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

Oceanographic Impact Assessment

March 2011

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On behalf of: Eskom Holdings Ltd

8 August 2010

DECLARATION OF INDEPENDENCE

I, Rhys Giljam as duly authorised representative of WSP Environment and Energy, hereby confirm my independence (as well as that of WSP Environment and Energy 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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EXECUTIVE SUMMARY

In South Africa economic growth and social needs are resulting in substantially greater energy demand to meet the power generation requirements. Eskom therefore proposes to construct a Nuclear Power Station (NPS) with a power generation capacity of up to 4000 MW using Pressurised Water Reactor (PWR) technology.

This report examines the impacts on the physical marine environment brought about by the construction and operation of the NPS at the three possible sites, namely; Duynefontein, Bantamsklip and Thyspunt. In addition to the impacts of the NPS on the physical marine environment, impacts of storm events, global warming and natural disasters such as tsunamis affecting the operation and safety of the NPS were considered.

Oceanographic impacts related to the construction phase are considered to be of low significance and relatively uniform across each of the three potential sites.

The extent of the thermal plume at each of the sites is highly variable and dependant on the wind and wave conditions at any particular time. Analysis of the thermal plume dispersion at each of the sites indicates that relatively unfavourable dispersion takes place at Thyspunt, where the plume is seen to hug the coastline and shallow near shore areas. The most efficient dispersal of the thermal plume is seen at Duynefontein.

Impacts to the NPS caused by the physical marine environment will arise from flooding from the sea and the interruption of the cooling water supply. Interruption of the cooling water was considered to be of low significance at each of the alternative sites due to the depth of the intake and the mitigation measures incorporated in the design of the cooling water intake system.

There is the potential for water levels to exceed the proposed elevation of the NPS at all three sites should a tsunami coincide with extreme meteorological conditions (a meteo-tsunami event). The occurrence of a tsunami is, however, improbable given the low risk of seismic activity in the surrounding ocean. Thyspunt is the only site where extreme high water levels resulting purely from meteorological factors are predicted to exceed + 10 m MSL during the expected lifetime of the installation. Consequently, the predicted water levels at Thyspunt during a meteo-tsunami are also significantly higher than at Bantamsklip and Duynefontein.

Appropriate mitigation measures are recommended for each of the potentially significant oceanographic issues that have been identified.

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Oceanographic Specialist Study

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ABBREVIATIONS

CD	**Chart Datum**
EIA	**Environmental Impact Assessment**
EMP	**Environmental Management Plan**
HAT	**Highest Astronomical Tide**
LAT	**Lowest Astronomical Tide**
m	**Metres**
Ma	**Megannus (Unit of time equal to 1 million years)**
MSL	**Mean Sea Level**
NPS	**Nuclear Power Station**
PRDW	**Prestige Retief Dresner Wijnberg**
PWR	**Pressurised Water reactor**
RO	**Reverse Osmosis**
SSR	**Site Safety Report**
TSS	**Total Suspended Solids**

GLOSSARY

Chart Datum - The height of the water at the lowest possible theoretical tide.

Lowest Astronomical Tide (LAT)
Highest Astronomical Tide (HAT)
Highest astronomical tide (HAT) is the highest level, and Lowest astronomical tide (LAT) the lowest level that can be expected to occur under average meteorological conditions and under any combination of astronomical conditions. HAT and LAT are determined by inspecting predicted sea levels over a number of years.

Mean High Water Springs (MHWS)
Mean Low Water Springs (MLWS)
The height of mean high water springs is the average throughout the year of two successive high waters during those periods of 24 hours when the range of the tide is at its greatest. The height of the mean low water springs is the average height obtained by the two successive low waters during the same period.

Mean Low Water Neaps (MLWN)
Mean High Water Neaps (MHWN)
The height of mean high water neaps is the average throughout the year of two successive high waters during those periods of 24 hours when the range of the tide is at its least. The height of the mean low water neaps is the average height obtained by the two successive low waters during the same period.

Mean Sea Level – A vertical reference level as determined by land surveyors, also known as Land Levelling Datum. It is approximately the average height of the surface of the sea for all stages of the tide over a 19 year period, usually determined from hourly readings.

Seiche - A wave that oscillates in lakes, bays, or gulfs from a few minutes to a few hours as a result of seismic or atmospheric disturbances.

Soakaway - A subsurface structure into which surface water is conveyed to allow infiltration into the ground.

Storm surge - An abnormal rise in sea level accompanying a hurricane or other intense storm, whose height is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the storm.

Tsunami - Waves generated by seismic activity, sometimes called seismic sea waves.
Tsunamis are also popularly, but inaccurately, called tidal waves. When Tsunami's reach shallow coastal regions, amplitudes may increase to several metres.

Tsunami Drawdown - A phenomenon in which the ocean recedes before a tsunami strikes a coast.

Wave set up - A phenomenon local to the surf zone wherein wave breaking causes a stress or a landward push of the water, which causes it to pile up against the shore until the seaward slope of this set-up is sufficient to oppose the wave stresses.

Wave run up - The maximum vertical extent of wave uprush on a beach or structure above the still water level.

Wind waves - Local, short period waves generated from the action of wind on the water surface (as opposed to swell).

1 INTRODUCTION

1.1 Background

1.1.1 Introduction

In South Africa economic growth and social needs are resulting in substantially greater energy demand. The South African government is currently targeting a six percent economic growth which requires an equivalent four percent increase in energy supply, which will require more than 40000 MW of new electricity generating capacity over the next 20 years.

To meet the power generation requirements Eskom proposes to construct a Nuclear Power Station (NPS) with a power generation capacity of up to 4000 MW using Pressurised Water Reactor (PWR) technology. The development for the NPS will require approximately between 200 and 280 ha of land, and will include a nuclear reactor, turbine complex, spent fuel and nuclear storage facilities, waste handling facilities, intake and outfall structures and various auxiliary infrastructure. In the event that the proposed project is authorised it is estimated that the construction will take 8 to 9 years..

The structure of the nuclear power plant is similar to that of a conventional fossil fuel powered power plant, with the most significant difference being the manner in which the heat is produced. The PWR is the most common power producing reactor worldwide and consists of two separate closed coolant loops and third coolant loop which flows through the condenser and discharges either to either a large dam or the sea.

Three potential nuclear sites situated in the Eastern Cape (namely Thyspunt) and Western Cape, (namely Duynefontein and Bantamsklip) have been identified (see Figure 1.1 for locations).

ARCUS GIBB (Pty) Ltd has been appointed by Eskom Holdings Ltd (Eskom) as the independent environmental practitioner to facilitate the Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP) for the construction, operation and decommissioning of the NPS and associated infrastructure at one of the three sites.

The scoping phase of the EIA identified potential environmental impacts caused by the construction and operation of the NPS. This report investigates the impacts of the development on the physical marine environment and additionally considers the impact of the physical marine environment on the safety and design of the NPS. An overview of the impacts relating to the physical marine environment was outlined in Appendix C of the Scoping Report and is summarised below:

- Continuous attack by waves, which may damage infrastructure and result in severe erosion;
- Gradual rise of sea level associated with global warming may induce significantly higher wave heights, which could damage infrastructure;
- The site will be subjected to the effects of corrosion, which could result in potential damage to infrastructure and high maintenance costs; and

- Slow transport of sediment either onshore or offshore, or along the shore, which could transform ecological processes of the affected beach.

1.1.2 Scope of Works

This report assesses the following Oceanographic processes and impacts associated with the NPS:

- Physical processes that affect the mean sea level and temperature, coastal currents and productivity;
- Potential for flooding (sea level rise, tsunamis, astronomical tidal levels);
- Potential for supply of cooling water and associated factors and impacts such as exposure, blockages and damage to cooling water intake and outfall structure;
- Observed projected water levels (including extremes);
- Tsunami risks;
- Wave height, period and direction (including extremes);
- Inshore, offshore, spatial variation, surface and subsurface currents as well as correlation with wind patterns;
- Spatial and temporal variation in sea water temperature;
- Hydrographic fluctuations based on climatic changes;
- Spatial and temporal variation in sediment characteristics;
- Beach survey and Coastline stability;
- Gross and net sediment transport rates;
- Assess the impact of potential spoil material as a result of excavations and the deposition at sea;
- Blockage and fouling; and
- Bathymetry.

1.2 Study Approach

The information included in this report is the result of a desktop analysis of available information for each the three sites. The following documents were used to compile this report:

- Eskom 2007: **Areva, EPR Technical Description**, Rev A. Received from Eskom, August 2007.
- Eskom 2008b: **Cooling water Intake and Outfall works for the Eskom Nuclear 1 Sites, Conceptual Arrangements.** Nuclear Programmes Department Nuclear-1.
- Eskom 2009: **Environmental Impact Assessment for the Proposed Nuclear Power Station ('Nuclear-1') and Associated Infrastructure, Marine Disposal of Sediment.** Report No. J27035. November 2009.
- IAEA, 2003: **Flood Hazards for Nuclear Power Plants on Coastal and River Sites**. International Atomic Agency. IAEA Safety Standards Series No . NS-G-3.5
- CGS2008: **A Probabilistic Tsunami Hazard Assessment for Coastal South Africa from Distant Tsunamogenic areas.** By A. Kijko, V. Midzi, J. Ramperthap and M. Singh. Council for Geoscience Report No. 2008 - 0156, Revision 2.
- ***Prestedge Retief Dresner Wijnberg*** (PRDW), 2008: **Eskom Nuclear -1 EIA: Modelling of Construction Stage Brine Discharge**. Report No 1010/5/001. .

- PRDW 2009a: **Nuclear Site Safety Reports, Coastal Engineering Investigations, Duynefontein.** Report No. 1010/4/102. October 2009.
- PRDW 2009b: **Nuclear Site Safety Reports, Numerical Modelling of Coastal Processes, Duynefontein.** Report No. 1010/4/101. September 2009.
- PRDW 2009c: **Nuclear Site Safety Reports, Coastal Engineering Investigations, Bantamsklip.** Report No. 1010/3/102. October 2009.
- PRDW 2009d: **Nuclear Site Safety Reports, Numerical Modelling of Coastal Processes, Bantamsklip.** Report No. 1010/3/101. September 2009.
- PRDW 2009e: **Nuclear Site Safety Reports, Coastal Engineering Investigations, Thyspunt.** Report No. 1010/2/102. October 2009.
- PRDW 2009f: **Nuclear Site Safety Reports, Numerical Modelling of Coastal Processes, Thyspunt.** Report No. 1010/2/101. October 2009.
- Shillington, F.A, 2008: **Nuclear 1: Environmental Impact Assessment and Environmental Management Programme. Specialist Study for Scoping Report: Oceanography.** Dept of Oceanography, University of Cape Town

1.2.1 Coastal Engineering Investigations and Numerical Modelling

PRDW, as part of a multi-disciplinary team preparing the Site Safety Reports (SSRs), is responsible for the Oceanography and Coastal Engineering Chapter of the SSR. Coastal Engineering Investigations and the Numerical Modelling of Coastal Processes Reports have been prepared by PRDW for each of the sites. The SSR's compiled by PRDW are available in Appendix C to Appendix H.

1.2.2 Field Measurements

As part of the Nuclear Site Programme, a comprehensive baseline data collection programme ***was*** developed and implemented at each of the three alternative sites. Data collection is ongoing for the following parameters:

- Beach profiles;
- Bathymetry;
- Sediment grain size;
- Water levels;
- Wave data;
- Currents;
- Seawater temperature;
- Salinity;
- Turbidity; and
- Biofouling.

The following table shows the start and anticipated end dates for the data collection efforts for each site. Since data collection is currently ongoing, the table also illustrates the period of data ***that*** was available for reporting and modelling.

Table 1-1: Data collection programme for each site

Site	Start data	Used in reporting	End date
Duynefontein	January 2008	February 2009	August 2010
Bantamsklip	February 2008	July 2009	August 2010
Thyspunt	February 2008	September 2008	August 2010

In addition to the data collected specifically for each of the sites, long-term data on various oceanographic parameters have been obtained from a number of sources. Where relevant, the source of the long-term data will be provided.

1.2.3 Assumptions and Limitations

Return periods of up to 1:10^6 have been analysed by PRDW. However, with the exception of tsunami events, only the values for the 1:1, 1:10 and 1:100 year return periods will be used within the Oceanographic Impact Assessment. Additionally, as stated within the PRDW reports, since predictions are based on datasets covering periods as short as three years, the predictions for longer return periods need to be interpreted with extreme caution.

Cooling water discharge may contain co-discharges such as chlorine. These co-discharges have not yet been quantified and therefore an assessment of the significance of impacts associated with co-discharges is not possible until concentrations of each parameter in the discharge are known. Increased levels of co–discharges are not expected to affect the operation of the NPS. ***However, t***hey may have an impact on the marine ecology depending on the type and concentration of the co-discharge. The ecological sensitivity of the receiving marine environment to these discharges is discussed further in the Marine Ecology Specialist Study ***(Appendix E15 of the Revised Draft EIR).***

A departure from the consistent data set supplied by Eskom was noted in the PRDW modelling reports. The modelled outlet position at Duynefontein is 3.5 km offshore compared to approximately 500 m offshore as stated in the Consistent Dataset, as it was necessary to move the outlet further offshore at Duynefontein in order to avoid recirculation back to the existing Koeberg intake. This is clearly explained in the Duynefontein Modelling report (Appendix D).

All assumption and input data used by PRDW are outlined in the Site Safety Reports which are available in Appendices C to I.

1.3 Project Description / Key Project Aspects

The design of the NPS is discussed in detail in the Environmental Impact Report. A brief project description and aspects of the NPS that may directly affect or will be affected by the physical marine environment are outlined in the sections below.

1.3.1 Cooling Water Intake and Outfall Structures

The following intake and outfall options have been considered for each of the sites:

1. ***Duynefontein***

- ***Offshore tunnel intake, offshore tunnel outfall***

2. ***Bantamsklip***

- ***Option 1: Offshore tunnel intake and offshore tunnel outfall***
- ***Option 2: Basin intake and nearshore channel outfall***

3. ***Thyspunt***

- ***Offshore tunnel intake and nearshore channel outfall***

Since no engineering feasibility studies on the intake and outfall structures had been completed by Eskom at the time the Nuclear Site Safety Reports were drafted, conceptual layouts were developed by PRDW to illustrate the thermal plumes and recirculation that can be anticipated for the chosen intake and outfall types. These conceptual layouts will need to be refined based on geotechnical and engineering considerations. Basic design details for each of the cooling water intake and outfall structures at each of the sites are outlined in the sections below.

<u>Offshore tunnel intake and tunnel outfall options</u>

The preferred design option for the cooling water intake consists of an undersea intake/s connected to the shore via an undersea tunnel/s. The intake structure is to be placed at the end of the intake tunnel at a depth of about 25-30m below mean sea level. This will result in an overall tunnel length from the onshore access shaft of approximately 1.0km to 2.0km. The intake openings will be positioned 3m to 5m above the sea bed to prevent drawing in large quantities of sediment. Construction of the intake structure may take place in a temporary cofferdam. Once complete the cofferdam will be breached and the structure floated out to sea and positioned over the tunnel on a prepared base.

It will be constructed from 6 to 8 pipes 3m in diameter placed beneath the sea floor. The ends of the pipes will be raised to prevent erosion of the sea floor. Construction of the outfall will take place within a temporary cofferdam, which will be removed once construction is complete (Eskom, 2008a).

