ENVIRONMENTAL IMPACT ASSESSMENT FOR THE PROPOSED NUCLEAR POWER STATION ('NUCLEAR 1') AND ASSOCIATED INFRASTRUCTURE

Marine Ecology Impact Assessment

June 2012

Prepared by: Professor CL Griffiths,Dr TB Robinson and Dr SH Elwen (Marine Mammals only)

Prepared for: Arcus GIBB Pty Ltd

On behalf of: Eskom Holdings Ltd

June 2012

DECLARATION OF INDEPENDENCE

I, Professor Charles Griffiths hereby confirm my independence as a specialist and declare that I do not have any interest, be it business, financial, personal or other, in any proposed activity, application or appeal in respect of which Arcus GIBB was appointed as environmental assessment practitioner in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998), other than fair remuneration for worked performed, specifically in connection with the Environmental Impact Assessment for the proposed conventional nuclear power station ('Nuclear 1'). I further declare that I am confident in the results of the studies undertaken and conclusions drawn as a result of it – as is described in my attached report.

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Full Name: Professor Charles L. Griffiths

Qualification(s): PhD
Experience (years/ months): 38 Years

EXECUTIVE SUMMARY

This specialist study was undertaken to assess the possible impacts of a 4 000 MW capacity power station on the marine environment at one of three potential sites along the Eastern and Western Cape coasts. Such a development at Duynefontein, Bantamsklip or Thyspunt will have a variety of potential impacts. These include:

- Disruption of surrounding marine habitats. When associated with the construction of the cooling water intake and outfall system, this effect will be focused within the construction phase and will be localised, of medium duration and significance. When associated with the marine discard of spoil, disruption to the marine environment is significant with high consequence and significance. When mitigated by disposing spoil offshore (and by using only a medium pumping rate and disposing of the spoil during winter at Thyspunt), the impact is minimised. The impacts associated with the disposal of spoil on chokka squid at Thyspunt will have limited impact on the overall squid stock, with an estimated 13.43% of catches by the inshore jig fishery being displaced as adult squid move to other spawning grounds.
- The entrainment and death of organisms associated with the intake of cooling water. At Duynefontein and Thyspunt entrainment it is not anticipated to have important ecological impacts. However, at Bantamsklip larval entrainment may have a significant negative impact on local stocks of the abalone *Haliotis midae*.
- The release of warm water used for cooling purposes. A tunnelled design of the release system mitigates potential negative impacts, through multiple points of release to aid dissipation of excess heat, by releasing cooling water above the sea bottom to minimise effects on the benthic environment and by utilising a very high flow rate at the point of release to maximise mixing with cool surrounding water. Comprehensive oceanographic modelling has demonstrated that the effects of elevated temperature are expected to be focused on the open water habitat. This is of particular relevance at Bantamsklip and to a lesser degree at Thyspunt, as it would help to mitigate impacts on abalone and chokka squid egg capsules respectively. While chokka squid at the Thyspunt site are expected to avoid water temperatures elevated above their thermal tolerance range, the area predicted to be affected represents less than one percent of the coastal spawning ground. It is strongly recommended that at Bantamsklip an offshore tunnel outfall be utilised for the release of warmed water in an effort to mitigate impacts on abalone. Importantly a nearshore release system at this site is considered to pose an unacceptable risk to abalone populations.

- The release of desalination effluent. During construction limited volumes of hypersaline effluent (brine) will be released beyond the surf zone via an angled diffuser, so as to ensure adequate mixing with surrounding seawater and minimal impact on the marine environment. During the operational phase the desalinisation effluent will be co-released with cooling water. As brine will be diluted to undetectable levels prior to release, no impact on the marine environment is predicted from this effluent during the operational phase.
- The unintentional release of radiation emissions. Technical design of the cooling system has minimised this risk, so that this impact is rated as having low consequence and low significance.
- The additional protection of marine organisms from exploitation due to a safety exclusion zone. The only site that would benefit from such an exclusion zone is Bantamsklip, as this could be of great benefit to what are currently illegally harvested abalone populations. However, for such a benefit to be realised, adequate enforcement of the exclusion zone would have to be provided.
- The release of treated sewage effluent. This effluent is predicted to meet the standards set by the Department of Water Affairs and Forestry and, as such, no significant impact on the marine environment is expected.
- Pollution of the marine environment by the discharge of groundwater polluted by organic, bacterial or hydrocarbon compounds. As this impact is unlikely to occur and will be spatially and temporally restricted, it is considered to be of low consequence and significance.

Besides the impacts of the proposed development on marine habitats, organisms in the marine environment may also impact on the development. This would take the form of fouling of cooling water pipes. This impact is anticipated to be most significant at Duynefontein, due to its location along the west coast, where jellyfish blooms appear to be increasing in frequency.

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ABBREVIATIONS

CW	Cooling water
DEA	Department of Environmental Affairs (previously Department of Environmental Affairs and Tourism)
DAFF	Department of Agriculture, Forestry and Fisheries
DWA	Department of Water Affairs
IUCN	International Union for Conservation of Nature
KNPS	Koeberg Nuclear Power Station
NNR	National Nuclear Regulator
NPS	Nuclear Power Station
ppt	Parts per thousand
SSWG	Squid Scientific Working Group (Branch: Fisheries Management, DAFF)

GLOSSARY

Benthic habitat	The area inhabited by organisms living on and in the seafloor sediments
Benthos	The biological communities inhabiting the benthic environment
Chlorination	The production of sodium hypochlorite (chlorine) from seawater
Demersal	Occurring on or near the sea floor
Dolosse	Concrete structures used to stabilise the seaward edge of reclaimed land
Entrainment	The unintentional intake of organisms along with cooling water
Fouling	The growth marine organisms on infrastructure. Also referred to as biofouling
Pelagic	Occurring in the middle and surface layers of the ocean
Sessile	Organisms living permanently attached to hard substratum (e.g. mussels on rocks)
Thermocline	The zone between layers of water of different temperatures

1 INTRODUCTION

1.1 Background

In the context of increasing economic growth and social development South Africa's energy demands have increased dramatically over the last decade. Despite substantial energy efficiency advancements, Eskom is currently experiencing increasing demand in excess of four percent per year. In order to help meet this ever-increasing demand for energy, while minimising South Africa's greenhouse gas emissions, Eskom has proposed the development of a fleet of Nuclear Power Stations (NPS). It is envisaged that this fleet will be composed of a 4 000 MW station (Nuclear-1) followed by Nuclear-2, and -3.

This specialist study was undertaken to assess the possible impacts of the development of Nuclear-1 on the marine environment at each of three potential sites along the coast. Impacts occurring during the construction, operation and decommissioning stages of development are considered. In particular, the impacts of disruptions to surrounding marine habitats during construction, the effect of abstraction of seawater for cooling purposes, the subsequent release of warmed water and the release of brine emanating from desalinisation and the effects radioactive releases on the marine environment are evaluated.

1.2 Study Approach

The information included in this report consists of dedicated field surveys at the proposed development sites, *combined with information gained from scientists specialising in particular areas of interest* and a review of the extensive body of relevant scientific research that has been conducted along the South African coast, as well as information gained from international peer reviewed works in the field of marine biology. Additionally, the large body of knowledge that has been gathered following the establishment of Koeberg Nuclear Power Station (KNPS) offers insight into the impacts of a nuclear power station on the marine environment in a South African context.

The following additional experts were consulted during the compilation of this report:

- Ms G. Maharaj, Inshore Resources, Fisheries Branch, DAFF (Abalone);
- Dr R. Anderson, Inshore Resources, Fisheries Branch, DAFF (Kelp);
- Dr L. Blamey, University of Cape Town (Abalone);
- Dr N. Downey, Bayworld Centre for Research and Education (Squid);
- Ms J. Mwicigi, Offshore Resources, Fisheries Branch, DAFF (Squid);
- Dr M. Roberts, Ocean Environment, Biodiversity and Research, DEA (Squid);
- Dr H. Verheye, Ocean Environment, Biodiversity and Research, DEA (Squid);
- Prof W. Sauer, Ichthyology and Fisheries Science, Rhodes Conservation Trust (Seabirds);
- Dr M. Lupinski, Ocean Environment, Biodiversity and Research, DEA (Squid);
- The Squid Scientific Working Group, DAFF (Squid);

- Dr S. Lamberth, Inshore Resources, Fisheries Branch, DAFF (Desalination); and
- Dr K. Hutchings, Anchor Environmental (Desalination).

Field surveys were undertaken between August and October 2007. Where present at each site, an exposed and sheltered rocky shore was sampled, as well as a long open beach and a pocket beach. This was to account for well-established differences in the biological communities, which inhabit these physically different habitats.

The impacts of a nuclear power station, viz. Nuclear-1 producing 4 000 MW output of power is assessed *based on the following parameters.*

1.2.1 Assumptions and limitations

The conclusions drawn in this report are based on the following assumptions:

- The temperature of released cooling water will be 12ºC above ambient sea temperature.
- A safety exclusion zone will be imposed around the proposed power station, but as far as possible access to the marine environment by the public will be maintained.
- The chlorination regime applied to abstracted cooling water will consist of an estimated 2 mg/kg of chlorine released on a continuous basis.
- Screens of similar specification to those used by KNPS will be used to prevent the intake of large marine organisms such as kelp, fish and jellyfish along with abstracted cooling water.
- Should disposal of spoil occur at sea, the spoil will be placed at the same location as that modelled by Prestedge *et al.* (2009a), the volumes disposed of will not exceed those considered in the models and sediment disposed of at sea will not contain significant organic matter. Should any of these constraints not be met, refinement of the current models and a reassessment of potential impacts should be undertaken prior to commencement of spoil disposal.

At present a technical feasibility study is underway, considering the logistics of spoil disposal at sea at the Thyspunt site. To date no technical fatal flaws have been identified (Eskom position paper 2011). As a necessity, recommendations made in this specialist report assume technical feasibility of the proposed spoil disposal options at all three alternative sites.

1.2.2 Assessment criteria

The assessment criteria on which this assessment is based have been provided by Arcus GIBB. These criteria are based on the EIA Regulations (Government Notice R. 385 of 2006), promulgated in terms of Section 24 of the NEMA and criteria drawn from relevant government guidelines. The criteria are briefly presented in the table below. More detail regarding the criteria can be found in Chapter 7 of the Revised Draft EIR.

Table 1. Impact Assessment Criteria

Criteria	***Rating Scales***	***Notes***
Nature	***Positive***	***This is an evaluation of the type of effect the construction, operation and management of the proposed NPS development would have***
	Negative	

Criteria	Rating Scales	Notes
	Neutral	on the affected environment
Extent	Low	Site-specific, affects only the development footprint
	Medium	Local (limited to the site and its immediate surroundings, including the surrounding towns and settlements within a 10 km radius);
	High	Regional (beyond a 10 km radius) to national
Duration	Low	0-3 years
	Medium	4-8 years (i.e. full duration of construction phase)
	High	More than 9 years to permanent
Intensity	Low	Where the impact affects the environment in such a way that natural, cultural and social functions and processes are minimally affected
	Medium	Where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way; and valued, important, sensitive or vulnerable systems or communities are negatively affected
	High	Where natural, cultural or social functions and processes are altered to the extent that the impact will temporarily or permanently cease; and valued, important, sensitive or vulnerable systems or communities are substantially affected.
Potential for impact on irreplaceable resources	Low	No irreplaceable resources will be impacted.
	Medium	Resources that will be impacted can be replaced, with effort.
	High	There is a high potential that irreplaceable resources will be lost.
Consequence (a combination of extent, duration, intensity and the potential for impact on irreplaceable resources).	Low	A combination of any of the following • Intensity, duration, extent and impact on irreplaceable resources are all rated low • Intensity, duration and extent are rated low but impact on irreplaceable resources is rated medium to high • Intensity is low and up to two of the other criteria are rated medium • Intensity is medium and all three other criteria are rated low
	Medium	• Intensity is medium and one other criterium is rated high, with the remainder being rated low. • Intensity is low and at least two other criteria are rated medium or higher. • Intensity is rated medium and at least two of the other criteria are rated medium or higher • Intensity is high and at least two other

Criteria	*Rating Scales*	*Notes*
		criteria are medium or higher • ***Intensity is rated low, but irreplaceability and duration are rated high***
	High	• ***Intensity and impact on irreplaceable resources are rated high, with any combination of extent and duration*** • ***Intensity is rated high, with all of the other criteria being rated medium or higher***
Probability (the likelihood of the impact occurring)	***Low***	***It is highly unlikely or less than 50 % likely that an impact will occur.***
	Medium	***It is between 50 and 74 % certain that the impact will occur.***
	High	***It is more than 75 % certain that the impact will occur or it is definite that the impact will occur.***
Significance (all impacts including potential cumulative impacts)	***Low***	• ***Low consequence and low probability*** • ***Low consequence and medium probability***
	Low to medium	• ***Low consequence and high probability*** • ***Medium consequence and low probability***
	Medium	• ***Medium consequence and low probability*** • ***Medium consequence and medium probability*** • ***Medium consequence and high probability*** • ***High consequence and low probability***
	Medium to high	• ***High consequence and medium probability***
	High	• ***High consequence and high probability***

2 DESCRIPTION OF AFFECTED ENVIRONMENT

Due to the design of the proposed development the impacts on the marine ecosystem will be focused within the nearshore environment. A detailed description of the potentially affected marine habitats at the three alternate sites is given below.

2.1 Duynefontein

Figure 1. The sandy beach at the proposed Duynefontein site

2.1.1 General Description

The area under consideration is located north of Melkbosstrand on the west coast, and falls within the Southern Benguela ecoregion and the southwestern Cape inshore ecozone (Sink *et al.* 2011). This region is dominated by the cold Benguela Current system, in which high biological productivity is supported by the upwelling of cool nutrient rich waters (Bustamante *et al.* 1995a, b, Walmsley *et al.* 2007). However, this section of coast is characterised by low marine species richness and very low endemicity (Awad *et al.* 2002). Nonetheless, some south coast species extend to this site, giving it slightly elevated species richness and endemicity rates, when compared to more northern areas along this coast. Recent work has classified the threat status of sandy and rocky shores in this region as vulnerable and moderately protected (Sink *et al.* 2012). To place this in context, the same report also states that 47% of marine and coastal habitat types along the South African coast are threatened (Sink *et al.* 2012). No sites of special biological significance occur within the area (Jackson and Lipschitz 1984).

This site is typified by long sandy beaches, interspersed with short stretches of rocky-shore (Currie and Cook 1975). Such beaches are notable for the low number of species they support, and the fact that they are physically controlled. As a result of the dominance of physical parameters, such as water movement, these beaches are very resilient to disturbance. All the beach species found here have extensive geographical distributions. There are no sites of special conservation value for marine species within the immediate area.

2.1.2 The Intertidal Zone

The intertidal zone in the vicinity of KNPS is dominated by sandy shores. To the north of the plant lies a 10 km long sandy beach, which is very wave exposed and as a result consists of coarse-grained quartz sand and weathered shell. To the south is a shorter beach, which is more sheltered, due to the presence of the Koeberg harbour breakwater. This shore consists of finer sediment and has a wider intertidal zone. Invertebrate species found on both these beaches are typical of the west coast (Appendix 1). During extensive sampling at this site only a single species endemic to South African shores was recorded i.e. the amphipod *Talorchestia quadrispinosa*. This species, however, has a range extending from False Bay up the entire west coast. High-shore macrofaunal communities are dominated by crustaceans (isopods and amphipods), while lower down the shore communities become dominated by polychaete worms (Griffiths and Robinson 2006). Although not numerically dominant, the White sand mussel *Donax serra* also occurs in the low shore. This species is common on exposed sandy beaches along the entire west and south coasts. Due to the dynamic nature of exposed sandy shores they demonstrate high tolerance to disturbance and are thus rated as low sensitivity habitats.

Very little natural rocky shore is present in the area under consideration and the two Koeberg harbour breakwaters represent the largest section of hard substratum available in the intertidal zone. On the seaward side the breakwaters are protected by concrete dolosse and loose rocks and the intertidal zone is very exposed with biological communities that are dominated by two alien species i.e. the mussel *Mytilus galloprovincialis* and the barnacle *Balanus glandula* (Appendix 2). A single South African endemic species, the whelk *Burnupena lagenaria* was also recorded. On the inside, the breakwaters are built up with rocks of assorted sizes, sloped to form a gentle intertidal zone. Communities within this sheltered habitat are far more diverse, but still include the alien mussel and barnacle recorded on the exposed side of the breakwater. Community biomass is dominated by *M. galloprovincialis,* the limpet *Scutellastra granularis* and numerous algae. All species recorded in the rocky intertidal zone are common on the west coast and none have ranges restricted to less than 100 km. Although they are more sensitive than sandy shores, the rocky shores at this site also represent a low-sensitivity habitat.


Figure 2. The exposed seaward side of the Koeberg breakwater

2.1.3 The Benthic Environment

Both rocky and sandy bottoms occur in the nearshore environment in the immediate vicinity of Koeberg Nuclear Power Station (Cook 1984a). These habitats were not sampled as part of this study. This is due to the fact that there has been relatively sparse sampling of the nearshore subtidal benthos off the entire South African coast and as such it would be almost impossible to say how representative the habitats present at each of the proposed Nuclear-1 sites might be, even if they were sampled. This is not considered a fatal flaw as:
(1) Sufficient information relating to commercially important benthic resources, such as abalone, exists to enable a scientifically rigorous evaluation of the relative importance of the sites; and
(2) Warm water effluent from the proposed development will be concentrated near the surface and is unlikely to impact these habitats. This approach has been endorsed by Professor GM Branch (Appendix 3).

Communities inhabiting rocky substrata off Koeberg are dominated by the sea urchin *Parechinus angulosa*, the mussel *Choromytilus meridionalis* and gastropods of the genus *Burnupena*. All species are typical of the South African west coast and are widely distributed. Both abalone *Haliotis midae* and West Coast rock lobster *Jasus lalandii* were recorded on nearby shallow reefs in the 1980s (Cook 1984a) and are likely to still occur there, due to the protection offered by the two nautical mile 'no go' safety area surrounding the power station. Sandy bottom communities in this area support no species of special note and are characterised by large numbers of polychaete worms, burrowing anemones and small crustaceans. This environment demonstrated medium sensitivity to disturbance.

2.1.4 The Open Water Environment

While the South African west coast supports highly productive fisheries, these are focused offshore. Nearshore fish productivity remains high, but diversity is low. A number of fish have been recorded in a survey of the harbour of KNPS, the most common of which are the Southern harder *Liza richardsoni* and the catshark *Poroderma africanum* (Cook 1984b).
The high productivity characterising the west coast region is driven primarily by high densities of phytoplankton and zooplankton. Blooms are, however, localised

and transient and depend to a large degree on prevailing weather and oceanographic conditions. Although a large number of species have been identified in the vicinity of the area under question, taxonomy of these groups is notoriously difficult and a large number of smaller species remain undescribed.

Several species of marine mammals inhabit the neashore waters of the southern Benguela region, although data in the immediate vicinity of the KNPS are sparse. Two species of delphinid, the Heaviside's dolphin (*Cephalorhynchus heavisidii*) and dusky dolphin (*Lagenorhynchus obscurus*) are resident year round (Elwen et al. 2010). The long beaked common dolphin (Delphinus sp.) has also been recorded on the west coast as far north as Cape Columbine (Findlay et al. 1992) and may be seen with some regularity in summer months in Table Bay. The Heaviside's dolphin occurs along this section of coast at a relatively high density of 1-2 groups/km with an average group size of 4.5 dolphins (Elwen et al. 2010). They use very near-shore waters (predominantly <1km) during the morning hours (04h00-12h00) for socialising and move offshore in the afternoons and evening for feeding.

Southern right whales (*Eubalaena australis*) and humpback whales (*Megaptera novaeangliae*) (Barendse *et al.* 2010, Barendse 2011) use the inshore waters of the west coast on a seasonal basis. Seasonality on the west coast is later than on the south coast due to feeding in upwelling areas in the southern Benguela. Numbers peak in the Saldanha Bay area (and probably Table Bay too) in spring and summer (Sep.-Feb.). Southern right whales regularly use very shallow, nearshore waters (<2 km from shore) when moving along the coast (Best 2000, Elwen and Best 2004), thus bringing them into potential contact with the proposed development site. While a number of marine mammals is known to frequent the west coast, only the South African fur seal *Arctocephalus pusillus pusillus* has been recorded spending extended periods in the immediate area of the KNPS.

This environment demonstrates relatively high tolerance to disturbance and is thus rated as having low sensitivity.

2.1.5 Avifauna

A number of marine birds are known to breed in the intertidal zone around the KNPS. These include Hartlaub's gull *Larus hartlaubii*, the Swift tern *Sterna bergii bergii* the 'Endangered' Bank cormorant *Phalacrocorax neglectus*, the 'Near-threatened' Crowned cormorant *P. coronatus*, Cape cormorant *P. capensis* and the 'Near-threatened' African black oystercatcher *Haematopus moquini*. Of these, three species are endemic to the region (Hartlaub's gull, the Bank cormorant and the African black oystercatcher). Recent research has identified the Koeberg harbour and surrounding reserve as an area of significant conservation importance, which meets the criteria for both the Ramsar convention and an Important Bird Area (Parsons 2006). In particular, the protection offered by the Koeberg reserve has resulted in a notable increase in density of breeding pairs of the African black oystercatcher, which has recently been re-categorised as 'Near-threatened' after being rated at 'Endangered' for a number of years. Besides the marine birds occurring at the power station African penguin and other seabird colonies are located at Robben Island, about 15 km to the south.

2.2 Bantamsklip

2.2.1 General Description

This site is located just to the east of Pearly Beach in the Western Cape Province and as such falls within the Agulhas ecoregion (Sink *et al.* 2012). Coastal habitats in this region are considered to have a threat status of least threatened to vulnerable and to be moderately to well protected (Sink *et al.* 2012). Marine invertebrate species richness in this region is dramatically higher than that along the west coast (and the Koeberg site), but somewhat lower than in the Thyspunt region. Very few range-restricted invertebrate species are reported from this region (Awad *et al.* 2002). The area supports a variety of marine mammals and is well known for Great White sharks. Dyer Island lies 10 km to the west of the Bantamsklip site and constitutes a 20 ha nature reserve and is the most easterly of the seabird islands of the Western Cape. This island is recognised as an Important Bird Area by BirdLife International. Besides the important Dyer Island seal and bird colonies (see details below), no sites of special biological significance are known from the area (Jackson and Lipschitz 1984). Species of conservation concern occurring in this area include the abalone *(Haliotis midae* - Endangered), Indo-Pacific humpback dolphin (*Sousa chinensis* (*plumbea* form - vulnerable), Great White sharks (*Carcharodon carcharias* - vulnerable), African penguin (*Spheniscus demersus - vulnerable*), Cape cormorant (*Phalacrocorax capensis* - near threatened), Bank cormorant (*P. neglectus* - endangered), Crowned cormorant (*P. coronatus* - near threatened) and African black oystercatchers (*H. moquini* - near threatened).

The shoreline at Bantamsklip consists of strongly-dissected exposed rocky shores, interspersed with small pocket beaches, upon which large quantities of kelp wrack are cast ashore. This kelp originates from the dense beds of *Ecklonia maxima* and *Laminaria pallida*, which dominate shallow subtidal areas at this site (Barker 1988). The broader region supports a number of significant fisheries (e.g. anchovy, sardine, abalone and rock lobster), as well as marine tourism activities such as white shark diving (close to Dyer Island) and whale watching (between Danger Point and Quoin Point).

Figure 3. The shoreline at Bantamsklip

2.2.2 The Intertidal Zone

At this site the intertidal zone is dominated by strongly dissected exposed rocky shores. In the high-shore the small gastropods *Afrolittorina africana* and *Tricolia capensis* dominate communities, while lower down the shore algae such as *Bifurcaria brassicaeformis* become important (Appendix 2). Sampling of this site revealed nine South African endemic species, all of which have extensive ranges along the coast. Although currently only harvested on a recreational basis, recent studies have considered the potential of commercial harvesting of the giant winkles *Turbo sarmaticus* (alikreukel), *Turbo cidaris* and *Oxystele sinensis* in this area (Pulfrich and Branch 2002). Sandy beaches along this section of coast take the form of small pocket beaches located between rocky outcrops. Faunal communities on these beaches are typical of sandy shores in the region and support large numbers of the polychaete worm *Scololepis squamata* in the low-shore (Appendix 1). No species of special conservation interest were recorded in the intertidal environment at this site (Appendix 4 & 5). The rocky and sandy shores at this site are considered to be tolerant to disturbance and thus demonstrate low sensitivity.

Figure 4. A pocket beach at Bantamsklip

2.2.3 The Benthic Environment

The nearshore benthic environment in the Bantamsklip area is represented by both rocky and sandy habitats. In rocky areas floral communities are typified by dense beds of the kelps *Ecklonia maxima* and *Laminaria pallida*. *E. maxima* occurs in the sublittoral fringe and has a canopy of fronds that lie on the water surface. In contrast *L. pallida* occurs beneath the *E. maxima* canopy and extends to deeper waters (8-15 m). Both these species are commercially exploited along the South African coast. Management of seaweed resources along the south and west coast is implemented through the designation of concession areas. Bantamsklip falls within area 5 (Uilenkraal River mouth to Cape Agulhas). This concession area supports a considerable *E. maxima* resource of 498 ha (Anderson et al. 2007) while the extent of *L. pallida* has not been quantified. For *E. maxima* this area supports 27% of south coast stock and less than 10% of overall stocks (calculated from figures given in Anderson *et al.* 2007). The present right-holder is permitted to collect any beach-cast kelp and harvest a maximum of 2625 tonnes of whole kelp (or 1313 tonnes frond material) annually (R. Anderson, Fisheries Branch, DAFF, Pers. Comm. June 2008). Harvesting is only allowed from the shore or a boat and diving is not permitted. As fresh fronds are sold to abalone farms for about R 950.00 per tonne, kelp represents a valuable resource in this area (R. Anderson, Fisheries Branch, DAFF, Pers. Comm. June 2008).

