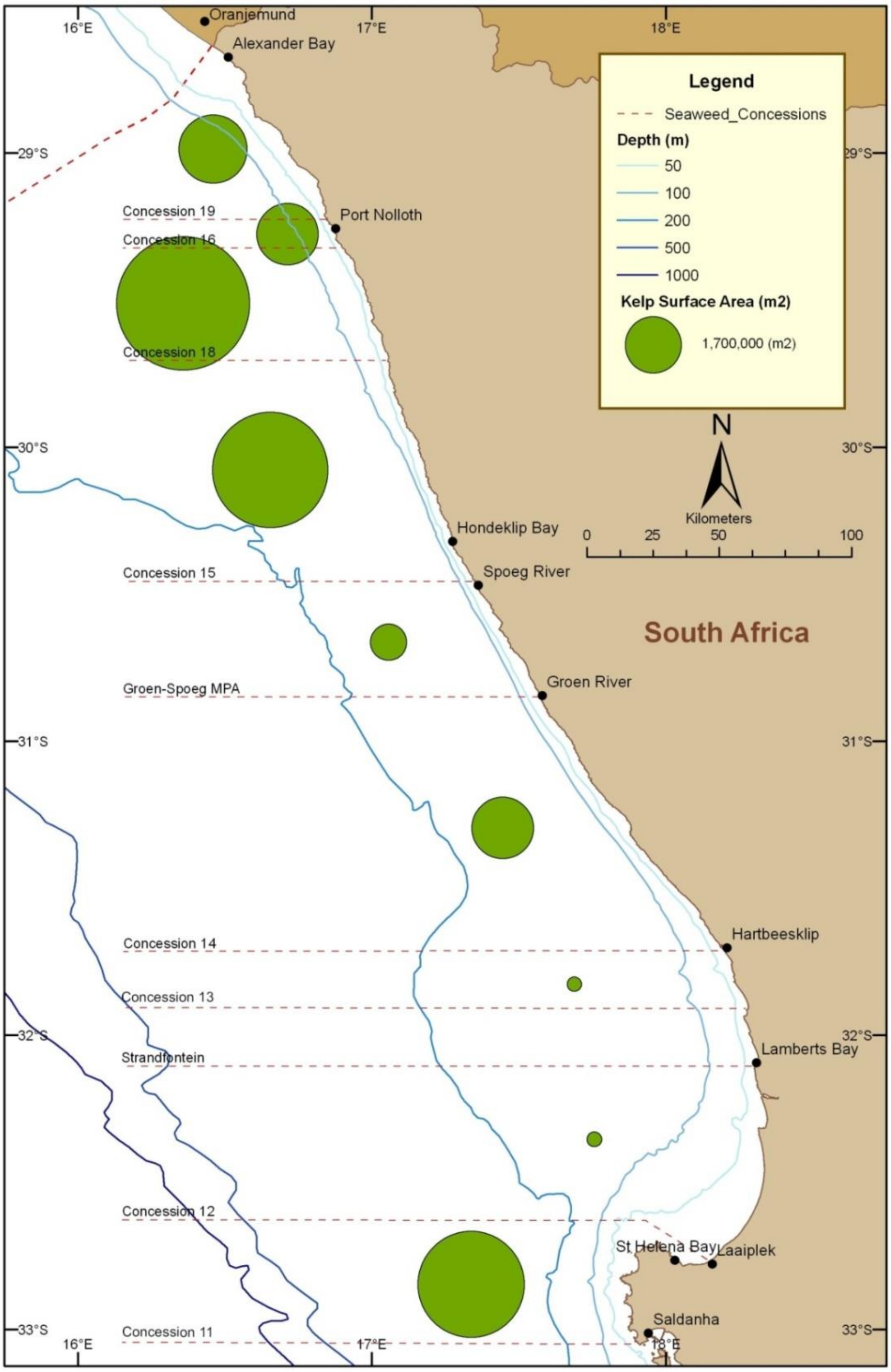

Figure 28: Estimated kelp bed areas in the South African kelp concessions between the Orange River mouth and Cape Columbine (from Penney *et al*. 2007).

Table 4: Beach-cast collections (in kg dry weight) for kelp concessions north of Lamberts Bay. (Data source: Seaweed Section, DAFF).

| Concession Number | Concession Holder | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|
| 13 | Eckloweed Industries | 65,898 | 94,914 | 122,095 | 61,949 | 102,925 | 53,927 | 40,511 | 43,297 | 20,485 |
| 14 | Eckloweed Industries | 165,179 | 145,670 | 79,771 | 204,365 | 117,136 | 166,106 | 72,829 | 151,561 | 97,283 |
| 15 | Rekaofela Kelp | 10,300 | 19,550 | 0 | 23,646 | 0 | 0 | 0 | 160,500 | 36,380 |
| 16 | Rekaofela Kelp | 35,920 | 28,600 | 84,445 | 16,804 | 0 | 0 | 0 | 156,000 | 24,000 |
| 18 | FAMDA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | Premier Fishing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Estimates of both kelp bed area and biomass for different stretches of coastline vary considerably depending on the survey method used. The values from Rand (2006) presented in Table 5 are used here to illustrate similarities in kelp bed area per kilometre of rocky coast (Kelp Concessions 15, 16 and 18). It must be kept in mind that the values in Table 5 are based on kelp beds that reach the surface at low spring tide and do not take into account the extensive *Laminaria* beds that extend into deeper water. As *Laminaria* is the dominant species in Namaqualand, both kelp bed area and biomass are thus likely underestimates of the available standing stock.

Table 5 The estimated total area of kelp beds for each of the kelp concessions between the Orange River mouth and Cape Columbine (Rand 2006).

| Kelp Concession/Area | Kelp bed area (ha) | Length of rocky coastline (km) |
|---|---|---|
| 19 | 254.95 | 48.5 |
| 18 | 976.0 | 18.25 |
| 16 | 206.44 | 5.0 |
| 15 | 732.22 | 104.5 |
| Groen-Spoeg | 71.94 | ~15.0 |
| 14 | 206.64 | 63.75 |
| 13 | 10.8 | 4.25 |
| Strandfontein | no data | ~15 |
| 12 | 15.9 | 1.25 |
| 11 | 617.95 | 28.75 |

### *Linefishing*

Commercial linefishing is conducted from a variety of vessels ranging from large deckboats to tiny rock lobster bakkies, most of which operate very close to the shore. In Namaqualand, the boats belong mostly to the rock lobster fishery, with most of the fishing undertaken during the rock lobster closed season. As with the rock lobster fishery, linefishing effort is centred around the harbours in the area. The main species targeted by the line-fishermen are Snoek, Yellowtail, Hottentot and Galjoen (Sauer & Erasmus 1997). The estimated annual linefish catch on the West Coast is 6,000 tons of which only 10% is contributed from inshore and offshore fishing in the northern regions. Sauer and Erasmus (1997) estimated that the inshore linefish catch along the Northern Cape coast amounts to <5 tons/km/yr.

The landings and effort in the linefishery show distinct seasonality, influenced to a large extent by the availability of the target species. Of the species targeted by the linefishery, the Hottentot is available to the fishermen throughout the year. The occurrence of Snoek is more seasonal with the fish being more abundant during late summer and autumn. Yellowtail show a similar seasonality with catches peaking in March/April. Catches of Galjoen are limited to the winter months, there being a closed season from 15 October to the end of February.

Clark *et al*. (2002) identified approximately 330 fishers in the area between Port Nolloth and Doring Bay. The increase in the number of artisanal fishers in the region since the 2002 survey is unknown, but in the interim many of these fishers will have received official recognition and have been granted small scale commercial or “interim relief” rights.

From 2002 to 2004, the Northern Cape provincial government initiated a small scale experimental fishery out off Port Nolloth and Hondeklip Bay which targeted Hake, Kingklip, Snoek, and St Joseph Shark in the near-shore zone (www.northern-cape.co.za).

***Recreational Fisheries***

Recreational and subsistence fishing on the West Coast is small in scale when compared with the south and east coasts of South Africa. The population density in Namaqualand is low, and poor road infrastructure and ownership of much of the land by diamond mining companies in the northern parts of the West Coast has historically restricted coastal access to the towns and recreational areas of Port Nolloth, McDougall’s Bay, Hondeklip Bay and the Groen River mouth.

Recreational line-fishing is confined largely to rock and surf angling in places such as Brand-se-Baai and the more accessible coastal stretches in the regions. Boat angling is not common along this section of the coast due to the lack of suitable launch sites and the exposed nature of the coastline. Fishing effort has been estimated at 0.12 angler/km north of Doring Bay. These fishers expended effort of approximately 200,000 angler days/year with a catch-per-unit-effort of 0.94 fish/angler/day (Brouwer *et al*. 1997; Sauer & Erasmus 1997). Target species consist mostly of Hottentot, White Stumpnose, Kob, Steenbras and Galjoen, with catches being used for domestic consumption, or sold.

Recreational rock lobster catches are made primarily by diving or shore-based fishing using baitbags. Hoop-netting for rock lobster from either outboard or rowing boats is not common along this section of the coast (Cockcroft & McKenzie 1997). The majority of the recreational take of rock lobster is made by locals resident in areas close to the resource. Due to the remoteness of the area and the lack of policing, poaching of rock lobsters both by locals as well as seasonal visitors is becoming an increasing problem. Large numbers of rock lobsters are harvested in sheltered bays along the Namaqualand coastline by recreational divers who disregard bag-limits, size-limits or closed seasons. This potentially has serious consequences for the sustainability of the stock in the area.

### 3.2.5 Cumulative Impacts

In 1994 the Department of Minerals and Energy established formal diamond-mining concessions covering the continental shelf off the west coast of South Africa between the Orange River mouth and Cape Columbine. The concessions are grouped into Land, Surf-zone and Marine Concession Areas

(Figure 29). The marine concession areas are split into four or five zones (Surf zone and (a) to (c) or (d)-concessions), which together extend from the high water mark out to approximately 500 m depth (Figure 30).

Nearshore shallow-water mining is typically conducted by divers using small-scale suction hoses operating either directly from the shore or from converted fishing vessels in small bays and out to ~30 m depth. Diver-assisted mining is largely exploratory and highly opportunistic in nature, being dependent on suitable, calm sea conditions. The typically exposed and wave-dominated nature of the west coast effectively limits the periods in which mining can take place to a few days per month. Sea conditions also control where safe operations can be conducted, as these often have to be in areas with some shelter from waves. As sea conditions vary enormously over small spatial and temporal scales, it is impossible to sequentially mine a concession from one end to the other. While some (typically calmer) sites may be systematically worked out over a sustained period of time, others are repeatedly revisited when conditions permit.

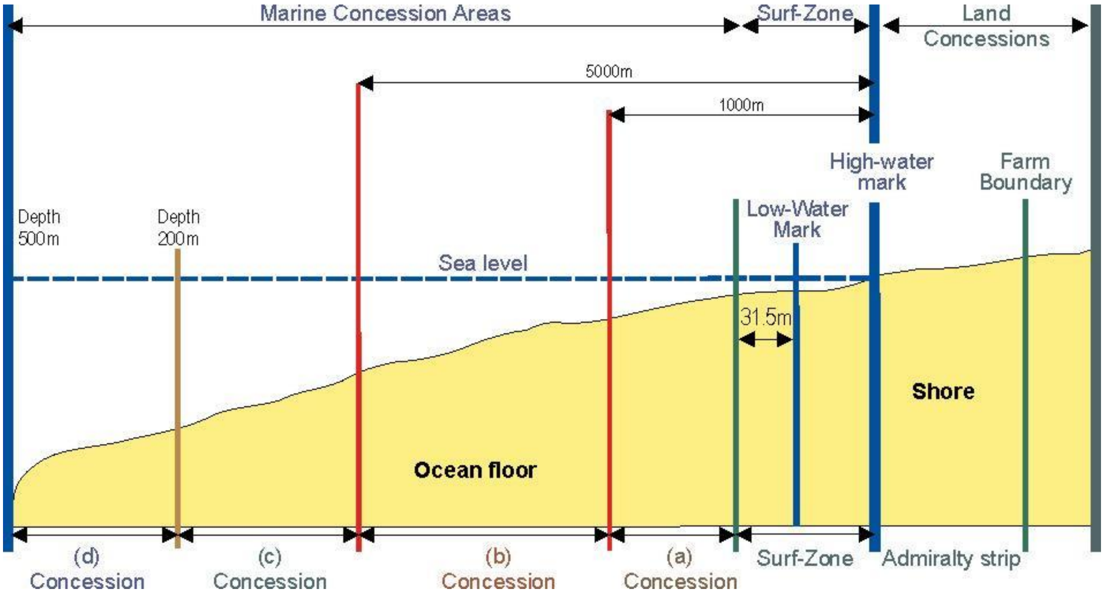

Figure 29: Diagram of the onshore and offshore boundaries of the South African (a) to (d) marine diamond mining concession areas.

As shore-based divers cannot excavate a gravel depth much more than 0.5 m, mining rates are low, being only about 35 m$^2$ worked by each contractor per year. Because of the tidal cycle and limitations imposed by sea conditions, such classifiers usually operate for less than 4 hours per day for an average of 5-6 days per month, although longer periods may be feasible in certain protected areas.

Vessel-based diver-mining contractors usually work in the depth range immediately seaward of that exploited by shore-based divers, targeting gullies and potholes in the sub-tidal area usually just behind the surf-zone. A typical boat-based operation consists of a 10 - 15 m vessel, with the duration of their activities limited to daylight hours for 3 - 10 diving days per month. Estimated mining rates for vessel-based operations range from 300 m$^2$-1,000 m$^2$/yr.