The cooling water intake and outfall structures will be designed to 'no damage' criteria using appropriate extreme conditions and conventional coastal engineering procedures and will be positioned in a depth (-25 to -35m amsl) where extreme wave conditions (do not have a damaging impact on the structure or any of its components. Design measures to reduce blockages by sand, oils slicks, marine debris and marine fauna and flora resulting in an interruption of the cooling water will be implemented and will include the following:

- The depth of the intake structure significantly reduces the risk of blockage. Furthermore the suspended sediment levels at these depths are much lower than closer inshore, thus reducing the amount of sand sucked in by the pumps.
- Suitable grids will prevent the ingress of large marine life. The velocity of water will be controlled, and the intakes will be positioned 3 -5m above the sea bed to prevent drawing in large quantities of sediment.
- The intake pipe will be covered by a velocity cap which converts vertical flow into horizontal flow at the intake entrance to reduce fish entrainment. It has been noted that fish will avoid rapid changes in velocity flow and velocity cap intakes have shown to provide an 80 to 90% reduction in fish impingement.
- Chlorine, produced by electrolysis, will be used to keep the cooling system free of marine growth.
- Cooling water will be discharged into a cooling water basin, the entrance of which will be provided with screens and a fixed dredging system to remove sedimentation (PRDW, 2009f).

<u>Design details for the basin intake and nearshore outfall</u>

Offshore intake systems will take in water of better quality and will require less pre-treatment than a nearshore intake system. A basin intake has, however, been considered at the Bantamsklip site. Water will be drawn from the basin via a pumphouse that will be designed to limit the possibility of blockage of the intakes. Water will be drawn at a suitable level to limit risk of blockage by flotsam, fuel oil and marine flora and fauna. Nevertheless, suitable coarse and fine screens will be provided to prevent a sudden complete blockage. The layout and position of the basin will be designed in such a way that it reduces the siltation rate of the basin. The depth of the basin will be maintained by maintenance dredging.

The settling basin needs to be designed to capture fine suspended sediments. The basin layout needs to fulfil the following requirements (PRDW 2009c):

- ***Sand larger than 0.15 mm should be removed;***
- ***Currents in the entrance channel U > 0.6 m/s;***
- ***Currents in the settling basin U < 0.1 m/s; and***
- ***Space needs to be allowed for installation of the pump houses.***

For the purposes of developing a basin concept, the main characteristics of the existing Koeberg basin were rescaled to meet the above requirements. Table 1-2 below summarises the basic design criteria for the basin. The minimum current in the entrance channel is significantly lower than the recommended 0.6 m/s. This will result in accretion of sediments at the entrance of the basin and will carry on until a natural equilibrium is reached. These shallow entrance conditions will not impact on the proper functioning of the intake basin.

The nearshore basin will be designed to a "no-damage" criteria (less than 5% damage) where the damage is defined as a percentage of the eroded volume.

Table 1-2: Criteria of basin used in modelling

Parameter	***Design criteria***	***New basin***
Cooling water intake	***-***	***380 m^3/s***
Basin entrance width		***145 m***
Basin entrance depth	***-***	***-12 m CD***
Width of the settling basin	***-***	***530 m***
Length of the settling basin	***-***	***750 m***
Dredge depth	***-***	***-7.5 m CD (dredge design depth)***
Current in entrance channel	***> 0.6 m/s***	***0.2 m/s***
Current in settling basin	***< 0.1 m/s***	***0.09 m/s***
Min. particle diameter able to settle	***150 microns***	***60 microns***

Source: PRDW (2009c).

1.3.2 Thermal Plume Dispersion and Recirculation

Cooling water discharged from the outfall will have a temperature of 12ºC above the ambient sea water temperature. Should the cooling water increase the sea water temperature in the vicinity of the intake structure, the cooling and subsequently the efficiency of the power station may be affected.

Dispersion of the thermal plume from the cooling water outflow at each of the three sites has been modelled by PRDW as part of the Nuclear Sites Safety Report. A number of conceptual layouts were developed to illustrate the thermal plumes and recirculation that can be anticipated for typical intake and outfall configurations.

1.3.3 Co-discharges

In addition to the increased temperature and potential for recirculation, the cooling water discharge may also contain co-discharges such as chlorine. Since these co-discharges have not yet been quantified. , they have been treated as conservative tracers, i.e. they undergo dilution by physical mixing only and any additional biochemical or physical processes are not modelled. The model results provide the achievable dilutions for any discharged constituent. Once the concentration of these constituents has been quantified, the potential impact of these constituents can be assessed by comparing the achievable dilutions from the model results to the dilution required to reduce the concentration at discharge to a level at which no impacts occur.

No assessment of the significance of impacts associated with co-discharges is possible until concentrations of each parameter in the discharge are known.

N.B. The result of the thermal plume dispersion modelling can also be interpreted as dilution factors for any co-discharges such as chlorine, nuclides, etc. as follows: divide 12 (the initial temperature increase) by the temperature increase shown in the plots, e.g. the 2℃ contour in the plots represents a dilution factor of 12/2 = 6. If the co-discharge is mixed with the cooling water prior to discharge into the sea, the co-discharge will undergo a pre-dilution in the pipe in addition to the subsequent dilution in the sea.

1.3.4 Potable Water Supply

Reverse Osmosis (RO) desalination will be used to provide freshwater during the construction and operational stages of the power station. During the operation of the NPS the brine discharge from the desalination plant will be mixed with the cooling water from the power station and discharged through the cooling water outfall. The volume of brine is significantly smaller than the volume of cooling water and therefore once the brine has been added to the cooling water it will be virtually undetectable. ***However, d***uring the construction stage the cooling water outfall structure will not be completed and the brine will have to be discharged independently to the cooling water.

Three discharge options for the brine have been considered, namely discharging the brine through a pipe located on the upper beach profile, from a pipe located in the surfzone at a depth of 5m or from a pipe located beyond the surfzone at a depth of 10m. The pipe located on the upper beach level will be situated above the maximum wave run up to prevent damage by wave action as well as scour, burial or blockage of by sand. Disposal of the brine in the turbulent surfzone will also improve mixing and reduce the risk of the brine forming a density current, which will potentially transport the brine offshore along the seabed without undergoing significant additional dilution.

Discharging the brine at a depth of approximately 5m would still result in the brine being discharged into the surfzone at all three of the sites. The pipe would be buried or extended from a jetty in the surfzone. It is not certain whether this option will increase dilution as current speeds and wave induced turbulence will be reduced with increasing depth. A further option is to discharge the brine beyond the surfzone at a depth of 10m. High initial dilutions could be achieved through discharging the brine upwards from the seabed at high velocities from one or more nozzles. This option will have significant cost and construction impacts associated with it (PRDW, 2008b).

1.3.5 Extreme Sea Levels

As per recommendations of the International Atomic Energy Agency (IAEA, 2003), the coastal engineering investigations have considered combinations of extreme events in order to derive the design basis for flooding and drying at each of the facilities.

The following hydrographic conditions contribute to the combined water level:

- Sea level rise;
- Tidal levels;
- Storm surge;
- Wave set-up and run-up;
- Positive and negative basin seiche;
- Long wave;
- Tsunami (described in detail in section 1.3.6 below)

Each of these conditions is studied individually and in combination within the coastal engineering investigations, which form part of the SSRs. The results of the combined extreme events analysis provides the theoretical extreme (maximum and minimum) water levels that are predicted at each of the sites over a range of return periods, excluding and including the effects of climate change and anticipated sea level rises.

1.3.6 Tsunami

A tsunami is a train of water waves generated by impulsive disturbances of the water surface due to non-meteorological but geo-physical phenomena such as submarine earthquakes, volcanic eruptions, submarine slumps and landslides or ice falls into a body of water.

Distant Tsunami
The Council for Geoscience compiled a report (CGS, 2008) titled ‘A Probabilistic Tsunami Hazard Assessment for Coastal South Africa from Distant Tsunamogenic Areas’. The report identifies Sumatra, Karachi and the South Sandwich Islands as tsunamigenic regions which can affect the coastal areas of South Africa. For each region the report provides the maximum credible earthquake magnitude and the corresponding fault parameters.

For each source region, a number of tests were performed using the hydrodynamic model to investigate which combination of fault parameters resulted in the worst tsunami reaching the nuclear site. Based on these tests, six distant tsunami events from three tsunamigenic regions have been modelled within the SSRs: Sumatra (3 events), Karachi (1 event) and South Sandwich Islands (2 events). The fault parameters and resulting maximum vertical seabed displacements for each tsunami event are provided in PRDW 2009a.

Local Tsunami
Offshore slump generated tsunamis are considered as the largest unknown risk factor for the South African coast (PRDW 2009a). A number of slump regions have been documented where historical slumping has occurred on massive scales in various

phases including late Mesozoic (148 million years ago - 65 million years ago), early to late Tertiary (65 Ma - 1.8 Ma) and possibly Quaternary (1.8 Ma-present). However, a quantitative assessment of the risk of occurrence and geometry of future slump events along the South African shelf margin is not available at present. This is in contrast to the distant tsunamigenic sources, which are comparatively well defined.

Three theoretical slumps have been modelled, with each slump located within one of the historical slumping regions and directly opposite one of the three proposed nuclear sites, as shown in Figure 1-2.

The magnitude of tsunami generated by a slump depends on a number of parameters, including slump volume, water depth, slump thickness, initial acceleration and maximum velocity of the slump. The geometry of the slumps that have been modelled is based on the measured geometry of the upper or proximal part of the Agulhas Slump. Setting the slump width equal to the slump length gives a slump volume of 80 km^3.

1.3.7 Seawater Temperature

The ambient temperature of the water is important as it affects the efficiency of the cooling process within the plant. The following data is for seawater intake temperatures of a typical Pressurised Water Reactor (PRW):

- Maximum cooling water temperature: 30℃;
- Minimum cooling water temperature: -0.4℃; and
- Extreme conditions for safety assessment: 34.5℃

The two main factors influencing the intake temperature are the ambient temperature at the intake depth and possible recirculation from the outfall back to the intake. The potential for impacts associated with extreme seawater temperatures at the intakes will be assessed for each of the possible sites.

1.3.8 Coastline Stability

The stability of a length of coastline depends on the difference between the volumes of sediment entering and leaving this section as a consequence of the net cross-shore and longshore sediment transport due to waves, currents and wind. The coastline will either be eroding, accreting or remaining in equilibrium. If equilibrium exists, it is most likely to be a dynamically stable equilibrium, whereby the coastline is evolving continuously in response to varying winds, waves and currents.

In order to assess the impacts of the driving mechanisms of coastline stability, the following physical processes of erosion/accretion are considered:

- Long-term coastline trends;
- Seasonal variations in the coastline;
- Storm event erosion; and
- Effects on coastline movement due to long term sea level rise.

Each of these factors have been assessed for each of the potential sites within the SSRs. The results of this analysis are summarised in Section 2 of this report.

1.3.9 Disposal of Spoil Material

One option being considered for disposing excess sediment from the excavations for Nuclear-1 is to discharge it offshore. The potential impacts resulting from this activity include an increase in suspended sediment during the disposal and an increase in heavier sediment on the ocean floor.

Numerical modelling has been used to simulate how the discharged sediment is distributed on the seabed and how this sediment moves over time due to wave and current forcing (Eskom, 2009). The finer sediment fractions will be suspended in the water column and the advection and dispersion of the resulting sediment plumes is also modelled. For each proposed nuclear site (i.e. Duynefontein, Bantamsklip and Thyspunt) two different disposal sites (one relatively deep and relatively shallow site), two different sediment volumes and two sediment discharge rates have been modelled.

The various disposal options have been assessed against a number of criteria. The criteria relevant to potential oceanographic impacts are as follows:

- To avoid the area around the intakes of the proposed cooling water intake tunnels (risk of sediment entrainment during power plant operation);
- To reduce the impact of the mound on wave refraction, the shore-normal dimension of the mound should be less than the shore-parallel dimension; and
- To reduce the impact of the mound on wave refraction, the thickness of the mound should be less than approximately 10% of the water depth.

The potential ecological impacts of disposing of the spoil material have been assessed within the Marine Ecology Specialist Study (Appendix E15 of the Revised Draft EIR) and will therefore not be covered within this report.

1.3.10 Climate Change

Scientific opinion suggests that changes to climate may occur within the design life of many coastal and ocean engineering activities. Consequently, consideration of the possible impacts of climate change have been included in the Oceanography and Coastal Engineering chapter of the Site Safety Reports developed for each of the potential sites.

The adopted oceanographic and coastal engineering climate change parameters for this site safety assessment are shown in Table 1-3. The 90 to 100 year horizon takes account of the likely life of the nuclear facility (60 years) and cognisance of the phasing in of facilities over the next 20 plus years.

Table 1-3: Adopted parameters for climate change to year 2100

Parameter	Change (Year 2100)
Sea level rise	+ 0.8 m
Sea temperature	+ 3℃
Wind speed	+ 10%
Wave height	+ 17%
Storm surge	+ 21%

Where relevant the result of modelling is presented with and without the effects of climate change.

2 DESCRIPTION OF AFFECTED ENVIRONMENT

Three alternative sites for the construction of the NPS have been identified namely: Duynefontein, Bantamsklip, and Thyspunt. The site locality and a description of physical environment at each of the sites are outlined in the sections below.

2.1 Duynefontein

2.1.1 Site Locality and Description

Duynefontein is situated adjacent to the existing Koeberg site on the West Coast approximately 30km north of Cape Town. The site consists of the northern part of Cape Farm No. 34 known as Duynefontein and the adjoining coastal strip farm 1375. The Duynefontein farm stretches 4.4 km along the coast and 3.5 km inland.

Duynefontein is a highly exposed section of sandy coastline. The site is characterised by a shallow sloping sandy beach with a reasonably stable sediment transport regime. The site is underlain by the rocks of the Malmesbury Group of Precambrian age at a depth of between 5 and 12 m below Chart Datum (PRDW, 2008e). The site locality is indicated in the Figure 2-1 and the Physical Oceanographic characteristics of the site are discussed further in Sections 2.1.2 to 2.1.9.