Closely associated with the above kelp beds is the abalone *H. midae*. This gastropod is of extremely high commercial value and has been intensively harvested on a commercial, recreational and illegal basis along the South African coast. This fishing pressure, combined with ecosystem changes, such as a dramatic eastward extension of predatory rock lobster stocks in recent years, has resulted in the dramatic reduction in wild stocks of *H. midae* since the early 1990s (Maharaj *et al.* 2008) and this species is listed as endangered in terms of CITES Appendix III (CITES 2007). Fisheries Independent Abalone Surveys conducted by the Department of Environmental Affairs have recorded a decrease in abundance (individuals per 60 m^2) from 35.7 (± 13.4 SE) in 1995 to 6.2 (± 1.7 SE) in 2007 (G. Maharaj, Fisheries Branch, DAFF, Pers. Comm. August 2008). As a result, the entire fishery was officially closed between February 2008 and July 2010. The objective of this closure was to allow the resource to recover from poaching and from the ecological effects of the West Coast Rock Lobster preying on abalone. Although the fishery has been reopened, abalone stocks are still very low. A few key areas have been identified as containing viable abalone populations with potential to recover to significant levels (G. Maharaj, Fisheries Branch, DAFF Pers. Comm. August 2008). Bantamsklip occurs within one such area (i.e. from Quoin Point to Danger Point). While the benthic environment as a whole demonstrates medium tolerance to disturbance (and hence medium sensitivity), the abalone population is thus considered highly sensitive.

Although no site-specific study of sandy bottom community composition has been undertaken, no species of special conservation importance (besides the abalone) are known or likely to occur from the area.

2.2.4 The Open Water Environment

The rich diversity of fish along the Southern Cape coast support both commercial line and pelagic fisheries, as well as significant recreational fishing activities. As the pelagic fisheries (such as those for Pilchards and Anchovy) occur offshore, and involve highly mobile species, they are not likely to be impacted by the development of a power station at Bantamsklip, so are not considered further within this report. The commercial lineboat fishery, as well as shore anglers, target species such as Kob (*Argyrosomus hololepidotus*), White steenbras (*Lithognathus lithognathus*), Musselcracker (*Sparodon durbanensis*), Galjoen (*Dichistius capensis*), Cape salmon (*Atractoscion aequidens*) and Yellowtail (*Seriola lalandi*) (Attwood and Farquar 1999). All of these species have extensive ranges along the South African coast and none breed exclusively in the area around Bantamsklip, but most are considered to be overexploited, some severely so (Attwood and Farquar 1999).

Since the protection of White sharks (*Carcharodon carcharias*) in 1991, the area between the Bantamsklip site and Gansbaai has become one of three major shark cage diving sites along the South African coast. In particular, the area around Dyer Island, which supports a large seal colony, is a common viewing spot. Although no recent assessment has been completed of the numbers of White sharks in South African coastal waters, over 1200 different individual sharks were identified in the Gansbaai area between 1998 and 2005 (Kock and Johnson 2006) and this species is currently rated as vulnerable by the IUCN (IUNC 2010). Sharks in this region show seasonal trends in abundance, with overall numbers peaking in winter. However, sharks are recorded near inshore areas most frequently from August to November (Kock and Johnson 2006).

’Indian Ocean Bottlenose Dolphin (*Tursiops aduncus*), Indo-Pacific humpback dolphin (*Sousa chinensis*) and the Cape fur seal (*Arctocephalus pusillus pusillus*) occur year-round. Together with the southern right whale, which is abundant in winter months, all these species predominantly use the near-shore environment, where they may interact with the proposed development. The humpback whale, Bryde’s whale (*Balaenoptera edeni*) and long beaked common dolphin also occur here regularly, although in lower numbers and usually further from shore (>2 km) (Vinding *et al.* 2012.), where they are unlikely to be affected by the proposed activities.

The South African population of southern right whales is considered to be healthy due to the rate of increase (approximately 7% per annum, Brandão *et al.* 2011) and current size of the population (~4600 individuals in 2008, Brandão *et al.* 2011). The rapid growth of the population is most obvious in the increase of whales in areas outside of the historically recognised breeding (St Sebastian Bay and De Hoop) and mating (Walker Bay) areas. The sandy substrate of Pearly Beach, near the proposed Bantamsklip site, is highly suitable habitat for right whales (Elwen *et al.* 2004a) and this area has seen a significant increase in right whale presence in recent years, with a local whale-watching company logging over 4500 encounters between 2003 and 2011 (Vinding *et al.* 2012). The vast majority of right whale sightings in this area occur from July to November, with calves being present predominantly from September to December (Vinding *et al.* 2012). Right whales show strong preference for coastal waters <2 km from shore with mother-calf pairs using shallower water than adults unaccompanied by calves (Elwen *et al.* 2004a). Although not considered to be feeding in the Bantamskip area, right whales may be mating or resting in the area and are susceptible to disturbance (especially calves) from activities associated with the construction and operation of the proposed development.

Both Indo-Pacific bottlenose (hereafter ‘bottlenose’) and Indo-Pacific humpback (hereafter ‘humpback’) dolphins occur year round in the Bantamsklip area and are predominantly found in the near-shore environment, less than 2 km from shore (Vinding *et al.* 2012). This area is near the western extreme of both species’ range, with False Bay considered the western limit for both species (Best 2007). Conditions may thus be more marginal for these species here thanthe region east of Cape Agulhas, with the impacts of any disturbance correspondingly higher. The population of bottlenose dolphins living along the Cape south coast is considered to be large and healthy with few major threats (e.g. Reisinger and Karczmarski 2010) with individuals likely ranging over 100s of km of coastline. They are thus likely to be resilient to localised threats. Conversely, it is important to note threats do not occur in isolation and localised activities may impact a large portion of the population.

No recent published information is available on the humpback dolphin from the Cape south coast. However, indications for the species are not positive. Humpback dolphins naturally occur in small populations, which combined with their extremely coastal and occasionally estuarine distribution, makes them extremely vulnerable to any anthropogenic threats. The humpback dolphin has the highest pollutant load of any cetacean in southern Africa (Cockcroft, 1999) and current information from existing photo-ID catalogues suggests that the populations along the south coast is extremely small with catalogues only containing in the 10’s of animals from Plettenberg Bay (Jobson 2006), Mossel Bay (Bridget James, Pers Comm) and in the Gansbaai/Dyer Island area. In total less than 40 individuals have been identified (Isabelle Dupre, Pers Comm). The population structure along the Cape south coast is not known (i.e. degree of isolation between the above-mentioned sites), but individual humpback dolphins in the Eastern Cape are known to move several hundreds km along the coast (Karczmarski *et al.* 1999), so the total population may be small, if individuals are shared between these sites. Extreme concern should thus be given to the humpback dolphin in all activities associated with the construction and operation of the proposed power station.

Two breeding colonies of South African fur seal occur in the vicinity of Bantamsklip, those at Geyser Rock (adjacent to Dyer Island), and Quion Rock to the east. Although five breeding colonies exist along the south coast, the abundance of this species is much lower in this region than along the west coast (Barker 1988). Numbers of individuals on the islands peak during the breeding season, which runs from late November to early January (Barker 1988). It is during this time that colonies are most sensitive to disturbance, with mothers abandoning pups if disturbance levels are too high. In contrast the colonies are least sensitive during October and early November, when most cows spend time at sea prior to the birth of their pups (Barker 1988). The area under consideration is unlikely to be of importance to feeding adult seals as they forage offshore, but in their first year juveniles may forage in the areas surrounding the breeding colonies.
Plankton productivity is dramatically lower on the south coast than on the west coast. Nonetheless, inshore waters tend to experience moderate sporadic spring blooms, followed by strong episodic coastal upwelling, which gives rise to intense blooms in summer (Mitchell-Innes *et al.*1999).

The open water environment is considered a low sensitivity environment due to its dynamic nature and high tolerance to disturbance.

2.2.5 Avifauna

To the west of Bantamsklip, Dyer Island supports colonies of African penguin (*Spheniscus demersus*), Roseate terns (*Sterna dougallii*), Whitebreasted (*Phalacrocorax carbo*), Cape (*P. capensis*), Bank (*P. neglectus*), and Crowned cormorants (*P. coronatus*), Kelp gulls (*Larus dominicanus*), Hartlaub's gulls (*L. hartlaubii*) and Swift terns (*Sterna bergii bergii*) (Waller and Underhill 2007). Huge roosts of migratory Common (*S. hirundo*) and Sandwich terns (*S. sandvicensis*), occur in summer. Kelp gulls (*Larus dominicanus*), African black oystercatchers (*H. moquini*) and a variety of Terns (Family Sternidae) frequent the intertidal zone at this site. A small number Leach's storm petrel also breed annually on the island. The conservation rating of each of these species by the IUCN is given in Table 2.

Table 2. Conservation rating of marine birds occurring at Dyer Island and Bantamsklip (IUCN 2010). Note: The category 'least concern' is used for species that are widespread and abundant.

Species	**Conservation rating**	**Endemic to SA**
African penguin	Vulnerable	
Roseate tern	Least concern	
Whitebreasted cormorant	Least concern	
Cape cormorant	Near-threatened	
Bank cormorant	Endangered	
Crowned cormorant	Near-threatened	
Kelp gull	Least concern	

Hartlaub's gull	Least concern	Yes
Swift tern	Least concern	
Common tern	Least concern	
Sandwich terns	Least concern	
African black oystercatchers	Near-threatened	Yes
Leach's storm petrel	Least concern	

A colony of Cape cormorant *Phalacrocorax capensis* has been observed roosting at this site. This is the most common of the cormorants found along the South African coast and breeds between Namibia and Port Elizabeth. This species is of no special conservation concern.

2.3 Thyspunt

2.3.1 General Description

Situated just to the west of Cape St. Francis within the Eastern Cape Province, Thyspunt falls within the Agulhas ecoregion (Sink *et al.* 2012). Coastal habitats in this region are considered to have a threat status of least threatened to vulnerable and to be moderately to well protected (Sink *et al.* 2012). . Although the general area is one of high marine species richness and high rates of endemism (Awad et *al.* 2002) site surveys detected no rocky or sandy shore species endemic to the south coast. Species of conservation concern occurring in this region include the abalone *(Haliotis midae* - endangered), African penguin (*Spheniscus demersus - vulnerable*), Cape gannet (*Morus capensis* – vulnerable) Cape cormorant (*Phalacrocorax capensis* - near threatened), African black oystercatchers (*Haematopus moquini* - near threatened), Caspian tern (*Sterna caspia* - near threatened) and humpback dolphins (*Sousa chinensis* (*plumbea* form) – vulnerable). In addition, fish species such Red Steenbras (*Petrus rupestris*) and Black Musselcracker (*Cymatoceps nasutus*) have wide distribution ranges that include the Thyspunt area. These fish have not been listed on the IUCN red data book but stocks are considered severely depleted. No sites of special biological significance occur within the designated area (Jackson and Lipschitz 1984), although fish traps of historical interest occur to the west of the site.

The shoreline at Thyspunt consists mainly of very exposed intertidal habitat, including both rocky and sandy shores. Due to the restricted access at this site these shores have been protected from all forms of utilisation. A lucrative fishery for chokka squid *Loligo vulgaris* is located in inshore waters along this region of coast.

Figure 5. Sandy and rocky shores at Thyspunt

2.3.2 The Intertidal Zone

Rocky shores at Thyspunt are steep and strongly dissected, as seen in Figure 5. The high-shore zone is dominated by the algae *Porphyra capensis* and the tiny gastropod *Afrolittorina africana* (Appendix 2). The mid-shore forms a distinct band dominated by the barnacle *Chthamalus dentatus,* but also supports low densities of the alien mussel *M. galloprovincialis.* In contrast low-shore communities are dominated by a variety of algae, all of which are common in this region. Three rocky-shore endemic species were recorded at this site, each with an extensive range along the South African coast (Appendix 5). Although not recorded during recent surveys, the giant periwinkle *Turbo sarmaticus* (alikreukel) occurs in the vicinity of Thyspunt, where it is harvested in large numbers on a recreational basis (Bruton et al. 1991). The exposed sandy beaches at this site consist of coarse sand and support a very low diversity of organisms (i.e. only four species were recorded, Appendix 4). The most common of these was the plough shell *Bullia digitalis* and no endemic species were recorded. No species of special conservation interest were recorded in the intertidal environment at Thyspunt. As for the other two sites, the intertidal zone (consisting of both sandy and rocky shores) is considered highly tolerant to disturbance, due to the natural variability which typifies these shores. As such the intertidal zone is considered a low sensitivity habitat.

Figure 6. The exposed rocky shore at Thyspunt

2.3.3 The Benthic Environment

Both sandy and rocky bottoms are present in the vicinity of Thyspunt (Nuclear Site Investigation Programme; Eastern Cape 1988). Rocky shores are often steep vertical rock-faces (Figure 6). Species composition and abundance in these habitats are typical of the region. Rocky reef communities are dominated by colonial ascidians, hydroids and sponges, with coralline algae being important to a depth of about 20 m (Nuclear Power Investigations; Eastern Cape 1988). The benthic environment demonstrates medium tolerance to disturbance and as a result is rated as a medium sensitivity habitat.

The distributional range of abalone *H. midae* occurs from north of Saldanha Bay along the west coast to Port St. Johns on the east coast (Muller 1986, Raemaekers and Britz 2009) and so encompasses the Thyspunt site. Despite this wide distributional range it is listed as endangered by CITES Appendix III (CITES 2007). Britz et al. (2003) noted that there is a general lack of even anecdotal information on the status of *H. midae* in the area to the west of Seal Point, although illegal diving for abalone is known. Due to the possible similarity in habitat between this and other areas known to support high densities, the authors suggested that there may be significant populations of abalone between Groot River and Seal Point (Britz et al. 2003). The area in the lee of Seal Point and Cape St. Francis (Figure 7) also supports abalone, but populations are patchier and affected by recreational harvesting and poaching (Britz et al. 2003). The difference in population density between the areas west and east of Seal Point is thought to be due differences in ease of human access and limited habitat availability in the east (Britz et al. 2003). A large-scale commercial fishery has never been established in this region, as marine resource managers historically believed that the distribution pattern and abundance of abalone in this region was too discontinuous and patchy to justify commercial exploitation (Tarr 2000). In an effort to gain an understanding of the status of abalone populations along the Eastern Cape coast and whether a viable fishery could be sustained in the province, DAFF announced a three-year research project in June 2012. Seven research areas have been identified and permits allocated (G. Maharaj, Fisheries Branch, DAFF Pers. Comm. June 2012). These include an area stretching from the Groot River to the Kabeljous River, which encompasses the Thyspunt site.

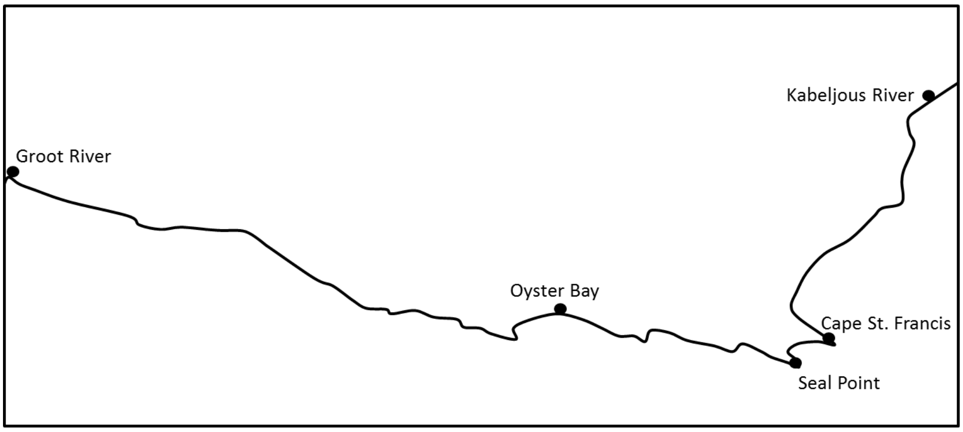

Figure 7. The region around Thyspunt showing locations mentioned in the text above.

2.3.4 The Open Water Environment

The chokka squid *Loligo reynaudii* is an important invertebrate species in the area surrounding the Thyspunt site. This species is recognised as occuring from southern Namibia to approximately East London (Augustyn 1989), although recent work has highlighted the potential of a genetic separation between west and south coast stocks (Shaw *et al.* 2010). These squid have a lifecycle that demonstrates an annual pattern of squid hatching in the east, subsequent migration westwards to offshore feeding grounds on the central and western Agulhas Bank and the west coast and finally return migration to the eastern inshore areas to spawn (Olyotte *et al.* 2006, 2007). Coastal spawning is largely focused in shallow bays along the South African south coast (Augustyn 1991), with the most important coastal spawning grounds occurring between Plettenberg Bay and Algoa Bay (Downey *et al*. 2010). Recently there has also been recognition of offshore spawning grounds in the mid-shelf region of the eastern and central Agulhas Bank (Roberts and Mullon 2010). The discrete location of spawning suggests that this area represents an environmental niche that favours egg development and / or paralarvae, despite the occurence of adults over a larger range (Roberts 2005). On coastal spawning grounds spawning occurs sporadically throughout the year (Augustyn 1990, Sauer *et al.* 1999), with a peak in spring / early summer (Sauer *et al.* 1992). *L. reynaudii* are recognised serial spawners with females spawning repeatedly in their lifetime (Melo & Sauer 1999). Spawning shows a daily cycle, with active periods of spawning occurring during the day (Melo & Sauer 2007). It has been estimated that the potential fecundity of females is about 17 000 eggs (Sauer *et al.* 1999). Egg capsules are deposited mainly on low-profile reef or fine sandy bottoms of large, relatively sheltered bays, such as that to the east of Thyspunt (Sauer *et al.* 1992). Generally egg deposition occurs at depths of less than 50 m (Sauer *et al.* 1992), but during years of severe winter storms, elevated swell and turbidity result in spawning at greater depths (Roberts and Sauer 1994). The most recent published account of egg beds recorded their presence to the east of Cape St Francis, with St Francis Bay appearing to support dense beds (Roberts and Mullon 2010). A variety of predators have been recorded predating on *L. reynaudii* e.g. octopus, fish and marine mammals (Smale *et al.* 2001), but none of these are reliant solely on squid.

Since the mid 1980s a coastal jigging fishery for *L. reynaudii* has developed along the south coast. While the species has an extensive distribution, the economically important part of the stock is distributed in the area between Plettenberg Bay and

Port Alfred (Lipinski and Soule 2007) where spawning aggregations of squid are targeted by the fishery . Catches are therefore determined to a large extent by the successful formation of numerous large aggregations (Roberts and Mullon 2010).

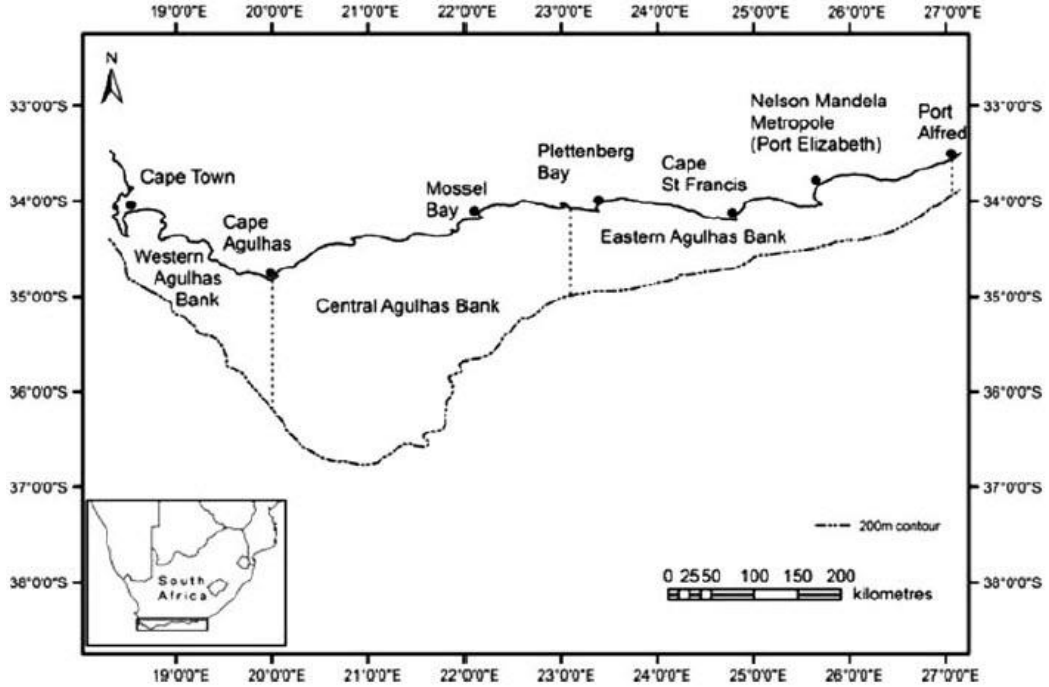

Figure 8. The south coast of South African showing the various regions of the Agulhas Bank (From Olyott *et al.* 2007)

Shore and skiboat based recreational angling occurs extensively along the Eastern Cape coast, including in the general Cape St. Francis area. Species of importance to these fisheries include Dusky kob (*Argyrosomus japonicus*), Silver kob (*A. inodorus*), Cape salmon (otherwise known as Geelbek, *A. aequidens*), Shad (otherwise known as Elf, *Pomatomus saltatrix*), White steenbras (*Lithognathus lithognathus*) and Bronze bream (*Pachymetopon grande*) (Brouwer and Buxton 2002). Although both demersal and pelagic fisheries operate in the area offshore from Thyspunt, these fisheries occur outside the area that will be impacted by the development of a power station and so are not considered further within this report.

Four marine mammal species are regularly observed in the vicinity of Thyspunt. These are the Indo-Pacific bottlenose dolphin and Indo-Pacific humpback dolphin, which are resident year round, and the southern right whale and humpback whale, which are common in winter months (Melly 2011). The Bryde's whale and long beaked common dolphin are also resident species in the Agulhas Bank area and occur here regularly, especially in conjunction with small prey fish such as sardine, but usually remain >2 km from shore are thus likely to have limited interactions with the proposed project (Penry *et al.* 2011, Melly 2011).

There are no current data (<10 years old) published on the distribution, abundance or seasonality of marine mammals in the Thyspunt area, although two theses provide some information from Plettenberg and Algoa Bays since 2005 (Penry *et al*. 2011, Melly 2011). This lack of data has important implications for animal presence within the impacted site, as both the southern right whale (Brandão *et al.* 2011) and humpback whale populations (Findlay *et al.* 2011), which use this area, have increased substantially in the last 10 years, resulting in longer periods within

South African waters, and increased use of areas previously regarded to be seldom used. Both humpback and southern right whales are likely to be transient through the proposed affected area, as the exposed coastline here is not preferred habitat for either species and humpback whales are mostly migrating past this area to breeding grounds further north (Mozambique). However, their presence (especially that of the very coastally distributed right whales) needs to be accounted for in any activities, particularly those involving explosives or excessive noise that may occur during construction. Right whales are most common in Algoa Bay in August - November, and humpback whales in September - January (Melly 2011).

The population of bottlenose dolphins using this section of coastline is large and transitory, with the entire south coast population estimated to be in the range of 16 000 to 40 000 animals, based on data collected in the early 1990's in Algoa Bay (Reisinger and Karczmarski, 2010). The population is thus not thought to be at risk, although care must be taken during any excessively noisy activities (see above) as for all marine mammals.

As with Bantamsklip, humpback dolphins are the marine mammal species of most concern in this area. Studies in Algoa Bay in the early 1990s (Karczmarski et al. 1999) and Plettenberg Bay in the early 2000's (Jobson 2006) identified 70 and 63 individuals using each area respectively, with a high proportion (>70%) of identifiable individuals, suggesting population sizes not much larger than this using each area. Some individuals are known to move between these sites and the total population moving along this section of coast (including Thyspunt) may be in the region of 400-500 animals (Karczmarski *et al.* 1999, Jobson 1996). Recent indications from Algoa Bay have shown smaller group sizes and lower sighting rates than those recorded in the early 1990s (Koper and Plön 2012), this may be indicative of a population decrease and all care should be taken to reduce impacts on this population.
Although plankton productivity is not considered to be high in this area, when compared with the west coast, nearshore waters are subjected to moderate sporadic coastal upwelling and resulting plankton blooms during summer (Mitchell-Innes *et al.* 1999). The highly dynamic nature of the open water environment translates into low sensitivity to disturbance.

2.3.5 Avifauna

Rocky shores in the vicinity of Thyspunt support a variety of coastal birds, which are typical of such shores in the Eastern Cape region. Species most often observed include the Kelp gull *L. dominicanus* and the African black oystercatcher *H. moquini*. On sandy shores Sandwich terns (*S. sandvicensis*) and Common terns (*S. hirundo*) are common in summer months.

Table 3. Conservation rating of marine birds occurring at Thyspunt (IUCN 2011). Note: The category 'least concern' is used for species that are widespread and abundant.