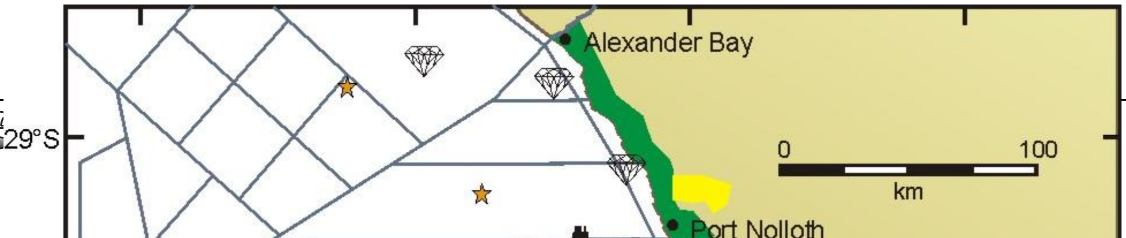

Figure 30: Project - environment interaction points on the West Coast, illustrating the marine diamond mining concessions, the terrestrial concessions held by various mining companies and the experimental abalone ranching area.

### 3.2.6 Development Potential of the Marine Environment in the Project Area

The economy of the Namaqualand region is dominated by mining. However, with the decline in the mining industry and the closure of many of the coastal mines, the economy of the region is declining and jobs are being lost with potential devastating socio-economic impacts on the region. The Northern Cape provincial government has recognized the need to investigate alternative economic activities to reduce the impact of minerals downscaling and has commissioned a series of baseline studies of the regional economy (Britz & Hecht 1997, Britz *et al*. 1999, 2000, Mather 1999). These assessments concluded that fishing and specifically mariculture offer a significant opportunity for long term (10+ years) sustainable economic development along the Namaqualand coast. The major opportunities cited in these studies include hake and lobster fishing (although the current trend in quota reduction is likely to limit development potentials), seaweed harvesting and aquaculture of abalone, seaweeds, oysters and finfish.

The Northern Cape provincial government is facilitating the development of the fishing and mariculture sectors by means of a holistic sector planning approach and has in partnership with a representative community and industry based Fishing and Mariculture Development Association (FAMDA), developed the Northern Cape Province Fishing and Mariculture Sector Plan. This plan forms part of the 'Northern Cape - Fishing and Mariculture Sector Development Strategy' (www.northern-cape.gov.za, accessed December 2013) whereby implementation of the plan will be coordinated and driven by FAMDA.

Abalone ranching (*i.e.* the release of abalone seeds into the wild for harvesting purposes after a growth period) has been identified as one of the key opportunities to develop in the short- to medium-term and consequently the creation of abalone ranching enterprises around Hondeklip Bay and Port Nolloth forms part of the sector plan's development targets (www.northern-cape.gov.za). In the past, experimental abalone ranching concessions have been granted to Port Nolloth Sea Farms in sea mining areas 5 and 6, effectively a 60-km strip of coastline, and to Ritztrade in the Port Nolloth area (www.northern-cape.co.za). These experimental operations have shown that although abalone survival is highly variable depending on the site characteristics and sea conditions, abalone ranching on the Namaqualand coast has the potential for a lucrative commercial business venture (Sweijd *et al*. 1998, de Waal 2004). As a result, the government publication 'Guidelines and potential areas for marine ranching and stock enhancement of abalone *Haliotis midae* in South Africa' (GG No. 33470, Schedule 2, April 2010) identified broad areas along the South African coastline that might be suitable for abalone ranching. Applications for abalone ranching projects have been submitted and permits for pilot projects for some of the zones have been granted.

Besides abalone sea-ranching, several other potential projects were identified in the sector plan. Most of these are land-based aquaculture projects (e.g. abalone and oyster hatcheries in Port Nolloth and abalone grow-out facility in Hondeklip Bay), but included was a pilot project to harvest natural populations of mussels and limpets in the intertidal coastal zone along the entire Northern Cape coast. The objective of the project was to determine the stock levels and to ascertain what percentage of the biomass of each species can be sustainably harvested, as well as the economic viability of harvesting the resource.

### 3.2.7 Threat status and Vulnerable Marine Ecosystems

'No-take' Marine Protected Areas (MPAs) offering protection of the Namaqua biozones (sub-photic, deep-photic, shallow-photic, intertidal and supratidal zones) are currently absent northwards from Cape Columbine (Emanuel et al. 1992; Lombard et al. 2004). Rocky shore and sandy beach habitats are generally not particularly sensitive to disturbance and natural recovery occurs within 2-5 years. However, much of the Namaqualand coastline has been subjected to decades of disturbance by shore-based diamond mining operations (Penney et al. 2007). These cumulative impacts and the lack of biodiversity protection have resulted in many of the coastal habitat types in Namaqualand being assigned a threat status of 'critically endangered' (Lombard et al. 2004; Sink et al. 2012) (Table 6).

Using the SANBI benthic and coastal habitat type GIS database, the threat status of the benthic habitats within Concessions 6a, 7a (Figure 31a), 8a and 8b (Figure 31b) and those potentially affected by proposed beach mining, were identified (Table 6). Although 'vulnerable', 'endangered' and 'critically endangered' habitats occur in the two concessions, the only overlap of note with proposed mining targets is the Namaqua Mixed Shore, which is categorised as 'endangered'. Within Concessions 6a and 7a, this habitat type accounts for ~15.4 km and ~12.3 km of coastline, respectively, of which ~2 km will fall within identified mining targets in 7a. Within the portion of Concession 8a not being relinquished to the proposed MPA, the Namaqua Mixed Shore accounts for ~1.0 km of coastline of which 0.15 km fall within identified mining targets within Mitchell's Bay. Potential loss of this endangered habitat will therefore constitute 16.3% of available Namaqua Mixed Shores habitat in Concession 7a, or 7.3% of the total Mixed Shores habitat in both Concession 6a and 7a.

Table 6: Ecosystem threat status for marine and coastal habitat types in Concessions 6a, 7a and 8a (adapted from Sink *et al*. 2011).

| Habitat Type | Threat Status | Occurs in Concessions | Occurs in Mining Targets |
|---|---|---|---|
| Namaqua Boulder Shore | CE | | |
| Namaqua Exposed Rocky Coast | LT | X | X |
| Namaqua Hard Inner Shelf | LT | | |
| Namaqua Inner Shelf Reef | CE | | |
| Namaqua Inshore Hard ground | CE | | |
| Namaqua Inshore Reef | CE | | |
| Namaqua Island | CE | | |
| Namaqua Mixed Shore | E | X | X |
| Namaqua Muddy Inner Shelf | LT | | |
| Namaqua Muddy Inshore | V | | |
| Namaqua Sandy Inner Shelf | LT | | |
| Namaqua Sandy Inshore | CE | X | |
| Namaqua Sheltered Rocky Coast | CE | X | |
| Namaqua Very Exposed Rocky Coast | V | X | |
| Southern Benguela Intermediate Sandy Coast | LT | X | X |
| Southern Benguela Dissipative-Intermediate Sandy Coast | LT | X | X |
| Southern Benguela Dissipative Sandy Coast | LT | X | |
| Southern Benguela Reflective Sandy Coast | LT | X | X |
| Southern Benguela Estuarine Shore | LT | X | |

CE = Critically Endangered E = Endangered V = Vulnerable LT = Least Threatened

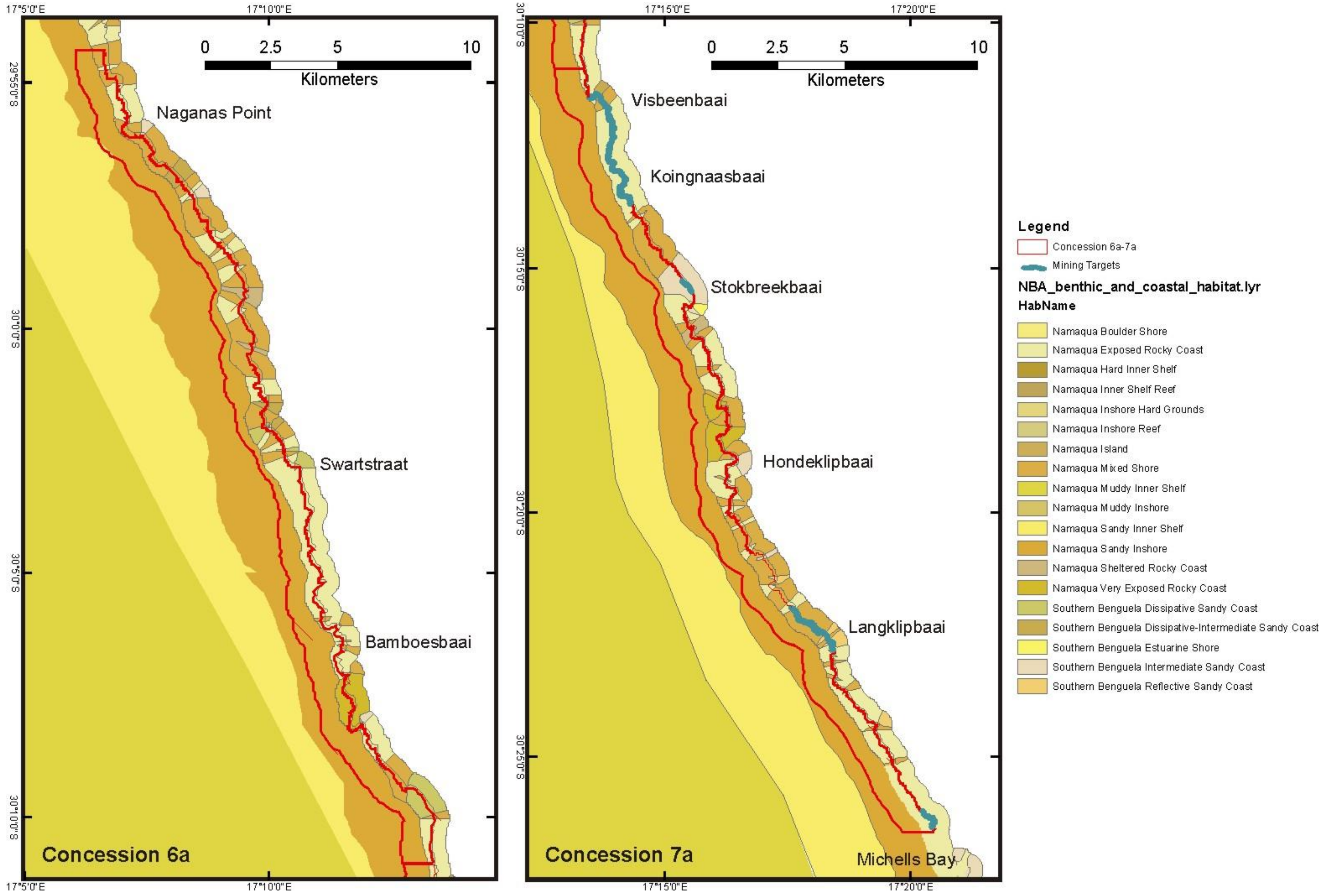

Figure 31a: Concession 6a (left) and 7a (right) in relation to the benthic and coastal habitat types identified by SANBI. The habitats within the concessions and affected by the proposed cofferdam mining operations are identified in Table 6.

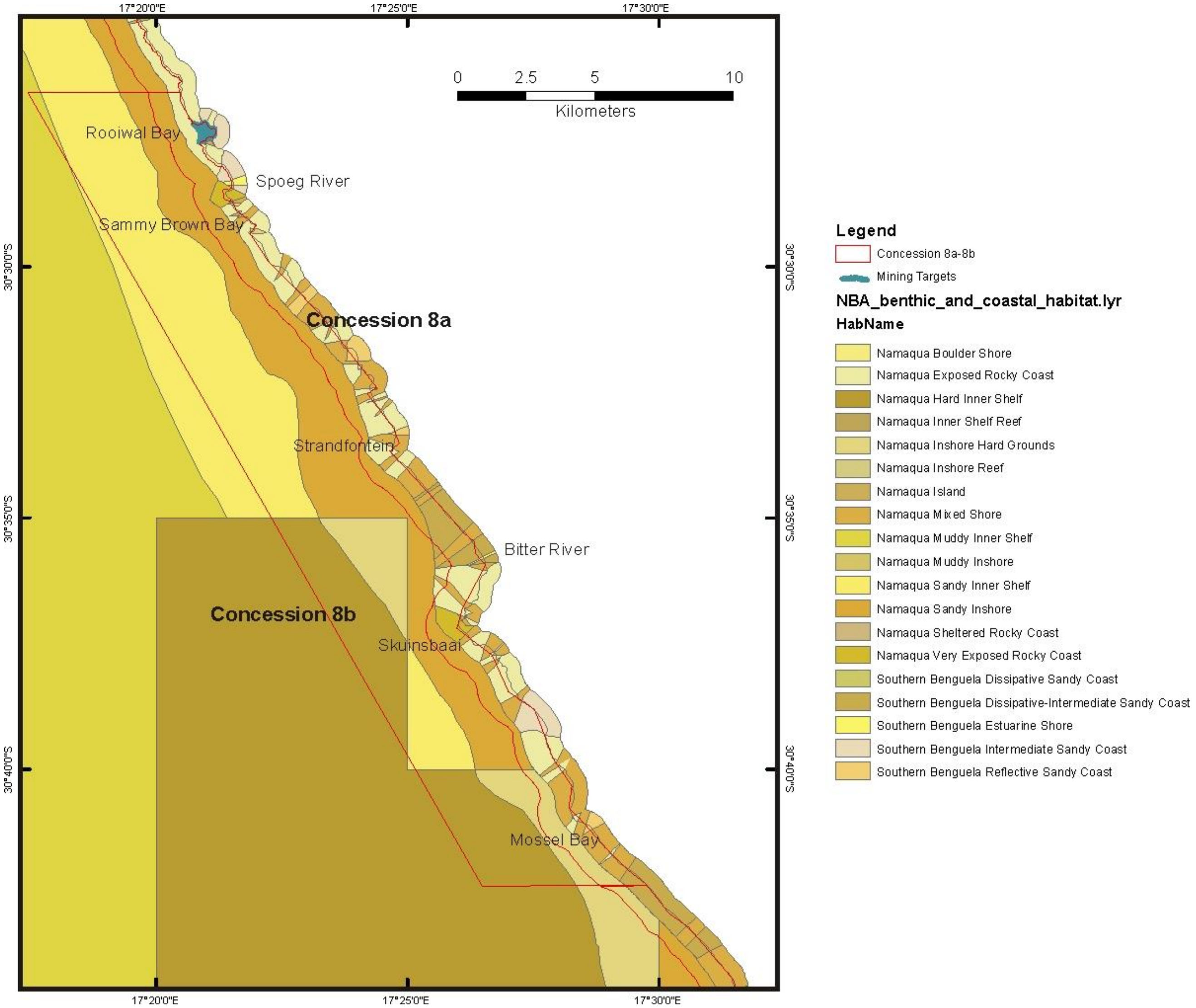

Figure 32b: Concession 8a and 8b in relation to the benthic and coastal habitat types identified by SANBI. The habitats within the concessions and affected by the proposed cofferdam mining operations are identified in Table 6.