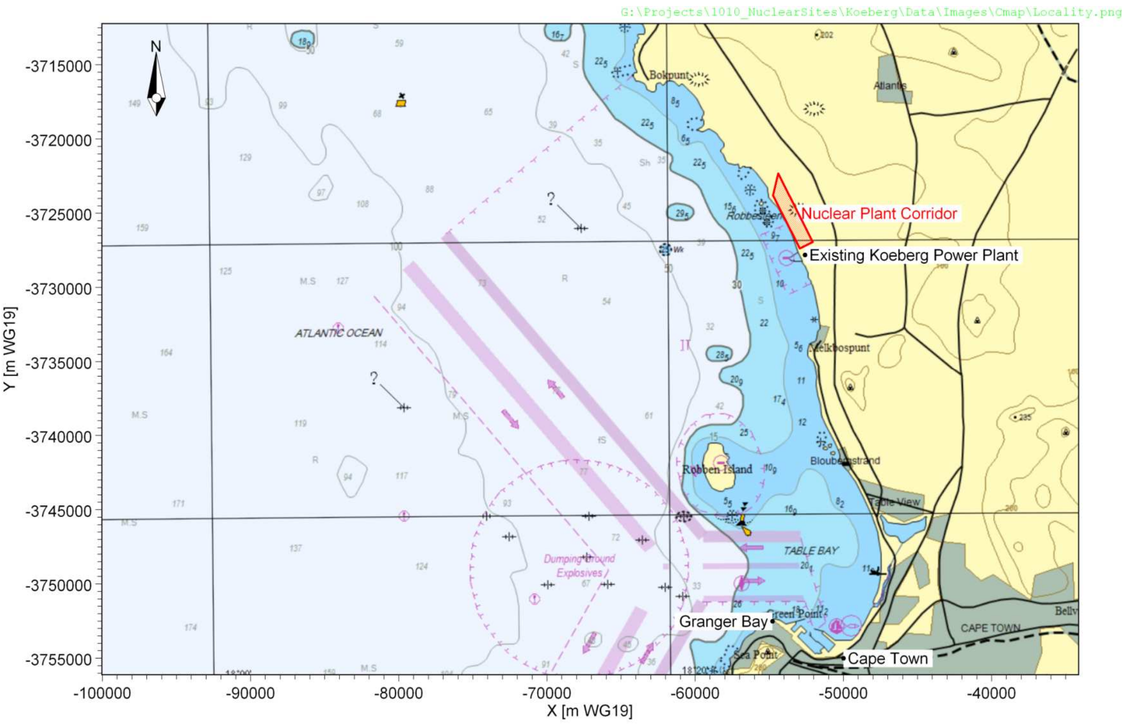

Figure 2-1: Site Locality of Duynefontein (Source PRDW2009a)

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2.1.2 Beach Profile and Bathymetry

The characteristic profile is a steep drop off at the beach edge followed by a gradually sloping area reaching -30 m approximately 3 km from the existing shoreline.

A number of cross sections have been taken along the Duynefontein site coastline from the -30 m to +10 m CD. Beach slopes for each of the four cross sections are summarised in Table 2-1 and Figure 2-2.

Table 2-1: Profile slopes of the coast at Duynefontein

	-30 m CD to -20 m CD		-20 CD to -5 m CD		-5 m CD to +10 m CD	
	Mean	Max	Mean	Max	Mean	Max
Profile 01	1:135	1:16	1:100	1:36	1:26	1:3
Profile 02	1:120	1:70	1:116	1:30	1:36	1:6
Profile 03	1:125	1:70	1:130	1:60	1:40	1:9
Profile 04	1:112	1:28	1:160	1:13	1:70	1:9

The Bathymetry of the seabed adjacent to the Nuclear Installation Corridor is shown in Figure 2-3.

2.1.3 Sediment Grain Size

Sediment samples were taken from the nearshore and from the beach (near the high and low water marks) on 13 March 2008.

The sand on the beach south of Koeberg has a D_{50}[*].of approximately 0.2 mm and a grading of approximately 1.2. The sand on the beach north of Koeberg has a D_{50} of approximately 0.4 mm and a grading of approximately 1.4, reflecting the steeper beach slope and larger waves north of Koeberg. The sand offshore has a D_{50} of approximately 0.15 mm and a grading of approximately 1.2, reflecting the deposition of finer sediments in deeper water.

2.1.4 Water Levels

The closest port to the Duynefontein site for which long term data is available is Cape Town. The predicted astronomical tidal levels (excluding other local effects) at Cape Town are as follows (PRDW 2009b):

Table 2-2: Predicated tidal levels at Cape Town

Parameter	Level (m CD)	Level (m MSL)
Lowest Astronomical Tide (LAT)	0.00	-0.83
Mean Low Water Springs (MLWS)	0.25	-0.58
Mean Low Water Neaps (MLWN)	0.70	-0.13
Mean Level (ML)	0.98	-0.16
Mean High Water Neaps (MHWN)	1.26	-0.44
Mean High Water Springs (MHWS)	1.74	-0.92
Highest Astronomical Tide (HAT)	2.02	-1.20

[*] D_N is the diameter for which N% of the sediment, by weight, has a smaller diameter. The sediment grading is defined as (D84/D16)0.5.

These levels are relative to Chart Datum, which is 0.825 m below Mean Sea Level or Land Levelling Datum. The values for MSL are accurate to the precision as supplied in the South African Tide Tables.

It should be noted that Highest Astronomical Tide and Lowest Astronomical Tide are the highest and lowest astronomical tides which can be predicted to occur under average meteorological conditions. They are not the extreme upper and lower levels which can be reached, as storm surges and other meteorological or geological (e.g. tsunami) conditions may cause considerably higher levels to occur.

The calculated extreme high water levels for the Duynefontein site including and excluding the effects of climate change are shown in Appendix 1 (Tables A1 and A2).

2.1.5 Wave Data

Waves have been measured at the Duynefontein site at Site A (water depth of 10 m) starting in January 2008 and at Site B (water depth of 30 m) starting in July 2008. Wave roses are shown in Figure 2.7

The largest storm recorded to date occurred on 9 August 2008, during which the significant wave height (H_{m0}) reached 6.7 m at Site B and 5.0 m at Site A (Figure 2.4). The dominant wave direction is 240° at both Sites A and B.

Based on analysis of fifteen years (November 1990 to October 2007, but excluding the period June 1991 to May 1993), the dominant wave direction is 230°, the median H_{m0} is 2.4 m and the maximum H_{m0} is 9.7 m.

2.1.6 Currents

The currents at Duynefontein are predominantly wind-driven. The currents near the surface reach 1 m/s and have a dominant direction of 340°, in response to the dominant south-easterly winds. The currents near the seabed are weaker and the directions are more evenly distributed between northward and southward. Summary statistics are presented in Table 2-3.

Table 2-3: Summary statistics of current speeds measured at the Duynefontein

	Site A (water depth 10 m)		Site B (water depth 30 m)	
	Near surface (-1.8 m)	Near Seabed (-7.8 m)	Near surface (-2.0 m)	Near Seabed (-25.5 m)
Main current speed (m/s)	0.17	0.11	0.19	0.07
Maximum current speed (m/s)	0.97	0.87	0.88	0.43

2.1.7 Coastline Erosion

Long-term Coastline Trends from Aerial Photographs

Three contour lines (the vegetation line, the high water mark and the +5 m MSL contour line) were digitised on each of the available geo-referenced aerial photographs.

Generally, the beaches to both the north and south of the existing Koeberg site appear to be dynamically stable for the period of observation from the aerial photographs. An accretional trend is evident on the northern section of Van Riebeeckstrand, while some erosion is evident on the Ou Skip north beach. Figure 2.5 provides an example of the photographic analysis undertaken.

The maximum expected horizontal erosion at the Duynefontein site is shown in Appendix 1, Table A4.

2.1.8 Sea Surface Temperature

A number of datasets are available for sea surface temperature at the Duynefontein site (PRDW 2009b). The data shows that the water column tends to be mixed in winter, while in summer the water temperature at 3 m depth may be up to 10℃ warmer than at 50 m depth. The average water temperatures at depths of 3 m, 10 m, 27 m and 50 m are approximately 13.3℃, 12.3℃, 11. 9℃ and 11.4℃ respectively.

The maximum expected seawater temperature at the Duynefontein site is shown in Appendix 1, Table A3.

2.1.9 Turbidity and Biofouling

To date 44 water samples have been collected and analysed for Total Suspended Solids (TSS), which comprise both organic (e.g. algae) and inorganic (e.g. silt) particles suspended in the water column. The average TSS measured is 4 mg/L. The TSS concentration is relatively uniform over the water column, implying that these are smaller cohesive sediment particles ($D50 < 0.063$ mm) rather than larger particles (which would show a significantly higher concentration near the seabed).

Biofouling has been measured at the Duynefontein site by mooring asbestos plates 3 m and 8 m below the water surface in 10 m water depth (Eskom, 2008a). Results are currently available for plates deployed in May 2008 and recovered in 18 October 2008, i.e. approximately 5 months in the sea. The average biofouling thickness measured on the plate deployed 3 m below the surface was 1.6 cm, while the plate deployed 8 m below the surface had an average thickness of 1.75 cm. The following organisms have been identified on the respective plates:

- Top Plate: Combination of flora and fauna, mostly barnacles, worms and algae. Higher density of algae at the corners; and
- Bottom Plate: Combination of flora and fauna, including algae, small sponges, barnacles, worms and small crabs. Higher density of organisms identified at the corners of the plate.

2.2 Bantamsklip

2.2.1 Site Locality and Description

Bantamsklip is situated in the Western Cape approximately 10km south east of Pearly Beach, between Danger Point to the northwest and Quoin Point to the south east. The site is on a coastal plain with an elevation of less than the 60m amsl, situated to the south west of a discontinuous line of hills which lies parallel to the coast at a distance of 4 to 5 km.

The site is covered by vegetated semi-consolidated dunes, consisting of light brown poorly sorted calcareous sands, with alternating calcarenite and boulder beds overlying the basement rock. The site is underlain by Peninsula Formation quartzites with minor green to grey shale bands. The Peninsula Formation quartzites have formed a rocky coastline with extensively developed joints sets causing the outcrop to have a very ragged appearance. A 10 – 60 m grass covered flat strip occurs between the beach and the first dunes minor groundwater seeps occur along the contact between the grassy flats and bedrock, with a few springs restricted to the faulted area on the northern portion of the site. A single dune with peaks between 10-15m amsl, with east and west dipping slopes, runs parallel to the immediate coastline (PRDW, 2009c).

The Bantamsklip site is situated on a highly exposed section of rocky coastline and is stable with respect to marine sediment dynamics (Shillington 2008). The two rocky headlands form an isolated cell with no sediment feeds or losses into or out of the cell. There are no rivers feeding significant sand volumes in the vicinity and despite the high wave energy and extensive offshore sandy seabed, the actual net long shore transport rate is expected to be negligible due to the near perpendicular approach of deep sea waves to the coastline. A redistribution of sand deposits is expected to occur under storm conditions and high concentration of sediments in the breaker zone.

The main sea bed features within a three kilometre radius of Bantamsklip are sandstone. A deep gully is situated north of the site and a large reef area characterised by breaking waves is situated in front of the headland of Bantamsklip. There is a gently sloping depression in the topography on the eastern side of the site.

The site locality is indicated in the figure below and the Physical Oceanographic characteristics of the site are discussed further in 2.2.2 to 2.2.9.

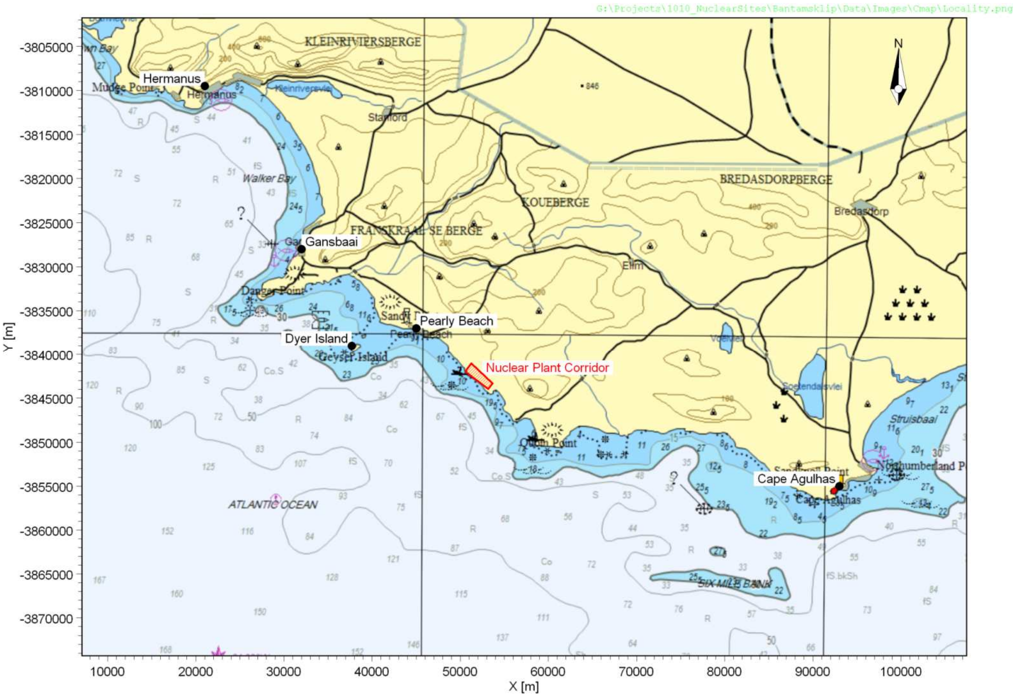

Figure 2-6: Site locality of Bantamsklip (Source: PRDW 2009c)

2.2.2 Beach Profile and Bathymetry

A number of cross-sections have been taken along the Bantamsklip site coastline. Beach slopes for each of the cross-sections have been assessed (refer to Figure 2-7 for profile details). Table 2-4 summarises slope information for all of the profiles.

Table 2-4: Profile slopes of the coast at Bantamsklip

	-30 m CD to -20 m CD		-20 CD to -5 m CD		-5 m CD to +10 m CD	
	Mean	Max	Mean	Max	Mean	Max
Profile 01[1]	1:185	1:18	1:78	1:17	1:37	1:0.9
Profile 02	1:45	1:12	1:150	1:12	1:42	1:12
Profile 03	1:114	1:19	1:81	1:24	1:34	1:9
Profile 04	1:162	1:17	1:53	1:25	1:32	1:7
Profile 05	1:33	1:17	1:24	1:24	1:42	1:11

Notes:
1) Profile information extrapolated from + 5 m CD due to lack of topographic information

The Bathymetry of the seabed adjacent to the Nuclear Installation Corridor is shown in Figure 2-8.

2.2.3 Sediment Grain Size

Sediment samples were taken on the beaches near the high and low water marks on 25 March 2008. Samples were also taken from the nearshore (10 to 30 m depth) on 26 and 27 March 2008. Of the 20 nearshore stations sampled, 13 were found to be located on rocky reef and sand samples were thus obtained from only 7 nearshore stations.

The results indicate that the sand on the beach at Pearly Beach is uniform with an average D_{50} of 0.20 mm and an average grading of 1.3. The sand on the beach in front of the Nuclear Plant Corridor is variable, with D_{50} varying from 0.14 to 0.61 mm, and the grading from 1.3 to 1.5. The 7 nearshore samples had a D_{50} ranging from 0.14 to 0.61 mm and a grading from 1.2 to 1.6. The nearshore sampling indicates extensive rocky reef offshore of the site

2.2.4 Tides

The closest port to the Bantamsklip site for which long-term tidal data is available is Hermanus. The predicted astronomical tidal levels (excluding other local effects) at Hermanus are as follows (PRDW 2009d):

Table 2-5: Predicated tidal levels at Hermanus

Parameter	Level (m CD)	Level (m MSL)
Lowest Astronomical Tide (LAT)	0.00	-0.79
Mean Low Water Springs (MLWS)	0.27	-0.52
Mean Low Water Neaps (MLWN)	0.75	-0.04
Mean Level (ML)	1.02	0.23
Mean High Water Neaps (MHWN)	1.29	0.50
Mean High Water Springs (MHWS)	1.78	0.99
Highest Astronomical Tide (HAT)	2.07	1.28

These levels are relative to Chart Datum, which is 0.788 m below Mean Sea Level or Land Levelling Datum. The values for MSL are accurate to the precision as supplied in the South African Tide Tables.