Species	Conservation rating	Endemic to SA
African penguin	Vulnerable	
Cape gannet	Vulnerable	
Cape cormorant	Near-threatened	
Kelp gull	Least concern	
Common tern	Least concern	
Sandwich terns	Least concern	

African black oystercatchers	Near-threatened	Yes
Caspian tern	Near-threatened	

3 IMPACT IDENTIFICATION AND ASSESSMENT

The development of a nuclear power station at Duynefontein, Bantamsklip or Thyspunt will have a variety of potential impacts on the marine environment. These include disruption of surrounding habitats during the construction phase, the entrainment of organisms during the intake of cooling water, the release of warmed cooling water, the release of desalination effluent and the possible but unlikely unintentional release of radiation emissions and contaminated groundwater. In addition to the impacts of the development on marine habitats, the marine environment may also impact the development. This would take the form of fouling of the cooling water system by marine organisms.

3.1 Duynefontein

3.1.1 Disruption of the marine environment during construction

To fulfil the need for cooling water for the condensers and auxiliary systems of the proposed power station, seawater will be utilised. A tunnel system is being considered at this site and both other alternative sites for the Cooling Water (CW) uptake. This design was chosen by Eskom over a basin intake so as to minimise impacts in the marine environment. As part of such a system two intake pipes will be tunnelled from a land-based cooling water reservoir out to sea. At a water depth of roughly 25 m the tunnels will emerge from the seafloor and water will be taken up via intake structures. Although some disruption to the benthic environment will occur during the construction of this intake system, a much smaller area will be affected than for the construction of an intake basin, resulting in significantly less disruption than that associated with the construction of KNPS. The proposed CW outfall system consists of up to ten outflow pipes (Breytenbach pers comm.) that are laid beneath the sea floor with cooling water being released offshore. In order to lay the outflow pipes, a temporary coffer dam extending just over 400 m out from the intertidal zone will be built during the construction phase. Following the laying of the pipes, the walls will be collapsed, burying the pipes, except for the release point. Regardless of the outfall system chosen, the effects on the subtidal benthic habitat due to the construction process will be the same. Impacts will be confined to the immediate area, with organisms being lost due to the physical disturbance of the sediment and smothering. This effect will, however, be of relatively short duration (construction time, plus progressive recovery to prior state over an estimated 5-10 years).

Cetaceans are sensitive to human activity and noise, such as that associated with the construction and running of the power station and desalination plant. Man-made sound, especially very loud, explosive sounds, such as those associated with explosions or pile driving, have the potential to both injure and disturb marine mammals. Marine mammals as a group have wide variations in ear anatomy, frequency range and amplitude sensitivity. The hearing threshold is the amplitude necessary for detection of a sound and varies with frequency across the hearing range (Nowacek *et al.* 2007). The hearing of baleen whales and large toothed whales is centred at below 1 kHz (Norris and Leatherwood 1981), while medium sized toothed whale and dolphin hearing is centred at frequencies of between 10 and 100 kHz (Richardson *et al.*1995), thus these two groups of animals have very different hearing sensitivities. Known physiological effects of sound include permanent or temporary threshold shift (Richardson *et al.* 1995), tissue damage (Ketten 1993) and non-auditory physiological effects, such as elevated blood pressures, increased heart and respiration rates, and increases in stress hormones (Bowles and Thompson 1996). Behavioural responses to medium level sound disturbance, such as that of pile driving or offshore drilling, include startle responses, changes in diving behaviour and avoidance of the construction area (Richardson *et al*. 1995). For example, harbour porpoises have been shown to move up to 22 km away from the construction site of a wind turbine in the north sea with lower detection rates lasting up to 72 hours post-impact (Gedamke and Scholik-Schlomer 2011, Brandt *et al.* 2011). Noise created by construction or pile driving may also mask the communication sounds of whales and dolphins, with loud pile driving potentially masking dolphin whistles up to 40 km from the source and clicks up to 6 km (David 2006), although these types of effect are highly influenced by the nature of the sound, environment and propagation effects (e.g. Madsen *et al.* 2006).

Since all the cetacean species known to use the proposed site have home ranges which are 10s (dolphins: 50-80 km along shore for Heaviside's, larger for dusky dolphins) to thousands (whales) of km in extent, it is likely that they will avoid any short term impacts and return to repopulate or re-use the area post-impact.
The disruption to the marine environment described above will thus occur only during the construction phase, with medium term recovery, and is likely to be spatially localised (hundreds of m radius).

Additionally, spoil from the excavation of the intake tunnel, intake basin, nuclear island and turbine hall and contractors' yards will be discarded out at sea. At this site 6.48 million m^3 of sand will need to be discarded. When disposed at sea this sediment will essentially have two impacts:

- Firstly as a sediment plume within the water column (consisting mainly of fine muds), which may block light penetration and filtering apparatus of filter feeders; and.
- Secondly as a layer covering the sea bottom (consisting mainly of coarser sands) that will bury the current benthic environment and biota.

The nature of these two impacts and how they are affected by currents and local water movement have been modelled by Prestedge et al. (2009a). These models considered the disposal of both the full volume (6.48 million m^3) and a mitigation option of half the volume of spoil (3.24 million m^3) at both a shallow and deep site. In addition, both a medium and high discharge rate were considered. See Table 4 and Prestedge et al. (2009a) for details of the various disposal alternatives, including depth and rate of discharge. At this site Alternatives 4 (i.e. disposal of all the spoil at a deep[1] site using a high discharge rate[2]), 5 (i.e. disposal of all the spoil at a deep site using a medium discharge rate[3]) and 6 (i.e. disposal of half the spoil at a deep site using a medium discharge rate) are considered preferred options from a marine ecology perspective. As the most severe impacts are associated with Alternative 4 this alternative is assessed. For this option the maximum suspended sediment concentration reaches levels above 80 mg/l near the water surface over a very limited area (i.e. not more than 3 km^2) at any time during or after disposal (Prestedge *et al.* 2009a). This is considered to be a restricted impact, as this sediment plume will occur offshore and avoids any potentially sensitive areas, such as near-shore kelpbeds. The level of 80 mg/l has

[1] 48 m
[2] 3.93m^3/s
[3] 2.06m^3/s

previously been identified as a threshold above which probable adverse ecological effects will occur, while 100 mg/l has been used as a critical value above which proven negative impacts occur (Carter 2006). These levels were applied in the environmental impact assessment of the deepening of the Ben Schoeman Dock Berth on the marine ecology of the Table Bay region. In addition, an area of only 0.5 km² will experience these elevated turbidity levels for longer than two days. Given the fact that this west coast region is exceptionally productive and this impact will be both spatially and temporally limited (and avoid sensitive areas) it is anticipated that the predicted increased turbidity will have little impact on the open water environment. By contrast, initial disposal of spoil will cover an area of 3 km² with sediment layered up to 2.95 m high, resulting in a dramatic affect on benthic communities, which will be totally smothered. However, this will occur over a limited area and will not affect any organisms of conservation importance. While recolonisation from surrounding areas is expected to occur, this will be over the long-term (years). In the first five years after disposal, the sediment on the sea bottom is expected to spread very little to cover an additional area of just 4.5 km² in greater than 5 cm of sediment. Very importantly, only 1 km² of this additional area is estimated to be covered by more than 10 cm of sediment (Prestedge *et al.* 2009a). In the period of six to ten years following disposal, sediment on the sea floor will continue to spread to cover 12.7 km² in more than 5 cm of sediment, with 60% of this area covered in sediment as shallow as 0.5 – 1 cm. While benthic communities at the initial disposal site will still not have recovered, a variety of species are likely to have become established on the disposal mound by this time and areas covered in less than 1 cm of sediment are expected to support communities similar to those of undisturbed areas. As the offshore benthic environment at this site is almost totally dominated by sandy bottoms, disposal of sediment will not affect rocky reefs.

In conclusion, while spoil will be discarded only during the construction phase, and the open water environment will be affected in the short term, the benthic environment will be negatively impacted for many years, although it is expected to recover to pre-disturbance conditions.

Table 4. Details of the proposed spoil disposal alternatives for Duynefontein (From Prestedge 2009a)

Alternative	***Depth***	***Distance from shore***	***Sediment volume***	***Discharge rate***
Alternative 1	***Shallow (21 m)***	***2 km***	***6.48 million m^3***	***3.93 m^3/s***
Alternative 2	***Shallow (21 m)***	***2 km***	***6.48 million m^3***	***2.06 m^3/s***
Alternative 3	***Shallow (21 m)***	***2 km***	***3.24 million m^3***	***2.06 m^3/s***
Alternative 4	***Deep (48 m)***	***6.5 km***	***6.48 million m^3***	***3.93 m^3/s***
Alternative 5	***Deep (48 m)***	***6.5 km***	***6.48 million m^3***	***2.06 m^3/s***
Alternative 6	***Deep (48 m)***	***6.5 km***	***3.24 million m^3***	***2.06 m^3/s***

3.1.2 Abstraction of cooling water and subsequent entrainment of organisms

As part of normal operations cold sea water will be extracted from the marine environment for use in the cooling system of the proposed plant. One of the problems associated with the use of marine water in this way is biological fouling of the cooling water system. In an effort to minimise such fouling, a number of measures will be employed by the proposed plant. These include continuous low-level chlorination of the uptake water to discourage settlement of sessile organisms and the use of screens to prevent the intake of larger marine organisms, such as fish. In addition, the technical design of the uptake system will result in water being drawn into the pipe at a rate of only 1 m/s or less. This slow rate of intake means that large organisms, such as fish and marine mammals, will easily be able to swim against the flow and will avoid entrainment without difficulty. Should an intake tunnel system be chosen for this site, the precise location of the intake point is not considered to change the implications from a marine ecology perspective.

Chlorination of cooling waters is commonly used by power plants throughout the world (Huggett and Cook 1991) as a means to remove fouling organisms that settle with in the cooling system. Due to its reactive nature chlorine reacts rapidly in seawater and in the process exerts it toxic effects on organisms through oxidation reactions. It is, however, very difficult to isolate the effects of chlorination from those of entrainment itself, as during entrainment organisms are also exposed to heat and physical stress, such as mechanical buffeting, acceleration and changes in hydrostatic pressure (Marcy et al. 1978). Thus, in this report, all the above impacts will be considered collectively as impacts resulting from entrainment of organisms. As part of the assessment of the environmental impacts of the KNPS the combined effect of chlorination, heat and physical stress on plankton entrained within the cooling system were quantified in detail (Cook 1984a, Huggett 1987, Huggett and Cook 1991). These studies revealed mortality rates of between 17 and 26 % for zooplankton and between 55 and 67 % for phytoplankton. These impacts are, however, very localised and are considered unlikely to have a significant negative impact on the receiving environment (Huggett and Cook 1991) given the rapid reproduction rate of phytoplankton in particular. Such localised effects of entrainment have also been recorded in international studies (Chaung and Yang 2009, White *et al.* 2010). Entrainment is also unlikely to have a negative impact on reproduction success of fish species, as 87% of fish eggs were found to survive passage through the cooling system (Huggett and Cook 1991). Also few commercially important fish are abundant near KNPS. Although thermal stress is not considered important under average conditions, it is likely to become locally significant during times of high ambient sea temperature, when the increase in temperature due to entrainment may result in water temperatures rising above the thermal tolerances of many west-coast plankton species. It is important to note, however, that sea surface temperatures along the South African west coast have in fact declined over the last two decades as a result of climate change (Rouault *et al.* 2009). This trend is opposite to the general prediction of a global rise in sea surface temperature (IPCC 2007), and is driven by intensifying upwelling, which is in turn related to changes in wind regimes (Reason and Rouault 2005, Rouault *et al.* 2009). As a result, warm water anomalies are likely to decrease in frequency and any chlorination affects are likely to be localized and unlikely to have detectable effects on productivity beyond the immediate vicinity of the power station (Huggett 1987). While 16 species of fish have been recorded in the screens that filter intake water at KNPS, no impact on commercially important or conservationally sensitive species has been recorded (Cook 1984b). It is expected that this impact would be greatly reduced in the proposed development, due to the very much lower rate at which water will be drawn into the cooling system.

Although the volume of water to be utilised by a 4 000 MW plant is roughly twice that of KNPS, the above conclusions are still deemed valid, as the extent of the impact is localised, heat and chlorine dissipate quickly beyond the outfall area (Huggett 1987) and plankton populations regenerate very rapidly, especially along the west coast (Huggett and Cook 1991). This impact will continue during the entire operational phase of the development.

3.1.3 Release of warmed cooling water

After being pumped through the cooling system, warmed cooling water is to be released directly back into the ocean. KNPS uses a shore-based channel to jet the warmed water beyond the surf zone in an effort to achieve good mixing with cold seawater. This warm water plume appears as a jet core of fairly uniform temperature within 200 m of the outfall. Outside of the surf zone the heated water rises to the surface layer and spreads laterally, with the exact shape, extent and dispersion characteristics of the warm water plume depending mainly on the power station status and the prevailing currents and sea state at the time (Koeberg Site Safety Report 2006), but even under the worst conditions the affected area is unlikely to extend more than 1 km from the outfall (Rattey and Potgieter 1987). Oceanographic modelling has demonstrated that in order to prevent recirculation of warmed water into the KNPS cooling system, cooling water from the Nuclear-1 development must be released via an offshore tunnel outfall (i.e. Layout 1 or 2 as modelled by Prestedge et al. 2009b). It is important to note that downward penetration of the plume is limited by the buoyancy of the warmed water. Should cooling water be released roughly 3.5 km from the shore at a depth of 30 m, the high velocity at which the water will leave the pipes will maximise mixing with cold seawater. In addition the proposed design of the outfall system releases the warmed cooling water from a 200 m diffuser, which prevents warmed water being released at a single point source and releases the cooling water above the sea bottom, so as to minimise thermal pollution of the benthic environment. This will be further enhanced by the buoyancy of the warm water. This design will thus minimise impacts on the benthic environment. The exact along-shore location of the outlet pipes at this site is not of importance from a marine ecology perspective.

In regular monitoring, spanning the last 26 years, no significant effects of thermal pollution have been detected in sandy beach communities at this site (Koeberg Site Safety Report 2006). While the number of species recorded during bi-annual sampling of sandy beaches has varied dramatically between six and 28 over the last 16 years, these changes reflect the natural long-term variability that typifies sandy shore communities (Griffiths and Robinson 2006). To date no invasion of warm water species has been recorded, with only a single typically South coast species, the Angular surf clam *Scissodesma spengleri* (normal range False Bay to East London) being found on a single occasion in 2003. Although regular monitoring of communities inhabiting the artificial rocky shore formed by the intake basin has not been conducted, surveys were conducted as part of the ecological baseline studies for KNPS (Cook 1984a) and again in 2007 as part of field surveys for the present environmental assessment. The only differences detected between the two time periods were the appearance of the alien barnacle *Balanus glandula* and the absence of the mussel *Choromytilus meridionalis* in the latter survey. This mussel has, however, disappeared from many west coast shores due to the extensive invasion of the alien mussel *Mytilus galloprovincialis* (Robinson *et al.* 2007). As such, this change cannot be ascribed to the release of warmed cooling water by the power station. Benthic habitats at this site also appear unaffected by the release of cooling water, as Cook (1984a) recorded no differences between benthic communities in areas that differed in their exposure to the warm water effluent. It should, however, be noted that this study took place before the power station was fully operational and no follow-up study has been undertaken subsequently. Nonetheless, the spatially limited extent and buoyancy of the warm water plume, together with these initial findings, suggest that no significant impact on subtidal benthic communities is likely.

Based on the lack of significant impacts caused by the release of cooling water by KNPS, it is similarly unlikely that the release of water warmed to 12ºC above ambient sea temperature by the proposed development will have significant impacts on the marine environment. Oceanographic modelling (Prestedge et al. 2009b) backs this conclusion, as a mean rise in sea surface temperature of 1ºC will be limited to an area of roughly 1.6 km^2 for a 4 000 MW plant. Importantly, no area of the seafloor will experience mean temperatures raised above 1ºC. The cooling water that will be released by the proposed Pebbled Bed Modular Reactor (should that development ever occur) would be released along with that of KNPS and would raise the temperature of the released water by only 1.5ºC. Thus even this cumulative impact (now unlikely to occur as the Pebble Bed Modular Reactor proposal has been shelved) is considered to be of low significance. Climate change related changes in sea temperature are not expected to alter the impact of released cooling water on the marine environment at this site. As sea temperatures appear to be cooling in this region (Rouault et al. 2009) any localised rise in sea temperature is unlikely to force any species above their thermal tolerance ranges. Any impacts from the release of warm water effluent will affect the marine environment during the operational phase of the development and will cease during the decommissioning phase.

3.1.4 Release of desalination effluent

Unlike KNPS, the proposed development will require a desalination plant. During construction, a fast track portable desalination plant will be installed to provide for all freshwater needs. This initial smaller plant will use beach wells for the intake of seawater and will discharge the brine into the ocean. A permanent desalinisation plant will function during the operational phase to provide demineralised water to the plant. Simply put, such desalination entails the removal of all salts from abstracted seawater. Typical pre-treatment of seawater required for the desalinisation process includes the use of both chlorination and de-chlorination, the addition of anti-scalant agents and surfactants, and the adjustment of pH through the addition of strong acids. The end result is purified water and a highly saline effluent. which could contain low concentrations of a variety of chemicals including sodium hypochlorite, ferry chlorite, sulphuric or hydrochloric acid and sodium hexamethaphosphate. This effluent will be released into the ocean and as such the chemical composition thereof will have to meet the requirements of the Operational Policy for the disposal of land-derived water containing waste to the marine environment of South Africa (Department of Water Affairs and Forestry 2004). Hopner and Windelberg (1996) divide the global marine habitats into 15 categories according to their sensitivities to the effects of desalination plants. According to their hierarchy, Duynefontein falls within the category of sites ranked as fourth most suitable for the construction of desalination plants, due to its location on a high-energy coast with associated upwelling. As such this site is considered the most suitable for the siting of a desalination plant.

The impacts of hypersaline effluent are generally focused on benthic communities, as brine has a higher density than seawater and thus settles on the sea bottom, where dispersion is limited (Einav *et al.* 2002). Elevated salinity can have sub-lethal effects on marine biota by altering development, metabolic and growth rates (Iso *et al.* 1994, Neuparath *et al.* 2002) as well as activity patterns (McLusky 1981). Limited information is available on species-specific responses to elevated salinity in the marine environment and includes reports of the oyster *Crassostrea gigas* tolerating salinities of up to 44 ppt (King 1977). Abalone *Haliotis midae* are known to tolerate salinities above 45 ppt when held in captivity (Hecht and Deacon 1996).

During the construction phase desalination effluent will be released independently from cooling water. While a release directly into the surf zone was first considered, recent experience with desalination plants along the South African coast (S. Lambeth, Fisheries Branch, DAFF Pers. Comm. June 2012) has prompted this option to be reconsidered. Experience has shown that, depending on bathymetry, weather and sea state, the surf zone may in fact act as a retention zone at certain times of the year (K. Hutchings, Anchor Environmental. Pers. Comm. June 2012). In order to avoid such retention it has now been decided that a piped outlet will be used. The brine will be discharged behind the surf zone from an angled diffuser so as to maximise mixing with surrounding waters. Under such conditions any impacts on benthic biodiversity are likely to be focused around the release site.

During the operational phase of this development, desalination effluent is not expected to affect the marine environment. This is due to the combination of hypersaline discharge together with the discharge of heated cooling water. Although the brine is expected to have a salinity of 58 ppt (in comparison with seawater which has a salinity of 35 ppt) this effluent will account for less than 1% of the water released. As such, the hypersaline brine will be diluted to undetectable levels within the outflow pipes, prior to release (Prestedge *et al.* 2008a). While no defined standards exist for the discharge of desalination plant effluent in South Africa, the South African Water Quality Guidelines for Coastal Marine Waters states a target range of 33 ppt to 36 ppt for salinity of effluents entering the sea (Department of Water Affairs and Forestry 1995). These guidelines will be met by this development during the operational phase. The chemicals co-released via the brine will be regulated by the Operational Policy for the disposal of land-derived water containing waste to the marine environment of South Africa (Department of Water Affairs and Forestry 2004).

3.1.5 Radiation emissions

A major concern associated with the development of any nuclear facility is the release of radiation emissions into the surrounding environment. In South Africa the National Nuclear Regulator (NNR) controls radiation emissions released into the environment. As such the proposed plant will be legally required to meet the NNR’s dose limits prior to approval. At the design level this risk has been minimised as the seawater in the cooling system never comes into direct contact with the reactor and simply cools a secondary coolant. It is important to note that at no stage is there direct contact between the reactor and the coolant, or between the coolant and the sea water.

Since the 1940s human activity has resulted in varying degrees of contamination of the world’s marine environment with anthropogenic radionuclides. Globally, the primary source of this contamination is fallout from over 520 atmospheric nuclear weapons tests (Friedlander et al. 2005). These radionuclides now occur alongside naturally occurring radioactive compounds at varying concentrations throughout the world’s oceans. In a recent review of radionuclides in the marine environment Friedlander et al. (2005) report the occurrence of a number of these compounds in marine organisms. Specifically, Cesium (Cs-137) and Strontium (Sr-90) have been found in bivalves along the west and east coast of America, in fish, mollusks, algae, seawater and sediment in Japan, in fish, seawater and sediments from the Arctic and related seas, and in fish, mollusks and crustaceans in the north Atlantic region. Equivalent data are not available for the southern hemisphere.

During routine environmental monitoring designed to detect radioactive releases into the marine environment from the KNPS, West Coast rock lobster, sediment and seawater samples have been found to be free of non-naturally occurring radionuclides (Alard 2005). Activation and fission products have, however, been detected in abalone, black mussel, fish and White sand mussel (Alard 2005). The levels detected at the KNPS have been below the levels at which further investigations or compulsory reporting to the NNR is required (Alard 2005). Importantly, due to radionuclides having been recorded in very few individual organisms at KNPS, the low concentrations at which they have been recorded and the fact that compounds at equivalent levels of radioactivity have previously been recorded in these species under natural conditions, these findings are not considered indicative of any significant effect resulting from the power station on the surrounding marine environment (Griffiths and Robinson 2005).

The likelihood of a nuclear accident affecting the marine environment is very low, as such an incident would require a breach of the entire cooling system. However, should such an event take place, the impacts are likely to be reflected in mortality focused in the general area of the power station. Highly mobile species, such as fish, exposed to low to intermediate levels of radiation may, however, move great distances. This would pose a threat to the general public if these fish were later caught and consumed.

Contamination of the marine environment by radionuclides is most likely to occur during the operational phase of this development, although even then the risk is exceedingly small.

3.1.6 Closure of the site to exploitation

Unlike at KNPS, there is no certainty that a mandatory security exclusion zone will be imposed in the marine habitat seawards of the proposed NPS. Instead a much smaller safety zone (800 m around the power station and 1 km out to sea) is likely to be implemented. The exact dimensions of a potential security zone out to sea are yet to be decided upon and are dependent on a recommendation by the National Key Points Act. As this site falls within the footprint of the KNPS, exploitation of marine resources is already prohibited in the area and no additional benefit will be gained from a further security exclusion zone.

3.1.7

3.1.8 Release of sewage effluent

During the construction and operational phases a sewage waste water treatment plant will treat a maximum of 1000 m^3 of water per day on site. Following treatment, this effluent may be discharged into the ocean via the cooling water outfall tunnels. As required by the Department of Water Affairs, this water will meet the required standards as set out in the South African Water Quality Guidelines for Coastal Marine Waters at the point of release. As such no significant impact on the marine environment is anticipated.

3.1.9 Unintentional discharge of polluted groundwater

The geohydrological specialist study has indicated that due to the proximity of the site of the proposed development to the coastline, it is located in a groundwater discharge zone. As a result, any polluted groundwater will discharge to the sea. Nonetheless, the study indicates that any pollution may be focused in a small area, and contaminants will dissipate. During the construction and operational phases potential pollution of groundwater and the subsequent contamination of the marine environment may originate from leaks and spillages from both on-site sanitation facilities, as well as from fuel, oil and grease storage facilities.

Organic enrichment of the marine environment along the South African west coast is associated primarily with the release of fish offal and mariculture operations in harbours, such as Saldanha Bay (Kruger *et al.* 2005). Such enrichment leads to a reduction in species diversity with numerical dominance of a few well-adapted species (Carvalho *et al.* 2006). Although the effects of organic enrichment of sheltered marine habitats, such as bays and harbours, can be dire, it is unlikely that such impacts will be observed along the highly wave-exposed shoreline around the proposed development. This is due to the extremely exposed nature of the coastline and the resulting mixing of nearshore waters, which would quickly dissipate any contaminants. Should pollution of groundwater by accidental spills of fuel, oil or grease occur, the possibility exists that contaminants could be passed through to the marine environment. Such pollution has been demonstrated to dramatically affect organisms in both intertidal and benthic habitats with recovery only occurring after a number of years in some cases (Lu and Wu 2006). Again the dynamic nature of the recipient nearshore environment is likely to aid in the dilution and dissipation of any contaminants.

3.1.10 Impacts of the environment on the proposed development

The potential impacts of marine biota on the proposed plant stem from the blockage of water intakes by jellyfish and floating kelp and the fouling of cooling pipes. Such impacts will be focused within the operational phase. Medusae of the phylum Cnidaria (jellyfish) and planktonic forms of the phylum Ctenophora (comb-jellies) are well known to cause blocking of power station cooling systems when they reach high densities (Mills 2001). During initial studies on the entrainment of plankton at KNPS, Huggett (1987) recorded medusae of the species *Obelia, Bougainvillia* and *Muggiaea* and a number of ctenophores with *Pleurobrachia pileus* being the dominant species. While large individuals of both groups were effectively excluded from intake water by screens, smaller individuals were taken up (Huggett 1987). Entrainment mortality of both medusae and ctenophores is surprisingly low and high survival rates may be explained by a remarkable tolerance of these organisms to the chlorination and temperature changes associated with entrainment. Considering the noticeable increase in jellyfish along the South African west coast since the 1970s (Mills 2001) and the high probability of this being linked to climate change (Richardson *et al.* in press), the probability of high densities of these organisms blocking the cooling water system of a proposed power station in this area appears to be increasing.