### 3.2.8 Conservation Areas and Marine Protected Areas

Using biodiversity data mapped for the 2004 and 2011 National Biodiversity Assessments a systematic biodiversity plan has been developed for the West Coast with the objective of identifying coastal and offshore priority focus areas for MPA expansion (Sink *et al*. 2011; Majiedt *et al*. 2013). The biodiversity data were used to identify nine focus areas for protection on the West Coast between Cape Agulhas and the South African – Namibian border. Those within the broad project area shown in Figure 33.

Of principal importance in the project area is the proposed Namaqua MPA, which stretches between the Groen and Spoeg Rivers and adjacent to the Namaqua National Park. This area meets habitat targets for 14 habitat types including 'Critically Endangered' habitat types such as Namaqua Inshore Reef, Namaqua Inshore Hard Grounds and Namaqua Sandy Inshore. Although the proposed Namaqua MPA inshore protected area overlaps with Concession 8a, 9a and 8b, all but a small area of interest in Concession 8a, which lies outside the proposed MPA, will be relinquished.

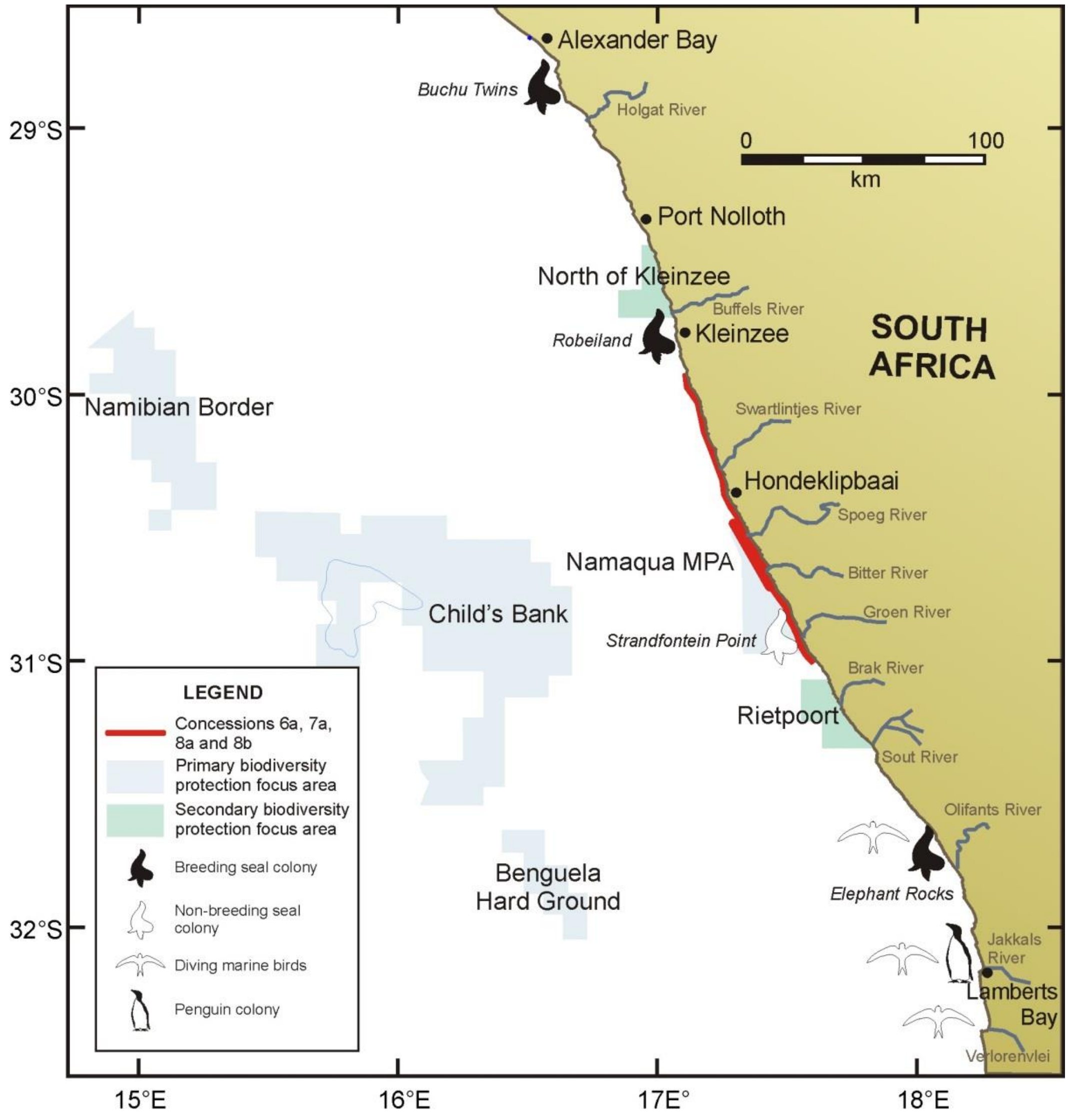

Figure 33: Project - environment interaction points on the West Coast, illustrating the location of seabird and seal colonies and priority areas for biodiversity protection in relation to the proposed project area.

## 4. IMPACT ASSESSMENT METHODOLOGY

Assessment of predicted significance of impacts for a proposed development is by its nature, inherently uncertain – environmental assessment is thus an imprecise science. To deal with such uncertainty in a comparable manner, standardised and internationally recognised methodology has been developed, and is applied in this study to assess the significance of the potential environmental impacts of the proposed exploration activities.

For each impact, the SEVERITY (size or degree scale), DURATION (time scale) and EXTENT (spatial scale) are described (Table 4-1). These criteria are used to determine the CONSEQUENCE of the impact (Table 4-2), which is a function of severity, spatial extent and duration.

Table 4-1: Ranking criteria for environmental impacts

| | | |
|---|---|---|
| SEVERITY/INTENSITY | H | Substantial deterioration (death, illness or injury). Recommended level will often be violated. Irreplaceable loss of resources. |
| | M | Moderate/ measurable deterioration (discomfort). Recommended level will occasionally be violated. Noticeable loss of resources. |
| | L | Minor deterioration (nuisance or minor deterioration). Change not measurable/ will remain in the current range. Recommended level will never be violated. Limited loss of resources. |
| DURATION | L | Quickly reversible. Less than the project life. Short term (0-5 years) |
| | M | Reversible over time. Life of the project. Medium term (6-15 years) |
| | H | Permanent. Beyond closure. Long term (>15 years) |
| SPATIAL SCALE | L | Localised - Within the site boundary. |
| | M | Fairly widespread – Beyond the site boundary. Local |
| | H | Widespread – Far beyond site boundary. Regional/ national |

Table 4-2: Determining the Consequence

| SEVERITY | DURATION | | SPATIAL SCALE | | |
|---|---|---|---|---|---|
| | | | Site Specific (L) | Local (M) | Regional/ National (H) |
| Low | Long term | H | Medium | Medium | Medium |
| | Medium term | M | Low | Low | Medium |
| | Short term | L | Low | Low | Medium |
| Medium | Long term | H | Medium | High | High |
| | Medium term | M | Medium | Medium | High |
| | Short term | L | Low | Medium | Medium |
| High | Long term | H | High | High | High |
| | Medium term | M | Medium | Medium | High |
| | Short term | L | Medium | Medium | High |

The SIGNIFICANCE of an impact is then determined by multiplying the consequence of the impact by the probability of the impact occurring (Table 4-3), with interpretation of the impact significance outlined in Table 4-4.

Table 4-3: Determining the Significance Rating

| PROBABILITY (of exposure to impacts) | | CONSEQUENCE | | |
|---|---|---|---|---|
| | | L | M | H |
| Definite/ Continuous | H | Medium | Medium | High |
| Possible/ frequent | M | Medium | Medium | High |
| Unlikely/ seldom | L | Low | Low | Medium |

Table 4-4: The interpretation of the impact significance.

| SIGNIFICANCE | CRITERIA |
|---|---|
| High | It would influence the decision regardless of any possible mitigation. |
| Medium | It should have an influence on the decision unless it is mitigated. |
| Low | It will not have an influence on the decision. |

Table 4-5: The interpretation of the status of the impact.

| IMPACT STATUS | CRITERIA |
|---|---|
| **Positive** | The impact benefits the environment |
| **Negative** | The impact results in a cost to the environment |
| **Neutral** | The impact has no effect on the environment |

Once the significance of an impact has been determined, the CONFIDENCE in the assessment of the significance rating is ascertained using the rating systems outlined in the Table 4-6.

Table 4-6: Definition of Confidence Ratings

| CONFIDENCE RATINGS* | CRITERIA |
|---|---|
| **High** | Wealth of information on and sound understanding of the environmental factors potentially influencing the impact. Greater than 70% sure of impact prediction |
| **Medium** | Reasonable amount of useful information on and relatively sound understanding of the environmental factors potentially influencing the impact. Between 35% and 70% sure of impact prediction. |
| **Low** | Limited useful information on and understanding of the environmental factors potentially influencing this impact. Less than 35% sure of impact prediction. |

* The level of confidence in the prediction is based on specialist knowledge of that particular field and the reliability of data used to make the prediction.

The degree to which the impact can be reversed is estimated using the rating system outlined in Table 4-7.

Table 4-7: Definition of Reversibility Ratings

| REVERSIBILITY RATINGS | CRITERIA |
|---|---|
| **Irreversible** | Where the impact is permanent. |
| **Partially Reversible** | Where the impact can be partially reversed. |
| **Fully Reversible** | Where the impact can be completely reversed. |

The degree to which there will be a loss of resources (Table 4-8) refers to the degree to which a resource is permanently affected by the activity, i.e. the degree to which a resource is irreplaceable.

Table 4-8: Definition of Loss of Resources

| LOSS OF RESOURCES | CRITERIA |
|---|---|
| **Low** | Where the activity results in a loss of a particular resource but where the natural, cultural and social functions and processes are not affected. |
| **Medium** | Where the loss of a resource occurs, but natural, cultural and social functions and processes continue, albeit in a modified way. |
| **High** | Where the activity results in an irreplaceable loss of a resource. |

Lastly, the degree to which the impact can be mitigated or enhanced is given

| DEGREE TO WHICH IMPACT CAN BE MITIGATED | CRITERIA |
|---|---|
| **None** | No change in impact after mitigation. |
| **Very Low** | Where the significance rating stays the same, but where mitigation will reduce the intensity of the impact. |
| **Low** | Where the significance rating drops by one level, after mitigation. |
| **Medium** | Where the significance rating drops by two to three levels, after mitigation. |
| **High** | Where the significance rating drops by more than three levels, after mitigation. |

Environmental Assessment Policy requires that, “as far as is practicable”, cumulative environmental impacts should be taken into account in all environmental assessment processes. EIAs have traditionally, however, failed to come to terms with such impacts, largely as a result of the following considerations:

- Cumulative effects may be local, regional or global in scale and dealing with such impacts requires coordinated institutional arrangements; and
- Environmental assessments are typically carried out on specific developments, whereas cumulative impacts result from broader biophysical, social and economic considerations, which typically cannot be addressed at the project level.

However, when assessing the significance of the project level impacts, cumulative effects have been considered as far as it is possible (as High, Medium or Low) in striving for best practice. The sustainability of the project is closely linked to assessment of cumulative impacts.

# 5. PUBLIC SCOPING AND IDENTIFICATION OF KEY ISSUES

## 5.1 Stakeholder Engagement

As part of the stakeholder engagement for this EMPr amendment, numerous meetings were held with commenting authorities. These are summarised below:

- 14 September 2015: Department of Agriculture, Forestry and Fisheries (Cape Town)
- 15 September 2015: Department of Environment and Nature Conservation (Springbok)
- 18 September 2015: Department of Environmental Affairs – Oceans and Coast (Cape Town)

The full minutes of these meetings and the Issues and Responses tables are provided as Appendix 5: Meetings, in the Scoping Reports and overall EIA for this project. The issues specifically associated with the marine environment raised by key stakeholders are summarised below. For the sake of clarity, these have been grouped into specific environmental aspects:

*Interaction with other users or future use scenarios*

- Overlap of proposed mining activities with proposed MPAs and with Operation Phakisa;
- Potential conflict with abalone ranching rights holders regarding water quality and habitat loss, particularly those companies that have already started seeding juveniles;
- Increased turbidity near mining site(s) may compromised water quality at the seawater intakes to land-based abalone farms.