The calculated extreme high water levels for the Bantamsklip site including and excluding the effects of climate change are shown in Appendix 1 (Tables A5 and A6).

2.2.5 Currents

Currents have been measured at the Bantamsklip site at Site A (water depth of 12 m) and Site B (water depth of 30 m) starting in March 2008. The currents show evidence of forcing by winds, waves and tides. The current speeds are moderate with a maximum speed of 0.73 m/s measured to date. Currents near the seabed are approximately half as strong as near the surface. The current direction show a high degree of variability, including predominantly north-westerly current near the surface at Site B and an easterly current near the seabed at Site A. Summary statistics are presented in Table 2-6.

Table 2-6: Summary statistics of current speeds measured at Bantamsklip

	Site A (water depth 12 m)		Site B (water depth 30 m)	
	Near surface (-1.2 m)	Near Seabed (-8.2 m)	Near surface (-3.8 m)	Near Seabed (-23.8 m)
Main current speed (m/s)	0.12	0.05	0.14	0.06
Maximum current speed (m/s)	0.73	0.60	0.62	0.41

2.2.6 Wave Data

Waves have been measured at the Bantamsklip site at Site A (water depth of 12 m) starting in January 2008 and at Site B (water depth of 30 m) starting in March 2008. Wave roses are shown in Figure 2.9

Two significant storms have been measured to date. Unfortunately in both cases only the instrument at Site B was operational. The storm of 24 June 2009 shows a steady increase in H_{m0} peaking at 7.5 m, while the H_{m0} level that is exceeded for 6 hours during the storm event is 7.2 m. At the peak of the storm the Tp is 17 s and the mean wave direction is 220°. In contrast, the storm of 9 August 2008 shows an erratic increase in H_{m0} reaching a peak of 8.6 m, while the H_{m0} level that is exceeded for 6 hours during the storm event is significantly lower at 5.8 m. The abrupt change in the measured H_{m0} (2.8 m increase in 1 hour) and wave direction (28° decrease in 1 hour) at the peak of the storm, along with the subsequent failure of the instrument, cast doubt on the accuracy of the peak values measured during this storm event.

2.2.7 Coastline Erosion

Long-term Coastline Trends from Aerial Photographs
Three contour lines (the vegetation line, the high water mark and the +5 m MSL contour line) were digitised on each of the available geo-referenced aerial photographs (Figure 2.10).

Though signs of both erosion and accretion are noticed in the analysis of the aerial photographs, these are believed to be indications of long term variations about dynamically stable beach shapes

The maximum expected horizontal erosion at the Bantamsklip site is shown in Appendix 1, Table A8.

2.2.8 Sea Surface Temperature

As part of the SSR, seawater temperature has been measured at Bantamsklip at sites A to D, starting in February 2008 (PRDW 2009b). The data shows that the water column tends to be vertically mixed in winter, while in summer the water temperature at 1.75 m depth may be up to 7℃ warmer than at 30 m depth.

The maximum temperatures for three sites within the vicinity of the Bantamsklip site are shown in Appendix 1, Table A7.

2.2.9 Turbidity and Biofouling

To date 78 water samples have been collected and analysed for TSS. The sampling was carried out at two sites, Site A and Site B. Site A has a water depth of approximately 12 m and samples are taken at depths of 4m and 8 m below the water surface. At Site B the total water depth is approximately 30 m and samples are taken at depths of 4, 12, 20 and 28 m below the water surface.

At Site A (total water depth = 12 m) the average TSS measured is 3.8 mg/L and the maximum is 16 mg/L. At the deeper Site B (total water depth = 30 m) the values are slightly lower, with an average TSS of 3.4 mg/L and a maximum of 10 mg/L. (For calculating the average values, TSS values of <5 mg/L and <2 mg/L have been set to 4 mg/L and 1 mg/L, respectively). The TSS concentration is relatively uniform over the water column (see Figure 10.12), implying that these are smaller cohesive sediment particles (D_{50} < 0.063 mm) rather than larger sand particles (which would show a significantly higher concentration near the seabed.

Biofouling has been measured at the Bantamsklip site by mooring asbestos plates 3 m and 8 m below the water surface in 10 m water depth (Eskom, 2008a) Results are currently available for plates deployed in October 2008 and recovered on 3 April 2009, i.e. approximately 6 months in the sea. However, the buoy line holding the plates at the required depth had been severed, resulting in no valid data being obtained.

2.3 Thyspunt

2.3.1 Site Locality and Description

The Thyspunt site is situated approximately 12km west of St. Francis Bay and 4km east of Oyster Bay. The Thyspunt site is located on an exposed section of coastline that faces towards the prevailing south westerly deep sea swell (Shillington 2008).

The area is underlain by quartzitic sandstones of the Kouga Formation, which are overlain by up to 50m of unconsolidated to consolidated sediments consisting of sand, calcrete and calcarenite of the Nanaga Formation. The main seabed feature to the east of Thyspunt is a wide band of rock with intermittent sediment cover. Offshore the seabed is composed of consolidated and partly consolidated sediments

A thin line of wetland vegetation not wider than 40m lies between the coast and the vegetated sand dunes. The vegetated stabilised dunes strike ENE and extend northwards from the marshy area. At approximately 300m inland to the north lies a large dunefield reaching more than 50m amsl. The vegetation consists of typical thicket, shrubs and coastal dune fynbos.

This is a highly stable section of coastline with respect to marine sediment dynamics, with areas of exposed rocky coastline and a few small beaches protected by rocky headlands. The significant headlands of Seal Point and Cape St. Francis form an isolated coastal cell with sediment feeds or losses unlikely to occur into or out of the cell from the adjacent sections of coastline. There are no major rivers discharging into this section of coastline.

Seabed slopes in the rocky western part of the site are steep (1:10) in the nearshore region (+2 to -10m CD) while the beach located east of the site has a gradual slope (1:100) (PRDW, 2009e).

The site locality is indicated in the figure below and the Physical Oceanographic characteristics of the site are discussed further in Sections 2.3.2 to 2.3.9.

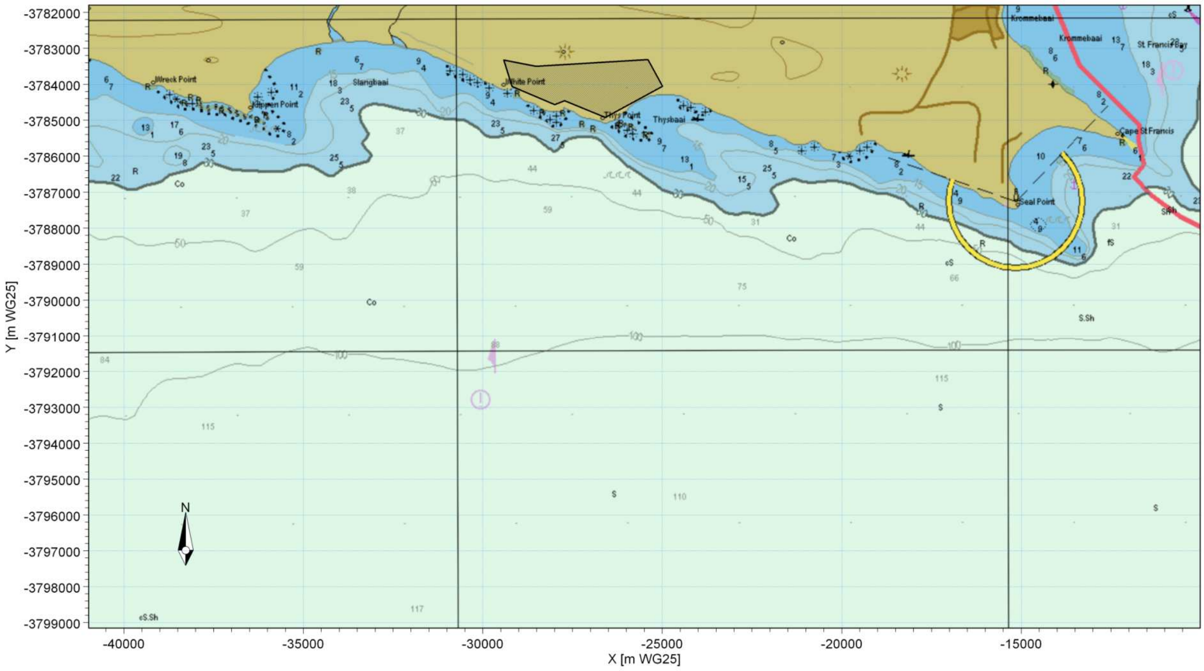

Figure 2-11: Site locality Thyspunt (Source: PRDW2009e)

2.3.2 Beach Profile and Bathymetry

A number of cross-sections have been taken along the Thyspunt site coastline. Beach slopes for each of the cross-sections have been assessed (refer to Figure 2-12 for profile details). Table 2-7 summarises slope information for all of the profiles.

Table 2-7: Profile slopes of the coast at Thyspunt

	-30 m CD to -20 m CD		-20 CD to -5 m CD		-5 m CD to +10 m CD	
	Mean	Max	Mean	Max	Mean	Max
Profile 01	1:50	1:6	1:10	1:7	1:25	1:6
Profile 02	1:50	1:8	1:17	1:10	1:25	1:7
Profile 03	1:10	1:6	1:40	1:8	1:13	1:7
Profile 04	1:60	1:15	1:60	1:14	1:25	1:7
Profile 05	1:25	1:17	1:70	1:14	1:26	1:7

The Bathymetry of the seabed adjacent to the Nuclear Installation Corridor is shown in Figure 2-13.

2.3.3 Sediment Grain Size

Sediment samples were taken from the nearshore and from the beach (near the high and low water marks) on 5 and 6 April 2008, respectively.

The sand on the beaches has a D_{50} of 0.2 to 0.4 mm, while further offshore D_{50} is generally 0.1 to 0.2 mm, except on the reef where larger sized gravel and shell fragments are found.

2.3.4 Tides

The closest port to the Thyspunt site for which long-term tidal data is available is Port Elizabeth. The predicted astronomical tidal levels (excluding other local effects) at Port Elizabeth are as follows (South African Tide Tables, 2009):

Table 2-8: Predicated tidal levels at Port Elizabeth

Parameter	Level (m CD)	Level (m MSL)
Lowest Astronomical Tide (LAT)	0.00	-0.84
Mean Low Water Springs (MLWS)	0.21	-0.63
Mean Low Water Neaps (MLWN)	0.79	-0.05
Mean Level (ML)	1.04	0.20
Mean High Water Neaps (MHWN)	1.29	0.45
Mean High Water Springs (MHWS)	1.86	1.02
Highest Astronomical Tide (HAT)	2.12	1.28

These levels are calculated relative to Chart Datum, which is 0.836 m below Mean Sea Level or Land Levelling Datum (South African Tide Tables, 2009). The values for MSL are accurate to the precision as supplied in the South African Tide Tables.

The calculated extreme high water levels for the Thyspunt site including and excluding the effects of climate change are shown in Appendix 1 (Tables A9 and A10).

2.3.5 Currents

Currents have been measured at the Thyspunt site starting in February 2008 at two sites (Site A and Site B). The dominant current direction is towards the east and the current speeds are moderate near the surface and low near the seabed, as shown in Table 2-9.

Table 2-9: Summary statistics of current speeds measured at Thyspunt

	Site A		Site B	
	Near surface (-2.3 m)	Near Seabed (-12.4 m)	Near surface (-2.2 m)	Near Seabed (-23.2 m)
Main current speed (m/s)	0.11	0.05	0.20	0.10
Maximum current speed (m/s)	0.70	0.45	0.72	0.57

2.3.6 Wave Data

Waves have been measured at the Thyspunt site starting in February 2008 at two sites (Site A and Site B). Wave roses for Sites A and B are shown in Figure 2.14.

The largest storm recorded to date occurred on 1 September 2008, during which the maximum waves measured at Site A were H_{m0} = 5.6 m, Tp = 19.4 s and mean direction = 210°. The instrument at Site B was not operational during the storm.

2.3.7 Coastline Stability

Long-term Coastline Trends from Aerial Photographs

Three contour lines (the vegetation line, the high water mark and the +5 m MSL contour line) were digitised on each of the available geo-referenced aerial photographs.

For Slangbaai and Thysbaai, the closest beaches to the nuclear installation corridor, though signs of both erosion and accretion are noticed in the analysis of the aerial photographs. These are believed to be indications of long term variations about dynamically stable beach shapes. Figure 2-15 provides an example of this photographic analysis.

The maximum expected horizontal erosion at the Thyspunt site is shown in Appendix 1, Table A12.

2.3.8 Sea Surface Temperature

Temperature measurements at site started in February 2008 (PRDW 2009d). The data shows water column stratification of up to 7℃ on occasion, while the water column is well mixed on other occasions. The available data indicates an average decrease in temperature of approximately 1.3℃ between a depth of 2 m and a depth of 27 m. These temperature measurements are ongoing and will provide valuable design data in the future, specifically once more than one year of data is available.

Long-term sea surface temperature data from two nearby sites (Tsitsikamma and Storms River Mouth) has been obtained in order to support the temperature measurements at the site. A minimum of 9.4℃ and maximum of 27℃ has been observed at these sites, with the average temperature approaching 17℃.

The maximum expected seawater temperatures for three locations within the vicinity of the Thuyspunt site are shown in Appendix A, Table A11.

2.3.9 Turbidity and Biofouling

One set of 11 seawater samples has been taken at the Thyspunt site on the 20th July 2008. The samples were taken between 2 and 8 m below the water surface in water depths between 4 and 30 m. The measured suspended solids concentrations are between 2 and 10 mg/L, with an average of 3 mg/L.

Biofouling has been measured at the Thyspunt site by mooring asbestos plates 3 m and 8 m below the water surface in 10 m water depth. Results are currently available for plates deployed on 1st July 2008 and recovered on 23rd October 2008, i.e. approximately 4 months in the sea. The average biofouling thickness measured on the plate deployed 3 m below the surface was 7.5 mm, while the plate deployed 8 m below the surface had an average thickness of 2.8 mm.

3 IMPACT IDENTIFICATION AND ASSESSMENT

Potential impacts on the physical marine environment brought about by the construction and operation of the NPS at each of the sites are identified below in the tables below. In addition to the impacts of the NPS on the physical marine environment, impacts of storm events, global warming and natural disasters such as tsunamis that will affect the operation and safety of the NPS have been identified based on substantiated environmental data and informed judgement based on experience. Issues considered to have no impact will not be considered further in the reporting.