3.2 Bantamsklip

3.2.1 Disruption of the marine environment during construction

At this site a CW uptake tunnel pipeline will be used to supply cooling water to the proposed power station and either a near shore channel or six to eight CW outflow pipes will be used to release the warmed cooling water back into the marine environment. As described for Duynefontein, the tunnelling process and the building of a temporary cofferdam or basin will result in temporary, severe but localised disruption to the marine environment.

Additionally, the benthic habitat is at risk due to the discarding of 10.07 million m^3 spoil from the excavation of the intake tunnel, intake basin, nuclear island and turbine hall. Oceanographic modelling of the characteristics of the turbidity plume and the sediment on the sea floor resulting from the discard of spoil was undertaken by Prestedge *et al.* (2009a). Details of the various disposal alternatives are given in Table 5 and Prestedge *et al.* (2009a). In order to avoid impacting the highly threatened abalone *H. midae* at this site, we strongly recommend that disposal of spoil must occur offshore ('Deep'[4] alternatives below). For contrast sake, disposal at both a shallow nearshore site and a deep offshore site are assessed in Table 7. Considering this constraint, Alternatives 4, 5 and 6 (i.e. either the full or half the volume of spoil disposed offshore at either a medium[5] or high[6] flow rate) are considered preferable. For the deep alternatives the area near the sea floor exposed to turbidity above 80 mg/l for greater than two days is expected to vary between 16.4 (Alternative 4) and 3.8 km^2 (Alternative 6). Following placement on the seabed, roughly 3 m of sediment will cover an area of 1.5 or 3 km^2, depending on whether only half or the full volume of sediment is disposed of. Following disposal, local water movement will result in shifting of this spoil. As no major currents flow in this region, oceanographic modelling indicated that within the first five years following disposal the sediment is likely to spread to cover an area of between 6 km^2 (Alternative 4) and 3.5 km^2 (Alternative 6) with more than 1 cm of sediment. Importantly as much as 32 % and 40 % of this covering of sand is expected to be between 0.5 cm and 1 cm deep. Due to the slow moving nature of this sediment and the lack of organic content, this sediment is expected to be progressively colonised by sandy bottom species and ultimately to support communities similar to those of surrounding undisturbed areas within 5 to 10 years.

[4] 52 m
[5] 2.06m^3/s
[6] 3.93m^3/s

Table 5. Details of the proposed spoil disposal alternatives for Bantamsklip (From Prestedge *et al*. 2009a).

Alternative	***Depth***	***Distance from shore***	***Sediment volume***	***Discharge rate***
Alternative 1	***Shallow (21 m)***	***1.8 km***	***10.07 million m^3***	***3.93 m^3/s***
Alternative 2	***Shallow (21 m)***	***1.8 km***	***10.07 million m^3***	***2.06 m^3/s***
Alternative 3	***Shallow (21 m)***	***1.8 km***	***5.04 million m^3***	***2.06 m^3/s***
Alternative 4	***Deep (52 m)***	***6 km***	***10.07 million m^3***	***3.93 m^3/s***
Alternative 5	***Deep (52 m)***	***6 km***	***10.07 million m^3***	***2.06 m^3/s***
Alternative 6	***Deep (52 m)***	***6 km***	***5.04 million m^3***	***2.06 m^3/s***

Both the disruption due to the construction of the cooling system and the discarding of spoil are of particular concern for the abalone *Haliotis midae*, which will experience mortality due to physical damage to individuals and smothering by fine sediments. This gastropod has been severely over-fished along the South African coast. As Bantamsklip falls within a small area that currently supports the largest remaining stocks of this species (G. Maharaj, Marine & Coastal Management, DEAT Pers Comm) the loss of any potential recruits is very undesirable. Thus, it is vital that disposal of spoil occur offshore (6 km) to minimise impacts on the abalone population, which are concentrated well inshore of the offshore disposal sites.

All cetacean species are likely to avoid the impact site during the construction phase of the cooling water intake system, due mainly to noise aversion. As discussed in section 3.1.1 above, there are multiple possible impacts of sound on whales and dolphins, especially during the construction phase of the project. The two populations most at risk in this area are the humpback dolphin and southern right whale mother-calf pairs, both of which use very shallow waters almost exclusively. It is important to consider that this shallow water habitat is effectively a long narrow strip and it may be difficult for animals to avoid disturbances therein or even 'go around' them, given the range at which sounds can be heard. To mitigate the risk of injury and disturbance to these animals it is strongly recommended that a marine mammal observer is used during any construction activities that require drilling or pile driving.

The disposal of spoil is unlikely to affect the cetacean species using the area. Bottlenose dolphins, humpback dolphins and southern right whales all use very coastal and often murky waters as part of their natural habitat range, while the more offshore species move over large spatial scales and are likely to avoid any plumes.
Although sharks are visual predators, the disposal of spoil is not expected to significantly impact Great white sharks. Prestedge *et al.* (2009a) showed that for the worst case scenario (Sediment disposal Alternative 4), suspended sediment concentrations above 80 mg/l at the water surface will be restricted to less than 1 km^2 and will occur for no more than two days (note that the level of 80 mg/l has previously been identified as a threshold above which probable adverse ecological effects will occur). Maximum suspended sediment concentrations reaching the Dyer Island remain five times below the ecological threshold of 80 mg/l, with turbidity above this level remaining at least 300 m clear of the Island (Prestedge *et al.* 2009a). This demonstrates that the plume will be spatially and temporally restricted, thus not impacting significantly on the sharks around the island.

Disruption due to tunnelling and the laying of pipes will be focussed within the construction phase and although severe, is likely to be localised and short-lived. The impact will be the same regardless of the output of the plant. In contrast, the discarding of spoil during the construction phase will have long-lived effects. The impact will be the same regardless of the output of the plant.

Depending on the final location of the nuclear plant, the construction process may disrupt a flock of Cape cormorant *Phalacrocorax capensis*, which roost at this site. This impact will be temporary and confined to the construction phase.

While some fish species show site fidelity and localised populations may be displaced from their home ranges (but not killed) during the construction phase, these species all occur over a wide geographic area and the specific populations at the affected site are not of exceptional conservation concern.

3.2.2 Abstraction of cooling water and subsequent entrainment of organisms

Although the impacts of cooling water abstraction and the resulting impacts on plankton have not been quantified for this site, as they have been for Duynefontein, the Koeberg experience does still offer useful insight into possible effects. Nonetheless, it should be noted that the effect of chlorination is likely to be more important at this site, as the toxicity of chlorine will be elevated by the slightly higher ambient sea temperatures (Huggett and Cook 1991) (maximum sea surface temperature for this site is 21.3ºC compared to 19ºC at Duynefontein (Shillington 2007). Nonetheless, climate change induced long-term decreases in nearshore sea surface temperatures have been recorded for this section of coast (Rouault *et al*. 2009) and may help to offset the negative effects of the higher water temperatures. As the productivity of south coast nearshore waters does not match that of the west coast, entrainment of plankton at Bantamsklip will be lower and is not likely to have a significantly negative impact on the marine environment in general, given the rapid turnover of planktonic species. It is likely that fish eggs from this area will demonstrate similar resilience to entrainment, as has been recorded at KNPS. However, entrainment of eggs, sperm or larvae of the abalone *H. midae* is of greater concern. Despite the presence of screens to exclude organisms from the cooling system and the low flow rate of intake water, eggs, sperm and larvae of this species will be impossible to exclude, due to their small size. However the further offshore the uptake pipes are located the less likely that abalone eggs, sperm and larvae will be entrained.

Due to the slow rate at which water will be taken into the cooling system (i.e. a maximum intake rate of 1 m/s), water flow will not be strong enough to entrain larger more mobile organisms, such as penguins, fish and marine mammals. In addition, filters used will have a grid size small enough to exclude fish and other larger biota from the intake pipes.

The impacts resulting from abstraction and entrainment will occur during the entire operational phase of the development.

3.2.3 Release of warmed cooling water

The impacts of releasing thermal effluent remain untested for this site, as no comparable operation has functioned in this area to date. The species most at risk due to thermal pollution are those that occur near the upper limits of their thermal range. As few species in this area have distributions predominantly along the cold west coast (only two rocky shore and no sandy shore species with such distributions were recorded during field surveys) it is unlikely that many organisms fall within this category.

Again the species of greatest concern is the abalone *H. midae.* Along the west coast this species demonstrates a temperature tolerance range of 8-24ºC, while temperatures above 26ºC have been found to induce acute temperature stress with mortality following rapidly (Department of Water Affairs and Forestry 1995). Although thermal tolerance levels have not been established for individuals along the south coast, there is no reason to suspect any differences in temperature tolerance between regions. It should be noted that no thermal tolerance has been established for gametes and larvae of this species. While *H. midae* occur up to depths of 23 m (Newman 1969), along this section of coast, approximately 80% of the population occurs in the 0-5 m depth range (Tarr 1993). The above adult distribution, combined with the fact that the degree of larval dispersal is thought to be fairly limited, as spawned ova stay in suspension for only a few minutes and *H. midae* has a short planktonic larval stage (Genade 1988), temperature changes in the depth range of 0-5 m are of greatest concern.

Based on a background temperature of 17ºC (i.e. the temperature used in the oceanographic models by Prestedge *et al.* 2009b) *H. midae* adults will be able to tolerate a maximum temperature increase near the sea bottom of 7ºC. Oceanographic modelling indicates that for an offshore tunnel releasing at a depth of 25 m the mean increase in temperature will not exceed 1ºC near the seabed (Prestedge *et al.* 2009b). However, for a nearshore release a mean increase of 7ºC or more near the seabed will affect an area of roughly 0.5 km² for a 4 000 MW plant and 1.5 km of shoreline will experience an maximum increase of 7ºC or more at depths of 0-10 m. As such, it is clear that a nearshore release system will cause mortality of *H. midae* adults in the immediate area of the outlet. What is unclear is the effect that elevated temperatures will have on the gametes of this species, although the impact is likely to act over a larger area, as gametes occur in the water column where temperature increases will be greater. Based on the above impacts the release of cooling water in the nearshore should be totally avoided. The release of cooling water further offshore will significantly reduce the impacts on this species and only this option will be considered further. Although significant climate change induced decreases in sea surface temperature have been measured in this region and are predicted to continue (Rouault *et al.* 2009), these decreases are unlikely to reduce the severity of this impact, as temperatures have declined at a rate of less than 1 ºC in the last two decades. Besides the direct effects on abalone, indirect effects could also result if the kelp on which this species feeds is negatively affected by elevated temperatures. While this will most certainly occur if a nearshore channel release is used, an offshore release system will prevent temperatures in the 0-10 m depth range (within which kelp occurs) from increasing by more than 4 ºC at any time, this being predicted to maintain temperatures within the thermal tolerances for both *Ecklonia maxima* (Bolton and Anderson 1987) and *Laminaria pallida* (Cook 1978).

The release of warmed cooling water is not expected to have a dramatic impact on nearshore fish species, as excess heat will be focused around a small area at the point or points of release and the warmed water will hence rise towards the surface. Many species currently caught by anglers at this site in fact breed in the warm waters of KwaZulu-Natal and so, while they may avoid the immediate point of release, where water temperatures will be highest, they are very unlikely to experience thermal stress. A similar scenario is likely to face the White shark *Carcharodon carcharias.* These mobile predators may avoid the source of warm water release, but will not be forced to the limits of their thermal tolerance once the heat has begun to dissipate. Although the exact temperature tolerance range for this species has not been established, the fact that it occurs in areas both warmer (off the warm Mozambique coast) and colder (off the cold South African west coast) than Bantamsklip is indicative of its broad temperature tolerance. Oceanographic modelling of the warm water plume has indicated that the temperature around Dyer Island (a popular site used by the shark cage diving industry) will not be affected. None of the marine mammals that occur in the vicinity of Bantamsklip are expected to be negatively impacted by the warmed water. This is due to the localised extent of the warmed water relative to the extensive ranges of these large species, combined with their mobility and ability to avoid undesirable conditions. As such, these species are likely to avoid the elevated temperatures immediately around the outfall, but are not expected to avoid the area in general. A similar response is likely to be demonstrated by some coastal fish, but no species are expected to be lost to the area. In fact, exploited fish species may benefit from the development (see section 3.2.6 below). Pelagic fisheries will not be affected by the release of warmed water, as they are focused further offshore than the outfall plume will reach.

Although predicted, but never in fact recorded at KNPS, the potential does exist for the establishment of warm-water species that do not currently occur at this site, but this would occur only over a very small area.

Impacts due to the release of warm water effluent will occur during the entire operational phase of the development.

3.2.4 Release of desalination effluent

The potential impacts of desalination on the marine environment have been described above for the Duynefontein site and remain the same for Bantamsklip. According to the classification of Hopner and Windelberg (1996) this site falls into the category fifth most suitable for construction of a desalination plant (out of fifteen categories). This ranking is due to the large intertidal areas present at this site, which offer large sediment surfaces. However, water exchange and sediment mobility are high.

3.2.5 Radiation emissions

As described above the most likely pathway for the release of radiation into the marine environment is through the release of contaminated cooling water. The dose limits allowed are, however, set by the NNR in the requirement document, RD-0022 and the development will not be approved if these limits are not met by the plant. The lack of any releases exceeding the limits at KNPS in over 20 years of operation indicates that such radiological releases are most unlikely and thus the same could be said for Bantamsklip. However, it is essential that monitoring of marine species be carried out, so as to maintain a close watch on the levels of non-naturally occurring radionuclides. In particular, radionuclide levels should be monitored in the abalone *H. midae* due to the extremely high commercial value of, and demand for, this species.

This impact has the potential to affect the marine environment throughout the operational phase.

In the unlikely event of a nuclear accident affecting the marine environment, mortalities will be focused in the general area of the power station. Highly mobile species, such as fish or sharks, exposed to low to intermediate levels of radiation may, however, move great distances. This could pose a threat to public health if these fish were later consumed.

3.2.6 Closure of site to exploitation

The closure of Bantamsklip to exploitation of marine resources due to the implementation of a safety zone around the proposed power station could offer much needed protection to local populations of the abalone *H. midae.* It should be noted, however, that the level of organisation and the brazenness of poachers in this area will necessitate dedicated active policing of this exclusion zone if this benefit is to be realised. It is anticipated that while Eskom will be responsible for monitoring access to the area (regulated assess by the public may well occur), the South African Police Services will be responsible for law enforcement in the zone. While this indirect approach has worked well at KNPS, the level of organised crime associated with abalone poaching in this region has resulted in this practise occurring relatively unchecked, despite the best effort of the police. As such the degree of benefit derived by abalone populations remains unclear. Depending on the conditions associated with regulated access to the safety zone, shore anglers may be excluded from this prominent fishing area. Although a detailed assessment of the line fish stocks in this area has not been made, Attwood and Farquar (1999) found these species to be significantly depleted in the area to the west of Bantamsklip, between Cape Hangklip and Walker Bay. As there is no reason to assume that stocks are in a better state at this site, an exclusion zone could offer a protected area for these species. It is envisaged that kelp harvesters will be granted access for harvesting, subject to the necessary permits being secured through DWA. Such access will be controlled by a permit issued by Eskom. This impact would continue to occur throughout the operational, decommissioning and closure phases.

3.2.7 Release of sewage effluent

This impact is described above for Duynefontein and remains the same for Bantamsklip.

3.2.8 Unintentional discharge of polluted groundwater

As at Duynefontein the potential exists for the discharge of organic, bacterial and hydrocarbon contaminants into the marine environment is via polluted ground water. Potential impacts on marine habitats are described above for Duynefontein and remain the same for Bantamsklip.

3.2.9 Impacts of the environment on the proposed development

Unlike at Duynefontein, the potential impacts of the marine environment on the proposed plant do not include the threat of blockage of water intakes by jellyfish, as high densities of these species are restricted to the west coast. However, the extensive kelp beds in the area do pose some threat, especially after winter storms, when drift kelp is common.

3.3 Thyspunt

3.3.1 Disruption of the marine environment during construction

As at the other sites, the construction of an intake and outfall system for cooling water will result in temporary but severe localised disruption to the marine environment. Under such circumstances the benthic habitat and in particular egg beds of the chokka squid *Loligo reynaudii* are at risk of damage due to smothering, while turbidity will result in adults temporarily moving out of the area. In addition, there may be populations of the endangered abalone *H. midae* in this area. As this species occurs to a depth of 23 m (Newman 1969) it would be affected by physical damage to individuals and smothering by fine sediments during the construction phase, if present. This disturbance will be focussed within the construction phase and is likely to be localised and of short duration. As hard substratum will only be introduced into the marine environment in the form of the openings of the two intake pipes and outflow pipes (a maximum of 10), the introduction of hard substratum to the marine environment will be negligible.

Additionally, the discarding of an estimated 6.37 million m^3 of spoil from the excavation of the nuclear island, turbine hall and contractors' yards hall poses a threat to the marine environment. As described for the previous two sites mentioned in this report, both the physical and biological marine environment would be affected. From a biological perspective impacts would occur due to increased turbidity in the water column as a result of the suspension of fine particles and due to smothering of the benthic habitat by spoil placed on the sea floor. The characteristics of these two components and how they are affected by oceanographic conditions have been modelled by Prestedge *et al.* (2009a). These models considered the disposal of both the full volume and half the volume of spoil at both a shallow[7] and deep[8] site. In addition, both a medium and high discharge rate were included. Details of the various disposal alternatives are given in Table 6 and Prestedge *et al.* (2009a). At this site only Alternatives 5 and 6 (i.e. disposal of all or half the spoil at a deep site using a medium discharge rate) are considered acceptable from a marine ecology perspective. The exclusion of Alternative 4 at this site is due to the fact that this option makes use of a high discharge rate, which elevates turbidity in the water column, which is unfavourable to squid. In addition, offshore disposal at a deep site will prevent impacts on abalone populations that may occur in the area, as these gastropods occur to depths of less than 23 m (Newman 1969). For comparison, the impacts of disposal at a shallow nearshore site are also assessed in Table 8.

Table 6. Details of the proposed spoil disposal alternatives for Thyspunt (From Prestedge *et al.* 2009a).

Alternative	***Depth***	***Distance from shore***	***Sediment volume***	***Discharge rate***
Alternative 1	***Shallow (57 m)***	***1.8 km***	***6.37 million m^3***	***3.93 m^3/s***
Alternative 2	***Shallow (57 m)***	***1.8 km***	***6.37 million m^3***	***2.06 m^3/s***
Alternative 3	***Shallow (57 m)***	***1.8 km***	***3.19 million m^3***	***2.06 m^3/s***

[7] 57 m
[8] 84 m

Alternative 4	***Deep (84 m)***	***6 km***	***6.37 million m^3***	***3.93 m^3/s***
Alternative 5	***Deep (84 m)***	***6 km***	***6.37 million m^3***	***2.06 m^3/s***
Alternative 6	***Deep (84 m)***	***6 km***	***3.19 million m^3***	***2.06 m^3/s***

Elevated turbidity related to the disposal of spoil is likely to impact on adult *L. reynaudii* squid, as visual cues are important in the formation of spawning aggregations (Roberts and Sauer 1994) and the mating process (Hanlon et al. 2002). It is important to note, however, that this region experiences natural bottom-turbidity events that last for several days (Dorfler 2002, cited in Downey et al. 2010). Under these conditions the squid move offshore to spawn (Roberts and Sauer 1994). Besides adults, squid paralarvae have physiological constraints that place them at risk due to elevated turbidity levels . This can result in impaired movement, impaired respiration and starvation due to inability to catch prey (Lipinski pers comm.). In order to assess the impacts of elevated turbidity on squid paralarvae, the Squid Scientific Working Group (SSWG) of the DAFF undertook Individual Based Modelling (IBM) (See Appendix 6 for details). The modelling approach was conservative and considered a 'worst-case' scenario, whereby turbidity levels above 20 mg/l resulted in 100% mortality of paralarvae. The area affected by this level of turbidity was extracted from Prestedge *et al.* 2011). Results of this process showed that even under this 'worst-case' scenario, only 5% of paralarvae are expected to encounter the turbidity plume and suffer mortality. This mortality can be further decreased by disposing of spoil during the winter months, when spawning is at a minimum (SSWG, Appendix 6). For spoil disposal alternatives 5 and 6, the maximum suspended sediment concentration is not expected to reach levels above 80 mg/l near the water surface at any time during, or after, disposal (Prestedge *et al.* 2009a) and will be confined to less than 1.4 km² near the seafloor. In addition, these turbidity levels will be very temporally limited outside the actual disposal site, occurring for a maximum of two days throughout the entire disposal period (Prestedge *et al.* 2009a).

Following disposal on the seafloor, roughly 3 m of sediment will cover an area of 1.5 or 3 km², depending on whether only half or the full volume of sediment is disposed of. Subsequently, local water movement will result in shifting of the spoil in a north-easterly direction towards Seal Point. Within the first five years following disposal the sediment is likely to spread to cover an area of between 8.3 km² (Alternative 5) and 6 km² (Alternative 6) with sediment to a depth of between 0.5 and 1 cm. In the next five years loose sediment originally placed on the disposal site is expected to continue to spread towards Seal Point (Prestedge *et al.* 2009a). If Alternative 5 (i.e. disposal of the full volume of sediment) is employed this spoil is likely to spread to cover a small area of less than 0.01 km² in the small bay east of Seal Point in 0.5 – 1 cm of sediment. If Alternative 6 (i.e. disposal of only half the volume of spoil) is utilised, this area will not be affected. The initial disposal site will definitely be lost as a breeding area to *L. reynaudii*.It is possible that adults will avoid the area to which the sediments spread during spawning. This would in turn result in no spawning aggregations forming in the impacted area (SSWG, DAFF Appendix 6) and a displacement of aggregations which are targeted by the squid fishery. Importantly, sediments will not spread into St Francis Bay (Prestedge *et al.* 2009a) and the areas where extensive egg beds were recently recorded by Roberts and Mullon (2010). In considering the impact of spoil on loss of spawning habitat the SSWG assumed a 'worst-case' scenario that any area covered by more than 0.5 cm of sediment would be permanently lost as suitable spawning habitat (Appendix 6). This conservative approach thus considered the loss of 18.1 km² of habitat (i.e. it includes the area to where spoil will move through time). This represents a loss of 20.5% of those nearshore spawning sites that have been recorded between Tsitsikamma and Algoa Bay (Sauer *et al.* 1992). It should be born in mind that the species is also known to spawn off-shore (Roberts and Mullon 2010). Information provided by the SSWG indicated that the two fishing blocks adjacent to Thyspunt that will be affected by spoil disposal accounted for an average of 13.43% of total catches between 2006 and 2011 (Appendix 6). By applying the precautionary principle and assuming that all spawning grounds in this these blocks would be lost due to spoil disposal, it is predicted that all 13.45% of catches would be displaced to other fishing blocks, as adult squid move to new spawning grounds.

Unlike at the other two sites, sandy bottom communities establishing within sediment originating from the disposal of spoil are likely to be dissimilar to those of surrounding areas. This is due to the fact that this site is dominated by consolidated sands (Prestedge *et al.* 2009a), which will naturally support different biotic communities to those occurring in loose sediments, such as those derived from spoil.

While some fish species show site fidelity and may be displaced from their home ranges during the construction phase, these species are widely dispersed along the South African coast. Thus while individuals may be affected, the species concerned will not be compromised and recovery is expected once the benthic community re-establishes.

All cetacean species are likely to avoid the impact site during the construction phase of the cooling water intake system, due mainly to noise aversion. As discussed in section 3.1.1 above, there are multiple possible impacts of sound on whales and dolphins, especially during the construction phase of the project. The two populations most at risk in this area are the humpback dolphin and southern right whale mother-calf pairs, both of which use very shallow waters almost exclusively. It is important to consider that this shallow-water habitat is effectively a long narrow strip and it may be difficult for animals to avoid disturbances therein or even 'go around' them, given the range at which sounds can be heard. To mitigate the risk of injury and disturbance to these animals, it is strongly recommended that a marine mammal observer is used during any construction activities that require drilling or pile driving.

The disposal of spoil is unlikely to affect the cetacean species using the area. Bottlenose dolphins, humpback dolphins and southern right whales all use very coastal and often murky waters as part of their natural habitat range, while the more offshore species move over large spatial scales and are likely to avoid plumes.

3.3.2 Abstraction of cooling water and subsequent entrainment of organisms

As with Bantamsklip, the effects of cooling water abstraction and the resulting impacts on plankton have not been quantified for this site. Again higher ambient water temperatures than those occurring at KNPS (i.e. maximum and minimum sea surface temperatures of 22.5 and 16.6ºC respectively (Shillington 2007)) are expected to increase the toxicity of chlorination (Huggett and Cook 1991) when compared to the west coast site. Long-term climate change induced decreases in sea-surface temperatures along this section of coast (Rouault *et al*. 2009) are unlikely to offset this effect as temperatures have decreased at a rate of less than 1°C in the last two decades. The lower productivity of nearshore waters along the south coast, when compared to the west coast (Bustemante *et al.* 1995b), will result in less plankton being taken up at this site than at the KNPS. The fact that no significant entrainment impacts have been forthcoming at the KNPS thus suggests that little impact is to be expected at the Thyspunt site. Should populations of *H. midae* occur at this site, entrainment of eggs, sperm or larvae would unavoidably occur. No other species of commercial value (including *L. reynaudii* squid) are likely to be affected by entrainment. This view is supported by the SSWG (Appendix 6). As at the other potential sites technical design aspects and screens will prevent the uptake of larger marine organisms, such as squid, fish and marine mammals. The exact positioning of the uptake pipes is not of importance from a marine ecology perspective. The impacts resulting from abstraction and entrainment will occur during the entire operational phase of the development.