*Water Quality*

- The impacts of suspended sediment plumes and elevated turbidity as a result of mining operations need to be assessed;
- Increased turbidity near mining site(s) may impact filter feeders;
- Requirements for discharge permits regarding discharges to the sea (particularly from diver-assisted shore units) is unclear.

*Disturbance of Habitats*

- Blasting in the marine environment should be avoided and materials used for the construction of berms re-used as much as possible;
- Concern regarding the introduction of non-native material onto the beach during berm construction;
- Concern regarding the disturbance to marine habitats and associated biota through mining in subtidal areas; and
- The impacts associated with coffer dam construction vs. accretion need to be carefully considered.

*Impacts on Seals*

- As seal colonies are unique habitats within the project area these should be mapped, and information available at DAFF and DEA should be used.

*Baseline Studies and Impact Monitoring*

- Quantitative marine baseline studies focussing on the specific mining sites need to be undertaken;
- Provide DEA with information on the experimental design of baseline and monitoring studies prior to commencement of surveys;
- Give consideration to co-ordination of monitoring programmes with DEA and sharing of research information;
- Baseline and monitoring studies should focus both on rocky habitats (including an assessment on the impacts on reef structure) as well as sandy beach habitats;
- The recovery of these habitats following mining needs to be understood from the perspective of species recruitment and colonisation;
- Monitoring programmes should be co-ordinated to ensure an upfront understanding of sensitive habitats in the project area, with subsequent avoidance of these in the mine plans; and
- Give consideration to implementing a Strategic Environmental Assessment approach in partnership with other role players in the area so as to gain a broader understanding of the coastline rather than focusing on the project specific sites.

*Rehabilitation, Closure and Biodiversity Offsets*

- Decommisioning and closure is required of old mining sites no longer used;
- As active rehabilitation below the low water mark is not practicable, there is concerns that wave action may not be sufficient to ensure natural rehabilitation of berms; and
- The viability of creating artificial habitats to offset habitat disturbance should be considered (e.g. leaving the rock armour of the berms in place to form islands as roosting habitats for seabirds);

*Environmental Management*

- There is a need for the development of beach management plans for management of mining impacts;
- Strict house-keeping is required at beach mining sites (e.g. no refueling on the beach, and all equipment to be removed on cessation of operations); and
- An Environmental Control Officer should be appointed to ensure compliance with the Environmental Management Plan;

## 5.2 Identification of Key Issues

The following specific issues relating to potential impacts on the marine environment were identified by the marine specialist and during the public scoping process:

*Shore-based diver-mining operations*

- Damage to and destruction of intertidal and shallow subtidal communities as a result of shore-based diver-mining activities.
- Reduction in kelp bed habitats, potentially reducing suitable rock lobster recruitment habitats, and affecting the long-term sustainability of the resource.

- Blanketing of near-shore reefs and bedrock outcrops and their associated communities by discharged tailings.

*Beach and offshore channel mining*

- Burial of rocky shore and sandy beach benthos as a consequence of accretion and berm construction;
- Alteration of the physical characteristics of the beach through construction of coffer dams and aggressive shoreline accretion;
- Changes in macrofaunal community structure in response to physical changes of the beach;
- Generation of suspended sediment plumes;
- Disturbance and loss of intertidal and subtidal habitat and associated communities in the berm footprint and within the mining block; and
- Sedimentation of reef habitats adjacent to the mining site due to redistribution of sediments

# 6. ASSESSMENT OF ENVIRONMENTAL IMPACTS

## 6.1 Impacts of Shore-Based Divers

### 6.1.1 Crushing and Trampling

On rocky coasts targeted by shore-based diver units, intertidal and subtidal organisms are damaged or destroyed by movement of mining equipment, removal of boulders from subtidal gullies into the intertidal zone or into rock piles, discard of tailings and the general activities of the contractors around the mining unit (Parkins & Branch 1995, 1996, 1997; Pulfrich 1998; Pulfrich et al. 2003a). This mining-related disturbance is very localized being limited to a scale of 10s of metres around each individual operation (Barkai & Bergh 1992; Pulfrich et al. 2003a) and effects are often difficult to detect above the natural variability inherent in rocky intertidal communities.

During mining the characteristic decline in grazers results in a proliferation of fast-growing, opportunistic, intertidal foliose algae. As grazer abundance recovers following cessation of mining, algal cover begins to diminish and within two years the community structure recovers to a pre-mining level (Pulfrich et al. 2003a). Recovery following wave disturbance and experimental removal of mussels and limpets on the Namaqualand coast similarly occurred within 24 months (Eekhout et al. 1992; Steffani & Branch 2003b, 2005). Studies conducted in other parts of the world have shown that high intensity trampling can result in the removal of most of the rocky intertidal assemblages, although the effects are dependent on the community present, with foliose algae (particularly fucoid species) being more susceptible than algal turfs, and barnacles more susceptible than dense patches of mussels. Recovery was typically achieved two years after the trampling event, although the interaction of season, location, the indirect effects of reduction in certain algal species and facilitative processes in recruitment of other algae all contributed to varying speeds of recovery (Povey & Keough 1991; Brosnan & Crumrine 1994; Schiel & Taylor 1999).

While recovery of the intertidal and subtidal communities is rapid, physical alteration and degradation of the shoreline in ways that cannot be remediated by swell action can be more or less permanent. For example, the discard of oversize tailings above the high water mark precludes natural redistribution by waves and unless these tailings dumps are actively removed, they remain a more or less permanent feature in the high shore.

The highly localised impact of crushing and trampling of rocky intertidal communities by shore-based divers and their equipment is consequently deemed to be of low intensity in the mining target areas and for the duration of operations and is considered to be of **LOW** significance both without and with mitigation.

### 6.1.2 Kelp Cutting

In areas where shallow-water kelp beds are particularly dense, shore-based divers may cut kelp to facilitate movement of the suction hoses and airlines. Kelp cutting results in a localised impact, the severity and duration of which depends on the extent of kelp removed, the frequency and method of removal and the age of the kelp. Increased light availability following harvesting of whole plants typically results in an increase in the diversity of understorey algae (Simons & Jarman 1981; Kennelly 1987a, 1987b; Christie et al. 1998; Levitt et al. 2002; Pisces Environmental Services 2007). No changes in the associated understorey faunal species diversity occurs, however (Levitt et al. 2002).

Although recovery following cutting is in most cases rapid (Parkins & Branch 1996; Christie et al. 1998; Levitt et al. 2002; Pisces 2007), long-term changes in kelp forest communities in response to various disturbances have been documented (Dayton et al. 1992), with disturbance potentially causing many lag-effects including the proliferation of understory algae (see also Foster 1975), changes in grazing patterns of herbivores and the availability of, and intraspecific competition for primary space.

Following harvesting of *Ecklonia maxima*, recovery of the kelp bed in terms of plant biomass and density, and understorey community structure can occur within two years (Anderson 2000; Levitt et al. 2002) ), whereas for *Laminaria pallida* recovery of kelp biomass to pre-harvest levels can occur within 4 - 8 months (Pisces 2007). However, extensive and repeated kelp cutting by diamond divers can result in kelp bed habitats being locally eliminated and replaced by extensive stands of mussels (Engeldow & Bolton 1994), or colonies of the Cape reef worm *Gunnarea capensis* (G. Koeglenberg & Q. Snethlage, diamond divers, pers. comm.). Kelp beds providing shelter for a wide diversity of marine flora and fauna (Field et al. 1980), and in the central and southern Benguela region are known to serve as an essential nursery area for rock lobster and several fish species (Velimirov et al. 1977; Velimirov & Griffiths 1979; Carr 1989, 1994). Reduction or loss of kelp beds may thus have knock-on effects on the recruitment success of commercially important species through reduction of suitable habitat and food sources.

The highly localised impact of kelp cutting by shore-based divers is thus considered to be of low intensity in the mining target areas and for the duration of operations and is considered to be of **LOW** significance both without and with mitigation.

### 6.1.3 Degradation of Nearshore Reef Habitats

Diver-assisted mining specifically targets gravel areas, which are typically sparsely inhabited by infauna or commercially important species such as rock lobsters. By removing the overlying gravel, mining exposes expanses of previously embedded boulders, which are rapidly colonised by benthic organisms and mobile predators such as rock lobsters. Within a year, the species richness on the exposed surfaces is similar to that of adjacent unmined reef areas (Barkai & Bergh 1992; Parkins & Branch 1995, 1996, 1997; Pulfrich 1998a, 1998b, 2004; Pulfrich & Penney 1998, 1999b, 2001; Pulfrich et al. 2003a, 2003b), although the structure of the developing community remains distinguishable from unmined areas for several years. Impacts are highly localised, however.

If oversize tailings are dumped below the high water mark, they are rapidly redistributed by wave action and their effects on the benthic communities remain highly localised and persist over the short-term only (Barkai & Bergh 1992; Parkins & Branch 1995, 1996, 1997; Pulfrich 1998b; Pulfrich & Penney 1998, 1999b, 2001). Although initial scouring of the benthic communities occurs, the affected communities recover within 1-2 years (Parkins & Branch 1996, 1997; Pulfrich 1998b; Pulfrich & Penney 2001; see also Hard et al. 1976). As a result of the change in seabed type, the structure of the communities in areas affected by discards persists for longer, particularly where excessive and repeated dumping in the same area precludes rapid dispersion.

The highly localised impact of tailings disposal around the pumping units is thus considered to be of low intensity in the mining target areas. As these tailings heaps can persist over the medium to long-term if located in areas where wave action precludes dispersion, the impact is considered to be of **MEDIUM** significance without mitigation, but reducing to **LOW** significance if correctly managed.

**Mitigation**

Recommendations for mitigation include:

- No disposal of tailings above the high water mark;
- Avoid re-mining of sites in the medium term;
- Prohibit blasting and large-scale removal of rocks from subtidal gullies into the intertidal;
- Designate and actively manage specific access, storage and operations areas;
- Remove all equipment on completion of activities; and
- Flatten all remaining tailings heaps on completion of operations.

| ***Physical damage and trampling of intertidal biota*** | | |
|---|---|---|
| | **Without Mitigation** | **Assuming Mitigation** |
| **Severity** | Low | Low |
| **Duration** | Short-term: recovery within 2 years | Short-term |
| **Extent** | Site specific: limited to mining area | Site specific |
| **Consequence** | Low | Low |
| **Probability** | Seldom | Seldom |
| **Significance** | Low | Low |
| **Status** | Negative | Negative |
| **Confidence** | High | High |

| | |
|---|---|
| **Nature of Cumulative impact** | The highly localised disturbance and loss of intertidal benthic communities through trampling and crushing is not expected to result in cumulative impacts |
| **Degree to which impact can be reversed** | The impact is fully reversible as natural recovery of communities will occur on cessation of operations |
| **Degree to which impact may cause irreplaceable loss of resources** | Low |
| **Degree to which impact can be mitigated** | Medium |

| *Changes in community structure through kelp cutting* | | |
|---|---|---|
| | **Without Mitigation** | **Assuming Mitigation** |
| **Severity** | Low | Low |
| **Duration** | Short-term: recovery within 1 year | Short-term |
| **Extent** | Site specific: limited to mining area | Site specific |
| **Consequence** | Low | Low |
| **Probability** | Seldom | Seldom |
| **Significance** | Low | Low |
| **Status** | Negative | Negative |
| **Confidence** | High | High |

| | |
|---|---|
| **Nature of Cumulative impact** | The highly localised removal of kelp is not expected to result in cumulative impacts |
| **Degree to which impact can be reversed** | The impact is fully reversible as natural recovery of communities will occur during and on cessation of operations |
| **Degree to which impact may cause irreplaceable loss of resources** | Low |
| **Degree to which impact can be mitigated** | Medium |

| *Degradation of reef habitat through disposal of tailings* | | |
|---|---|---|
| | **Without Mitigation** | **Assuming Mitigation** |
| **Severity** | Low | Low |
| **Duration** | Short-term | Short-term |
| **Extent** | Site specific: limited to mining area | Site specific |
| **Consequence** | Low | Low |
| **Probability** | Possible | Unlikely |
| **Significance** | Medium | Low |
| **Status** | Negative | Negative |
| **Confidence** | High | High |

| | |
|---|---|
| **Nature of Cumulative impact** | The highly localised disturbance and loss of intertidal benthic communities through tailings disposal is not expected to result in cumulative impacts |
| **Degree to which impact can be reversed** | The impact is fully reversible as natural recovery of communities will occur on cessation of operations and redistribution of tailings by wave action |
| **Degree to which impact may cause irreplaceable loss of resources** | Low |
| **Degree to which impact can be mitigated** | Medium |

## 6.2 Impacts of Beach and Offshore Channel Mining

Both intertidal and subtidal rocky habitats and unconsolidated sediments will be affected by beach accretion, berm construction and subsequent mining of the impounded area. Within the mining target footprint, these habitats will be severely disturbed and their associated communities completely eliminated. In the case of the reclamaion of Mitchell's Bay through accretion, rocky habitats within the bay will be smothered by sediments and a shift in communities from those characterising rocky shore to those typical of sandy beaches will occur. A change in the invertebrate macrofaunal communities present on the beach within the bay can also be expected in response to the accretion. The anticipated impacts are discussed in more detail below.

### 6.2.1 Loss of Benthic Biota

The benthic communities occurring within the project area are largely ubiquitous to the central Benguela region, and no rare or endangered species have been recorded (Awad *et al*. 2002). Mitchell's Bay is, however, topographically unusual as it provides a localised relatively sheltered marine environment comprising exposed rocky shores, endangered Namaqualand mixed shores and two small intermediate sandy beaches along an otherwise comparatively exposed and predominantly rocky coastline. Although the impacts will be highly localised, the bay is of some importance from a biodiversity perspective. The loss of biota as a consequence of accretion of the Mitchell's Bay shoreline or berm construction and subsequent mining of the impounded area along the adjacent coast is considered to be of medium to high intensity in the mining target areas. Impacts are likely to persist over the medium (open coast berms) to long term (Mitchell's Bay) and are thus considered to be of **MEDIUM** to **HIGH** significance both without and with mitigation.