3.1 Duynefontein

3.1.1 Construction Impacts

Issue	Baseline Condition	Potential Impact	Significance
Short term disruption of sediment transport	The beaches to both the south and north of the existing Koeberg site appear to be dynamically stable. Net sediment transport levels are low but vary along the beach due to the presence of rip cells. There is little transport out of the cell and clear seasonal trends are evident due to changes in wind direction.	Cofferdams constructed in the surfzone may interrupt longshore sediment transport.	*Low*
Erosion due to brine discharge	Sandy coastline changes in beach profile due to seasons and storm events.	Brine discharged from pipe at the RO plant will result in erosion channel across the beach.	*Low*
Impact on existing Koeberg cooling water intake due to disposal of spoil	The existing Koeberg NPS intake pumps may be impacted negatively by increased suspended sediment concentrations during the spoil disposal operations.	The cooling water pumps at the existing Koeberg NPS can cope with sediment concentrations up to 130 mg/l. The model results indicate that for all alternatives studied, the suspended sediment concentration in the Koeberg intake basin is 80 mg/l, implying that the Koeberg intake pumps are unlikely to be impacted negatively.	*No Impact*

3.1.2 Operational Impacts

Issue	Baseline Condition	Potential Impact	Significance
Long term disruption of sediment transport	The beaches to both the south and north of the existing Koeberg site appear to be dynamically stable. Net sediment transport levels are low but vary along the beach due to the presence of rip cells. There is little transport out of the cell and clear seasonal trends are evident due to changes in wind direction.	The offshore tunnel intakes and outfall structures will only have very localised impacts on the sediment transport field.	*Low*
Discharge of desalination brine	The brine from the RO plant will be mixed into the cooling water and discharged at the outfall.	Mixing the brine will result in significant dilution and the brine will be undetectable at the outfall.	*No impact*
Potential impact as a result of non-nuclear accidents and incidents	No non-nuclear accidents that are expected to affect the oceanography of the surrounding area have been identified	N/A	*No impact*

3.1.3 Environmental Impacts on the NPS

Issue	Baseline condition	Potential Impact	Significance
Extreme sea level			
Flooding from sea	Extreme tides, waves or storm surge may result in the sea level being raised above the level of the NPS.	The NPS is to be constructed at10 m MSL. The maximum calculated sea level for the life of the NPS including the effects of climate change is 6.92 m MSL.	*No Impact*
Distant tsunami	Extreme water levels brought about by a tsunami originating from distant tsunamigenic regions may result in flooding of the NPS.	The recommended maximum tsunami induced water levels relative to still water level is 1.5 m, therefore under normal conditions no impact is expected from distant tsunami events. However, the total water level will include the effect of tide, wave run-up, wave set up and storm surge (see meteo-tsunami events below).	*No Impact*
Local tsunami	Offshore slump generated tsunami from three slump regions identified relevant to the proposed sites have been modelled in order to predict possible impacts upon the NPS.	The maximum risk to the site from a local source is from the Cape Town (North) slump region with maximum water levels of 2.0 m MSWL being predicted from a 80 km^2 theoretical slump. No impact is expected from local tsunami events. However, the total water level will include the effect of tide, wave run-up, wave set up and storm surge (see meteo-tsunami events below).	*No Impact*

Meteo-tsunami events	The potential 'worst case' of a tsunami event occurring at the same time as extreme meteorological conditions	The maximum high water level predicted during a tsunami event (including the effects of climate change) is 10.54 m MSL (upper 95% confidence). Since the site will be constructed at 10 m MSL there is the potential for flooding.	*Medium*
Interruption of marine cooling water supply			
Exposure of cooling water intake pipes	A drop in sea level caused by either the effects of a tsunami or negative storm surge could cause the pipes to be exposed.	The maximum low water level predicted for the site is -7.10 m MSL (upper 95% confidence) and occurs during a meteo-tsunami event. The intake is situated at approximately -30 m depth and therefore no impact is expected.	*No Impact*
Damage to cooling water intake pipes.	Abnormal sea conditions may result in damage to the cooling water intake structure.	Damage to cooling water intake pipes is unlikely, as the pipes have been designed to 'no damage criteria'. Further details are outlined in Section 1.3.1.	*No Impact*
Blockages of cooling water intake pipes	Entrainment of sediment and sea life may block the cooling water intake pipes.	The design of the cooling water intake pipes will sufficiently mitigate against the entrainment of sediment and sea life. Further details outlined in Section 1.3.1.	*No impact*
Sedimentation risk	Sand drawn in through the intake has implication on the final design as it will have to be removed from the proposed settling basin located on land.	Due to the depth of the intake structure, typical sand intake rates will be low and will not result in an impact upon the facility. The greatest risk of sedimentation to intake pipes is associated with inundation scour during a tsunami event. However, scour depths are predicted to be limited to less that 2.5 m and seen to occur within 200 m of the coastline.	*No Impact*
Elevated sea water temperature	Natural variation in sea water temperature or the effects of global warming may result in an increase in the temperature of the intake water.	Making the very conservative assumption that the maximum recirculation event may correspond to the maximum ambient temperature, then the maximum intake temperature for the 1:100 year period would be 25.9℃ + 1.2℃ = 27.1℃. This is less than the maximum intake temperature limit of 30℃. Therefore, no impact is expected.	*No Impact*
Coastal stability	Severe erosion of the beach at the site could result in damage to proposed nuclear facility.	The maximum total erosion (including the effects of climate change) is predicted to be ≥ 158 m inland for the expected installation life. This value will be used in order to inform the final design of the facility. Therefore, no impact is expected.	*No Impact*

Thermal plume dispersion resulting in recirculation of cooling water.	***The currents are seen to be predominantly wave driven in the surf zone and wind and tidally driven beyond the surf zone. Background sea temperature varies on a seasonal and, synoptic and diurnal time-scale. The resulting thermal plume behaviour is dynamic.***	***Due to the buoyancy of the plume and the upward dispersion affected by the diffuser, the plume moves towards the surface and away from the intake pipes. The intake and outfall configuration tested results in acceptable recirculation (maximum increase < 1.5℃) at the new intake, therefore no impact is predicted.***	***No Impact***

3.2 Bantamsklip

3.2.1 Construction Impacts

Issue	Baseline Condition	Potential Impact	Significance
Short term disruption of sediment transport- Option 1	The beach at the Bantamsklip site is considered to be dynamically stable in the long term. A point of low net sediment transport is present in front of the nuclear installation corridor.	Cofferdams constructed in the surfzone may interrupt longshore sediment transport**.** Low net sediment transport will limit the impact of the temporary cofferdam structures.	*Low*
Short term disruption of sediment transport – Option 2	***The beach at the Bantamsklip site is considered to be dynamically stable in the long term. A point of low net sediment transport is present in front of the nuclear installation corridor.***	***The construction of the basin intake and nearshore outfall is expected to have the same impacts as during operation. See section 3.2.2***	***Low***
Erosion due to brine discharge	Rocky coastline interspersed with sandy beaches. Some erosion is therefore expected.	Brine discharged from the pipe at the RO plant will result in an erosion channel across the beach.	*Medium*
Disposal of spoil	At Bantamsklip, Dyer island is considered a sensitive receptor as an increase in suspended sediment may effect the local tourism industry. It is suggested that an impact will be realised should the suspended sediment plume resulting from the spoil disposal operation be visible at Dyer Island.	A sediment plume may be visible at concentrations as low as 10 mg/l. Maximum concentrations predicted at Dyer Island generally exceed this threshold, suggesting that the plume may be visible during the disposal operation.	*Medium*

3.2.2 Operational Impacts

Issue	Baseline Condition	Potential Impact	Significance
Long term disruption of sediment transport – Option 1	The beach at the Bantamsklip site is considered to be dynamically stable in the long term. A point of low net sediment transport is present in front of the nuclear installation corridor.	The offshore tunnel intakes and outfall structures will only have very localised impacts on the sediment transport field.	*Low*
Long term disruption of sediment transport – Option 2	***The beach at the Bantamsklip site is considered to be dynamically stable in the long term. A point of low net sediment transport is present in front of the nuclear installation corridor.***	***The intake basin used is positioned where the net sediment transport is low, implying that a sand-bypassing scheme is unlikely to be required.***	***Low***
Discharge of desalination brine	The brine from the RO plant will be mixed into the cooling water and discharged at the outfall.	Mixing the brine will result in significant dilution and the brine will be undetectable at the outfall.	*No Impact*

Potential impact as a result of non nuclear accidents and incidents	No non-nuclear accidents that are expected to affect the oceanography of the surrounding area ***have been identified.***	N/A	*No Impact*

3.2.3 Environmental Impacts on the NPS

Issue	Baseline condition	Potential Impact	Significance
Extreme sea level			
Flooding from sea	Extreme tides, waves, or storm surge may result in the sea level being raised above the level of the NPS.	The NPS is to be constructed at10 m MSL. The maximum calculated sea level for the life of the NPS including the effects of climate change is 7.46 m MSL.	*No Impact*
Distant tsunami	Extreme water levels brought about by a tsunami originating from distant tsunamigenic regions may result in flooding of the NPS.	The recommended maximum tsunami induced water levels relative to still water level is 2.0 m. Therefore, under normal conditions no impact is expected from distant tsunami events. However, the total water level will include the effect of tide, wave run-up, wave set up and storm surge (see meteo-tsunami events below).	*No Impact*
Local tsunami	Offshore slump generated tsunami from three slump regions identified relevant to the proposed sites have been modelled in order to predict possible impacts upon the NPS.	The maximum risk to the site from a local source is from the Cape Town (North) slump region with maximum water levels of 2.0 m MSWL being predicted from a 80 km^2 theoretical slump. No impact is expected from local tsunami events. However, the total water level will include the effect of tide, wave run-up, wave set up and storm surge (see meteo-tsunami events below).	*No Impact*
Meteo-tsunami events	The potential 'worst case' of a tsunami event occurring at the same time as extreme meteorological conditions	The maximum high water level predicted during a tsunami event (including the effects of climate change) is 11.03 m MSL (upper 95% confidence). Since the site will be constructed at 10 m MSL there is the potential for flooding.	*Medium Impact*
Interruption of marine cooling water supply			
Exposure of cooling water intake pipes	A drop in sea level caused by either the effects of a tsunami or negative storm surge could cause the pipes to be exposed.	The maximum low water level predicted for the site is -7.64 m MSL (upper 95% confidence) and occurs during a meteo-tsunami event. The intake is situated at -45 m depth. Therefore, no impact is expected.	*No Impact*

Exposure of basin intake	***A drop in sea level caused by either the effects of a tsunami or negative storm surge could result in an interruption of cooling water.***	***The maximum low water level predicted in the basin design is -7.64m MSL and occurs during a tsunami event. The modelled basin depth is -8.29m MSL. Therefore, there is the possibility that water intake in the basin may be affected during a tsunami event.***	***High impact***
Damage to cooling water intake pipes	Abnormal sea conditions may result in damage to the cooling water intake structure.	Damage to cooling water intake pipes is unlikely, as the pipes have been designed to 'no damage criteria'. Further details are outlined in Section 1.3.1.	*No Impact*
Damage to cooling water intake basin	***Abnormal sea conditions may result in damage to the cooling water intake structure.***	***The design of the cooling water intake pipes will sufficiently mitigate against the entrainment of sediment and sea life. Further details outlined in Section 1.3.1.***	***No impact***
Blockages of cooling water intake pipes	Entrainment of sediment and sea life may block the cooling water intake pipes.	The design of the cooling water intake pipes will sufficiently mitigate against the entrainment of sediment and sea life. Further details outlined in Section 1.3.1.	*No Impact*
Blockage of basin intake	***Entrainment of sediment and sea life may block the intakes at the pumphouse.***	***The design of the cooling water intake pipes will sufficiently mitigate against the entrainment of sediment and sea life. Further details outlined in Section 1.3.1.***	***No impact***
Sedimentation risk- Option 1	Sand drawn in through the intake has implication on the final design as it will have to be removed from the proposed settling basin located on land.	Due to the depth of the intake only limited volumes of sand will be drawn in. The greatest risk of sedimentation to intake pipes is associated with inundation scour during a tsunami event. However, scour depths are predicted to be limited to less that 2.5 m and seen to occur within 200 m of the coastline.	*No Impact*

Sedimentation risk- Option 2	***Sediment transport or deposition of sediment by a tsunami has potential to block the intake of cooling water.***	***The modelled net sediment transport rate across the entrance of the intake basin was used estimate the maintenance dredging volumes for the basin. The results show an estimated 20 000 m ^{3} /year maintenance dredging , which is significantly less than the average of 132 000 m^{3} /year for the existing Koeberg intake basin .*** ***Bottom shear by a strong tsunami current may be significant in shallow water. The deposition of a large amount of sediment could affect the safety features of the plant. In particular, the deposition of sediment around cooling water structures or the water inlet and outlet might disrupt the operation of the plant.***	***High Impact***
Elevated sea water temperature	Natural variation in sea water temperature or the effects of global warming may result in an increase in the temperature of the cooling water.	Making the very conservative assumption that the maximum recirculation event may correspond to the maximum ambient temperature, then the maximum intake temperature for the 1:100 year period would be 25.9℃ + 1.0℃ = 26.9℃. This is less than the maximum intake temperature limit of 30℃. Therefore, no impact is expected.	*No Impact*
Coastal stability	Severe erosion of the beach at the site could result in damage to proposed nuclear facility.	The maximum total erosion (including the effects of climate change) is predicted to be ≥ 134 m inland for the expected installation life. This value will be used in order to inform the final design of the facility. Therefore, no impact is expected.	*No Impact*

Thermal plume dispersion and recirculation – Option 1	***The currents are seen to be predominantly wave-driven in the surf zone and wind and tidally driven beyond the surf zone. Background sea temperature varies on a seasonal and, synoptic and diurnal time-scale. Since the currents are continually changing as the wave, wind and tidal conditions change, the position and size of the plume shows corresponding changes.***	***The buoyancy of the plume due to the increased temperature tends to keep the plume near the surface rather than seabed. Maximum temperature contours near the seafloor and surface are seen to impinge upon extensive areas of shoreline and areas of shallower waters (>5 m depth). However, the intake and outfall configuration tested results in acceptable recirculation (maximum increase <1.5℃) at the new intake. Therefore, no impact is predicted.***	***No Impact***
Thermal plume dispersion and recirculation – Option 2	***The currents are seen to be predominantly wave-driven in the surf zone and wind and tidally driven beyond the surf zone. Background sea temperature varies on a seasonal and, synoptic and diurnal time-scale. Since the currents are continually changing as the wave, wind and tidal conditions change, the position and size of the plume shows corresponding changes.***	***The nearshore channel outfall design results in a significantly larger thermal plume than the offshore tunnel outfall. This is due to the nearshore channel outfall discharging into shallow water with a limited volume of ambient water available for mixing. However, the intake and outfall configuration tested results in acceptable recirculation at the intake. Therefore, no impact is predicted.***	***No Impact***

3.3 Thyspunt

3.3.1 Construction Impacts

Issue	Baseline Condition	Potential Impact	Significance
Short term disruption of sediment transport	The beach at the Thyspunt site is considered to be dynamically stable in the long term. Based on the results of the modelling, net sediment transport near the site is likely to be low.	Cofferdams constructed in the surfzone may interrupt longshore sediment transport**.**	*Low*
Erosion due to brine discharge	Rocky coastline interspersed with sandy beaches. Some erosion is therefore expected.	Brine discharged from pipe at the RO plant will result in erosion channel across the beach.	*Low*
Disposal of spoil	***Sediments from the disposal site are predicted to move rapidly in an easterly direction across the existing reef towards Seal Point and Cape St. Francis Bay.***	***Non-ecological sensitive receptors (i.e. physical infrastructure) that have been identified in the vicinity of the Thyspunt site with regard to spoil disposal and suspended sediment concentrations, include a possible impact to the local surf breaks (Appendix A) and impact to the St Francis Bay Marina.***	***Medium***