3.3.3 Release of warmed cooling water

No input of warmed water comparable to that of the proposed development exists along this section of coast. As this site lies at the warm end of the Agulhas Bioregion it could be argued that a portion of species occurring here may be near the upper end of their temperature tolerance range and hence could be particularly vulnerable to further temperature increase. Although theoretically possible, this is however, unsubstantiated.

The fishery of greatest importance in the Thyspunt area is the coastal jigging fishery for chokka squid *L. reynaudii.* The major coastal spawning grounds of this species occur between Plettenberg Bay and Algoa Bay and it is here that these squid are targeted during the spawning season. Adult squid are adapted to a wide temperature range of between 8 and 22ºC and are able to cope with rapid changes in water temperature, which allow them to move easily through thermoclines (Augustyn *et al.* 1994). Although the exact role of temperature in the spawning process is not fully understood (Downey *et al.* 2010), a drop in temperature associated with upwelling may trigger spawning (Roberts 1998). This is reflected in catches by the fishery peaking following drops in temperature resulting from coastal upwelling (Sauer *et al.* 1991), and a general trend of decreasing catches with increasing water temperatures (Schon 2000, cited in Downey *et al.* 2010). It should be noted, however, that temperature alone does not control spawning, but rather a complex interplay between a variety of factors, such as dissolved oxygen, temperature, turbidity and swell size, is thought to be important (Roberts and Sauer 1994, Roberts 1998). The egg capsules of this species are deposited directly onto the seafloor and develop optimally at temperatures between 12 and 20ºC (Augustyn *et al.* 1994, Oosthuizen *et al.* 2002, Roberts 2005). At temperatures above 22ºC egg development is retarded and mortality increases (Sauer *et al.* 1991) and above 24ºC, 100% mortality is reached (Augustyn *et al.* 1992). In their early planktonic existence, squid paralarvae demonstrate lower survival rates at temperatures between 16ºC and 19ºC than at 12ºC (Martins *et al.* 2010), indicating that this life stage would also be vulnerable to elevated water temperatures.

Based on a background temperature of 19ºC (i.e. the temperature used in the oceanographic models by Prestedge *et al.* 2009b) egg beds will be able to tolerate a maximum temperature increase near the sea bottom of 3ºC. While the previous version of this report considered only an offshore outflow release of warmed water, this report considers an additional alternative, that of a nearshore outfall. Oceanographic modelling indicates that if a nearshore outfall is used a mean increase of 3ºC near the seabed will be limited to an area of roughly 0.2 km^2 (2 ha) around the outlets of a 4 000 MW plant and an area of 0.7 km^2 will experience a maximum increase of 3ºC or more at any time (Prestedge *et al.* 2009b). This temperature increase will be focused at depths shallower than 15 m. Modelling also showed that if an offshore outflow system is used for a 10 000 MW plant, the seafloor would not experience an increase in water temperature, while a mean increase of 3ºC would affect less than 2.5 km² near the surface (Prestedge *et al* 2008b). It is important to note that models were not constructed to consider this release system for a 4 000 MW plant, but its impact would be less than that of the larger 10 000 MW plant. As egg beds are laid down predominantly in areas shallower than 50 m (unless unfavourable conditions force adult squid offshore) (Roberts and Sauer 1994), a certain amount of egg mortality is expected. However, this would be minimised if the deep offshore outflow alternative was selected.

As squid paralarvae may be affected by elevated water temperature due to increased metabolic demands the SSWG undertook Individual Based Modelling in order to quantify potential effects of the released warm water on this life stage (for full details see Appendix 6). This model was conservative, in that it assumed a 'worst-case' scenario that the area experiencing a temperature increase of only 2°C above ambient represented 100% mortality to larvae. Results of this process showed that only 5.28% of paralrvae will be impacted by the release of warm water, even under this worst case scenario (Appendix 6).

It is expected that adults will avoid an area of about 0.2 km² if a nearshore release is chosen where they are likely to experience temperatures above 22ºC and a certain amount of egg mortality is to be expected. Nonetheless, the area to be affected is less than one percent of the coastal spawning ground centred between Plettenberg Bay and Port Alfred (Roberts and Mullon 2010, SSWG (Appendix 6)). If an offshore outflow site is chosen, this impact will be marginally (although not significantly) reduced as the water column will still experience elevated temperatures although the seafloor will not. It is also important to note that individuals of this species show no dependence on specific spawning grounds and move great distances between spawning grounds (Sauer et al. 2000). As such, adults avoiding the warm water plume are likely to simply move to another spawning ground (SSWG Appendix 6). Nonetheless, it is possible that long-term changes in squid migration patterns could result due to changes in water temperature (SSWG Appendix 6).

As described for Bantamsklip in section 3.2.3 above, the known temperature tolerance range for abalone is 8-24ºC, while temperatures above 26ºC have been found to induce acute temperature stress with mortality following rapidly (Department of Water Affairs and Forestry 1995). Although this thermal tolerance range was established along the west coast, there is no reason to suspect any differences in temperature tolerance between regions. Based on a background temperature of 19ºC (i.e. the temperature used in the oceanographic models by Prestedge *et al.* 2009b) abalone will be able to tolerate a maximum temperature increase of 5ºC near the sea bottom. Oceanographic modelling has shown that for a nearshore release at 5 m depth at the Thyspunt site, a localised area of roughly 0.01 km² will experience an increase of 5ºC or more at the sea floor. Modelling of the thermal plume for a 10 000 MW plant indicated that for an offshore release the seafloor will not experience an increase in temperature and an area of less than 1.5 km² at the water surface will experience an increase of 5ºC or more (Prestedge *et al* 2008b). Note modelling results for the offshore release represent the effect of a much larger plant than the proposed 4,000 MW of the Nuclear-1 development. As such, the area affected by the Nuclear-1 development would be much smaller than 1.5 km².

As at Bantamsklip, the release of warmed water is not predicted to have a significantly negative effect on fish, or marine mammals. This is due to their mobility and ability to avoid the localised warm water plume. In addition all of these species have wide-ranging distributions, which extend far beyond the Thyspunt area. Although these species are likely to avoid the elevated temperatures immediately around the outfall, they are not expected to avoid the area in general. Impacts on these species are expected to be the same regardless of the choice of outflow alternative.

At Thyspunt there is notable potential for the establishment of new warm-water species, due to the already high ambient sea temperatures at this site and its proximity to the sub-tropical Natal marine bioregion, which could act as a source of immigration of warm-water species. Climate change related declines in sea surface temperature in this region (Rouault *et al*. 2009) are unlikely to reduce the risk of establishment of warm water species, as water temperatures have declined by less than 1ºC over the last two decades. Should the establishment of warm water species occur, it is, however, unlikely to have dramatic impacts on the local ecology, as immigrant species will be restricted to a small area warmed to within their thermal tolerance range by the plume.

3.3.4 Release of desalination effluent

The potential threats to the marine environment resulting from desalination are described above for the Duynefontein site and remain the same for Thyspunt. The release of effluent at this site will occur in a sandy area to the east of Seal Point. According to the classification of Hopner and Windelberg (1996) this site falls into the category fifth most suitable for construction of a desalination plant (out of fifteen categories). This ranking is due to the large intertidal areas present at this site, which offer large sediment surfaces. Water exchange and sediment mobility are, however, high. The fact that little if any abalone habitat occurs in this area means that abalone are not expected to be affected by the release of desalination effluent during the construction phase. The release of desalination effluent is unlikely to impact on the squid resource or fishery.

3.3.5 Radiation emissions

As described for both Duynefontein and Bantamsklip the most likely source of radiological releases into the marine environment is the release of contaminated cooling water. These releases will, however, be controlled by the National Nuclear Regulator. The KNPS experience has demonstrated that such radioactive contamination is very unlikely. It is, however, vital that monitoring of radionuclide levels in marine species be carried out. In particular, radionuclide levels should be monitored in chokka squid *Loligo reynaudii* which are caught in the area and abalone *Haliotis midae,* which may be removed as part of the proposed experimental fishery in the region.

This impact may affect the marine environment during the operational phase of the development.

In the improbable event of a nuclear accident affecting the marine environment, mortalities are expected to be focused in the general area of the power station. Highly mobile species, such as fish, exposed to low to intermediate levels of radiation may, however, move great distances. This could pose a threat to public health if these fish were later consumed.

3.3.6 Closure of the site to exploitation

As access to this site has been restricted for well over a decade, no additional benefit will be gained by closure of this site to exploitation. Development of a power station at this site will, however, prevent future exploitation of marine resources within any safety exclusion zone. Should the dimensions of the safety zone be confirmed as an area 800 m around the power station and 1 km out to sea, the exclusion zone is not anticipated to significantly affect the chokka squid fishery, due to its small size relative to the vast area over which this fishery operates. This view is supported by the SSWG (Appendix 6). This fishery's efforts are focused, but not restricted, to the area between Plettenberg Bay and Algoa Bay (Augustyn *et al*. 1992). This impact would act throughout the operational, decommissioning and closure phases of the development.

3.3.7 Release of sewage effluent

This impact is described above for Duynefontein and remains the same for this site.

3.3.8 Unintentional discharge of polluted groundwater

Potential impacts associated with the release of ground water containing organic, bacterial or hydrocarbon contaminants have been described for the Duynefontein site and remain the same for Thyspunt.

3.3.9 Impacts of the environment on the proposed development

Jellyfish do not pose a large threat to the cooling water system of a proposed power station, as these organisms simply do not reach high enough densities along this section of coastline. Kelp is also absent from this region The dominant threat to the proposed development from the marine environment at Thyspunt is the blockage of pipes by settlement of sessile organism, such as mussels and barnacles. However, given the diameter of the pipes and chlorination regime, this impact is expected to be minimal. This impact will act throughout the operational phase of the development.

4 ENVIRONMENTAL ASSESSMENT

The following section offers an assessment of the potential impacts identified in Section 3 above. Impacts were accessed in accordance with Government Notice R.385 of 2006, promulgated in terms of Section 24 of the NEMA and the criteria drawn from the IEM Guidelines Series, Guideline 5: Assessment of Alternatives and Impacts, published by the DEAT (April 1998).

The decommissioning phase is not formally considered, as it will not impact on the marine environment.

4.1 Duynefontein

4.1.1 Disruption of the marine environment during construction

Disruption due to construction of the cooling water intake and outflow systems
Due to mortality of organisms as a result of construction of the cooling water system this impact will exert a negative effect on benthic marine habitats. The impact will occur in the medium term and will be restricted in spatial extent. Thus it is considered to be of medium overall consequence. As disruption to marine habitats will definitely occur during the construction process this impact is rated as having medium significance (Table 7). The cumulative impacts are considered low, as the marine environment will maintain its ability to respond to future changes.

Disruption due to discarding of spoil
This impact will negatively affect the marine environment. When spoil is placed at a shallow nearshore site, this impact acts with medium intensity. The discarding of spoil will have long-term effects, resulting in this impact being rated as having medium consequence and significance.

4.1.2 Abstraction of cooling water and subsequent entrainment of organisms

The intake of cooling water and the resulting entrainment of marine organisms will have a negative impact on the environment, which will act throughout the operational life-time of the proposed power station, albeit with low intensity. The consequence of this impact is rated as low, with low to medium significance (Table 7). No irreplaceable resources will be impacted upon. Due to the highly productive nature of this coastline the cumulative impacts are rated as low, even in the context of their effects being additive to those of KNPS and the proposed Pebble Bed Modular Reactor development (now in any event shelved).

4.1.3 Release of warmed cooling water

Regardless of the release system chosen, the impact of the release of warmed cooling water is expected to have medium consequence and be of medium significance due to the restricted area that will be affected by elevated temperatures, as well as the high resistance of this site to changes induced by the release of cooling water.

4.1.4 Release of desalination effluent

As desalination during the operational phase of the development will not have an impact on the marine environment only impacts associated with the construction phase will be considered. As the brine will be sufficiently diluted within 110 m from the point of release (Prestedge *et al.* 2008a) any impacts will be extremely localised. The intensity of the impact is rated as low as few species are restricted to the surf zone. As a result this impact is considered to be of low consequence and low-medium significance.

4.1.5 Radiation emissions

Due to the design of the proposed Nuclear-1 plant, coupled with the experience gained at KNPS, there is no reason to anticipate that contamination by radionuclides would occur as a result of the Nuclear-1 development. As such contamination is considered improbable. The threat of this impact will operate in the long term (i.e. throughout the operational phase of the development). Should the marine environment be contaminated, the extent of the impact would be local. As such the consequence of this impact is ranked as low, with a low significance.

4.1.6 Closure of the site to exploitation

This impact would have no effect on the marine environment at this site.

4.1.7 Release of sewage effluent

As the effluent to be released will meet the standards set out in the South African Water Quality Guidelines, no impact on the marine environment is expected.

4.1.8 Unintentional discharge of polluted groundwater

The discharge of organic bacterial and hydrocarbon contaminants into the marine environment will occur only as a result of accidental pollution of ground water. This will have negative effect over a small area and will be of short duration as dilution will rapidly occur. As such, both the consequence and significance of this impact are considered to be low.

4.1.9 Impacts of the environment on the proposed development

As this impact focuses on how the marine environment may affect the development, the standard methodology for impact assessment is not appropriate. This threat will persist throughout part of the construction phase (i.e. during the intake of seawater for desalination) and throughout the operational phase. See section 3.1.7 for a full description.

4.2 Bantamsklip

Note: Where cumulative impacts for this site have been rated as high, it is due to these impacts acting on already severely depleted stocks of the abalone *Haliotis midae.*

4.2.1 Disruption of the marine environment during construction

Disruption due to construction of the cooling water intake and outflow systems

This impact will have a negative effect on benthic marine habitats, acting in the medium term, but will be restricted in extent to the local area. The intensity of the impact is rated as medium, due to effects on the abalone *H. midae.* Thus it is considered to be of medium consequence. Disruption to marine habitats will definitely occur during the construction phase and this impact is rated as having medium significance (Table 8). Note: Although the overall rating of the impact remains the same regardless of the design chosen, the use of a tunnel-based intake will have less affect on the marine environment than the construction of an intake basin.

Disruption due to discarding of spoil

This impact will negatively affect the marine environment. When placed at a shallow nearshore site, this impact acts with high intensity. This intensity is reduced to a rating of medium when the disposal site is placed further offshore at a deep site. This impact has long-term affects acting on the benthic habitat and is rated as having high consequence and high significance when placed at a nearshore site. Placement offshore results in these ratings being downgraded to medium consequence and significance.

4.2.2 Abstraction of cooling water and subsequent entrainment of organisms

While this impact will be restricted in extent, it will affect the marine environment over the long term (i.e. the operational life of the proposed power station) and will be of low intensity. As a result this impact is rated as having low consequence and low significance.

4.2.3 Release of warmed cooling water

The release of heated cooling water is expected to affect the marine environment with a medium extent, although over the long term. The intensity of the impact is rated as low. As such this impact is considered to be of medium consequence and medium significance.

4.2.4 Release of desalination effluent

As desalination during the operational phase of the development will not have an impact on the marine environment (due to dilution with cooling water), only impacts associated with the construction phase will be considered. As the hypersaline effluent will be sufficiently diluted within 110 m from the point of release (Prestedge *et al.* 2008a) any impacts will be extremely localised. Nonetheless the abalone *H. midae* may be affected within this small area. Thus the intensity of the impact is rated as medium, with medium consequence and medium significance.

4.2.5 Radiation emissions

The unintentional release of radiation into the marine environment is considered very unlikely to occur. The negative impacts associated with this are rated as having low consequence and low significance.

4.2.6 Closure of the site to exploitation

At this site there is the potential for the removal of exploitation pressures on the marine environment due to a security exclusion zone. This would positively impact the marine environment in the long-term, particularly with regards to the abalone *H. midae.* This positive impact is considered to have medium consequence and medium significance.

4.2.7 Release of sewage

No impact on the marine environment is expected as the effluent to be released will meet the standards set out in the South African Water Quality Guidelines.

4.2.8 Unintentional discharge of polluted groundwater

The release of polluted ground water into the marine environment is unlikely to occur. However, should this impact be realised both the consequence and significance would be low, as the effect would be restricted in extent and duration.

4.2.9 Impacts of the environment on the proposed development

As this impact focuses on how the marine environment may affect the development, the standard methodology for impact assessment is not appropriate. This threat will persist throughout part of the construction phase (i.e. during the intake of seawater for desalination) and throughout the operational phase. See section 3.2.7 for a full description.

4.3 Thyspunt

Note: in the absence of quantitative data about the status of abalone stocks in Eastern Cape in general and for this site in particular, ratings have been made by applying the precautionary principle and assuming the presence of large abalone stocks will be found in the area around Thyspunt.

4.3.1 Disruption of the marine environment during construction

<u>Disruption due to construction of the cooling water intake and outflow systems</u>
This impact of disrupting the marine environment during tunnelling and laying of pipes for the cooling system will have a negative effect on benthic marine habitats due to physical damage to the seabed and smothering or organisms. This impact will act in the medium term. The extent of this impact will be restricted to the area in the immediate vicinity of the cooling water system infrastructure (0.075 km^2). As such it will have negligible effects on the spawning of squid as they spawn over a much larger area (an estimated 90 km^2 (SSWG, Appendix 6)). The intensity of the impact is rated as medium. Due to the possible existence of abalone populations in the surrounding area, the impact on irreplaceable resources is rated as medium. These ratings result in the consequence of the impact being rated as medium. Disruption to marine habitats will definitely occur during the construction phase and this impact is rated as having medium significance (Table 9). Due to the uncertainty of the status of abalone populations at this site the confidence level of this assessment is rated as medium.

Disruption due to discarding of spoil

This impact will negatively affect the marine environment. Acting with high intensity when spoil is placed at either a shallow nearshore site or a deep offshore site, this impact will have long term effects, resulting in this impact being rated as having high consequence and high significance. The confidence level of the ratings for the shallow disposal site is set at medium, because of the unknown status to the abalone stocks in the area. Although disposal at the shallow and deep sites results in high consequence and significance levels, disposal at the shallow site is considered more detrimental to the marine environment as it will impact squid to a greater degree, as well as potential abalone populations.

4.3.2 Abstraction of cooling water and subsequent entrainment of organisms

The intake of cooling water and the concurrent entrainment of organisms will occur with low intensity in the long term. This is unlikely to impact the squid resource or fishery (SSWG (Appendix 6)). The consequence of this impact is rated as low with a low-medium significance. No irreplaceable resources will be affected.

4.3.3 Release of warmed cooling water

Warmed water will be released into the marine environment throughout the operational phase of the development. If released at a depth of 5 m, the impact will act with medium intensity and with a medium spatial extent and consequently this impact is rated as having medium consequence. Thus the significance of the impact is considered to be medium. If released at a depth greater than 35 m, the intensity of the impact of warmed cooling water will be reduced to a rating of low, but the consequence and significance will remain medium.

4.3.4 Release of desalination effluent

As desalination during the operational phase of the development will not have an impact on the marine environment (due to dilution with cooling water) only impacts associated with the construction phase will be considered. As the brine will be sufficiently diluted within 110 m from the point of release (Prestedge *et al.* 2008a) any impacts will be extremely localised. The intensity of the impact is rated as low, as few species are restricted to the surf zone and chokka squid will not be affected. As a result this impact is considered to be of low consequence and low-medium significance.

4.3.5 Radiation emissions

The negative nature of this impact is rated as having low consequence and low significance, due the fact that it is very improbable that it will occur.

4.3.6 Closure of the site to exploitation

As access to this site has been restricted for well over a decade, no additional benefit will be gained by closure of this site to exploitation, thus the nature of this potential impact is considered to be neutral. The SSWG supports the view that this closure will represent a negligible loss in area to the squid fishing industry (Appendix 6).

4.3.7 Release of sewage effluent

Due to the fact that the effluent to be released will meet the standards set out in the South African Water Quality Guidelines no impact on the marine environment is expected.

4.3.8 Unintentional discharge of polluted groundwater

As at the other two sites pollution of the marine environment via seepage of polluted ground water is considered unlikely to occur. Any negative effects would be short lived and spatially limited, resulting in the consequence and significance of this impact being rated as low.

4.3.9 Impacts of the environment on the proposed development

As this impact focuses on how the marine environment may affect the development, the standard methodology for impact assessment is not appropriate. This threat will persist throughout part of the construction phase (i.e. during the intake of seawater for desalination) and throughout the operational phase. See section 3.3.7 for a full description.

4.4 The no-go Alternative

The no-go alternative will of course reduce or negate any negative impact on the marine environment at all sites (although Duynefontein already houses the existing KNPS, which has had very limited demonstrable environmental impacts on the marine environment). At Bantamsklip and Thyspunt species of specific concern (not significant at Duynefontein) are abalone and chokka squid, respectively and at least some impact on these commercially important stocks and/or the fisheries that catch them, can be anticipated, At Bantamsklip any loss of abalone needs to be balanced against the potential positive impact associated with the exclusion of abalone poaching at this site. It is important to note, however, that there is uncertainty about how effective the policing of the exclusion zone will be and thus how much of a positive impact would be derived.

4.5 Relevant legislation

The following South African legislation is relevant to the proposed development at all three of the alternate sites in the context of loss / modification of habitat:

National Environmental Management Act, 1998 (Act No. 107 of 1998)
National Environmental Management: Biodiversity Act, 2004
National Environmental Management: Integrated Coastal Management Act, 2008
The Environment Conservation Act, 1989 (Act No. 73 of 1989)
The Sea-Shore Act, 1935
The Development Facilitation Act, 1995
White Paper for Sustainable Coastal Development in South Africa (2000)
White Paper for Environmental Management Policy (1997)

Should spoil be discarded out to sea a water usage licence from the Department of Water Affairs and Forestry is likely to be required.

5. MITIGATION MEASURES

While a variety of potential impacts on the marine environment are associated with the proposed power station, most of these are inherently mitigated through the technical design of the plant. The discussion below applies to nuclear power plants of 4 000 MW output and to all three alternate sites, unless otherwise stated.

5.1 Mitigation objectives: what level of mitigation is being targeted?

5.1.1 Disruption of the marine environment during construction

The impacts associated with tunnelling for intake pipes and laying of outflow pipes will occur only during the construction phase. Mitigation measures are only possible in relation to marine mammals. Such efforts should take the form of deployment of a marine mammal observer during any construction activities that require drilling or pile driving. In the case of any activities creating loud noises, such as use of explosives, pile driving, or seismic assessment of sediments the following mitigation strategies for cetaceans are suggested:

1. Use of the minimum source level to achieve the result.
2. Use of "soft starts" whereby power is increased gradually over periods of 20 minutes or more (e.g. pile driving, seismic).
3. Care should be taken with line lay outs to avoid restricting animals' ability to avoid the source.
4. Equipment should be shut down if cetaceans are observed within a distance of the source defined by the source power, directionality and propagation characteristics.
5. Care should be exercised to minimise impacts in inshore water where cetaceans are likely to occurs as well as during the whale season.

In contrast the impacts resulting from the discarding of spoil will act over the long-term are of medium to high consequence and significance depending on the site and the location of the disposal site. Nonetheless, the placement of disposal sites offshore (and the use of a medium pumping velocity at Thyspunt) will mitigate these impacts to a point of medium consequence and significance. It is further recommended that the disposal of spoil should take place during winter, when spawning of squid is at a minimum. This will help to minimise disturbance of adult squid and mortality of paralarvae.

5.1.2 Abstraction of cooling water and the subsequent entrainment of organisms

The technical design of the intake system will result in water being drawn into the intake pipe at a rate of 1 $m.s^{-1}$ or less. This very slow rate of intake means that large organisms, such as fish and marine mammals, will easily be able to swim against the flow and will avoid entrainment without difficulty. In addition, the use of screens will further help to prevent the intake of large organisms. Despite the above, eggs, sperm and larvae will be impossible to exclude, due to their small size. While this is of concern in the context of abalone *Haliotis midae* at Bantamsklip, no measures can be applied to mitigate this impact without compromising the efficiency of the cooling system.

Due to the sound design of the intake system no mitigation measures are possible to further reduce entrainment of marine organisms.

5.1.3 Release of warmed cooling water

At Duynefontein and Thyspunt the current design of the outfall system does in itself significantly mitigate negative impacts associated with the release of warmed cooling water i.e. multiple points of release to aid dissipation of excess heat, release of cooling water above the sea bottom to minimise thermal pollution of the benthic environment and a very high flow rate at the point of release to maximise mixing with cool surrounding water. As such, no further mitigation measures are recommended at these sites. However, due to the impacts on the abalone *H. midae*, it is recommended that at Bantamsklip an offshore tunnel outflow must be used to prevent the thermal pollution of the nearshore benthic environment, which would be associated with a nearshore channel outflow.

5.1.4 Release of desalination effluent

The effect of the release of hypersaline effluent will be avoided during the operational phase of the development, as desalinisation effluent will be co-released with cooling water and adequate mixing will occur prior to release from the outflow pipe. During the construction phase brine will be released independently. Sufficient dilution will be achieved within 110 m from the point of release. Due to the effectiveness of this design in minimising impacts on the marine environment no additional mitigation measures are required.

During the normal operation of the plant, routine maintenance will require that the cooling system be shutdown and brine will continue to be released. As this will occur for limited periods only (days) the impact is considered negligible and no mitigation measures are deemed necessary.

5.1.5 Radiation emissions

At a design level the risk of radiological releases into the marine environment has been minimised through the incorporation a 'triple cooling system' whereby at no stage is there direct contact between the reactor and the coolant or between the coolant and the sea water. Besides these measures imposed by the technical design of proposed development, no further mitigation measures are necessary.