### 6.2.2 Burial of Benthic Biota

The immediate impact of both beach accretion and berm construction would be the burial of the intertidal and subtidal benthos beneath a massive layer of non-native overburden sands and quarried sediments. This would commence in the upper shore and progress seawards as beach accretion and/or construction of the coffer dam advances thereby affecting benthic biota across the full width of the shore and/or target mining block and into the surf-zone. Depending on their size fraction, the sediments discharged in the intertidal zone would spread to a greater or lesser degree down the shore and into the surf-zone where they would be redistributed by wave action and surf-zone currents.

Factors known to determine the effect of burial on species are 1) the depth of burial; 2) the nature of depositing sediments; 3) burial time; 4) tolerance of species (life habitats, escape potential, tolerance to hypoxia etc.); 5) presence of contaminants in the depositing sediments, and 6) season (mortality rate by burial higher in summer than winter) (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; Janssen et al. 2011). Many benthic invertebrates inhabiting unconsolidated sediments are able to burrow or move through the sediment matrix, and numerous studies have shown that 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; Lynch 1994; Ellis 2000; Schratzberger et al. 2000a; but see Harvey et al. 1998; Blanchard & Feder 2003). Lynch (1994) conducted vertical migration experiments with beach macrofauna to determine their tolerance to sand overburdens, and found that several species were capable of burrowing through sediments between 60 and 90 cm, and 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 & Rule (2001) found difference in species composition detectable only if the layer of instantaneous applied overburden exceeded 15 cm. 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, depends not only on their ability to migrate upwards through the deposited sediment, but also on the nature of the deposited non-native sediments (Turk & Risk 1981; Chandrasekara & Frid 1998; Schratzberger et al. 2000a; Speybroeck et al. 2004). 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 (Maurer et al. 1981a, 1981b, 1982, 1986; Smit et al. 2006; Smit et al. 2008), migration ability and survival rates generally being 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. 2000a). 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 burial time, or duration of burial, will also determine the effect on benthos. Here a distinction must be made between incidental deposition, where species are buried by deposited material within a short period of time (e.g. during berm construction), and continuous deposition, where species are exposed to an elevated sedimentation rate over a long period of time (as would occur during accretion of Mitchell's Bay). Whereas the volumes deposited per unit time will likely be lower under conditions of continuous deposition, such deposition can nonetheless have negative effects when the sedimentation rate is higher than the velocity at which the organisms can move or grow upwards. The sensitivity to long-term continuous deposition is species dependent and also dependent on the sediment type, with continuous 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 is a further aspect influencing the susceptibility of the fauna to mortality. Kranz (1972, cited in Hall 1994) studied the burrowing habits of 30 species of bivalves and 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. The most resistant species were deep-burrowing siphonate suspension-feeders, which could escape from up to 50 cm of overburden. Menn (2002) reported that meiofaunal species appeared less susceptible to burial than macrofauna, and Carey (2005) was unable to detect any effects of beach replenishment on benthic microalgae.

The exact depth of sand through which beach biota can successfully migrate ('fatal depth') thus depends on the species involved (reviewed by Essink 1993). Although numerous studies have investigated the burrowing efficiency of local species under different swash conditions or grain size composition (e.g. Brown & Trueman 1991, 1995; Nel et al. 2001), information on successful upward migration and survival following heavy deposition of sediments is largely lacking (but see Trueman & Ansell 1969). However, benthic organisms living in nearshore wave influenced areas in the Benguela region are likely to be adapted to relatively high sedimentation rates. Nonetheless, it is safe to assume that most beach infauna and rocky habitat communities in the berm/accretion footprint would be smothered in the berm-building process, and in the immediate vicinity of the sediments deposited during active beach accretion.

Burial can also lead to a chain of other stressors on benthic species communities like oxygen depletion and high sulphide concentrations. These are discussed further in Section 6.2.5.

The localised impacts of smothering, burial and loss of intertidal and shallow subtidal benthic communities through beach accretion, berm construction and subsequent mining of the impounded area is considered to be of medium to high intensity in and adjacent to the mining target areas. Impacts are likely to persist over the medium (open coast berms) to long term (Mitchell's Bay) and are thus considered to be of **MEDIUM** to **HIGH** significance both without and with mitigation.

### 6.2.3 Changes in Biophysical Characteristics

On sandy beaches, the physical characteristics of the beach, namely the sand particle size, wave energy and beach slope, play an important role in determining the composition of the biological communities inhabiting the beach (McLachlan et al. 1993; McLachlan 1996). The nature of the sediments used for shoreline accretion will thus not only affect the immediate survival potential of impacted communities, but will determine the physical characteristics of the beach over the medium- to long-term. This in turn will influence the recovery rate of the impacted communities as well as the ultimate community structure (Pulfrich & Branch 2014a; Pulfrich et al. 2015).

When the sediments used for beach accretion have similar properties (grain size and organic matter) to the native sediments, replenishment results in the least impact on benthic infauna and the shortest recovery time of affected communities (Hayden & Dolan 1974; Culter & Mahadevan 1982; Gorzelany & Nelson 1987; Hurme & Pullen 1988; Nelson 1993; Löffler & Coosen 1995; Birklund et al. 1996; Le Roy et al. 1996; Rakocinski et al. 1996; Peterson et al. 2000; Van Dalfsen & Essink 2001; Menn 2002; Menn et al. 2003; Pulfrich et al. 2004; amongst other). Effects, however, differ depending on what part of the shore receive the fill material. When the application of sediments of similar size occurs high on the beach, recovery of infaunal communities occurs relatively quickly (reviewed in USACE 1989; Greene 2002), due to the gradual redistribution of sands across the beach (Dankers et al. 1983; Baptist et al. 2009). In contrast, communities in the deeper subtidal show higher sensitivity to disturbance due to a higher abundance of long-lived species than in the highly dynamic intertidal and surf-zones (Parr et al. 1978; Reise 1985; Brown & Mclachlan 1994; Rakocinski et al. 1996; Menn 2002).

In the case of the accretion of the Mitchell's Bay shoreline, the entire shore from the high water mark to the deepest protions of the bay would be affected.

The effects of using sediments that poorly match the native beach sediments result in more substantial changes in macrofaunal community structure (Naqvi & Pullen 1982; Nelson 1989; Hackney et al. 1996; Peterson et al. 2000; Lindquist & Manning 2001; Peterson & Manning 2001; Bishop et al. 2006; Fanini et al. 2009). The addition of coarser sediments onto a beach results in changes in the beach morphodynamics, which in turn influences both the species diversity and abundance of the associated invertebrate fauna, thereby causing changes in community structure, as has been clearly demonstrated in numerous biological monitoring studies of beach mining operations in southern Namibia (Pulfrich 2004b; Clark et al. 2004, 2005, 2006; Pulfrich & Atkinson 2007; Pulfrich et al. 2007, 2008; Clark et al. 2009; Pulfrich et al. 20010, 2011; Pulfrich & Branch 2014; Pulfrich et al. 2015).

Due to the intrinsic tolerance of the assemblages inhabiting intertidal beaches, declines in infaunal abundance, biomass, and diversity following disturbances such as beach replenishment or small-scale mining are short term, with recolonisation following the cessation of disturbance occurring within weeks (Schoeman et al. 2000) and recovery of communities to a condition of functional similarity to the original state occurring after 2 to 7 months (Nelson 1985, 1993; Hackney et al. 1996). Recovery of macrofaunal diversity and abundance following replenishment of beaches typically occurs within 1 year (Dankers et al. 1983; Van Dolah et al. 1994; Essink 1997; Jutte et al. 1999a, 1999b; USACE 2001; Menn 2002; Menn et al. 2003), with full recovery of the benthic community and age structure considered to take between 2 and 5 years (USACE 1989; Kenny & Rees 1994, 1996; Rakocinski et al. 1996; Essink 1997; Van Dalfsen & Essink 1997; van Dalfsen et al. 2000; Newell et al. 2004; Boyd et al. 2005; Mulder et al. 2005; Baptist et al. 2009). Recovery after repeated replenishment or disturbance, however, takes longer, particularly if this results in medium- to long-term changes in sediment structure (Menn et al. 2003; Janssen & Mulder 2005). In a study investigating the impacts of beach diamond-mining north of the Olifants River on the South African West Coast, which employed cofferdams constructed of native beach sediments, it was demonstrated that despite a significant immediate negative impact on the biotic parameters studied (abundance, biomass, species richness, and community structure), recovery of macrofaunal communities following the cessation of mining was rapid, with recovery to pre-mining conditions occurring after 20-50 months (Nel et al. 2003; Pulfrich et al. 2004).

Recolonisation of disturbed beaches takes place by passive translocation of animals from adjacent areas during successive tidal cycles or storms, 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; Menn 2002). Usually, undisturbed sediments adjacent to the impacted site provide an important source of colonising species, enabling faster recovery (van Moorsel 1993, 1994; Cheshire & Miller 1999). Should accretion of the Mitchell's Bay shoreline occur, the recovery of communities to a condition of functional similarity to those inhabiting the original beach may take a little longer as recolonisation would depend on immigration of species from adjacent beaches, the nearest of which is at the mouth of the Spoeg River ~1.5 km to the south.

When the sediment used for replenishment contain a high proportion of fines, the recovery of macrobenthic communities is generally retarded (Saloman & Naughton 1984; Gorzelany & Nelson 1987; Rakocinski et al. 1996; Bilodeau & Bourgeois 2004). This effect is intensified when the fill sediments have high organic loads or are polluted (Colosio et al. 2007). Prolonged recovery following the addition of fine fill sediments has partly been attributed to an increase in turbidity in the surf-zone (see section 5.4.1) and to compaction of beach sediments (Ryder 1991; Greene 2002), which negatively affects the abundance of burrowing organisms (Maurer et al. 1978). The effects of compaction are also manifested through changes in the interstitial space, the water retention ability, sediment permeability and the exchange of gasses and nutrients. Compaction is usually temporary, as wave action and bioturbation turns over the sediments, and fine sediments will ultimately be winnowed out and redistributed in the surf-zone (USACE 1989).

In summary, large-scale disturbances of beach habitat, associated with activities such as beach mining and shoreline accretion, are evident on all the biotic parameters (abundance, biomass, species richness, and community structure), and at all taxonomic levels of the sandy beach infaunal communities (see also Defeo & Lecari 2003). However, if the surface sediment is similar to the native beach material when operations cease, and if the final long-term beach profile has similar contours to the original profile, the addition or removal of layers of sediment does not have enduring adverse effects on the sandy beach benthos and recovery following the initial disturbance can occur within a few years. In contrast, structural changes in grain size over the medium- to long-term due to repeated nourishment or seawall construction results in either permanent changes in community structure or longer recovery times.

The construction of berms and the accretion of Mitchell’s Bay is highly likely to result in localised changes in the physical characteristics of the impacted beaches, and changes in community structure of invertebrate macrofauna in response to these physical changes can be expected. Such changes are considered to be of medium intensity in mining target areas. Impacts are likely to persist over the short (open coast berms) to medium term (Mitchell’s Bay) and are thus considered to be of **MEDIUM** significance both without and with mitigation.

**Mitigation**

Berm construction and/or shoreline accretion, overburden stripping and removal and processing of target gravels are all an integral part of the mining approach and other than the ‘no-go’ option, there is no feasible mitigation for these proposed operations. Disturbance of beach habitat adjacent to the mining blocks can, however, be minimised through stringent environmental management and good house-keeping practices. Active rehabilitation involving backfilling of mined out areas, active removal of as much of the berms above the low water mark as feasible and re-structuring of the mining area to resemble the natural beach morphology should be undertaken on completion of mining operations.