3.3.2 Operational Impacts

Issue	Baseline Condition	Potential Impact	Significance
Long term disruption of sediment transport	The beach at the Thyspunt site is considered to be dynamically stable in the long term. Based on the results of the modelling, net sediment transport near the site is likely to be low.	The pipelines for the intakes and outfalls will be constructed under the existing seafloor. Only the intake and outfall structures have the potential to influence long-term sediment transport.	*Low*
Discharge of desalination brine	The brine from the RO plant will be mixed into the cooling water and discharged at the outfall.	Mixing the brine will result in significant dilution and the brine will be undetectable at the outfall.	No impact
Potential impact as a result of non-nuclear accidents and incidents	No non-nuclear accidents that are expected to affect the oceanography of the surrounding area ***have been identified.***	N/A	*No impact*

3.3.3 Environmental Impacts on the NPS

Issue	Baseline condition	Potential Impact	Significance
Extreme sea level			

Flooding from sea	Extreme tides, waves or storm surge may result in the sea level being raised above the level of the NPS	The NPS is to be constructed at10 m MSL. The maximum calculated sea level for the life of the NPS including the effects of climate change is 11.56 m MSL.	*Medium*
Distant tsunami	Extreme water levels brought about by a tsunami originating from distant tsunamigenic regions may result in flooding of the NPS.	The recommended maximum tsunami induced water levels relative to still water level is 2.5 m. Therefore, under normal conditions no impact is expected from distant tsunami events. However, the total water level will include the effect of tide, wave run-up, wave set up and storm surge (see meteo-tsunami events below).	*No Impact*
Local tsunami	Offshore slump generated tsunami from three slump regions identified relevant to the proposed sites have been modelled in order to predict possible impacts upon the NPS.	The maximum risk to the site from a local source is from the Agulhas Slump region with maximum water levels of 2.5 m MSWL being predicted from a 80 km^2 theoretical slump. No impact is expected from local tsunami events. However, the total water level will include the effect of tide, wave run-up, wave set up and storm surge (see meteo-tsunami events below).	*No Impact*
Meteo-tsunami events	The potential 'worst case' of a tsunami event occurring at the same time as extreme meteorological conditions	The maximum high water level predicted during a tsunami event (including the effects of climate change) is 14.77 m MSL (upper 95% confidence). Since the site will be constructed at 10 m MSL, there is a high potential for flooding, although the probability of such an event is low.	*Medium*
Interruption of marine cooling water supply			
Exposure of cooling water intake pipes	A drop in sea level caused by either the effects of a tsunami or negative storm surge could cause the pipes to be exposed.	The maximum low water level predicted for the site is -6.10 m MSL (upper 95% confidence) and occurs during a meteo-tsunami event. The intake is situated at approximately -30 m depth and therefore no impact is expected.	*No Impact*
Damage to cooling water intake pipes.	Abnormal sea conditions may result in damage to the cooling water intake structure.	Damage to cooling water intake pipes is unlikely, as the pipes have been designed to 'no damage criteria'. Further details are outlined in Section 1.3.1.	*No Impact*
Blockages of cooling water intake pipes	Entrainment of sediment and sea life may block the cooling water intake pipes.	The design of the cooling water intake pipes will sufficiently mitigate against the entrainment of sediment and sea life. Further details outlined in Section 1.3.1.	*No Impact*
Sedimentation risk	Sand drawn in through the intake has implication on the final design as it will have to be removed from the proposed	The preliminary modelling presented above indicates that only limited volumes of sand are likely to be drawn into the	*No Impact*

	settling basin located on land.	proposed cooling water intake, which is a tunnel intake located in 30 m water depth with the intake openings located 3 to 5 m above the seabed. The greatest risk of sedimentation to intake pipes is associated with inundation scour during a tsunami event however scour depths are predicted to be limited to less that 2.5 m and seen to occur within 200 m of the coastline.	
Elevated sea water temperature	Natural variation in sea water temperature or the effects of global warming may result in an increase in the temperature of the cooling water.	Making the very conservative assumption that the maximum recirculation event may correspond to the maximum ambient temperature, then the maximum intake temperature for the 1:100 year period would be 28.0℃ + 1.0℃ = 29.0℃. This is less than the maximum intake temperature limit of 30℃ therefore no impact is expected.	*No Impact*
Coastal stability	Severe erosion of the beach at the site could result in damage to proposed nuclear facility.	The maximum total erosion (including the effects of climate change) is predicted to be ≥ 158 m inland for the expected installation life. This value will be used in order to inform the final design of the facility therefore no impact is expected.	*No Impact*
Thermal plume dispersion and recirculation	***The dominant current direction is towards the east and the current speeds are moderate near the surface and low near the seabed. The currents are predominantly wave driven in the surf zone and wind and tidally driven beyond the surf zone. The thermal plume is advected and dispersed by these currents.***	***The results of the modelling demonstrate the effect of the buoyancy of the plume due to the increased temperature which tends to keep the plume near the surface. However, it can be observed in the maximum temperature increase plot that the plume tends to move towards the shallow nearshore zone and hug the shoreline for a significant distance. The intake and outfall configuration would result in acceptable recirculation (maximum increase <1.5℃) at the new intake. Therefore, no impact is predicted.***	***No Impact***

4 ENVIRONMENTAL ASSESSMENT

The following section offers an assessment of the potential impacts identified in Section 3 above.

4.1 Duynefontein

CONSTRUCTION PHASE

4.1.1 Short term disruption of sediment transport

The possible construction of the cofferdams at the Duynefontein site will influence sediment transport along the coast in the short term over the construction phase of the development.

Although the sediment transport varies along the beach due to the presence of rip cells, the net transport along the beach is low (PRDW, 2009b). The cofferdams are therefore expected to have a limited effect on the sediment transport and coastal erosion. Once construction has been completed the cofferdams will be removed. The overall significance of the impact is therefore considered to be low.

4.1.2 Erosion due to brine discharge

The discharge of brine from the RO Plant will result in the creation of an erosion channel across the beach. The extent of the channel is expected to be localised and will only impact the beach in the short term. Once construction is complete it is anticipated that the beach profile will quickly return to normal. The intensity of the impact is low however the probability is high; the impact is therefore considered to have a low - medium significance. Alternative methods of discharge have, however, been identified to significantly reduce the erosion impact of the brine and subsequently the significance with mitigatory measures is low. Details of the mitigatory measures are outlined in Chapter 5.1.2.

OPERATIONAL PHASE

4.1.3 Long term disruption of sediment transport

The inlet pipes will be placed beneath the sea floor and will therefore not impact sediment transport along the coast, whilst the discharge point of the outlet pipes may form a minor barrier to sediment movement. Studies on the existing intake basin at Koeberg (a much larger structure) indicated minor coastal erosion in the first three years after construction but over the last ten years no erosion has taken place. The significance of the impact is therefore considered to be low - medium.

4.1.4 Thermal Plume Dispersion

The discharge of heated water and other co-discharges such as chlorine and nuclides has the potential to negatively impact upon the local marine ecology. This section will only consider physical factors such as the size, distribution and location of the mixing zone in quantifying potential impacts. For a specific assessment of the potential impacts upon the ecological receptors present please refer to the EIA Marine Ecology Study ***(Appendix E15 of the Revised Draft EIR).***

At the Duynefontein site it has been necessary to include the existing Koeberg intake and outfall within the base case model. This allows for an assessment of the cumulative impacts and also the potential for temperature increases at the Koeberg intake.

The intake and outfall configuration tested for the Duynefontain plant comprises two submarine intake tunnels extending to a depth of 20 m approximately 2.2 km offshore and two southerly outfall tunnels extending to a depth of 30 m approximately 3.5 km offshore.

Intake structures will be positioned at the end of each intake tunnel with the intake openings positioned 3 to 5 m above the sea bed to prevent the drawing in of large quantities of sediment. To reduce fish entrainment the intake openings should be designed to draw in water horizontally with a velocity of less than 0.3 m/s. The diffuser layout for the outfall was selected to achieve an initial dilution of at least 10 and to ensure that the plume surfaces under all current and ambient stratification conditions.

The modelling predicts no significant (> 1℃) increase in mean or maximum seawater temperature at the seabed as illustrated in Figure 4-1 and 4-2 respectively. The discharge forms a discreet mixing zone at the surface with a 1-2 ℃ mean temperature increase contour extending a maximum of approximately 1.0 km from the outfall. The maximum increase in seawater temperature at the surface is shown by the 7 ℃ contour in the immediate vicinity of the o utfall in Figure 4-2.

Due to the buoyancy of the plume and the upward dispersion affected by the diffuser the plume will not impact to any great extent upon sensitive ecological receptors within the benthic environment.

Elevated water temperatures can deplete the dissolved oxygen in the water, leading to unfavourable ecological conditions. However, the ecological receptors within the water column, where the mixing zone is predicted to occur, are largely mobile and will avoid areas with unfavourable conditions. The significance of the impact of the thermal plume upon the marine environment is therefore considered to be low. ***This is of course a generalisation and does not take into account the varying sensitivity of marine organisms to temperature fluctuations. Some marine organisms are much more sensitive to temperature fluctuations that others. The impacts of an increase in water temperature are more fully assessed in the Marine Ecology report (Appendix E15 of the Revised Draft EIR).***

4.1.5 Extreme Sea Levels

The key potential impacts associated with extreme water levels are flooding of the nuclear facility or reduced water levels resulting in interruption of the cooling water supply. The theoretical extreme water levels are a function of a combination of (worst-case) hydrographic conditions (as discussed in Section 1.3.5).

The extreme high and low water levels are seen to occur during a meteo-tsunami event (i.e. extreme meteorological conditions in combination with maximum probable tsunami run-up and run-down values). Taking into account the effects of climate change upon sea level rise, the maximum water level under these conditions is predicted to be 10.54 m above MSL (at the upper 95% confidence limit). Due to the site being constructed at 10 m above MSL there is the potential for the flooding. Flooding of the ***power station*** site is a potential major negative impact, although the probability of such an occurrence is statistically very low. The impact of extreme water levels is therefore considered to be a negative impact of low - medium significance in lieu of appropriate mitigation.

The cooling water intakes will be situated at -20 m MSL. Therefore, there will be no potential for drying associated with the extreme low water level during a meteo-tsunami event (calculated to be -7.10 m MSL).

4.2 Bantamsklip

CONSTRUCTION PHASE

4.2.1 Short term disruption of sediment transport

Offshore intake and offshore outfall

The potential impacts upon short term sediment transport at the Bantamsklip can be considered to be the same as at the Duynefontein site (low significance).

Basin intake and nearshore outfall

The impacts are expected to be similar to the long-term disruption of sediment. Please see Section 4.2.4

4.2.2 Erosion due to brine discharge

The impact of the brine discharge at Bantamsklip can be considered to be the same as at the Duynefontein site (low significance).

4.2.3 Disposal of spoil

Dyer Island, situated approximately 15 km to the east of the power station installation corridor is a popular tourist destination with a number of operators offering shark cage diving adjacent to the island. An increase in suspended sediment in the vicinity of the island will reduce visibility and has the potential to impact on the tourism in the area.

Although many factors determine whether or not a sediment plume will be visible, available information (CSIR, 2003) suggests that the plume may be visible at suspended sediment concentrations as low as 10 mg/l. Since the maximum concentrations predicted by the model at Dyer Island generally exceed 10 mg/l, this suggests that the plume will occasionally be visible at Dyer Island during the sediment disposal operation. Discharge Alternatives 5 and 6 pose the lowest risk in this regard.

Table 4-1: Maximum suspended sediment concentrations reaching Dyer Island

Alternative number	Maximum suspended sediment concentration near surface (mg/l)	Maximum suspended sediment concentration near seabed (mg/l)
1	23	35
2	12	18
3	12	18
4	15	25
5	9	15
6	9	15

OPERATIONAL PHASE

4.2.4 Long term disruption of sediment transport

Offshore intake and offshore outfall
The potential impacts upon long term sediment transport at the Bantamsklip can be considered to be the same as at the Duynefontein site (low- medium significance).

Basin intake and nearshore outfall

Directly in front of the Nuclear Plant Corridor is a point of low net sediment transport. The intake basin used is positioned in this area implying that a sand-bypassing scheme is unlikely to be required. This however needs to be confirmed as part of the detailed design studies.

The nearshore channel outfall is located in an area with a large net northerly sediment transport. Although the actual transport will be significantly reduced by the rocky seabed and associated limited sediment availability, sediment accretion can be expected on the southerly updrift side of the channel and also on the northerly side due to current eddies and wave sheltering effects. Sediment will eventually bypass around the end of the channel, but there is little risk of blocking the outfall since the invert level at the offshore end of the channel is raised above the seabed (and the high-velocity discharge will scour away any localised accretion).

4.2.5 Thermal Plume Dispersion

Two intake and outfall configurations were tested at the Bantamsklip site, namely:

- ***ffshore tunnel intake and offshore tunnel outfall; and***
- ***Basin intake and nearshore channel outfall***

Offshore tunnel intake and offshore tunnel outfall

The intake and outfall configuration tested for the Bantamsklip site comprises two submarine tunnel intakes extending approximately 3.5 km offshore (45 m depth) and two offshore tunnel outfalls extending approximately 2.5 km offshore (25 m depth). Other aspects of the intake and outfall design are the same as described above for Duynefontein.

The mean and maximum increase in seawater temperatures due to the offshore power station outfall is shown in Figure 4-3 and 4-4 respectively.

A small mixing zone near the seafloor surrounds one of the tunnel outfalls indicating that a minor impact upon the benthic environment is to be expected in this area however the depth of the outfall, buoyancy of the plume and action of the diffusers insures that this impact is minimised as the plume is encouraged to move towards the surface.

The maximum increase in temperature near the seafloor is shown by the 3 - 4℃ contour, which extends in a narrow band towards the shore. The 1 - 2℃ and 2 - 3℃ maximum temperature contours near the seafloor extends for a large area and impinges upon a significant extent of coastline.

The mean temperature increase in seawater temperature near the surface resulting from both outfalls is an area approximately 700 m in diameter 1 - 2℃ higher than ambient. The maximum temperature near the surface is shown by a very small 5-6℃ contour, indicating that a high level of initial dilution is achieved at this site. However, as with the near seabed contour, the maximum temperature increase mixing zone appears to be forced towards the shallower nearshore waters where the impacts upon marine ecology are potentially greater.

Although the mixing zone has a relatively small extent the fact that it impinges upon the shallow near shore waters and shoreline results in a potential for low negative significance.

<u>Basin intake and nearshore channel outfall</u>

In the case of the nearshore outfall a small mixing zone is noted at the channel outfall at the sea bed, with a significantly larger zone indicated at the surface. as the buoyancy of the plume, due to the increased temperature, tends to keep the plume near the water surface rather than the seabed, particularly as the plume is advected into deeper water.

The mean and maximum increase in seawater temperatures due to the offshore power station outfall is shown in Figure 4-5 and 4-6 respectively.

The maximum increase in temperature near the seafloor is shown by the 10-12 ℃ contour directly at the exit of the outfall. The maximum temperature contours indicate that the maximum temperature increase will dissipate within a short distance of the channel outfall. The 1 - 2°C and 2 - 3℃ maximum temperature contours near the seafloor extend for a large area and impinges upon a significant extent of coastline.

The mean temperature increase is indicated to extend in a northerly direction from the outfall in both the near-surface water and along the seabed. The area of greatest temperature increase is depicted by the 5-6℃ contour in the near-surface and the 4-5 ℃ contour on the seabed.

The maximum increase in temperature is significantly higher and more extensive than the mean increase in temperature. This is due to the dynamic plume behaviour which results in the plume remaining at one position for short periods of time only.