5.1.6 Closure of site to exploitation

This impact has the potential to have a positive effect on the marine environment. In particular a safety exclusion zone at Bantamsklip may be of great benefit, as it could offer much needed protection to the abalone *H. midae.* However, the level of organisation and the brazenness of poachers in this area will necessitate dedicated active policing of this exclusion zone if this benefit is to be realised. It should be noted that this positive impact will not compensate for the negative impacts on the abalone. No additional benefit will be gained at the Duynefontein and Thyspunt sites. Should no development occur and the sites were reopened to exploitation and development, no significant negative impact is anticipated for any of the sites.

5.1.7 Release of sewage water

As the effluent to be released will meet the standards set out in the South African Water Quality Guidelines no further mitigation measures are necessary.

5.1.8 Unintentional release of polluted groundwater

In order to reduce environmental risks it is recommended that mitigation measures ascribed in the hydrogeological specialist study to minimise organic, bacterial and hydrocarbon pollution of groundwater (and subsequently the marine environment) should be applied. No further mitigation measures are necessary.

5.1.9 Impacts of the environment on the proposed development

The potential impacts of marine biota on the proposed plant stem from the blockage of water intakes by jellyfish and the biofouling of cooling pipes. Due to the tolerances of these organisms, physical removal from the water column surrounding the intake pipe offers a first line of defence. This would, however, be labour intensive and may not be viable at times of extreme jellyfish densities. Chemical shock treatment may offer a more practical option for decreasing the impacts of jellyfish. However, laboratory testing would be required to isolate the appropriate chemical that would have the desired effect on the jellyfish, while having as small an effect as possible on the surrounding environment. The use of exclusion screens and diversion of trapped debris offer an effective method of clearing debris from intake water, while low-level chlorination regimes can effectively control fouling of pipes. Such mechanisms are well established at KNPS and can be utilised at any new plant.

Table 7. Assessment of impacts on the marine environment at the Duynefontein site

Impact	*Nature*	*Intensity*	*Extent*	*Duration*	*Impacting on irreplaceable resources*	*Consequence*	*Probability*	*Significance*	*Confidence level*
Impacts resulting from disruption of the marine environment during construction Due to construction of the cooling water intake and outflow systems	***Negative***	***Medium***	***Low***	***Medium***	***Low***	***Medium***	***High***	***Medium***	***High***
Impacts resulting from disruption of the marine environment during construction Due to discarding of spoil at a deep offshore site	***Negative***	***Medium***	***Medium***	***High***	***Low***	***Medium***	***High***	***Medium***	***High***
Impacts resulting from the abstraction of cooling water & entrainment of organisms	***Negative***	***Low***	***Low***	***High***	***Low***	***Low***	***High***	***Low - Medium***	***High***
Impacts resulting from the release of warmed cooling water	***Negative***	***Low***	***Medium***	***High***	***Low***	***Medium***	***High***	***Medium***	***High***
Impacts resulting from the release of desalination effluent during the construction phase	***Negative***	***Low***	***Low***	***Medium***	***Low***	***Low***	***High***	***Low - Medium***	***High***
Impacts resulting radiation emissions	***Negative***	***Low***	***Low***	***High***	***Low***	***Low***	***Low***	***Low***	***High***
Impacts resulting from the unintentional discharge of polluted groundwater	***Negative***	***Low***	***Low***	***Low***	***Low***	***Low***	***Low***	***Low***	***High***

Table 8. Assessment of impacts on the marine environment at the Bantamsklip site

Impact	*Nature*	*Intensity*	*Extent*	*Duration*	*Impact on irreplaceable resources*	*Consequence*	*Probability*	*Significance*	*Confidence level*
Impacts resulting from disruption of the marine environment during construction Due to construction of the cooling water intake and outflow systems	***Negative***	***Medium***	***Low***	***Medium***	***Medium***	***Medium***	***High***	***Medium***	***High***
Impacts resulting from disruption of the marine environment during construction Due to discarding of spoil at a shallow nearshore site	***Negative***	***High***	***Medium***	***High***	***Medium***	***High***	***High***	***Medium***	***High***
Impacts resulting from disruption of the marine environment during construction Due to discarding of spoil at a deep offshore site	***Negative***	***Medium***	***Medium***	***High***	***Medium***	***Medium***	***High***	***Medium***	***High***
Impacts resulting from the abstraction of cooling water & entrainment of organisms	***Negative***	***Low***	***Low***	***High***	***Low***	***Low***	***High***	***Low - Medium***	***High***
Impacts resulting from the release of warmed cooling water	***Negative***	***Low***	***Medium***	***High***	***Medium***	***Medium***	***High***	***Medium***	***Medium***
Impacts resulting from the release of desalination effluent during the construction phase	***Negative***	***Medium***	***Low***	***Medium***	***Medium***	***Medium***	***High***	***Medium***	***High***
Impacts resulting from closure of the site to exploitation	***Positive***	***Medium***	***Low***	***High***	***Medium***	***Medium***	***Medium***	***Medium***	***High***
Impacts resulting from radiation emissions	***Negative***	***Low***	***Low***	***High***	***Low***	***Low***	***Low***	***Low***	***High***
Impacts resulting from the unintentional discharge of polluted groundwater	***Negative***	***Low***	***Low***	***Low***	***Low***	***Low***	***Low***	***Low***	***High***

Table 9. Assessment of impacts on the marine environment at the Thyspunt site

Impact	Nature	Intensity	Extent	Duration	Impact on irreplaceable resources	Consequence	Probability	Significance	Confidence level
Impacts resulting from disruption of the marine environment during construction ***Due to construction of the cooling water intake and outflow systems***	***Negative***	***Medium***	***Low***	***Medium***	***Medium***	***Medium***	***High***	***Medium***	***Medium***
Impacts resulting from disruption of the marine environment during construction ***Due to discarding of spoil at a shallow nearshore site***	***Negative***	***High***	***Medium***	***High***	***Medium***	***High***	***High***	***High***	***Medium***
Impacts resulting from disruption of the marine environment during construction ***Due to discarding of spoil at a deep offshore site***	***Negative***	***High***	***Medium***	***High***	***Low***	***High***	***High***	***High***	***High***
Impacts resulting from the abstraction of cooling water & entrainment of organisms	***Negative***	***Low***	***Low***	***High***	***Low***	***Low***	***High***	***Low - Medium***	***High***
Impacts resulting from the release of warmed cooling water ***At an offshore site at a depth of greater than 35m.***	***Negative***	***Low***	***Medium***	***High***	***Low***	***Medium***	***High***	***Medium***	***Medium***
Impacts resulting from the release of warmed cooling water ***At an nearshore site at a depth of 5m.***	***Negative***	***Medium***	***Medium***	***High***	***Medium***	***Medium***	***High***	***Medium***	***Medium***
Impacts resulting from the release of desalination effluent during the construction phase	***Negative***	***Low***	***Low***	***Medium***	***Low***	***Low***	***High***	***Low - Medium***	***High***
Impacts resulting from radiation emissions	***Negative***	***Low***	***Low***	***High***	***Low***	***Low***	***Low***	***Low***	***High***
Impacts resulting from the unintentional discharge of polluted groundwater	***Negative***	***Low***	***Low***	***Low***	***Low***	***Low***	***Low***	***Low***	***High***

5.2 Recommended mitigation measures

5.2.1 Effectiveness of mitigation measures

As the recommended mitigation measures take place during the construction phase and reduce the severity of the particular impacts, it is not possible to define mitigation targets or measure ‘success’ of these actions, as we have no measure of the impact without mitigation. The approach applied has been that it is better to minimise impacts, rather than allow them to happen and then try to rehabilitate the environment. As such, in the context of this study no performance criteria are applicable.

5.2.2 Recommended monitoring and evaluation programmes

Monitoring of thermal pollution

At each site both the benthic and intertidal habitats should be sampled before construction, after construction, but before the onset of the operational phase, annually during operation and then for a minimum of five years after closure of the power station. Both benthic and intertidal sites predicted to be impacted (i.e. based on oceanographic modelling of the release plume) should be paired with comparable control sites. If suitable sites exist, both sheltered and exposed rocky shores should be considered. At Bantamsklip special note should be taken of the abalone *H. midae* and dedicated surveys should be conducted to assess the densities of this gastropod. At Thyspunt surveys should be conducted to monitor for the presence of egg capsules of Chokka squid *Loligo reynaudii.* Note: the use of indicator species is not recommended as the densities of marine invertebrates often varies dramatically through time, while changes in overall community composition are far more relevant. While sampling need not be repeated in different seasons it is important that annual monitoring take place at the same time each year.

Monitoring of spoil disposal sites

Prior to disposal of spoil at sea, benthic communities at the disposal site, and in the areas predicted to be affected by spoil over the first ten years following disposal (Prestedge *et al.* 2009a) should be sampled for at least two years. Following disposal of spoil, these sites should be sampled at the same time of the year as the initial samples for at least ten years. Importantly, communities establishing on the actual spoil site should be monitored to establish to what extent these communities recover through time.

Monitoring of intertidal and shallow benthic environments during the construction phase

In order to track recovery in the intertidal and nearshore habitats following the unavoidable disruption to these areas caused during the construction of the cooling water intake and outfall systems, sandy and rocky shores, as well sandy benthic and rocky reefs (if present) should be monitored. Sites should be chosen to represent increasing distances away from the site and should include the area between Oyster Bay and Seal Bay. If appropriate habitat is present, sites should be placed at the construction site, 50 m, 100 m, 500 m and 1 km away from the site of the construction activities. Sites should be sampled before construction activities start and then annually after completion of the intake system the same time of the year as the initial samples and for at least ten years.

Monitoring of radiation emissions

An environmental surveillance programme should be implemented to monitor for radiation emissions in the marine environment. This would form part of the strict requirement of the National Nuclear Regulator Act. The design of such a programme is outside our area of expertise, but is likely to follow the Eskom Radiation Protection Environmental Surveillance Standard. Organisms which we recommend for inclusion in such a monitoring programme are abalone *H. midae* at Bantamsklip and Thyspunt and chokka squid *Loligo reynaudii* at Thyspunt, as both are consumed commercially.

Monitoring of sewage effluent

A routine monitoring programme of water exiting the cooling water outlets should be established to ensure that sewage effluent entering the sea meets the standards set by the Department of Water Affairs and Forestry.

Monitoring of organic, bacterial and hydrocarbon pollution resulting from polluted groundwater

Should pollution of groundwater be detected, monitoring of seawater quality in the area of groundwater discharge should commence immediately to ensure the safety of public health.

Monitoring of coastal dolphin in the area around Bantamsklip

Should Bantamsklip be chosen as the site for the power station, Professor Peter Best of the University of Pretoria should be asked to evaluate whether a monitoring programme considering behaviour and density of the Indo-Pacific humpback dolphin (*Sousa chinensis*) and the Indo-Pacific bottlenosed dolphin (*Tursiops aduncus*) should be designed and implemented. Such monitoring could, inter alia, take into account the potential affects of noise levels and turbidity during the construction phase, noise levels and the thermal plume during the operational phase. Note: the Dyer Island Conservation Trust is involved in cetacean research in the area and any monitoring programme should be placed within the context of existing research.

Monitoring of African penguin (*Spheniscus demersus*) populations on Dyer Island

A long-term monitoring programme should be established to track populations of African penguins on Dyer Island near the Bantamsklip if this site is developed (Prof L. Underhill, University of Cape Town, Pers. Comm.). Monitoring should take place before, during and after construction. Such monitoring should take place in conjunction with the penguin monitoring programme which is currently underway on the island and is run by the Avian Demography Unit at the University of Cape Town.

6 CONCLUSIONS AND RECOMMENDATIONS

The development of a nuclear power station at Duynefontein, Bantamsklip or Thyspunt will have a variety of potential impacts on the marine environment. These include disruption of surrounding habitats during the construction phase, the entrainment of organisms during the intake of cooling water, the release of warmed cooling water, the release of desalination effluent, the unintentional release of radiation and organic, bacterial or hydrocarbon pollution due to seepage of polluted ground water and the protection of organisms from exploitation due to a safety exclusion zone. Experience at KNPS has shown that many of these impacts can in fact have minimal effect on marine habitats and although the proposed plant will be larger than the Koeberg plant (4 000 MW in comparison with 1 800 MW), the findings at KNPS offer a sound base from which to assess potential impacts.

In summary the effects of disruption to the marine environment during construction are associated with two processes. Firstly, the construction the cooling water uptake and outfall system. This impact will be localised and of short to medium duration. Secondly, disturbance will be associated with the discarding of spoil from excavation of the take tunnel, intake basin, nuclear island and turbine hall. This impact will have a significant and negative affect on the marine environment which will act in the long term. In an effort to minimise this impact, it is recommended that spoil only be discarded offshore and that at Thyspunt only a medium pumping rate be used. Spoil disposal at Thyspunt should also take place during winter when squid spawning is minimal. These measures would minimise ecological impacts particularly on abalone at Bantamsklip and chokka squid at Thyspunt. The impacts associated with the disposal of spoil result in limited potential impact on the squid when taken within the context of the extensive area over which this species spawns. This impact would manifest in up to 13.43% of the inshore jig fishery catches being displaced as adult squid move to other spawning grounds.

At Duynefontein and Thyspunt the entrainment of organisms along with cooling water is not anticipated to have significant ecological effects, as plankton populations are able to rapidly regenerate and the low intake rate of water, along with the use of screens, will help prevent the intake of larger marine organisms, such as fish and marine mammals. However, at Bantamsklip such entrainment could have significant effects on the early stages of the abalone *H. midae*.

Comprehensive oceanographic modelling has demonstrated that the effects of elevated temperature are expected to be focused on the open water habitat if a tunnelled release system is used. This is of particular relevance at Bantamsklip and to a lesser degree at Thyspunt, as it would help to mitigate impacts on abalone and chokka squid egg capsules respectively. However, at Bantamsklip it is strongly recommended that the cooling water release pipes be placed offshore to further mitigate this impact. Importantly, a channel release system at this site is deemed to pose an unacceptable risk to abalone populations. While chokka squid are expected to avoid water temperatures elevated above their thermal tolerance range, the area predicted to be affected represents less than a percent of the coastal spawning ground.

During the construction phase small volumes of hypersaline effluent will be released beyond the surf zone via a piped diffuser so as to maximise mixing and dilution of the brine and minimise impacts on the marine environment. During the operational phase the hypersaline effluent will be co-released with cooling water. As brine will be diluted to undetectable levels prior to release no impact on the marine environment is predicted during this phase of the development.

The most likely source of radiological releases into the marine environment is through the unintentional release of contaminated cooling water. This risk has been minimised through the technical design of the cooling system. This approach has proved adequate at KNPS, where no radionuclide release has been detected.

The site that would benefit from an exclusion zone would be Bantamsklip, as this could benefit abalone populations if supported by adequate enforcement.

Sewage from the proposed development will be treated and then released via the cooling water outlet pipe. At the point of release this effluent will meet the standards set by the Department of Water Affairs and Forestry. Thus no impact on the marine environment is expected.

Accidental pollution of groundwater by organic, bacterial or hydrocarbon compounds may result in pollution of the marine environment as ground water releases into the ocean. Should this occur the impact would be minimal as only a small area would be affected and contaminants would rapidly be diluted and dispersed by water movements.

Besides the impacts of the proposed development on marine habitats, the marine environment may also impact the development. This would take the form of blockage of water intakes by jellyfish and floating kelp and the fouling of cooling pipes. This impact is anticipated to be most significant at Duynefontein, due to its location along the west coast, where jellyfish blooms appear to be increasing in frequency.

Prevention mechanisms for jellyfish blockage during cooling water intake are well established at KNPS and can be utilised at any new power station.

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8 APPENDICES

Appendix 1: Density (per $0.027m^3$) of species recorded in the high-, mid- and low-shore on sandy shores at the three sites.

Duynefontein

Species	Status	High 1	High 2	High 3	High 4	High 5	Mid 1	Mid 2	Mid 3	Mid 4	Mid 5	Low 1	Low 2	Low 3	Low 4	Low 5
Bullia digitalis		0	0	0	0	0	0	0	0	0	0	1	0	0	2	0
Donax serra		0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Eurydice longicornis		8	5	4	3	2	0	0	0	1	0	2	0	0	0	0
Gastrosaccus psammodytes		0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Pontageloides laticeps		0	1	0	0	0	8	11	5	1	2	0	1	0	0	0
Scololepis squamata		0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Talorchestia quadrispinosa	SA endemic	17	0	5	13	9	0	0	0	0	0	0	0	0	0	0

Bantamsklip

Species	Status	High 1	High 2	High 3	High 4	High 5	Mid 1	Mid 2	Mid 3	Mid 4	Mid 5	Low 1	Low 2	Low 3	Low 4	Low 5
Bullia digitalis		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Clasybranchus spp.		0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Eurydice longicosta		0	4	3	1	1	6	0	0	0	0	1	1	3	0	0
Gastrosaccus psammodytes		0	0	0	0	0	0	0	0	0	0	0	0	0	0	23
Pontageloides laticeps		0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Scololepis squamata		3	0	0	0	0	2	47	15	64	49	0	32	4	30	51
Urothoe grimaldii		0	0	0	0	0	0	0	0	0	0	0	0	2	1	0

Thuyspunt

Species	Status	High 1	High 2	High 3	High 4	High 5	Mid 1	Mid 2	Mid 3	Mid 4	Mid 5	Low 1	Low 2	Low 3	Low 4	Low 5
Bullia digitalis		1	0	2	0	2	4	4	3	7	2	1	4	3	0	0
Donax serra		0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
Euridice longicornis		0	0	0	0	0	4	6	0	0	0	0	0	0	0	0
Pontageloides laticeps		1	1	0	0	0	0	0	0	1	0	4	0	1	0	0

Appendix 2: Biomass ($kg.m^{-2}$) of species recorded in the high-, mid- and low-shore on rocky shores at the three sites.

Duynefontein

Exposed Site

Species	Status	High 1	High 2	High 3	High 4	High 5	Mid 1	Mid 2	Mid 3	Mid 4	Mid 5	Low 1	Low 2	Low 3	Low 4	Low 5
Balanus glandula	Alien	3.45	5.75	1.15	0.00	1.15	1.61	2.30	8.05	11.50	12.65	0.00	0.00	0.00	0.00	0.00
Aulactinia reynaundi		0.00	0.00	0.00	0.00	0.00	3.20	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00
Burnupena lagenaria	SA endemic	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00
Helcion pectunculus		0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mytilus galloprovincialis	Alien	0.00	0.19	0.00	0.00	0.00	4.89	3.52	8.81	5.87	6.85	0.00	0.00	0.00	0.00	0.00
Afrolittorina africana		10.64	16.80	1.68	0.56	5.04	0.00	0.63	7.28	5.60	8.40	0.00	0.00	0.00	0.00	0.00
Nucella dubia		0.00	0.96	0.00	0.00	0.08	0.16	0.08	0.08	1.04	1.04	0.00	0.00	0.00	0.00	0.00
Porphyra		0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ralfsia verrucosa		0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scutellastra granularis		0.00	0.20	0.39	0.00	0.00	0.46	0.72	0.20	0.07	0.26	0.00	0.00	0.00	0.00	0.00
Ulva		0.00	0.00	0.00	0.00	0.00	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Sheltered Site

Species	Status	High 1	High 2	High 3	High 4	High 5	Mid 1	Mid 2	Mid 3	Mid 4	Mid 5	Low 1	Low 2	Low 3	Low 4	Low 5
Actinia equina		0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aeodes		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.19	1.24	3.71	0.00	0.00	4.95	0.00
Balanus glandula	Alien	1.15	1.15	3.45	0.23	0.23	4.60	2.30	5.75	0.00	8.05	0.23	0.00	0.00	0.00	0.00
Aulactinia reynaundi		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.80	0.00	0.00	1.20	0.00	1.20
Burnupena lagenaria		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.25	0.75	0.50
Caulacanthus ustulatus		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.00
Cymbula granatina		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.00	0.28
Gigartina polycarpa		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.92	2.92	4.38	2.92	0.00	36.53	0.00
Sarcothalia stiriata		0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Helcion pectunculus		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00
Mytilus galloprovincialis	Alien	0.19	0.19	0.00	0.00	0.00	9.79	16.64	3.92	0.98	3.92	20.10	23.87	2.51	22.61	22.61
Oxystele tigrina	SA endemic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00
Patiriella exigua		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.16	0.08
Porphyra		38.25	25.50	8.50	0.00	0.00	4.25	0.00	0.85	4.25	2.55	0.00	0.00	0.00	0.00	0.00
Scutellastra granularis		0.07	0.20	0.00	0.00	0.00	0.39	0.00	1.82	0.65	0.07	0.52	0.00	0.00	0.00	1.63
Ulva		0.00	0.00	0.00	0.00	0.00	6.09	0.00	21.31	0.00	0.00	0.61	0.00	0.61	1.83	0.61

Bantamsklip

Exposed Site

Species	Status	High 1	High 2	High 3	High 4	High 5	Mid 1	Mid 2	Mid 3	Mid 4	Mid 5	Low 1	Low 2	Low 3	Low 4	Low 5
Aeodes		0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acanthochitona garnoti		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Bifurcaria brassicaeformis	SA endemic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	32.94	27.13	29.06	7.75	31.00
Burnupena cincta		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.03	0.00
Burnupena lagenaria	SA endemic	0.13	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.06	0.00	0.00	0.06	0.13
Caulacanthus ustulatus		0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ceramium diaphanum		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00
Codium lucassi		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.85	0.00	0.00	0.00	0.00
Cymbula granatina		0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Cymbula oculus		0.00	0.00	0.00	0.00	0.00	0.07	0.09	0.00	0.00	0.00	0.09	0.00	0.05	0.00	0.09
Encrst. Spongites yendoi		0.00	0.00	0.00	0.00	0.00	0.16	0.32	0.00	0.16	0.00	3.20	3.20	2.40	1.60	1.60
Gibbula multicolor	SA endemic	0.00	0.00	0.00	0.00	0.00	0.04	0.03	0.05	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Gunnarea capensis		0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.00	0.00	0.00	1.43	3.57	3.57	0.71	4.99
Helcion dunkeri		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.02	0.00	0.00	0.05	0.00
Helcion pectunculus		0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.59	0.08	0.21	0.00	0.00	0.00	0.05	0.00
Hildenbrandia lecannellierii	SA endemic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00
Leathesia difformis		0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00
Afrolittorina africana		0.05	0.15	1.12	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nucella dubia		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Octomeris angulosa	SA endemic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.00	0.00	0.00	0.00	0.00
Oxystele sinensis	SA endemic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
Oxystele variegata		0.02	0.00	0.00	0.00	0.00	0.33	0.41	0.13	0.00	0.26	0.00	0.00	0.00	0.00	0.00
Plocamium cornutum		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.00	0.00	0.53	0.00
Porphyra		0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.00	0.00	2.55	0.00	0.00	0.00	0.00	0.00
Ralfsia verrucosa		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
Scutellastra longicosta	SA endemic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.07	0.17	0.20	0.07
Scutellastra cochlear		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18
Scutellastra granularis		0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.54	0.03	0.00	0.00	0.00	0.00	0.00
Siphonaria serrata	SA endemic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
Tetraclita serrata		0.00	0.00	0.00	0.00	0.00	0.00	0.00	90.00	720.00	270.00	0.00	0.00	0.00	0.00	0.00
Tricolia capensis		0.07	0.00	0.00	12.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turbo sarmaticus	SA endemic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Thuyspunt
Exposed Site

Species	Status	High 1	High 2	High 3	High 4	High 5	Mid 1	Mid 2	Mid 3	Mid 4	Mid 5	Low 1	Low 2	Low 3	Low 4	Low 5
Gymnogongrus polyclada	SA endemic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.28	25.10	2.09	18.83	18.83
Caulacanthus ustulatus		0.00	0.00	0.00	0.00	0.00	0.35	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ceramium pumosa		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.30	13.50	0.00
Centroceras clavulatum		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.44	4.86	2.43	0.00	14.58
Chthamalus dentatus		0.00	0.00	0.00	0.00	0.00	17.10	12.60	8.10	5.40	5.40	0.00	0.00	0.00	0.00	0.00
Coralline spp		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.35	0.53	1.50	0.08	0.00
Encrst. Spongites yendoi		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	1.60	0.00
Epymenia capensis		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.07	0.00
Helcion pruinosus		0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Hildenbrandia	SA endemic	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hypnea spicifera		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00
Mytilus galloprovincialis	Alien	0.00	0.00	0.00	0.00	0.00	0.59	0.20	0.98	0.00	0.39	0.00	0.00	0.00	0.00	0.00
Afrolittorina knysnaensis		1.40	2.38	1.71	0.98	2.10	0.00	5.88	1.96	2.52	3.36	0.00	0.00	0.00	0.00	0.00
Nothogenia erinacea		0.00	0.00	0.00	0.00	0.00	0.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oxystele variegata		0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Pterosiphonia cloiophylla		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00
Porphyra		42.50	0.85	0.85	0.85	0.00	0.00	0.00	6.80	3.40	0.00	0.00	0.00	0.00	0.00	0.00
Siphonaria serrata	SA endemic	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Scutellastra granularis		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Ulva		0.00	0.00	0.00	0.00	0.00	0.61	0.61	0.00	0.00	0.00	0.61	0.61	0.00	0.61	0.00

Appendix 3: Letter from Professor GM Branch referring to the sampling methodology applied to the benthic environment.

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To whom it may concern:

It is my professional opinion that with respect to the Nuclear 1 EIA, sampling of subtidal marine benthic communities was not is not a necessary part of the procedure. There are four reasons for my conclusion.

First, there has been very limited sampling of the subtidal benthos in the regions involved. As a result it would be difficult to know how representative the ecosystems at each of the proposed Nuclear 1 sites might be, or to identify unique or vulnerable ecosystem features that need preservation.