Further recommendations for mitigation include:

- Mine beach targets in blocks sequentially from the north to the south along the beach, rehabilitating mined-out blocks immediately on cessation of mining in that block;
- Avoid re-mining of sites in the medium to long term;
- Designate and actively manage specific access, storage and operations areas;
- Remove all equipment on completion of activities; and
- Flatten all remaining tailings heaps on completion of operations.

| ***Loss of biota in the construction and mining footprint*** | | |
|---|---|---|
| | **Without Mitigation** | **Assuming Mitigation** |
| **Severity** | Medium - High | Medium |
| **Duration** | Medium (open coast berms) – Long term (Mitchell's Bay) | Medium – Long term |
| **Extent** | Site specific: limited to the mining footprint | Local |
| **Consequence** | Medium (open coast berms) – High (Mitchell's Bay) | Medium - High |
| **Probability** | Definite | Definite |
| **Significance** | Medium - High | Medium - High |
| **Status** | Negative | Negative |
| **Confidence** | High | High |

| | |
|---|---|
| **Nature of Cumulative impact** | The highly localised loss of intertidal and shallow subtidal benthic communities may result in cumulative impacts in threatened or endangered habitats |
| **Degree to which impact can be reversed** | The impact is only partially reversible as active rehabilitation below the low water mark is not possible and recovery of habitats and communities will depend on natural processes. Natural erosion of accreted sediments in Mitchell's Bay and recovery of biota are likely to only be reversible over the long term. |
| **Degree to which impact may cause irreplaceable loss of resources** | Medium |
| **Degree to which impact can be mitigated** | Very Low |

| ***Disturbance and loss of intertidal and subtidal benthic biota through burial by sediments*** | | |
|---|---|---|
| | **Without Mitigation** | **Assuming Mitigation** |
| **Severity** | Medium - High | Medium |
| **Duration** | Medium (open coast berms) – Long term (Mitchell's Bay) | Medium – Long term |
| **Extent** | Local: may extend beyond the mining area due to distribution of sediments | Local |
| **Consequence** | Medium (open coast berms) – High (Mitchell's Bay) | Medium - High |
| **Probability** | Definite | Definite |
| **Significance** | Medium - High | Medium - High |
| **Status** | Negative | Negative |
| **Confidence** | High | High |

| | |
|---|---|
| **Nature of Cumulative impact** | The localised disturbance and loss of intertidal and shallow subtidal benthic communities burial and removal is not expected to result in cumulative impacts |
| **Degree to which impact can be reversed** | The impact is only partially reversible as active rehabilitation below the low water mark is not possible and recovery of habitats and communities will depend on natural processes. Natural erosion of accreted sediments in Mitchell's Bay are likely to only be reversible over the long term. |
| **Degree to which impact may cause irreplaceable loss of resources** | Medium |
| **Degree to which impact can be mitigated** | Very Low |

***Changes in the biophysical characteristics of the beach***

| | **Without Mitigation** | **Assuming Mitigation** |
|---|---|---|
| **Severity** | Medium | Medium |
| **Duration** | Short (open coast berms) – Medium term (Mitchell's Bay) | Short – Medium term |
| **Extent** | Local: may extend beyond the mining area due to distribution of sediments | Local |
| **Consequence** | Medium | Medium |
| **Probability** | Definite | Definite |
| **Significance** | Medium | Medium |
| **Status** | Negative | Negative |
| **Confidence** | High | High |

| | |
|---|---|
| **Nature of Cumulative impact** | The changes in biophysical characteristics on open coast beaches may result in cumulative impacts as adjacent blocks are mined |
| **Degree to which impact can be reversed** | The impact is only partially reversible as active rehabilitation below the low water mark is not possible and recovery of habitats and communities will depend on natural processes. Sediments accreted in Mitchell's Bay would be naturally eroded over the long term |
| **Degree to which impact may cause irreplaceable loss of resources** | Medium |
| **Degree to which impact can be mitigated** | None |

Other potential impacts on the marine environment associated with beach accretion and berm construction include increased turbidity in the surf-zone opposite and down-stream of the mining site, possible hypoxia in the sediments following organic loading, introduction of contaminants, and mobilisation and deposition of eroded sediments onto adjacent reef habitats.

### 6.2.4 Increased turbidity

The coarser fractions of the sediments and boulders used for berm construction and for beach accretion settle out rapidly, but any silts and clays in the material will remain in suspension for longer and disperse further. Depending on the proportion of fines in the stripped overburden used for accretion, or the quarried material used as the berm core, wave action will winnow these from the coarser components resulting in increased turbidity in the surf-zone and nearshore water column (Greene 2002; Speybroek et al. 2004). Sediment plumes can become trapped in the surf-zone and may subsequently be transported for considerable distances alongshore with relatively little further dilution, thereby reducing their effective dispersion. The suspended sediment concentrations, the extent and area over which plumes disperse, and their duration, depend largely on the proportions of silts, muds and clays (<63 µm) in the discharged sediments, as well as local sea conditions. The higher the proportion of fine material, the larger and more persistent the suspended sediment plume is likely to be (Newell et al. 1998; Johnson & Parchure 1999; Posford Duvivier Environment 2001; Greene 2002).

One of the more apparent effects of increased concentrations of suspended sediments and consequent increase in turbidity, is a reduction in light penetration through the water column with potential adverse effects on the photosynthetic capability of phytoplankton (and other aquatic plants) (Poopetch 1982; Kirk 1985; Parsons et al. 1986a, 1986b; Monteiro 1998; O'Toole 1997) and the foraging efficiency of visual predators (Clark et al. 1998; Simmons 2005; Braby 2009; Peterson et al. 2001).

Suspended sediments also load the water with inorganic particles, which may have biological effects such as a reduction of invertebrate egg and larval survival (thereby potentially affecting the recovery rate of the impacted shoreline), and diminish the filter-feeding efficiency of suspension feeders (reviewed by Clarke & Wilber 2000). Increased turbidity following addition of finer sediments during beach replenishment has been reported to result in increased mortality of adult surf clams, and reduced survival of juvenile surf clams and polychaetes, resulting in delayed recovery of impacted populations (Reilly & Bellis 1983; Rakocinski et al. 1996; Speybroek et al. 2005; but see also Spring 1981; Gorzelany & Nelson 1987). However, in most cases sub-lethal or lethal responses occur only at concentrations well in excess to those of sediment plumes from mining operations. Furthermore, as marine communities in the Benguela are frequently exposed to naturally elevated suspended-sediment levels, they can be expected to have behavioural and physiological mechanisms for coping with this feature of their habitat.

It is anticipated that the sediments proposed for berm construction will have a negligible clay and silt fraction, so the generation of suspended sediment plumes above natural background levels during construction are expected to be insignificant. Likewise, the proportion of fines (<63 µm) in the overburden dune sands used to facilitate accretion, is expected to be insignificant. Turbidity offshore of the mine site(s) is thus unlikely to exceed levels attained naturally during turn-over of nearshore sediments by wave action or seasonal inputs in river discharges. As turbid water is a natural occurrence along the southern African west coast, any turbidity-related effects in the near-shore environment as a direct result of mining operations are likely to be insignificant.

The construction of berms and the accretion of Mitchell's Bay will result in the generation of localised suspended sediment plumes, which may affect primary productivity and larval survival, reduce the availability and suitability of food for higher order consumers or trigger emigration of higher order consumers from the area in search of food, thereby potentially having cascade effects through the marine food web. If the mining area is in the immediate vicinity of the seawater intakes for land-based abalone farms, the water quality requirements for abalone mariculture may be compromised. Due to the transient nature of such plumes, the potential impacts are, however, considered to be of low intensity and are thus considered to be of **LOW** significance both without and with mitigation. Suspended sediment concentrations within plumes are unlikely to exceed maximum levels occurring naturally along the wave-dominated coastline.

**Mitigation**
No mitigation measures are possible or deemed necessary.

| ***Effects of suspended sediment plumes*** | | |
|---|---|---|
| | **Without Mitigation** | **Assuming Mitigation** |
| **Severity** | Low | Low |
| **Duration** | Short-term: as plumes would be transient and their effects temporary | Short-term |
| **Extent** | Site specific: limited to mining area | Site specific |
| **Consequence** | Low | Low |
| **Probability** | Seldom | Seldom |
| **Significance** | Low | Low |
| **Status** | Neutral: unlikely to exceed natural suspended sediment concentrations | Neutral |
| **Confidence** | High | High |
| | | |
| **Nature of Cumulative impact** | Biota in the Benguela ecosystem have behavioural and physiological mechanisms for coping with this feature of their habitat so cumulative impacts are unlikely | |
| **Degree to which impact can be reversed** | The impact is fully reversible | |
| **Degree to which impact may cause irreplaceable loss of resources** | Low | |
| **Degree to which impact can be mitigated** | None | |

### 6.2.5 Hypoxia

Besides the physical effect of burial, a further indirect impact potentially associated with beach replenishment is the chemical effects of the fill sediments on the receiving communities. Studies from elsewhere have identified that the addition of either anaerobic sediments, or sediments with a high organic content, can result in the development of hypoxic/anoxic conditions in the sediments. Fine sediments are more likely to have a higher organic content and thus more likely to trigger a reduction in oxygen. Under conditions of limited oxygen, rates of nitrate and phosphate remineralisation, and sulfate reduction in the sediments increase. The resulting production of nitrite, ammonia, and sulfide in combination with low oxygen can have sub-lethal and lethal effects on benthic organisms (Baptist et al. 2009). Decreased dissolved oxygen levels can thus amplify the effects of increased sedimentation.

The high wave exposure in combination with the comparatively coarse nature of the beach sediments ($D_{50}$ = ~270 µm; WSP 2015) in the project area make it highly unlikely that hypoxic conditions will develop as a consequence of the shoreline accretion. Addition of coarse sediment will ensure penetrability and flushing rates will remain high. Furthermore, the dune sands to be used for shoreline accretion will likely have a low organic content.

Accretion may result in the formation of hypoxic conditions in the sediments with potentially deleterious effects on the invertebrate infauna. The potential impacts of hypoxia are considered to be of low intensity and although the effects may persist over the short- to medium term, they are considered to be of **LOW** significance both without and with mitigation.

**Mitigation**

No mitigation measures are possible or deemed necessary.

| ***Development of hypoxic sediments*** | | |
|---|---|---|
| | **Without Mitigation** | **Assuming Mitigation** |
| **Severity** | Low | Low |
| **Duration** | Short to Medium term: although hypoxic conditions would be transient, their effects on infaunal communities would extend over the short- to medium-term | Short-term |
| **Extent** | Site specific: limited to area of accretion | Site specific |
| **Consequence** | Low | Low |
| **Probability** | Seldom | Seldom |
| **Significance** | Low | Low |
| **Status** | Neutral: unlikely to vary beyond natural oxygen concentrations | Neutral |
| **Confidence** | High | High |

| | |
|---|---|
| **Nature of Cumulative impact** | Biota in the Benguela ecosystem have behavioural and physiological mechanisms for coping with this feature of their habitat so cumulative impacts are unlikely |
| **Degree to which impact can be reversed** | The impact is fully reversible |
| **Degree to which impact may cause irreplaceable loss of resources** | Low |
| **Degree to which impact can be mitigated** | None |

### 6.2.6 Sediment mobilisation and redistribution

The overburden sands placed on the shoreline to achieve accretion will to some extent be reworked into the nearshore zone by wave action until the long-term equilibrium profile of the new beach is reached. The addition of sediments will result in the steepening of the beach profile, which in turn will lead to increased erosion of sediments by wave action. Some sediments will be carried offshore by undertow and rip currents and deposited beyond the surf-zone, to be returned shoreward again in calm conditions. Modelling studies suggest that the eroded sediments would be rapidly redistributed alongshore by wave-driven currents, initially leaking southwards out of Mitchell's Bay and ultimately extending seawards on the seabed beyong the mouth of the bay (WSP 2015).

These indirect effects manifest themselves as the inundation of reefs by sand, and corresponding responses by the benthic faunal and floral communities. In South Carolina, the effects of increased siltation and smothering from sand movement following beach replenishment were considered to have a greater impact on hard substratum habitats than on the replenished sandy shoreline. Smothering of nearshore reef habitats resulted in the loss of productive fishing grounds and declines in the nearshore fish communities (Van Dolah et al. 1994). Monitoring at various mining sites in southern Namibia has shown that such mobilised and re-deposited sediments can have severe impacts on intertidal and shallow subtidal rocky shore habitats bordering the mined beaches and at some distance away, with both temporary and permanent loss of rocky intertidal habitats being reported as a result of shoreline accretion (Clark et al. 2004, 2005, 2006; Pulfrich & Atkinson 2007; Pulfrich et al. 2007, 2008; Pulfrich et al. 2010, 2011; Pulfrich & Branch 2014a, 2014b; Pulfrich et al 2015).

There are three possible avenues for depositing sediments to influence rocky-shore communities: (1) smothering that depletes all or some groups thereby affecting community diversity (Littler et al. 1983; McQuaid & Dower 1990); (2) alteration of supply of particulate materials with potential enhancement of suspension-feeders (Menge 1992); (3) ripple effects by which depletion of taxa in higher trophic levels influences the abundance of those in lower trophic levels (Littler & Murray 1975; Hawkins & Hartnoll 1983, Littler et al. 1983; Hockey & Bosman 1986; Branch et al. 1990; Eekhout et al. 1992). These predicted effects have all, to a greater of lesser extent, been observed in rocky shore communities in the vicinity of coastal mining operations in southern Namibia, and would, to some extent, be expected in the Mitchell's Bay area. Once constructed, the erosion and mobilisation of sediments from the berms is not expected to significantly exceed natural long-shore littoral drift, and natural cyclical sedimentation processes on adjacent rocky shores or nearshore reefs will in all likelihood mask any mining-related effects. However, during the accretion of Mitchell's Bay with overburden sands, smothering of reef habitats in and beyond the mining site are expected, with concomitant changes in benthic communities, or in the worst case, complete loss of the reef habitat. Although likely only affecting a few kilometres of coastline, some of the coastal habitats in Namaqualand have been identified as 'vulnerable', 'endangered' or 'critically endangered' and any deterioration or loss of such habitats should be actively avoided.

The impacts associated with the mobilisation and redistribution of sediments from berms or accretion of the Mitchell's Bay shoreline are considered to be of high intensity and as they may persist over the short- (open coast) to medium term (Mitchell's Bay), they are considered to be of **MEDIUM** significance both without and with mitigation.