Comparison

The nearshore channel outfall design results in a significantly larger thermal plume than the offshore tunnel outfalls. This is due to the nearshore channel outfall discharging into shallow water with a limited volume of ambient water available for mixing, rather than a deep offshore tunnel with a diffuser and high near-field mixing.

These results indicate no significant recirculation problems for either of the layouts tested. However, the maximum recirculation temperatures occur for the layout with a nearshore channel outfall and a basin intake

For a specific assessment of the potential impacts upon the ecological receptors present please refer to the EIA Marine Ecology Study (Eskom 2008a).

4.2.6 Disruption of Cooling Water Supply

Bottom shear by a strong tsunami current may be significant in shallow water. The deposition of a large amount of sediment could affect the safety features and subsequent operation of the plant. In particular, the deposition of sediment around cooling water structures or the water inlet and outlet might disrupt the operation of the plant. The probability of such an occurrence is however considered to be statistically low

Furthermore, the maximum low water level predicted in the basin is -7.64m MSL and occurs during a tsunami event. The modelled basin depth is -8.29m MSL therefore there is the possibility water intake of cooling water in the basin may be affected during a tsunami event. This is a potential major negative impact, although the probability of such an occurrence is statistically very low.

4.2.7 Extreme Water Levels

The extreme high and low water levels predicted for the Bantamsklip site are seen to occur during a meteo-tsunami event (i.e. extreme meteorological conditions in combination with maximum probable tsunami run-up and run-down values). Taking into account the effects of climate change upon sea level rise, the maximum water level under these conditions is predicted to be 11.03 m MSL (at the upper 95% confidence limit). Due to the site being constructed at 10 m MSL there is the potential for the flooding, although the probability of such an occurrence is statistically low. The maximum meteorological extreme high water levels are 7.46 m over a 1:100 year return period.

The cooling water intakes will be situated at -45 m MSL. Therefore, there will be no potential for drying associated with the extreme low water level during a meteo-tsunami event.

Due potentially severe consequences but extremely low probability of a meteo-tsunami event occurring that may result in flooding of the proposed facility, the potential impact at the Bantamsklip site associated with the predicted extreme high water levels has been assigned a low- medium negative significance.

4.3 Thyspunt

CONSTRUCTION PHASE

4.3.1 Short term disruption of sediment transport

The potential impacts upon long term sediment transport at the Thyspunt site can be considered to be the same as at the Duynefontein site (low significance).

4.3.2 Erosion due to brine discharge

The impact of the brine discharge at Thyspunt can be considered to be the same as at the Duynefontein site (low-medium significance).

4.3.3 Disposal of Spoil

As part of the construction of the Nuclear Power Station (NPS) it has been postulated that a large amount of spoil material will be disposed of offshore. Modelling of the movement of the spoil has been undertaken by PRDW (Eskom, 2009). The numerical modelling simulated how the discharged sediment is distributed on the seabed and sediment movement over time due to wave and current forcing. For the proposed nuclear site at Thyspunt two different disposal sites (one relatively deep and one relatively shallow site), two different sediment volumes and two sediment discharge rates were modelled. The modelling report is available in Appendix J.

The results of the modelling at the Thyspunt site indicate that halving the sediment discharge rate significantly reduces the suspended sediment concentrations. However, halving the sediment discharge rate does not reduce the sediment thickness, since the transport of the coarser sediment away from the disposal mound occurs over a much longer time scale than the disposal operation. Moving the sediment disposal to deeper water reduces the transport of the coarser sediment away from the disposal site (due to the reduced orbital velocities of the waves). For all alternatives assessed a significant proportion of the disposed sediment remains on the disposal site after 10 years.

The disposal of spoil at the shallow disposal site results in transport of sediment in an easterly direction. The sediment moves rapidly across the reef as a thin sheet (<0.005m) and then slows down and accumulates in the bay between Seal Point and Cape St Francis. After approximately five years some sediment bypasses Cape St Francis and moves towards St Francis Bay. The disposal of spoil at the deep disposal site results in a column of sand between 0.005m and 0.010m thick extending towards Seal Point, with another small portion of spoil settling in the bay (at approximately 10 m depth) between Seal Point and Cape St Francis six to 10 years after the disposal has taken place.

Therefore disposal at the shallow site will result in an increase in sediment in the south western portion of St Francis Bay. The St Francis marina is situated in this area and therefore more frequent dredging of the marina may be required. Sediment from the deep disposal site does not get transported into St Francis Bay and therefore no impact from the deep disposal site is expected.

The impact on surf breaks in the area is discussed in Appendix I.

OPERATIONAL PHASE

4.3.4 Long term disruption of sediment transport

The potential impacts upon long term sediment transport at the Thyspunt site can be considered to be the same as at the Duynefontein site (low significance).

4.3.5 Extreme Water Levels

The extreme high and low water levels predicted for the Thyspunt site are seen to occur during a meteo-tsunami event. Taking into account the effects of climate change upon sea level rise, the maximum water level under these conditions is predicted to be 14.77 m above MSL (at the upper 95% confidence limit). Due to the site being constructed at 10 m above MSL there is significant potential for the flooding.

The maximum meteorological extreme high water levels are 11.56 m (at the upper 95% confidence limit) over a 1:100 year return period.

The cooling water intakes will be situated at -45 m MSL. Therefore, there will be no potential for drying associated with the extreme low water level during a meteo-tsunami event.

Due to the potential for flooding during both a meteo-tsunami event and meteorological extreme high water levels the probability of such an occurrence at the Thyspunt site is relatively greater than the two other sites. The significance of the impact is therefore considered to be medium.

4.3.6 Thermal Plume Dispersion

The intake is a submarine tunnel extending to a depth of -29 m CD approximately 1000 m offshore. Either a single tunnel with an internal diameter of approximately 9 m, or two tunnels with diameters of approximately 6.4 m will be used. The outfall comprises six ***to eight*** 3 m diameter pipes buried below the seabed in a 27.5 m wide trench and discharging approximately 250 m offshore in a water depth of approximately -5 m CD.

The mean and maximum increase in seawater temperatures due to the power station outfall is shown in Figure 4-7 and 4-8 respectively.

The mean increase in seawater temperature near the seabed is shown in Figure 4-5. The temperature is seen to decrease rapidly from almost 8°C above ambient immediately adjacent to the outfall to less than 2°C within a discreet mixing zone only a few hundred metres in diameter indicating that good initial mixing is achieved despite the shallow depth. The 1-2°C contour, however is seen to extend a significant distance and hug the coastline to the east of the outfall.

The mean increase in seawater temperature plume near the surface behaves similarly although is larger in its extent illustrating the buoyancy of the plume.

The maximum temperature increases shown in Figure 4-7 with the proposed outfall layout are sub-optimal in terms of protecting the marine environment. Both the near seabed and near surface contour plots illustrate that the plume has a tendency to hug the shoreline and shallow nearshore area where the potential for impacts upon benthic ecology are greatest. Significant temperature increases (>2℃) are predicted to extend over a large area of coastline. However, it should be noted that the maximum temperature increases shown in Figure 4-7 may only be experienced for a short time over the typical 14 day tidal cycle.

For a specific assessment of the potential impacts upon the ecological receptors present please refer to the EIA Marine Ecology Study ***(Appendix E15 of the Revised Draft EIR).***

4.4 Key issues summary of the three sites

Generally all three of the sites are suitable for the construction of the NPS. However, different impacts of varying significance are expected at each of the sites.

Construction related oceanographic impacts are likely to be similar at each of the sites. However, the potential for suspended sediment plumes to impact upon tourism (in particular shark cage diving at Dyer Island) should be considered if Bantamsklip is selected.

The extent of the thermal plume at each of the sites is highly variable and dependant on the wind and wave conditions at a particular time. Analysis of the thermal plume dispersion at each of the sites indicates that relatively unfavourable dispersion takes place at Thyspunt, where the plume is seen to hug the coastline and shallow near shore areas. The most efficient dispersal of the thermal plume will occur at Duynefontein.

In the case of Bantamsklip, where both an offshore intake and offshore outfall and basin intake and nearshore outfall were considered, the nearshore channel outfall design results in a significantly larger thermal plume than the offshore tunnel outfall. The maximum recirculation temperatures occur for the layout with a nearshore channel outfall and a basin intake. However, results indicate no significant recirculation problems for either of the layouts tested.

Impacts to the NPS caused by the physical marine environment will arise from flooding from sea and the interruption of the cooling water supply.

Due to the depth and design of the intakes, interruption of the cooling water is not considered to a potential impact at any of the alternative sites.

There is the potential for water levels to exceed the proposed elevation (+10 m MSL) of the NPS at all three sites should a tsunami coincide with extreme meteorological conditions (a meteo-tsunami event). However, the occurrence of a tsunami is improbable, given the low risk of seismic activity in the surrounding ocean. Thyspunt is the only site where extreme high water levels resulting purely from meteorological factors are predicted to exceed + 10 m MSL during the expected lifetime of the installation. Consequently, the predicted water levels at Thyspunt during a meteo-tsunami are also significantly higher than at Bantamsklip and Duynefontein.

Table 4-2: Assessment of environmental impacts at Duynefontein

Impact	Mitigation	Nature	Intensity	Extent	Duration	Irreplaceable Resource	Consequence	Probability	Significance
Construction Impacts									
Short term disruption of sediment transport	Without Mitigation	Negative	Low	Medium	Low	Medium	Low	Medium	**Low**
	With Mitigation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Beach erosion due to brine discharge	Without Mitigation	Negative	Low	Low	Low	Medium	Low	High	**Low - Medium**
	With Mitigation	Negative	Low	Low	Low	Medium	Low	Low	Low
Operational Impacts									
Long term disruption of sediment transport	Without Mitigation	Negative	Low	Medium	High	Medium	Medium	Low	**Low - Medium**
	With Mitigation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Extreme sea levels affecting operation of NPS	Without Mitigation	Negative	Medium	Low	High	Low	Medium	Low	**Low - Medium**
	With mitigation	Negative	Medium	Low	High	Low	Medium	Low	**Low - Medium**

Table 4-3: Assessment of environmental impacts at Bantamsklip

Impact	Mitigation	Nature	Intensity	Extent	Duration	Irreplaceable Resource	Consequence	Probability	Significance
Construction Impacts									
Short term disruption of sediment transport outfall option 1	Without Mitigation	Negative	Low	Medium	Low	Medium	Low	Medium	Low
	With Mitigation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Short term disruption of sediment transport outfall option 2	Without Mitigation	Negative	Low	Medium	Low	Medium	Low	Medium	Low
	With Mitigation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Disposal of spoil	Without Mitigation	Negative	Medium	High	Low	High	Medium	High	Medium
	With Mitigation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Beach erosion due to brine discharge	Without Mitigation	Negative	Low	Low	Low	Medium	Low	High	Low - Medium
	With Mitigation	Negative	Low	Low	Low	Low	Low	Low	Low
Operational Impacts									
Long term disruption of sediment transport by outfall option 1	Without Mitigation	Negative	Low	Medium	High	Medium	Medium	Low	Low - Medium
	With Mitigation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Long term disruption of sediment transport by outfall option 2	Without Mitigation	Negative	Low	Medium	High	Medium	Medium	Medium	Medium
	With Mitigation	Negative	Low	Medium	High	Medium	Medium	Low	Low - Medium
Extreme sea levels affecting operation of NPS	Without Mitigation	Negative	Medium	Low	High	Low	Medium	Low	Low - Medium
	With Mitigation	Negative	Medium	Low	High	Low	Medium	Low	Low - Medium
Disruption of cooling water supply- Option 1	Without Mitigation	Negative	Medium	Low	High	Low	Medium	Low	Low - Medium
	With Mitigation	Negative	Medium	Low	High	Low	Medium	Low	Low - Medium
Disruption of cooling water supply- Option 2	Without Mitigation	Negative	Medium	Low	High	Low	Medium	Low	Low - Medium
	With Mitigation	Negative	Medium	Low	High	Low	Medium	Low	Low - Medium

Table 4-4: Assessment of environmental impacts at Thyspunt

Impact	Mitigation	Nature	Intensity	Extent	Duration	Irreplaceable Resource	Consequence	Probability	Significance
Construction Impacts									
Short term disruption of sediment transport	Without Mitigation	Negative	Low	Medium	Low	Medium	Low	Medium	Low
	With Mitigation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Beach erosion due to brine discharge	Without Mitigation	Negative	Low	Low	Low	Medium	Low	High	Low - Medium
	With Mitigation	Negative	Low	Low	Low	Medium	Low	Low	Low
Disposal of spoil – St Francis marina	Without Mitigation	Negative	Low	Medium	Medium	Medium	Low	Medium	Low
	With Mitigation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Operational Impacts									
Long term disruption of sediment transport	Without Mitigation	Negative	Low	Medium	High	Medium	Medium	low	Low- Medium
	With Mitigation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Extreme sea levels affecting operation of NPS	Without Mitigation	Negative	Medium	Low	High	Low	Medium	High	Medium
	With Mitigation	Negative	Medium	Low	High	Low	Medium	Low	Low - Medium

5 MITIGATION MEASURES

The construction of the NPS will have limited impact on the physical marine environment. Appropriate design requirements are however required to protect the NPS against the effects of the marine environment. The mitigation measures discussed apply to all three of the alternative sites.

5.1 Recommended mitigation measures and objectives

5.1.1 Erosion across the beach from brine discharge

Brine from the RO Plant will erode a channel from discharge point to the surfzone. The erosion will be quickly reversed once the discharge has ceased, however discharging the brine into a soakaway or infiltration gallery above the high water mark will result in minor impact to the beach profile. Furthermore discharging the brine to ground will increase dilution prior to mixing in the surfzone. Discharging brine into an infiltration gallery does however have the potential to negatively affect ground water resources on the site. The impact on local aquifers and groundwater fed surface water systems should be assessed at each site prior to considering discharging brine to ground.

5.1.2 Disposal of spoil

The results of the marine sediment disposal modelling (Eskom , 2009) identifies three options for mitigating the impacts associated with the disposal of spoil; reducing the discharge rate, reducing the volume and / or disposing of the spoil in deeper water.

The modelling demonstrates that halving the sediment discharge rate significantly reduces the suspended sediment concentrations. However, halving the sediment discharge rate does not reduce the sediment thickness, since the transport of the coarser sediment away from the disposal mound occurs on a much longer time scale than the disposal operation.

Reducing the volume of sand disposed reduces the number of days that the threshold suspended sediment of 80 mg/l is exceeded, but has little influence on the maximum suspended sediment concentration.

Moving to deeper water reduces the suspended sediment concentrations (since there is more water depth available for mixing) and reduces the transport of the coarser sediment away from the disposal site (due the reduced orbital velocities of the waves).

In addition to the above, environmental management measures should be considered during the disposal operations. For example, spoil disposal should cease during stormy conditions where sediments are less likely to settle upon the seafloor. The sediment plume should also be monitored visually and via water quality sampling frequently to ensure that the relevant water quality objectives established for the project are met.

5.1.3 Sediment transport disruption

The option of basin intake at the Bantamsklip site will result in greater disruption of longshore sediment transport than the offshore intake offshore outfall option. The modelling report (PRDW 2009d) indicates that the intake basin is positioned where the net sediment transport is low. Mitigation measures are therefore unlikely to be required. However, this still requires confirmation as part of the detailed design studies. Mitigation measures that can be applied to reduce the impact of the basin on sediment transport include the installation of a sand bypassing scheme.