Second, sufficient information already exists in the report that has been submitted to evaluation the relative importance of the sites with respect to individual commercially important benthic resources such as abalone.

Thirdly, effluent from nuclear power stations releases warmed water that will concentrated near the surface, so I would not expect any major impact on the subtidal benthos. This contrasts with the intertidal benthos, which will be prone to the effects of effluents and a useful indicator of any impacts, and was thoroughly surveyed and reported on as part of the EIA.

Fourthly, on a purely logistic note, it is an arduous process to sample the subtidal benthic communities in a manner that is sufficiently quantitative to compare statistically among sites or to be used to monitor potential impacts. Working under water is taxing. It would take several years to complete sufficient replicate samples that are adequately stratified by depth to obtain a statistically valid number of samples - and to span any seasonality that exists in the benthos. For this to be useful in the future one a nuclear station is established, the surveys would have to be repeated on a sufficiently regular basis to monitor any changes. All of this could be done, but it is not a trivial exercise. If I felt that this information was necessary for the EIA and subsequent monitoring, I would not hesitate to recommend that it be done, irrespective of the time and cost involved; but I do not. There are better ways of assessing the rival merits of the sites and of monitoring any impacts.

Finally, I would note that it was I who undertook the review of the report submitted on the marine component of the EIA, and I indicated that I was satisfied by the coverage and scope of that report.

George M Branch
(Emeritus Professor)
Marine Biology Research Centre & Zoology Department
University of Cape Town
South Africa

Appendix 4: Diversity and status of sandy shore species recorded at the three sites.

	Duynefontein	Bantamsklip	Thuyspunt
Total spp number	7	8	4
Number of west coast endemics	0	na	na
Number of south coast endemics	na	0	0
Number of SA endemics	1	0	0
Number of alien spp	0	0	0
Number of spp restricted to < 100 km	0	0	0

Appendix 5: Diversity and status of rocky shore species recorded at the three sites.

	Duynefontein		Bantamsklip	Thuyspunt
	Exposed Site	Sheltered Site	Exposed Site	Exposed Site
Total spp number	11	16	32	20
Number of west coast endemics	0	0	na	na
Number of south coast endemics	na	na	0	0
Number of SA endemics	1	1	9	3
Number of alien spp	2	2	0	1
Number of spp restricted to < 100 km	0	0	0	0

Company name	Not applicable
Specialist signature	
Date	27 June 2012

agriculture,
forestry & fisheries

Department:
Agriculture, Forestry and Fisheries
REPUBLIC OF SOUTH AFRICA

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Enquiries: Dr K Prochazka

COMMENTS BY THE SQUID SCIENTIFIC WORKING GROUP ON THE THYSPUNT "NUCLEAR 1" ENVIRONMENTAL IMPACT ASSESSMENT REPORT

The attached recommendation provided by the Squid Scientific Working Group is:

Supported	
Supported subject to the notes below	X
Not supported, for the reasons outlined below	

Additional considerations by the Director: Resources Research:

For the most part I found the recommendation well-researched and well-articulated. I have only one comment to make, concerning the release of desalination effluent in the inshore zone. Although I find the conclusion of the Squid SWG satisfactory in relation to the likely impact on squid, I have some reservations around the accuracy of the statement made that discharging the brine into the breaker zone will "facilitate mixing". My reservation comes from the experience of the Plettenberg Bay desalination plant, where discharge of brine into the breaker zone (or surf-zone) in fact has the opposite effect of entraining the brine in the surf-zone, rather than facilitating mixing. I therefore suggest that Dr Stephen Lamberth is consulted in relation to the accuracy of this statement.

Dr Kim Prochazka
Director: Resources Research
Date: 14/03/2012.

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forestry & fisheries

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COMMENTS BY THE SQUID SCIENTIFIC WORKING GROUP ON THE THYSPUNT "NUCLEAR 1" ENVIRONMENTAL IMPACT ASSESSMENT REPORT

MARCH 2012

SUMMARY

The Squid Scientific Working Group (Branch: Fisheries Management, Department of Agriculture, Forestry and Fisheries) has been requested to comment on the report of the Marine Ecology Impact Assessment of the construction and operation of a 4000-MW nuclear power station that Eskom is proposing to develop at Thyspunt on the South African southeast coast. Specifically, the Working Group was requested to address issues that were identified as being of relevance to the chokka squid (*Loligo reynaudi*) resource and fishery. Two major issues of concern were identified by the Working Group as requiring further investigation; specifically the impacts of the disposal of spoil in the offshore marine environment during construction and the continuous release of warmed cooling water at either a nearshore or offshore location. The first issue involves two components; namely the loss of spawning habitat through smothering of the sea floor by the spoil and the impacts of fine sediment particles suspended in the water column (i.e. turbidity) on squid spawning behaviour and paralarval survival. Published information suggests that paralarvae will not survive in waters saturated with suspended particulate matter. However, the area that will be affected by the spoil is relatively small and it is uncertain to what extent it will elevate paralarval mortality. This depends upon paralarval transport routes, which are presently not well documented. An Individual Based Modelling (IBM) approach was employed to assess this latter component.

The conclusions of the Squid Scientific Working Group (SSWG) were:

- The SSWG agrees with the independent marine consultants that the impact of the construction of the inflow and outflow systems is of limited spatial extent and can be considered to be negligible in comparison with the overall area available to squid for spawning.
- The SSWG agrees with the conclusion that closure of the safety zone to exploitation reflects a negligible area lost to the squid fishery.

- The squid fishing industry (SASMIA) is advised to collect the required information on spatial distribution of catches, which would enable it to provide a more accurate assessment of the magnitude of the catches that may be impacted by Nuclear 1
- The squid fishing industry (SASMIA) should enter into dialogue with Eskom and broker a compensation agreement that clearly specifies the criteria on the basis of which the extent of the impact of Nuclear 1 on squid fishing operations is measured. These criteria should include presence-absence of main fishable concentrations in the vicinity of the Thyspunt site, i.e. Aasvogels, Oysters Bay, Seals Bay and Kromme. These concentrations were a constant feature of the squid jig fishery since its inception.
- The SSWG agrees with the conclusion that the abstraction of cooling water and the release of desalination plant effluent are unlikely to impact on the squid resource or the fishery.
- The issues of radiation contamination, release of sewage effluent and polluted groundwater, while representing potentially major threats to the marine environment, are adequately discussed in the Marine Ecology Report and were not considered further by the SSWG. It should be noted, however, that perceptions of the international squid market should be taken into consideration. The SSWG cannot provide specific advice on this aspect and suggests that this should rather be researched by the squid industry itself.
- In assessing the impacts of spoil disposal on squid spawning habitat, the SSWG assumed that the differences between the disposed spoil and the naturally occurring sediments would reflect a permanent loss of spawning habitat. The worst-case scenario (area covered to a depth of more than 0.5 cm of spoil sediment by the disposal of the full volume of spoil) represents an area of 18.1 km^2. The SSWG considers this to reflect an appreciable (20%) loss of nearshore squid spawning sites in relation to the total number of sites in the core inshore spawning area, recorded between the Tsitsikamma River and Algoa Bay.
- The SSWG considers that the mortality of paralarvae arising from the plume of turbid water resulting from the release of the spoil is negligible. Even in the worst-case scenario of the release of the full volume of spoil, only about 5% of all hatched paralarvae will encounter the plume of turbid water and die. If the disposal of the spoil could be conducted during the winter months when squid spawning is at a minimum, the impacts of this component on squid recruitment will be even further reduced.
- The SSWG considers that the mortality of paralarvae arising from the plume of warmed cooling water is negligible. Even in the worst-case scenario where water warmed to only 2 °C above ambient will result in 100% mortality of paralarvae entering the plume, only about 5% of all hatched paralarvae will be impacted. Even though the warmed cooling water will be a permanent source of paralarval mortality, the low level of this impact can only be considered to be negligible in terms of squid recruitment.

BACKGROUND

Eskom is considering the development of a fleet of nuclear power stations in an effort to meet dramatically increasing energy demands, and has consequently embarked on an Environmental Impact Assessment (EIA) to assess the possible impacts of the first of these proposed nuclear power stations ("Nuclear 1", a 4000-MW station). The consultants tasked with conducting this EIA, Arcus GIBB Pty Ltd, have contracted a number of specialist studies to assess the impacts of the proposed Nuclear 1 at three potential sites on South Africa's coast, namely Duynefontein, Bantamsklip and Thuyspunt. In June 2011, Arcus GIBB formally approached the Squid Scientific Working Group (SSWG) for comment on one of these specialist studies, namely the Marine Ecology Impact Assessment conducted by independent marine consultants. This study is described in the document "Environmental Impact Assessment for the Proposed Nuclear Power Station ('Nuclear 1') and Associated Infrastructure – Marine Ecology Impact Assessment (March 2011)". The SSWG was requested to comment specifically on issues relevant to the impacts of the proposed Nuclear 1 at Thyspunt on the chokka squid (*Loligo reynaudi*) resource and fishery. The issues identified by the consultants Arcus GIBB as relevant to the squid resource, and their assessments, are summarised below.

1. Disruption of the marine environment during construction - temporary

1.1. Construction of intake and outflow systems - estimated to be of 1-2 year duration

According to information from the independent marine consultants, construction of the outflow system is expected to take 2 years. The intake system will take 4 years but little of this time will disrupt the marine environment as most construction consists of subterranean tunnelling and onshore work. Exact timing has not been planned; however, according to the independent marine consultants ~~independent marine consultants~~, a 1- to 2-year disruption at some stage in the 4-year period should be anticipated. Construction of temporary coffer dams, excavation of trenches, laying of the intake and outflow pipes followed by the deliberate collapse of the walls and burial of the pipes will take place over a 4-year period. As reported by the independent marine consultants, an area of 500 m x 150 m will be lost during the construction of the outflow system. Two intake pipes will extend from the shore out to a depth of about 25 m, while up to ten outflow pipes will extend to about 400 m from the intertidal zone. According to the independent marine consultants, an area of not more than 2500 m^2 will be lost during the construction of each of the intake structures (i.e. assuming a worst case of 50 m x 50 m for each of two intake structures). Construction is expected to negatively impact squid through physical disturbance, smothering/loss of potential spawning area and egg beds, and increased turbidity.

Assessment: Severe disruption, but spatially localised and of short duration.

1.2. Dumping of spoil (sediment from excavation of the site) in the offshore zone - estimated to be of 143 days (5 months) duration

Note: the SSWG was verbally notified by the consultants Arcus GIBB that although a number of options had been proposed and assessed in the report, disposal of the spoil at medium discharge rate at a deep site offshore was the most likely option to be implemented. As the most severe of these options is the disposal of full volume this is the scenario which the SSWG considered and comments on. This scenario involves approximately 6.37 million m^3 of spoil being mixed with seawater to form slurry (sediment concentration of 15% by volume) that is then pumped at a rate of 3.5 m^3/s to the offshore disposal site (5 km offshore, water depth of about 84 m) through three temporary marine pipelines (internal diameter: 0.5 m) laid on the seabed, discharging at a rate of 2.06 m^3/s. Two aspects of the spoil disposal were identified by the independent marine consultants as potentially exerting profound negative impacts on the squid resource:

1.2.1. Smothering of the seafloor resulting in destruction of egg beds and loss of spawning habitat

Following disposal of the spoil, roughly 3 m of sediment will cover an area of 3 km^2 around the discharge site. Subsequently, local water movement will result in a shifting of the spoil in a north-easterly direction towards Seal Point. Within the first 5 years following disposal, the sediment is likely to spread to cover an area of approximately 8.3 km^2 with sediment to a mean depth of between 0.5 and 1 cm (Figure 1). In the next 5 years the spoil is expected to continue to spread towards Seal Point (Figure 2), eventually covering approximately 0.01 km^2 of the small bay east of Seal Point in sediment 0.5 – 1 cm thick. Sediments will not spread into St Francis Bay. The Marine Ecology Report does not specify the total area that will be affected, but the results of the marine sediment disposal study indicate that for alternative 5 (full volume of spoil discharged at the offshore site at a depth of 84 m) the area impacted in the first 5 years after disposal will range from 2.6 km^2 covered to a depth of more than 1 cm, to 11.1 km^2 covered to a depth of more than 0.5 cm (see Table 19 in "Marine Sediment Disposal Report 27Nov09.doc"). In years 6 to 10 after disposal, while the area covered in sediment of more than 1 cm in thickness will not increase, the area covered in more than 0.5 cm of sediment will increase to 18.1 km^2.

It is likely that benthic communities that establish on the spoil will be dissimilar to those currently existing owing to the differences in sediment characteristics between the current consolidated sands and the loose sediments derived from the spoil.

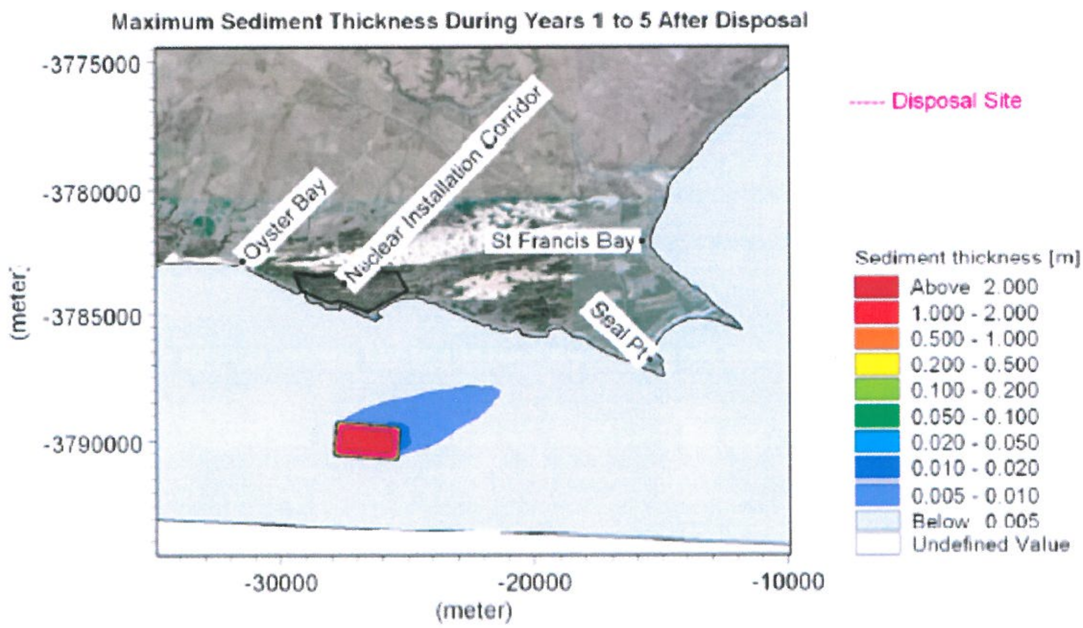


Figure 1: Maximum sediment thickness during years 1 to 5 after spoil disposal (extracted from the presentation to the Squid Scientific Working Group by the independent marine consultants)

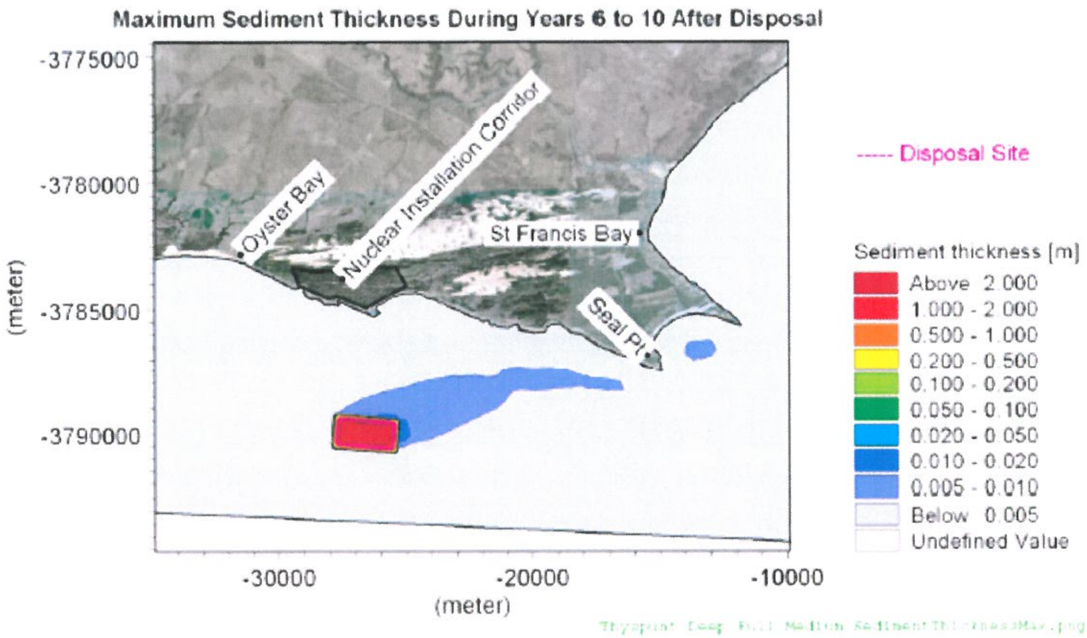


Figure 2: Maximum sediment thickness during years 6 to 10 after spoil disposal (extracted from the presentation to the Squid Scientific Working Group by the independent marine consultants)

1.2.2. Increased turbidity and the suspension of fine sediment particles in the water column during discharge could influence squid spawning behaviour

Maximum suspended sediment concentration is not expected to exceed 80 mg/l near the sea surface at any time during or after disposal (Figure 3), and will be confined to an area of less than 1.4 km^2 near the seafloor (Figure 4). Turbidity levels of this magnitude will also be temporally limited outside the disposal site, occurring for a maximum of 2 days throughout the entire disposal period.

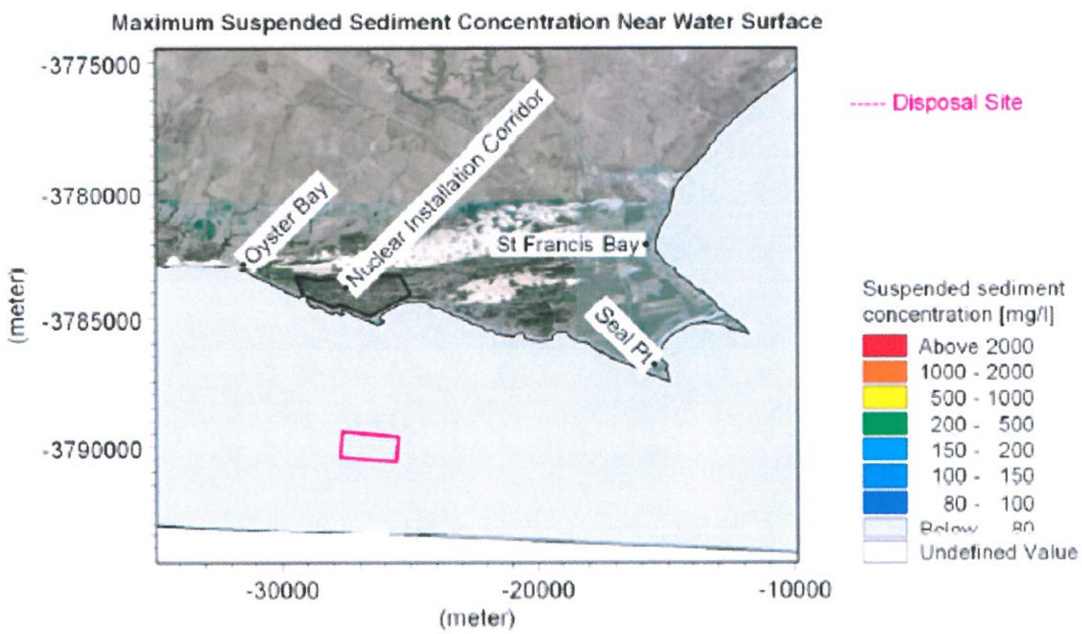


Figure 3: Maximum suspended sediment concentration near the surface during disposal of the full spoil volume (extracted from the presentation to the Squid Scientific Working Group by the independent marine consultants)

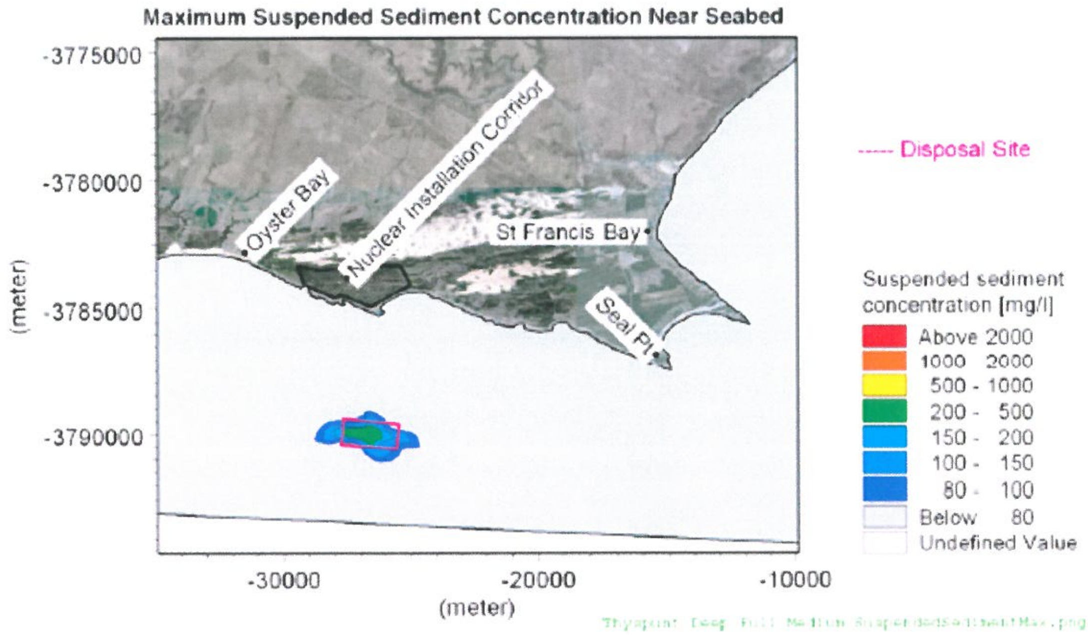


Figure 4: Maximum suspended sediment concentration near the seabed during disposal of the full spoil volume (extracted from the presentation to the Squid Scientific Working Group by the independent marine consultants)

The possibility that re-suspension of fine particles during storms could result in more frequent and more intense turbidity events than is the norm at present is unlikely considering that the spoil comprises only 7.1% "fines" that will be rapidly dispersed out of the area.

Assessment: While squid will be locally affected, the limited spatial and temporal extent of the spoil dispersal and the elevated turbidity relative to the entire area in which the species spawns suggest that impacts will not be significant to the squid resource as a whole. However, limited information on paralarval dispersal and transport routes makes an adequate assessment of the impact on paralarval survival difficult. The inshore jig fishery is unlikely to be greatly affected as only a small proportion of the catches are taken in the area expected to be impacted

2. **Abstraction of cooling water and subsequent entrainment of organisms – permanent**

   Extraction of cold seawater from the marine environment (for cooling of the proposed plant) will occur at a slow rate (maximum of 1 m^3/s). A number of measures to minimise fouling of the system by organisms (including continuous low-level chlorination of the intake water) will be implemented, and screens will be used to prevent the intake of lager marine organisms.

   Assessment: No species of commercial value are likely to be affected by entrainment and ecological impacts are not anticipated to be important.

3. **Release of warmed cooling water containing low levels of chlorine at either a nearshore or offshore site – permanent**

   The oceanographic models used to estimate the extent of warm-water release assumed a background (ambient) temperature of 19 °C. Release of warmed cooling water will occur from multiple points above the seafloor to maximise mixing with cool surrounding water. A nearshore outflow will result in a mean increase of 3 °C near the seafloor, limited in spatial extent to an area of roughly 0.2 km^2 around the outflow (Figure 5). An area of 0.7 km^2 will experience a maximum increase of 3 °C or more at any time. Such temperature increases are predicted to be limited to depths shallower than 15 m. Offshore release will result in no temperature increase at the seafloor (Figure 6), while a mean increase of 3 °C will affect an area of less than 2.5 km^2 near the surface (Figure 7). Note that the offshore estimates were obtained assuming a 10 000-MW plant (i.e. a plant more than double the size of the proposed Nuclear 1 plant). It is likely that the temperature effects of the proposed 4000-MW plant will be less than those described above.