**Mitigation**

No mitigation is feasible other than the 'no-go' option.

| ***Sedimentation of intertidal and subtidal reefs*** | | |
|---|---|---|
| | **Without Mitigation** | **Assuming Mitigation** |
| **Severity** | High | High |
| **Duration** | Short to Medium term: although sediments in the nearshore will be continuously resuspended by wave action, natural erosion following accretion of Mitchell's Bay is likely to only occur over many years. Erosion of accreted sediments on rocky shores on the open coast will occur over the short term | Short to Medium term |
| **Extent** | Local: extending beyond the boundary of the mining target | Local |
| **Consequence** | Medium | Medium |
| **Probability** | Continuous: for the duration of the mining operation | Continuous |
| **Significance** | Medium | Medium |
| **Status** | Negative | Negative |
| **Confidence** | High | High |

| | |
|---|---|
| **Nature of Cumulative impact** | Cumulative impacts are highly likely during the life-of-mine |
| **Degree to which impact can be reversed** | The impact is only partially reversible over time |
| **Degree to which impact may cause irreplaceable loss of resources** | Medium |
| **Degree to which impact can be mitigated** | None |

### 6.2.7 Impacts on higher-order consumers

Although recovery of invertebrate macrofaunal communities following disturbance of beach habitats generally occurs within 3 – 5 years after cessation of the disturbance, the species inhabiting beaches are all important components of the sandy-beach food chain. Most are scavengers, particulate- and filter-feeders that depend on inputs of detritus or beach-cast seaweeds (Brown & Odendaal 1994). As such, they assimilate food sources available from the detrital accumulations typical of this coast and, in turn, become prey for surf-zone fishes and shorebirds that feed on the beach slope and in the swash- and surf-zones. By providing energy input to higher trophic levels, they are important in nearshore nutrient cycling. The reduction or loss of these assemblages in the long-term may thus have cascade effects through the coastal ecosystem (Dugan et al. 2003). Similarly, recovery of rocky intertidal habitats occurs over the short-term, but these also serve as important feeding habitats for shore birds. The negative effects on higher order consumers (surf-zone fish and shorebirds) of changes in abundance of macrofaunal prey items as a consequence of beach nourishment operations in North Carolina have been demonstrated (Peterson et al. 2000; Lindquist & Manning 2001). However, considering the extremely localised nature of the proposed mining operations in comparison to the available coastal feeding-ground habitat for the fish and shorebirds, and the relatively quick recovery of benthic communities following disturbance, the effects of these higher order consumers can be considered negligible (see also Essink 1997; Baptist et al. 2009).

Due to recovery over the short-term of the invertebrate communities that serve as a food source for higher-order consumers, the potential impacts are considered to be of low intensity and are thus considered to be of **LOW** significance both without and with mitigation.

| ***Indirect effects on higher-order consumers*** | | |
|---|---|---|
| | **Without Mitigation** | **Assuming Mitigation** |
| **Severity** | Low | Low |
| **Duration** | Short-term: as recovery of invertebrate communities that serve as food sources occurs within 2-5 years | Short-term |
| **Extent** | Site specific: limited to mining area | Site specific |
| **Consequence** | Low | Low |
| **Probability** | Seldom | Seldom |
| **Significance** | Low | Low |
| **Status** | Negative | Negative |
| **Confidence** | High | High |

| | |
|---|---|
| **Nature of Cumulative impact** | Cumulative impacts are unlikely as being highly mobile, affected species can move to adjacent available feeding grounds |
| **Degree to which impact can be reversed** | The impact is fully reversible |
| **Degree to which impact may cause irreplaceable loss of resources** | Low |
| **Degree to which impact can be mitigated** | None |

### 6.2.8 No-development Alternative

The “no-development” alternative implies that the beach and offshore channel mining operations will not go ahead. From a marine perspective this is undeniably the preferred alternative, as all impacts associated with beach disturbance, shoreline accretion, loss of habitat and indirect sedimentation will not be realised. This must, however, be seen in context with existing mining and exploration rights and sustainability of the associated mines, and thus needs to be weighed up against the potential positive socio-economic impacts undoubtedly associated with accessing the potentially rich diamond deposits present in the surf zone.

# 7. CONCLUSIONS AND RECOMMENDATIONS

## 7.1 Environmental Acceptability and Impact Statement

The main marine impacts associated with the proposed mining activities are related to disturbance and loss of sandy and rocky habitats and their associated benthic flora and fauna in the mining footprint. From the results of past studies, it is now well established that mining in the intertidal zone of sandy beaches using seawall/coffer dam technology and active beach accretion severely influences the diversity and community structure of the invertebrate macrofauna of the beach itself, and potentially the benthic biota of adjacent rocky intertidal and shallow subtidal habitats as well. However, as shoreline accretion and berm construction are an unavoidable consequence of the proposed mining, there can be no direct mitigation for their impacts on marine biological communities. Other than the 'no go' option, the impacts to the intertidal and shallow subtidal marine biota are thus unavoidable should mining go ahead. As mining operations have been ongoing along this section of the coast for decades, however, the proposed mining targets cannot be considered particularly 'pristine'. Nonetheless, from a marine perspective the 'no go' option is undeniably the preferred alternative, as all impacts associated with the disturbance of beach and rocky habitats will no longer be an issue.

The proposed mining operations behind berms, or the accretion of Mitchell's Bay will without a doubt severely impact the affected habitats and their associated communities. However, the impacts will remain localised, and will therefore not be substantial on a regional scale. Provided construction and mining activities are not phased over an extended period, the beaches and rocky shores are not repeatedly disturbed through persistent activities, and suitable post-construction rehabilitation measures are adopted, the impacted communities are likely to recover in the short- to medium-term (i.e. over a period of 2-5 years). Recolonisation of the mined area will be rapid and natural ecological functions and processes will thus continue albeit in a modified way. The benthic populations of the beaches and rocky shores are highly variable, on both spatial and temporal scales, and subject to dramatic natural fluctuations, particularly as a result of episodic disturbances such as unusual storms, low oxygen events and periodic flooding of the ephemeral coastal rivers. As a consequence, the biota are considered to be relatively resilient, being well-adapted to the dynamic environment, and capable of keeping pace with rapid changes (McLachlan & De Ruyck 1993).

The highly localised, yet significant impacts of coffer dam mining along the open coast will endure over the short- to medium term, and these impacts thus need to be weighed up against the long-term benefits of the mining project. Provided the impacts are meticulously managed and pro-active rehabilitation is undertaken as far as is feasible in the coastal environment, there is no reason why the proposed mining of the open-coast beaches using coffer dams should not go ahead.

However, it is not the faunal communities which are the most distinctive feature of these shorelines, but rather the geomorphology and landforms resulting from natural erosional processes, particularly the cliffs in Mitchell's Bay. Although the beach and rocky shore communities within this bay are unlikley to be unique from a marine biodiversity perspective nor even particularly species rich, the bay itself with its landward fringing cliffs and dunes is scenically attractive and geomorphologically distinctive on the Namaqualand coast. Every effort should thus be made to protect such coastal landforms from visual degradation and disturbance, particularly when engineering designs implemented to realise productive mining within the bay will persist over the long term as active rehabilitation below the low water mark is not feasible.

If all environmental guidelines, and appropriate mitigation measures advanced in this report, and the SEIA for the proposed project as a whole, are implemented, there is no reason why the marine mining operations proposed along the open coast should not proceed. However, every effort should be made to avoid disturbance, even on a localised scale, of benthic habitats identified as 'endangered' or 'critically endangered' by Sink et al. (2012). Mining of Mitchell's Bay, either by beach accretion or berm or groyne construction, is however, not recommended from a biodiversity and geomorphological perspective.

The impacts identified above, along with other areas of concern raised by stakeholders during the scoping process and highlighted in this document, are addressed in more detail in the EMPr. The process followed meets the requirements of the MPRDA and of NEMA to ensure that the regulatory authorities receive sufficient information to enable informed decision-making.

## 7.2 Mitigation Measures and Management Actions

Environmental management actions for implementation in WCR's Environmental Management System should focus on the following aspects to be considered prior to, during and on cessation of mining activities in an area:

- Develop the mine plan to ensure that mining proceeds systematically and efficiently from one end of the target area to the next, and that the target area is mined to completion in as short a time as possible.
- To allow impacted communities to recover to a condition where they are functionally equivalent to the original condition, the beaches should not be re-mined for at least five years, if at all. Efficient, high intensity mining methods are thus preferable to repeated operations.
- To prevent degradation of the sensitive high-shore beach areas, all activities must be managed according to a strictly enforced Environmental Management Plan. High safety standards and good house-keeping must form an integral part of any operations on the shore from start-up, including, but not limited to:
  - drip trays and bunding under all vehicles and equipment on the shore where losses are likely to occur;
  - no vehicle maintenance or refuelling on shore;
  - accidental diesel and hydrocarbon spills to be cleaned up accordingly; and
  - collect and dispose polluted soil at appropriate bio-remediation sites.
- To avoid unnecessary disturbance of communities and destruction of habitats, heavy vehicle traffic in the high- and mid-shore must be limited to the minimum required, and must be restricted to clearly demarcated access routes and operational areas only. The operational footprint of the mining site should be minimised as far as practicable.
- Initiate restoration and rehabilitation as soon as mining is complete in an area. This should involve removal (and re-use) of as much of the rock armour off the berms as possible, levelling of seawalls above the low water mark to facilitate more rapid natural erosion by the sea, back-filling excavations using seawall material, tailings and discards and restoring

the beach profile to that resembling the pre-mining situation. No accumulations of tailings should be left above the high water mark.

- Berms or groynes should be designed in such a way that they will erode naturally as rapidly as possible as soon as active maintenance ceases. Once mining has been completed in an area, as much of the berms as possible should be actively removed, leaving only those portions below the low water mark to be eroded naturally.
- On cessation of operations, all mining equipment, artificial constructions or beach modifications created during mining must be removed from above and within the intertidal zone.
- To quantify the full impact of the mining using berms on the beaches in the mining and prospecting licence areas, it is recommended that a structured Before-After/Control-Impact (BACI) monitoring programme be implemented. The experimental design and details of this programme should be compiled in collaboration with the DEA: Oceans & Coasts. Monitoring should commence before mining starts, be undertaken for at least as long as mining remains in operation, and thereafter to determine the rate of recovery. Monitoring should continue until communities in the impacted areas show evidence of having recovered to within 80% of levels at suitable ‘reference’ sites (bioequivalence tests) over a minimum of at least three successive years. However, following each survey the status of the beach should be re-assessed and the sampling programme revised to reflect both changes in the impacted communities as well as changes to the mining plan(s). The requirements for a monitoring programme and the proposed methodology are presented in Appendix I.
- In the case of diver-assisted shore-based mining operations, the following mitigation measures should be implemented:
  - No disposal of tailings above the high water mark;
  - Avoid re-mining of sites in the medium term;
  - Prohibit blasting and large-scale removal of rocks from subtidal gullies into the intertidal;
  - Designate and actively manage specific access, storage and operations areas;
  - Remove all equipment on completion of activities; and
  - Flatten all remaining tailings heaps on completion of operations.

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# APPENDIX I

## REQUIREMENTS FOR A MONITORING PROGRAMME TO DETECT ENVIRONMENTAL IMPACTS OF COFFER DAM MINING AND ACCRETION ON THE MARINE ENVIRONMENT

In identifying and assessing environmental impacts it is important to acknowledge that change is not necessary unnatural nor is it due to human disturbance alone (Green 1979, 1993). An impact should not therefore be characterised as being the difference in some measure at a particular site before and after a disturbance only. An impact should be characterized as being the relative difference between changes at a disturbed site (*i.e.* the change from before to after a disturbance) compared with changes that have occurred in a similar undisturbed (or control or reference) site (Underwood 1992, 1993, 1994). In other words there must be some change from before to after a disturbance and such change must be different from what occurred in undisturbed control areas. To achieve this it is necessary to study communities in impacted and reference sites prior to (provided that this is of course possible) and after an impact has occurred. If such conditions are not met, the interpretation of the impact will be compromised (Underwood 1996).

Having established the basic protocol required for an impact assessment, several decisions have to be taken with regard to how one should proceed with the research or monitoring program. The most important of these include how much monitoring should be undertaken (intensity, frequency and duration), what in terms of community parameters should be monitored and, if monitoring is continued through to the recovery stage, when can a site be declared fully rehabilitated. Central to all of these is the question of how much change or disturbance matters. Two sorts of mistakes are inherent in monitoring programs because of the need for statistical analyses. Type I error occurs where results of a monitoring program suggest that there has been an environmental changes when there has not. Type II errors occur when there has been an environmental change but the monitoring program fails to detect it. The most common reason for the occurrence of Type II error is a sampling program that it poorly designed or one that is not comprehensive enough (i.e. insufficient samples) (Underwood 1996). Assuming that the whole point of a monitoring program is to illicit managerial response in the event that there is an impact, Type I error should become self-correcting (further investigation is likely to expose the error). (It may however result in a waste of money, time, resources, reputations and possible loss of economic activity). In contrast Type II error elicits no response. The cost is in terms of the environment – environmental degradation continues unnoticed.

In terms of environmental management, precautionary principals require that more attention be paid to Type II error, such that this is unlikely to occur (Mapstone 1995; Underwood 1996). The only realistic trade-off is to increase the probability of the Type I error until costs of errors (the cost of responding to a non-existent environmental threat) are likely to be unacceptably high. Then trade back the rate of the Type I error in return for more resources for sampling. The potential costs to society through crying wolf – mistakenly declaring there to be an environmental change because of a Type I error – can be reduced provided proper resources are made available to detect real changes (i.e. to have a small probability of Type II error).

To quantify the full impact of the proposed coffer dam mining or accretion of Mitchell's Bay on the marine environment, all affected habitats and/or communities should be monitored before, during and after mining. However, prior research has indicated that this is impractical, impossible or simply unnecessary. Monitoring should rather focus on what are likely to be the most sensitive, significantly affected and/or representative species, communities, habitats and resources. The proposed mining areas comprises intertidal sandy beach and rocky shore habitat, as well as subtidal sandy and rocky habitats. A suite of standard, and widely accepted techniques have been developed for the monitoring of benthic communities associated with these habitats, and it is proposed that these be adopted for this study. These techniques include both univariate and multivariate statistical analyses. Vertebrate communities, specifically birds and fish, associated with surf-zone habitats require a different approach. Previous studies have shown that these highly mobile animals are generally not significantly affected by beach mining operations. Monitoring of these populations is therefore considered unnecessary.

The final question that needs to be resolved, is how long should a habitat appear to be restored before it can be declared restored? It is now widely accepted that when assessing recovery following a disturbance event, the classic scientific approach of testing a null hypothesis is not really valid (Dixon & Garrett 1992; McDonald & Erickson 1994; Underwood 1996). The classic approach is an attempt to reject or disprove the “null” hypothesis, which assumes that two populations are identical. The alternative hypothesis, that the two populations are not identical, can only be accepted if the probability that any differences detected are due to chance alone is less than 5%. In deciding whether an impact has occurred, this approach is perfectly acceptable, as it largely eliminates the probability of declaring a false positive i.e. that an impact has occurred when this is not the case. However, when we are assessing recovery, this is not the case. We have accepted that an impact has occurred (otherwise we would not be monitoring recovery), and we now wish to establish an end point at which we can declare recovery complete. The approach proposed as an alternative to the classic significance testing is known as the test for bioequivalence. The approach is to define two areas to be bioequivalent if, for example, the mean density of a particular organism or organisms on the impacted site exceed a predefined percentage (R say 80%) of the mean density on the reference site for a defined time interval. Conversely, a site is said to be impacted or disturbed until the selected variable(s) exceed(s) the predefined level over a defined time interval. This procedure is commonly used in testing the equivalence of drugs (Kirkwood 1981; Westlake 1988) and is becoming more popular in other biological sciences (Dixon & Garret 1992; McDonald & Erickson 1994). It has recently been successfully applied in assessing recovery of deepwater invertebrate macrofauna following remote mining (Clark 2014), as well as beach macrofauna following seawall mining and shoreline accretion in southern Namibia (Pulfrich et al. 2015). Full details of the test are contained in McDonald & Erickson (1994).

One of the greatest merits of this approach is that it recognises (a) that systems are naturally variable and (b) that one does not always have “adequate” baseline data for the assessment of the significance of a particular impact. It also recognises that while physico-chemical factors are an important determinant of the structure of biotic communities, other biological factors (such as timing of recruitment and variations in recruitment success which, to some extent are linked to the abundance of adults in neighbouring areas, as well as competition and predation) also play an important role in structuring biotic communities, which can vary greatly in both space and time even when biophysical conditions remain constant (see for example Hall 1994; Kenny & Rees 1994, 1996; Herrmann et al. 1999; Ellis 2000; Schratzberger et al. 2004a).

The predefined percentage is necessarily site- or situation-specific, but the value of 80% seems to have attained fairly wide acceptance (McDonald & Erickson 1994; Underwood 1996). Similarly, the number of successive intervals over which this value should be achieved is site- and situation-specific but also depends on the sampling interval. It is proposed that sampling of sandy beach invertebrates, and rocky intertidal and subtidal benthic communities be conducted annually. Selected parameters include measures of the abundance and/or biomass of the communities or certain key species in each case, as well as a measure of the diversity of the community as a whole (e.g. Shannon-Weiner Diversity), and that the value of R must exceed 80% in each case for at least three to five years before a site can be considered to have recovered. For the purposes of this study, the term recovery would thus be defined as: "the re-establishment of ecological function through colonisation of previously mined areas by marine faunal communities that can be considered to be functionally equivalent to those that exist in comparable undisturbed sites, taking into account natural variability, as judged by the fact that they are at least 80% similar in terms of their species composition, abundance and biomass, measured over a period of at least 3-5 years". The bioequivalence tests should also be supplemented with standard multivariate graphical and statistical tests (e.g. hierarchical cluster analysis, multidimensional scaling, ANOSIM) for which no bioequivalent alternatives exist. Levels of significance for these tests should be set at 95%.

A graphic depicting how such a process may play out in the case of the assessment of mining impacts, as presented in Clark 2014) is shown in Figure 1 below. The blue and purple line represents the average number of individuals, biomass or species at a suite of stations at reference sites outside of the mining area, and a second group in close proximity to the area being mined (Discharge), but potentially affected by other mining-related activities, respectively (in the example the 'indirect' effect was the discharge onto the beach of a sediment slurry of fine tailings from an on-site processing plant to aid with accretion). The red line represents average abundance at a suite of stations in an area that is subject to mining during the course of the study. The dots on each line represent average values derived from discrete samples collected, in the example, at quarterly intervals (every 3 months) at these respective sites. The horizontal dotted lines indicate abundance/biomass/no. species for all the reference sites averaged across the full time period of the study, and the 80th percentile for these sites. Sampling at all sites commenced 2 years before mining started and continued until it was established that the biota at the reference sites in close proximity to the impact site (Discharge) and at the mined sites (Impact) had recovered to a level where the average abundance/biomass/no. species (dotted red line) had recovered within the 80th percentile for the reference stations (blue shaded area). Note that in this diagram abundance at the reference station in close proximity to the impact site (Discharge) dropped during the construction phase but recovered again shortly thereafter.

In light of the above, an impacted site would be considered recovered or "functionally equivalent" if the data measured over a period of at least three years falls between the 20th and 80th percentiles of the reference and baseline data. Should the pre-mining and reference site data show extremely high variability, the more conservative approach of using the 25th to 75th percentile can be adopted.

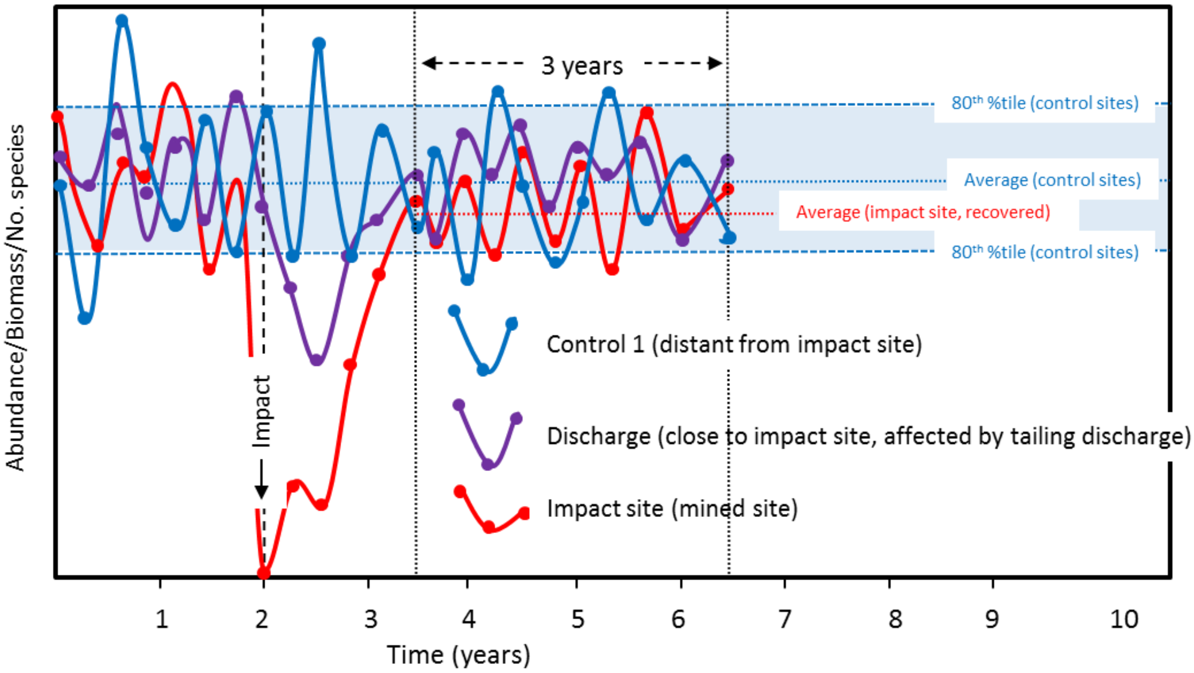

Figure 1: Graphic demonstration of procedures for monitoring environmental impacts and recovery. See text for details. Source: Clark (2014)

## PROPOSED METHODOLOGY FOR MONITORING OF SANDY BEACHES, ROCKY SHORES AND SUBTIDAL REEFS

The monitoring study should consider both physical and biological parameters at reference sites some distance from the mining sites and at sites targeted for cofferdam mining or beach accretion. Monitoring sites would span three habitat types, namely 1) sandy beaches, 2) intertidal rocky shores, and 3) shallow subtidal reef habitats. It is recommended that the respective sites be selected following a site visit and in close collaboration with both the mine planners and DEA: Oceans & Coast. Monitoring should be conducted on an annual basis starting a minimum of two years prior to that in which mining commences, and continuing until all impacted communities have recovered to acceptable levels as defined in the monitoring program requirements outlined above. It is recommended that sampling be conducted at approximately the same time (March-June) each year to eliminate any seasonal variations.

The intertidal beach and rocky-shore surveys have to be undertaken over a spring tide period when the tides are low enough to permit access to the low shore. Because the amplitude of any given spring tidal movement can vary considerably during the course of a year, the timing of surveys is crucial if accurate and reliable data are to be collected. Consequently, surveys must be scheduled over spring tides when the height of the low tides above chart datum ( = Lowest Astronomical Tide) is at a minimum. A 'rule of thumb' for intertidal surveys is that data is only collected when the height of the low tide is 0.25 m or less, above chart datum. As natural variables such as oceanic swell and wind-induced waves will affect the predicted tidal levels, it is all the more critical that surveys are conducted during the lowest possible tides. The lowest spring tides during the year usually occur between February - June and in some years between August - October. Commencement of the monitoring programme will be determined by the mine plan.

The recommended methodologies for the quantitative collection of community data in each of the habitat types is detailed below.

### Sandy Beach Macrofauna

Beach faunal community sampling would be carried out using established sandy-beach sampling techniques. At each identified sampling site three transects, perpendicular to the shore and spaced 5 m apart, would be surveyed from above the drift line to the lowest point of the swash during spring low tide. Ten stations would be positioned along each transect line at equal horizontal intervals across the beach face. At each station, three 0.1-$m^2$ quadrat samples would be excavated to a depth of 30 cm, and the sediments rinsed in a 1-mm mesh sieve bag. All macrofauna retained in the sieves would be preserved in 96% alcohol, and identified to the lowest taxonomic level possible. Dry biomass of all fauna would be obtained by drying the specimens at 60°C for 24 hours. Macrofaunal densities would be expressed as the number of individuals per square metre, and the biomass as $g.m^{-2}$.

A variety of physical parameters will also be measured at each site. These will include wave height and period, surf-zone width, beach profile and water table depth. Sediment samples will be collected from Station 1 (the drift line), Station 5 (mid-shore) and Station 10 (spring low water mark). In the laboratory, the sediment samples will be passed through a series of graded sieves to determine the grain-size composition. Graphic methods will be used to obtain the mean particle diameter, sorting and skewness of the sediments. These physical data will be used to calculate the dimensionless fall velocity (or Dean's value, $\Omega$) and to rate each site in terms of wave exposure. Using the dimensionless fall velocity an indication of the beach morphodynamic state will be provided.

### Rocky Intertidal Macrobenthos

The macrobenthos of rocky intertidal areas would be sampled in six 0.5-$m^2$ quadrats along each of five replicate transects laid perpendicular to the shore between the mean low water spring and mean high water spring marks. The quadrats are divided into a regular 50x50 mm grid pattern giving 171 intersecting points in a 1 x 0.5 m frame. The individual species occurring in the algal canopy would be recorded under each intersecting point as primary and secondary cover, as would be rare species and mobile organisms within the quadrat. The point counts would be used to calculate the mean percentage cover of all species (both mobile and sessile), and the counts of individual mobile organisms to calculate densities within the quadrat area. Data on mean percent cover and abundance for the community as a whole, individual species and trophic groups would then be compared.

### Shallow Subtidal Reefs

Experienced scientific divers, familiar with underwater census techniques and identification of benthic organisms, will be used to conduct the underwater benthic assessments within Mitchell's Bay and at an equivalent reference site. Dive sites will be selected in three depth zones namely, 1-5 m, 5-10 and 10-15 metres below mean sea level. At each dive site, two divers will each conduct 5 point counts at 5-m intervals along transects across the seabed. Within a 2-m diameter circle at each point, the seabed type (percentage composition of rock, boulders, gravel or sand), reef profile (height in metres) and structure (degree of ledging and under-cutting – see Table I) will be recorded. To minimise individual dive time at the depths surveyed, and maximise the number and coverage of dives over the survey area, quantitative benthic quadrats will not be attempted. Instead, the percentage cover of principal benthic community components within the surveyed 2 m will be estimated and ranked using the Braun-Blanquet scale of coverage categories (Kent & Coker 1992, see Table 1). This scale uses smaller categories at lower coverage, ensuring that scarcer species are not outweighed by abundant species in subsequent analyses.

Various benthic studies have indicated that there is considerable redundancy in the species which characterise the composition of benthic communities (Clarke & Warwick 1994; Warwick 1993). This redundancy often allows analysis at higher taxonomic levels, rather than at species level, without weakening the results (Warwick 1988a, 1988b, 1993; Ferraro & Cole 1990; Vanderklift et al. 1996; Bowman & Bailey 1997). As many of the taxa encountered in the southern African west coast hard-bottom epifauna are undescribed and detailed identification by divers is slow underwater, organisms recorded during dives will be aggregated into larger, predefined taxonomic groups (Classes or Families) during actual data collection.

The successful completion of the shallow subtidal surveys will be dependent on sea conditions. Typically a wave height of <1.5 m is required for confident and accurate underwater data collection.

Table 1. Ranking scales used for estimating the percentage cover of benthic organisms and the degree of crevicing or overhang of reef structure.

| Benthic Communities Rank | Braun-Blanquet scale % Coverage | Reef structure Rank | Extent of crevicing/overhang |
|---|---|---|---|
| 0 | <1% | 0 | Flat |
| 1 | 1-5% | 1 | 0.5 m |
| 2 | 6-25% | 2 | 1.0 m |
| 3 | 26-50% | 3 | 1.5 m |
| 4 | 51-75% | | |
| 5 | 76-100% | | |

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