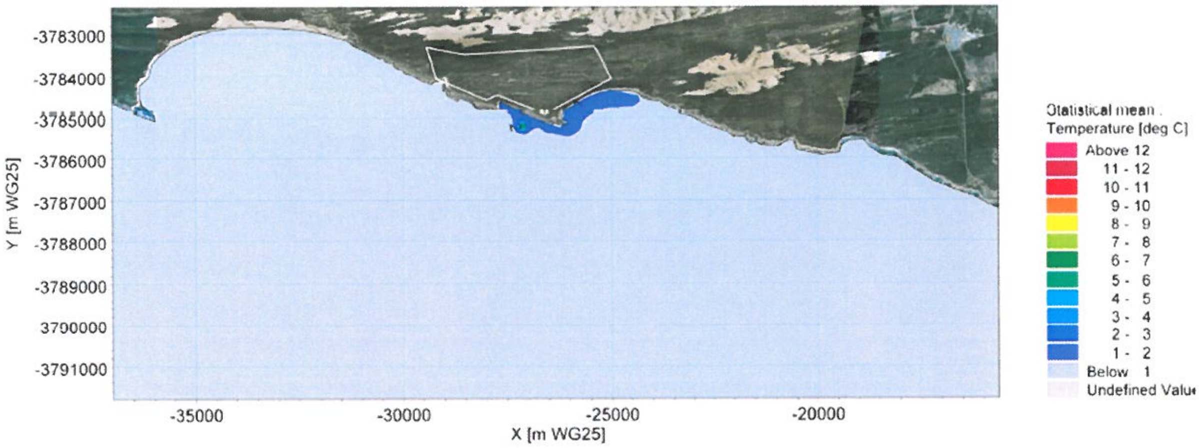


Figure 5: Mean temperature increase arising from the release of warmed cooling water from a nearshore piped outlet (extracted from the presentation to the Squid Scientific Working Group by the independent marine consultants)

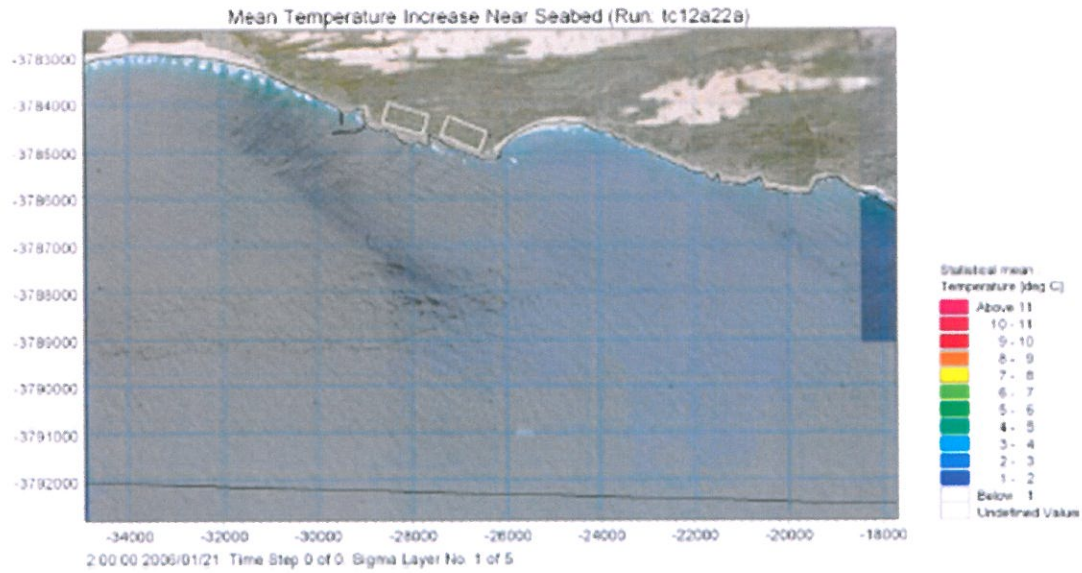


Figure 6: Mean temperature increase near the seabed arising from the release of warmed cooling water from an offshore piped outlet (extracted from the presentation to the Squid Scientific Working Group by the independent marine consultants)

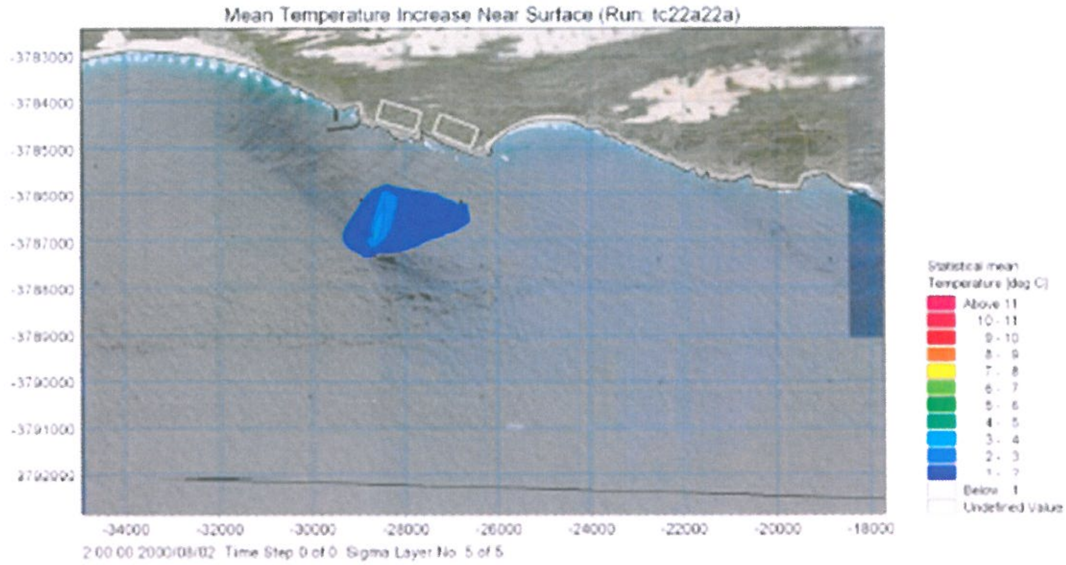


Figure 7: Mean temperature increase near the surface arising from the release of warmed cooling water from an offshore piped outlet (extracted from the presentation to the Squid Scientific Working Group by the independent marine consultants)

Assessment: Squid will be impacted by the release of warmed cooling water. In the case of a nearshore outflow, adult squid are expected to avoid an area of about 0.2 km^2, and a certain amount of egg mortality is to be expected. This area is, however, less than 1% of the coastal spawning area. In the case of an offshore outflow, the impact will be marginally reduced (although the water column will experience elevated temperatures, the seafloor will not). It is likely that adults avoiding the warm-water plume will move to another spawning ground.

4. **Release of desalination effluent in the inshore zone - permanent**

   Construction and normal operation of the proposed development will require access to freshwater. A portable desalination plant will be installed to provide for freshwater needs during the construction phase. This plant will use beach wells for the intake of seawater and will discharge the brine into the breaker zone to facilitate mixing. A permanent desalination plant will be constructed for use during the operational phase, from which the hypersaline effluent will be released together with the warmed cooling water in a ratio of less than 99 : 1 (seawater : brine). The brine will consequently be diluted to undetectable levels prior to discharge into the marine environment.

   Assessment: Not an issue during the operational phase owing to dilution of the desalination effluent prior to release. Release into the surf zone during construction will minimise the impact, which is unlikely to influence squid.

5. **Radiation emissions – permanent**

   The most likely source of radiological release into the marine environment is through the release of contaminated cooling water. Such releases are, however, controlled by the National Nuclear Regulator and previous experience at Koeberg Power Station has demonstrated that such radioactive contamination is very unlikely.

   Assessment: Such an event may impact the marine environment. Mortalities are expected to be limited to the general area of the plant, but mobile species exposed to low/intermediate radiation levels can move great distances and pose a threat to public health if consumed. It is vital that radionuclide levels in marine species (squid in particular) be monitored.

6. **Closure of the site to exploitation – permanent**

   The safety zone is planned to cover an area of 800 m around the power station, extending 1 km out to sea. All fishing activities will be excluded from the safety zone.

   Assessment: The exclusion zone is not expected to significantly impact the squid fishery owing to its small size relative to the overall fishing grounds.

7. **Release of sewage effluent – permanent**

   During both construction and operational phases, a sewage waste-water treatment plant will treat a maximum of 1000 m^3 per day on site. The effluent, if discharged via the cooling water outflow tunnels, will meet the required national standards for water quality in coastal marine waters.

   Assessment: No impact on the marine environment.

8. **Unintentional discharge of polluted groundwater – permanent**

   During the construction and operational phases, potential pollution of groundwater and subsequent contamination of the marine environment may originate from leaks and spillages from both on-site sanitation facilities as well as from fuel, oil and grease storage facilities.

   Assessment: Impacts of both organic and inorganic pollution through discharge of contaminated groundwater can be dire, but the exposed nature of the coastline with resultant nearshore mixing will facilitate the dilution and dissipation of any contaminants.

9. **Impacts of the environment on the proposed development - permanent**

   Not relevant to squid.

COMMENTS BY THE SQUID SCIENTIFIC WORKING GROUP

The construction of the intake and outflow systems clearly represents a major disruption to the marine environment, including squid. Adult squid will avoid the area and will probably not engage in spawning activities in the area during construction. Existing squid egg beds will be destroyed, and it is possible that they will not be re-established once construction is completed.

The SSWG agrees with the independent marine consultants that this impact is of limited spatial extent (0.075 km^2) and can be considered to be negligible in comparison with the overall area available to squid for spawning (estimated to be about 90 km^2 – see below).

The exclusion of fishing from the safety zone represents a loss of fishing area of 0.8 km^2. This can only be considered to be negligible in terms of the entire area in which squid fishing occurs.

The SSWG agrees with the conclusion that closure of the safety zone to exploitation reflects a negligible area lost to the squid fishery.

The fishing block immediately adjacent to the Thyspunt site yields on average 9.61% of the total squid catch (Figure 8). Vessel Monitoring System (VMS) data indicate that squid vessels spend most of their stationary time (presumably the time spent fishing) relatively close to the coast (Figure 8). The average catches calculated for each fishing block may therefore not reflect an accurate perception of the potential impacts of the Nuclear 1 development on the squid fishery in terms of lost catch.

The squid fishing industry (SASMIA) is advised to collect the required high-resolution information on spatial distribution of catches, which would enable it to provide a more accurate assessment on the magnitude of the catches that may be impacted by Nuclear 1.

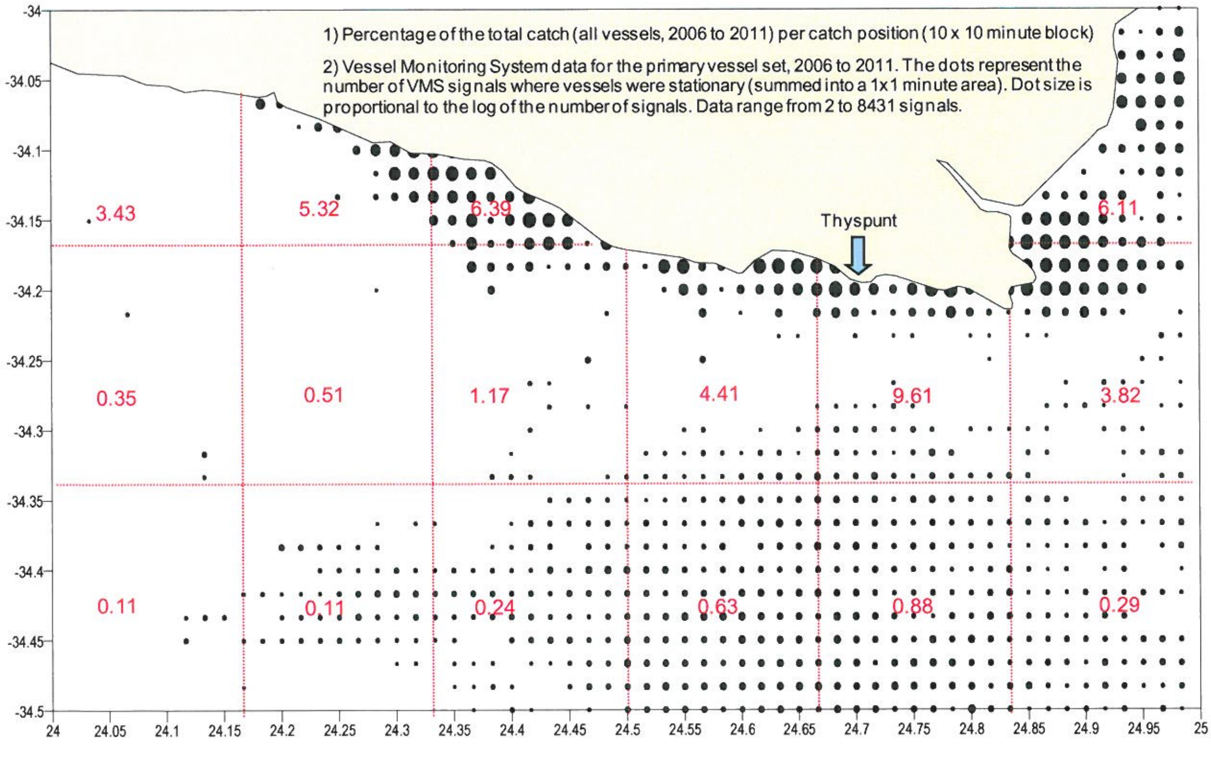


Figure 8: Average squid catches per fishing block (expressed as a proportion of the total catch) and squid fishing vessel presence (computed from VMS data) over the period 2006 - 2011

It is possible that long-term effects in terms of changes in squid migration patterns and spawning behaviour may arise from the disruptions/alterations to the substrate (seafloor) and water temperature regime (i.e. impacts that extend beyond the spatial and temporal limits of the disruptions). However, there is little or no information to properly assess this and the SSWG cannot provide comment on the likelihood of such changes in the squid population, or the implications for the resource or the fishery.

The squid fishing industry (SASMIA) should enter into dialogue with Eskom on this possibility and broker a compensation agreement that clearly specifies the criteria on which the extent of the impact of Nuclear 1 on squid fishing operations is measured. These criteria should include presence-absence of main fishable concentrations in the vicinity of the Thyspunt site, i.e. Aasvogels, Oysters Bay, Seals Bay and Kromme. These concentrations were a constant feature of squid jig fishery since its inception.

The SSWG agrees with the conclusion that the abstraction of cooling water and the release of desalination plant effluent are unlikely to impact on the squid resource or the fishery.

The issues of radiation contamination, release of sewage effluent and polluted groundwater, while representing potentially major threats to the marine environment, are adequately discussed in the Marine Ecology Report and were not considered further by the SSWG. It should be noted, however, that perceptions of the international squid market should be taken into consideration. The SSWG cannot provide specific advice on this aspect and suggests that this should rather be researched by the squid industry itself.

Of primary concern are the short-, medium- and long-term impacts on the squid resource and fishery arising from the disposal of the spoil during the construction phase, and the continuous release of warmed cooling water during the operational phase.

- Disposal of the spoil will smother the seabed in loose sediment, destroying existing egg beds and potentially resulting in the long-term loss of spawning habitat. Adult squid may consequently avoid this area during spawning, with no spawning aggregations forming in the impacted area.
- Elevated turbidity levels will result in increased mortality of squid paralarvae passing through the impacted area owing to numerous physiological constraints such as impaired movement and respiration, but also starvation due to inability to catch prey. Published information suggests that paralarvae will not survive in dirty water saturated with suspended particles.
- Elevated water temperatures may increase mortality of paralarvae owing to metabolic effects.
- Adult squid will avoid turbid water as a result of decreased vision.

The SSWG wishes to emphasise that the impacts of spoil disposal and warmed cooling water release on squid spawning and recruitment cannot be taken lightly, even in view of the relatively short duration of spoil disposal. *Loligo reynaudi* is a relatively short-lived species, most individuals in the population completing their entire life history in about a year. As such, the entire population of the species is based on the successful recruitment of a single year class. Significant increases in the mortality of the paralarvae and juveniles over a short period of time may seriously impact on recruitment and therefore the population as a whole.

In view of these observations, the SSWG felt that further investigation was required. In considering the impacts of the disposal of the spoil (in terms of both the substrate and turbidity) during the early construction phase and the long-term release of warmed cooling water, the SSWG adopted a spatial comparison approach based on "worst-case" scenarios in an attempt to bound each problem (i.e. establish whether the spatial extent of a specific impact would be negligible or non-negligible relative to the overall habitat available to squid):

Problem	"Worst-case" scenario
Impacts of the disposal of spoil on spawning habitat (specifically the seafloor)	The area covered by the spoil to a depth of 0.5 cm or more (including the area impacted by spoil shift over time) represents a long-term loss of squid spawning habitat. Adult squid will not form spawning aggregations over this area and will not deposit egg capsules in the affected area.
Impacts of elevated turbidity levels	The area of elevated turbidity represents a 100% mortality zone for paralarvae. Adult squid will avoid the affected area for both feeding and spawning.
Impacts of elevated water temperatures	The area of elevated temperature represents a 100% mortality zone for paralarvae. Adult squid will avoid the affected area for both feeding and spawning

There were some reservations regarding estimates of the spatial extent of elevated turbidity levels that were generated by the hydrographic models. These models considered turbidity levels in excess of 80 mg/l. This is the value indicated by the marine ecology specialist above which biological impacts can be anticipated. The SSWG is of the opinion that paralarval mortalities may result from turbidity levels substantially lower than this value, and recommended an investigation based on turbidity levels of 20, 40 and 60 mg/l. The Marine Sediment Disposal Report indicates that background suspended sediment concentrations (measured in water depths of 5 to 30 m) average 5 mg/l with a maximum of 29 mg/l.

Spatial components against which the extent of the "worst-case" Nuclear 1 impacts were compared:

a) **Area of known spawning sites/egg beds:** Squid spawning habitat is defined as an area over which squid form an aggregation, engage in reproductive behaviour and then deposit egg capsules. This includes the area within which adult squid move at night when spawning activity ceases. Each patch of squid spawning habitat (i.e. spawning site) is assumed to be about 1 km^2 in extent, therefore, it is important to note that some inshore sites overlap. Thirty nine sites were identified in shallower water between the Tsitsikamma River and Algoa Bay (Sauer et al., 1992) with eight of these possibly impacted, representing 20.5% of the total recorded.

b) **Transport patterns of squid paralarvae from spawning sites to nursery areas:**
This was modelled using an Individual Based Model (IBM) linked to a hydrographic model employing simple Lagrangian particle transport dynamics. The approach was to simulate the "release" (hatching) of paralarvae from squid egg beds and monitor their transport over time. The proportion of the paralarvae passing through the elevated turbidity and temperature plumes relative to the entire "population" of paralarvae was computed; this proportion assumed to reflect the total mortality arising from the Nuclear 1 impacts.

Two elevated-turbidity and three elevated-temperature scenarios resulting in paralarval mortality were considered:

- Plumes of elevated turbidity (> 20 mg/l) resulting from disposal of either the full spoil volume (mortality zone D in Figure 9) or half of the spoil volume (mortality zone E in Figure 9).
- Plumes of water temperature that were on average 2 °C (mortality zone A in Figure 9), 3 °C (zone B) or 4 °C (zone C) warmer than ambient.

Within the model, "paralarvae" were released from 6 release zones (Figure 9) and their transport was driven by the hydrodynamic model, incorporating diel vertical migration effects.
Paralarvae were considered to have died if advected off the shelf ("Agulhas Bank Mortality Zone" in Figure 9) when older than 4 days (to account for yolk-sac depletion), or if they came into contact with the elevated temperature and turbidity plumes. A number of simulations were run for each scenario in order to measure the variance associated with the mortality estimates.

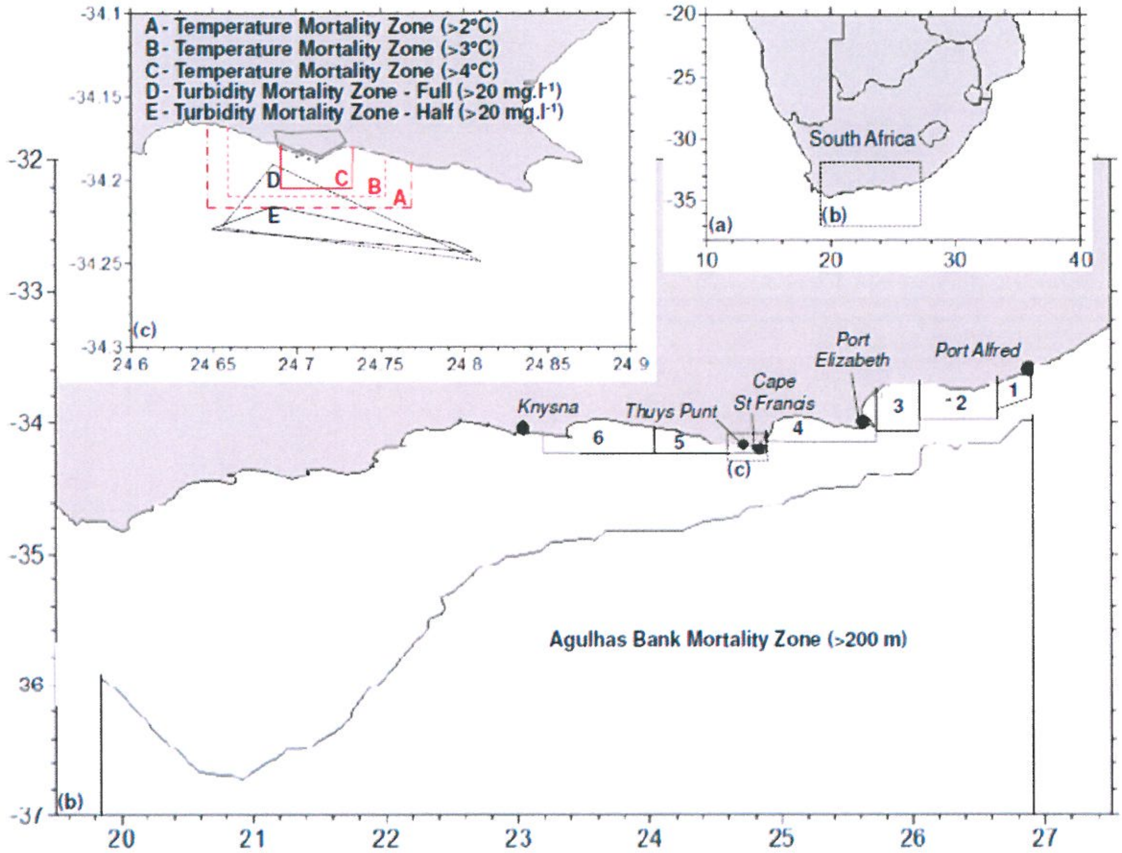


Figure 9: The 6 "paralarvae" release zones and the "mortality" zones used during the IBM model of paralarval transport.

Results and Conclusions:

1. **Impacts of spoil disposal and subsequent movement over time:**
The sediment characteristics of the spoil have been described in the Marine Sediment Disposal Report, and were found to fall within the range of the naturally occurring sediments. It should be noted, however, that the samples of naturally occurring sediments, which were used for this comparison, were collected from water depths of between 10 and 30 m, considerably shallower than the depth of the proposed offshore disposal site (84 m). An additional factor to consider is that the naturally occurring sediments are consolidated, whereas the spoil will comprise loose sediments.
The SSWG consequently assumed that the differences between the disposed spoil and the naturally occurring sediments would reflect a permanent loss of spawning habitat.

Assuming the "worst-case" scenario, a total area of 18.1 km^2 would be lost as squid spawning habitat over a 10-year period subsequent to spoil disposal. This represents 20.5% of the total nearshore spawning sites recorded between the Tsitsikamma River and Algoa Bay.

The SSWG is consequently of the opinion that the disposal and subsequent shift of spoil may result in an appreciable impact on squid in terms of loss of spawning habitat.

2. Impacts of elevated temperature and turbidity levels:

The results of the simulations are provided in Table 1 below.

Table 1: The average percentage of paralarvae released from each of the release zones (1-6) that were killed in the various mortality zones (A-E)

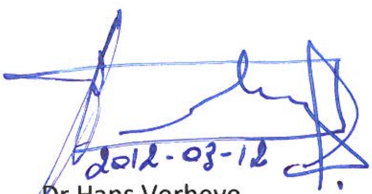
Release zone	Agulhas Bank advection	A Temp > 2 °C	B Temp > 3 °C	C Temp > 4 °C	D Turbidity full	E Turbidity half
1	54.62 ± 9.19	0.25 ± 0.06	0.20 ± 0.03	0.09 ± 0.04	0.72 ± 0.13	0.39 ± 0.07
2	23.44 ± 5.47	0.92 ± 0.17	0.46 ± 0.15	0.20 ± 0.07	0.94 ± 0.30	0.73 ± 0.25
3	0.24 ± 0.16	0.59 ± 0.15	0.61 ± 0.28	0.34 ± 0.10	1.47 ± 0.37	1.38 ± 1.39
4	0.24 ± 0.10	2.71 ± 0.44	1.95 ± 1.31	1.00 ± 0.22	3.94 ± 1.03	3.14 ± 0.84
5	0	19.64 ± 4.77	14.50 ± 8.95	6.60 ± 2.63	14.26 ± 4.68	10.72 ± 3.75
6	0	0	0	0	0	0
TOTAL	**5.95**	**5.28**	**3.88**	**1.80**	**4.47**	**3.42**

The results indicate that 5.95% of all paralarvae that hatched from nearshore spawning sites will be advected off the shelf area and die. In terms of Nuclear 1 impacts:

- assuming that paralarvae entering a plume of released cooling water that is 2 °C or more warmer than ambient will die, 5.28% of all hatched paralarvae will die as a result of the release of warmed cooling water by Nuclear 1. This percentage decreases to 3.88% if mortality only results from water 3 °C warmer than ambient, and to 1.80% if mortality only results from water that is 4 °C warmer than ambient.
- If only half of the spoil volume is released offshore, the resulting plume of turbid water will lead to a mortality of 3.42% of all paralarvae that hatched from nearshore spawning sites. This percentage increases to 4.47% if the full volume of spoil is released offshore.

The SSWG considers that the mortality of paralarvae arising from the plume of turbid water resulting from the release of the spoil is negligible. Even in the "worst-case" scenario of the release of the full volume of spoil, only about 5% of all hatched paralarvae will encounter the plume of turbid water and die. If the disposal of the spoil can be conducted during the winter months when squid spawning is at a minimum, the impacts of this component on squid recruitment will be even further reduced.

The SSWG considers that the mortality of paralarvae arising from the plume of warmed cooling water is negligible. Even in the "worst-case" scenario where water warmed to only 2 °C above ambient will result in 100% mortality of paralarvae entering the plume, only 5.28% of all hatched paralarvae will be impacted. Even though the warmed cooling water will be a permanent source of paralarval mortality, the low level of this impact can only be considered to be negligible in terms of squid recruitment.



Dr Hans Verheye
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