5.1.4 Extreme water levels

Flooding from sea will occur if the level of the sea rises due to climate change, storm events or a tsunami to a level above the footprint of the development. This can be mitigated during the design stage of the project by building the NPS above the maximum predicted rise in sea level for each of the sites. At each of the three sites the highest predicted sea level rise is brought about by a tsunami combined with the effects of climate change. The IAEA (2003) does not state a level above the maximum run-up that the facility should be built. However, an elevation of at least 0.5m above the maximum run-up is recommended. The maximum predicted rise in sea level for each site and the recommend elevation to prevent flooding is indicated in the table below.

Table 16: Recommended elevation of the NPS at each site

Alternative	Meteo-tsunami Best estimate (m MSL)	Meteo-tsunami Upper 95% confidence level (m MSL)	Recommended elevation (m MSL)
Duynefontein	9.51	10.54	**>11.04**
Bantamsklip	9.98	11.03	**>11.53**
Thyspunt	13.61	14.77	**>14.27**

It should be noted that the run-up levels do not take into account the presence of the nuclear power installation, since this has yet to be designed. The coastal engineering investigations (PRDW 2009a, c & e) state that the design of the nuclear power installation will need to consider the following:

- The extent to which the infrastructure will modify the topography of the site and thus modify the run-up levels, e.g. excavations or revetments.
- The type and position of intake and outfall structures.
- The volume rate of wave overtopping of the specific structures (in addition to wave run-up levels).
- An evaluation of the risk to the specific design of an extreme upper limit sea level rise of 2 m by 2100. Depending on the specific design, it may be cost effective to design for this extreme level from the start, or to plan future design adaptations or make specific contingency plans.

For the inclusion of climate change in the calculations of extreme flood levels, values are based on the information available at present, and need to be continually reassessed as new data and research results become available. One approach to deal with the uncertainties associated with future climate change is adaptive design. For example, provision can be made for a sea wall in front of the terrace to be raised in future as necessary. The phased development of the site also allows for the design of the second and third phases to respond to the more accurate climate change predictions that will be available in future.

5.1.5 Thermal Plume Dispersion

The key mitigation measures for minimising the potential impacts of a thermal plume ***relate to optimising the positioning of the outfalls to minimise the size and subsequent impact of the thermal plume. In the case of the offshore outfall and intake options the*** outfalls will be placed at a depth of between 25 and 30 m. The mixing zones resulting from deep offshore outfalls are typically far smaller than nearshore channel outfalls. Moving the plume away from the shoreline and shallow nearshore area also ensures that the potential for ecological impacts is minimised.

The ***proposed*** engineering design ***in the SSRs indicate*** that each outfall ends in a 200 m long diffuser with 5 ports at 50 m spacing. The ports have a diameter of 2 m and discharge vertically upwards from a height of 2 m above the seabed. The diffuser layout was selected to achieve an initial dilution of at least 10 and to ensure that the plume surfaces under all current and ambient stratification conditions. If such an engineering solution is amended any new solution should ensure that results are either optimised or equivalent to the current design proposal. It is preferable that the plume is not trapped near the seabed as there is then an increased risk of ecological impacts at the seabed and also of recirculation back to the intakes, which in this case are located near the seabed at a depth of 20 m.

5.2 Recommended monitoring and evaluation

5.2.1 Monitoring recommended by the IAEA

The International Atomic Energy Agency (IAEA, 2003) recommends that the following monitoring networks should be considered when constructing a NPS:

- *A monitoring system of basic atmospheric parameters*

Weather stations should be installed at each of the three sites to monitor the atmospheric conditions. The results should be recorded and long term trends in the data assessed.

- *A water level gauge system*

Water levels are recorded at Cape Town, Hermanus, and Port Elizabeth for Duynefontein, Bantamsklip and Thyspunt respectively.

- *Tsunami warning system*

Parts of the world considered to be in high risk areas for tsunamis have both regional and national tsunami warning systems. However, there is no specific warning system for the South African coastline. It is unlikely that this will be implemented, given the low risk of seismic activity in the Southern Atlantic Ocean.

5.2.2 Construction and Operation Environmental Monitoring

It is recommended that the construction and operation environmental management plans developed for the project include the methodology for monitoring key oceanographic parameters during construction and operation.

During construction this should include monitoring the levels of total suspended sediments within the water column during all marine works and spoil disposal operations. During operation ambient temperature and concentrations of co-discharges should be frequently measured.

6 CONCLUSIONS AND RECOMMENDATIONS

This report has examined the impacts on the physical marine environment brought about by the construction and operation of the NPS the three sites namely; Duynefontein, Bantamsklip and Thyspunt. In addition to the impacts of the NPS on the physical marine environment, impacts of storm events, global warming and natural disasters such as tsunamis affecting the operation and safety of the NPS were considered.

This study has identified and compared the key oceanographic impacts at each of the three potential sites and provided, where relevant, appropriate mitigation measures. It is highly recommended that a comprehensive and site-specific marine environmental mitigation and management strategy is developed for the project site ultimately selected. This should include detailed marine environmental management measures that are based on the specific sensitivities of the site, the final design and the construction plans.

7 REFERENCES

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8 APPENDIX A

The maximum water levels, sea temperatures and coastline erosion for the expected installation life at Duynefontein, Bantamsklip and Thyspunt

TABLE A1: Extreme high water levels at Duynefontein

Return Period (years)	Individual component of extreme water level calculations	Units	Excluding climate change		Including climate change	
			Best estimate	Upper 95% confidence	Best estimate	Upper 95% confidence
1	HAT(Cape Town)	m MSL	1.20	1.20	1.20	1.20
	Sea level rise	m	0.00	0.00	0.80	0.80
	Positive storm surge	m	0.44	0.46	0.53	0.56
	Set-up and run-up[1]	m	2.93	2.97	3.31	3.36
	Extreme high water level	**m MSL**	**4.57**	**4.63**	**5.84**	**5.92**
10	HAT(Cape Town)	m MSL	1.20	1.20	1.20	1.20
	Sea level rise	m	0.00	0.00	0.80	0.80
	Positive storm surge	m	0.59	0.64	0.71	0.77
	Set-up and run-up[1]	m	3.15	3.23	3.56	3.65
	Extreme high water level	**m MSL**	**4.94**	**5.07**	**6.27**	**6.42**
100	HAT(Cape Town)	m MSL	1.20	1.20	1.20	1.20
	Sea level rise	m	0.00	0.00	0.80	0.80
	Positive storm surge	m	0.74	0.84	0.90	1.02
	Set-up and run-up[1]	m	3.33	3.45	3.77	3.91
	Extreme high water level	**m MSL**	**5.27**	**5.49**	**6.67**	**6.93**

Notes:
1) Used in calculations for maximum water levels for flood conditions on beaches

TABLE A2: Maximum high and low water levels during a tsunami event at Duynefontein

Individual component of extreme water level calculations	**Units**	**Excluding climate change**		**Including climate change**	
		Best estimate	**Upper 95% confidence**	**Best estimate**	**Upper 95% confidence**
90th percentile high tides	m MSL	0.92	0.92	0.92	0.92
Sea level rise	m	0	0	0.8	0.8
Positive storm surge[1]	m	0.59	0.64	0.71	0.77
Tsunami[2]	m	2.91	3.64	3.52	4.4
Set-up and run-up[3]	m	3.15	3.23	3.56	3.65
Extreme high water level	**m MSL**	**7.57**	**8.43**	**9.51**	**10.54**

Notes:
1) Based on a 1:10 year return period
2) Maximum value of 1:106 year return period long wave and maximum probable tsunami run-up and run-down values
3) Based on the 1:10 year return period, used in calculations for maximum water levels on beaches or offshore intake layout configurations

TABLE A3: Extreme seawater temperatures at 3 metres depth at Duynefontein

	Maximum temperature (℃)	
Return Period (years)	**Best estimate**	**Upper 95% confidence**
1	19.7	20.1
10	21.8	22.8
100	24.2	25.9

TABLE A4: Maximum expected horizontal coastline erosion at Duynefontein Beach for the expected installation life

	Long-term Trend	**Seasonal Erosion**	**Storm Event Erosion**	**Long-term Sea Level Rise**	**Total Coastline Erosion**
Excluding climate change	60 m	25 m	24 m	N/A	109 m
Including climate change	≥ 60 m *	≥ 25 m **	31 m	42 m	≥ 158 m

Notes:
* Erosion rate may increase due to increase in wave height. Future changes in wave direction could also modify the long term trend (no information available at present);
** Likely to exceed 25 m based on future increase in wave height.

TABLE A5: Extreme high water levels at Bantamsklip

Return Period (years)	Individual component of extreme water level calculations	Units	Excluding climate change		Including climate change	
			Best estimate	Upper 95% confidence	Best estimate	Upper 95% confidence
1	HAT(Hermanus)	m MSL	1.28	1.28	1.28	1.28
	Sea level rise	m	0.00	0.00	0.80	0.80
	Positive storm surge	m	0.61	0.63	0.74	0.76
	Set-up and run-up[1]	m	2.95	3.00	3.34	3.40
	Extreme high water level	**m MSL**	**4.84**	**4.91**	**6.16**	**6.24**
10	HAT(Hermanus)	m MSL	1.28	1.28	1.28	1.28
	Sea level rise	m	0.00	0.00	0.80	0.80
	Positive storm surge	m	0.78	0.83	0.94	1.00
	Set-up and run-up[1]	m	3.25	3.35	3.67	3.78
	Extreme high water level	**m MSL**	**5.31**	**5.46**	**6.69**	**6.86**
100	HAT(Hermanus)	m MSL	1.28	1.28	1.28	1.28
	Sea level rise	m	0.00	0.00	0.80	0.80
	Positive storm surge	m	0.94	1.04	1.14	1.26
	Set-up and run-up[1]	m	3.50	3.65	3.95	4.12
	Extreme high water level	**m MSL**	**5.72**	**5.97**	**7.17**	**7.46**

Notes:
1) Used in calculations for maximum water levels for flood conditions on beaches

TABLE A6: Maximum high and low water levels during a tsunami event at Bantamsklip

Individual component of extreme water level calculations	Units	Excluding climate change		Including climate change	
		Best estimate	Upper 95% confidence	Best estimate	Upper 95% confidence
90th percentile high tides	m MSL	1.04	1.04	1.04	1.04
Sea level rise	m	0.00	0.00	0.80	0.80
Positive storm surge[1]	m	0.78	0.83	0.94	1.00
Tsunami[2]	m	2.91	3.64	3.52	4.40
Set-up and run-up[3]	m	3.25	3.35	3.67	3.78
Extreme high water level	**m MSL**	**7.98**	**8.86**	**9.97**	**11.02**

Notes:
1) Based on a 1:10 year return period
2) Maximum value of 1:106 year return period long wave and maximum probable tsunami run-up and run-down values
3) Based on the 1:10 year return period, used in calculations for maximum water levels on beaches or offshore intake layout configurations

TABLE A7: Extreme seawater temperatures at three locations in the vicinity of Bantamsklip

	Cape Agulhas		Gansbaai		Hermanus	
Return period (years)	**Best estimate**	**Upper 95% confidence**	**Best estimate**	**Upper 95% confidence**	**Best estimate**	**Upper 95% confidence**
1	23.6	23.8	20.6	20.9	21.0	21.3
10	24.6	24.9	22.5	23.2	23.1	23.8
100	27.6	25.9	24.3	25.5	25.2	26.5

TABLE A8: Maximum expected horizontal coastline erosion at Duynefontein Beach for the expected installation life (PRDW 2009a)

	Long-term Trend	Seasonal Erosion	Storm Event Erosion	Long-term Sea Level Rise	Total Coastline Erosion
Excluding climate change	Dynamically stable	14 m	74 m	N/A	88 m
Including climate change	* Dynamically stable	** 14 m	85 m	35 m	≥ 134 m

Notes:
* Future changes in wave direction could modify the long-term trend.
** Likely to exceed 14 m based on future increase in wave height.

TABLE A9: Extreme high water levels at Thyspunt

Return Period (years)	Individual component of extreme water level calculations	Units	Excluding climate change		Including climate change	
			Best estimate	Upper 95% confidence	Best estimate	Upper 95% confidence
1	HAT(Port Elizabeth)	m MSL	1.28	1.28	1.28	1.28
	Sea level rise	m	0.00	0.00	0.80	0.80
	Positive storm surge	m	0.57	0.60	0.69	0.73
	Set-up and run-up	m	6.04	6.15	6.79	6.90
	Extreme high water level	**m MSL**	**7.89**	**8.03**	**9.56**	**9.71**
10	HAT(Port Elizabeth)	m MSL	1.28	1.28	1.28	1.28
	Sea level rise	m	0.00	0.00	0.80	0.80
	Positive storm surge	m	0.74	0.80	0.90	0.97
	Set-up and run-up	m	6.59	6.78	7.41	7.62
	Extreme high water level	**m MSL**	**8.61**	**8.86**	**10.39**	**10.67**
100	HAT(Port Elizabeth)	m MSL	1.28	1.28	1.28	1.28
	Sea level rise	m	0.00	0.00	0.80	0.80
	Positive storm surge	m	0.90	1.00	1.09	1.21
	Set-up and run-up	m	7.04	7.34	7.92	8.27
	Extreme high water level	**m MSL**	**9.22**	**9.62**	**11.09**	**11.56**

TABLE A10: Maximum high and low water levels during a tsunami event at Thyspunt

Individual component of extreme water level calculations	Units	Excluding climate change		Including climate change	
		Best estimate	Upper 95% confidence	Best estimate	Upper 95% confidence
90th percentile high tides	m MSL	0.98	0.98	0.98	0.98
Sea level rise	m	0.00	0.00	0.80	0.80
Positive storm surge	m	0.74	0.80	0.90	0.97
Tsunami	m	2.91	3.64	3.52	4.40
Set-up and run-up	m	6.59	6.78	7.41	7.62
Extreme high water level	**m MSL**	**11.22**	**12.20**	**13.61**	**14.77**

TABLE A11: Extreme seawater temperatures at three locations in the vicinity of Thyspunt

	Tsitsikamma (am)		Tsitsikamma (pm)		Storms River Mouth	
Return period (years)	Best estimate	Upper 95% confidence	Best estimate	Upper 95% confidence	Best estimate	Upper 95% confidence
1	23.7	24.0	24.6	24.9	22.6	22.8
10	25.4	26.0	26.0	26.5	23.5	23.9
100	26.8	27.9	27.2	28.0	24.3	24.9

TABLE A12: Maximum expected horizontal coastline erosion at Duynefontein Beach for the expected installation life (PRDW 2009c)

	Long-term Trend	Seasonal Erosion	Storm Event Erosion	Long-term Sea Level Rise	Total Coastline Erosion
Excluding climate change	Dynamically stable	48 m	34 m	N/A	82 m
Including climate change	Dynamically stable *	≥ 48 m **	41 m	22 m	≥ 111 m

Notes:
* Future changes in wave direction could modify the long-term trend.
** Likely to exceed 48 m based on future increase in wave height.

9 APPENDIX B - FIGURES

10 **APPENDIX C -** COASTAL ENGINEERING INVESTIGATIONS, DUYNEFONTEIN

11 **APPENDIX D -** NUMERICAL MODELLING OF COASTAL PROCESSES, DUYNEFONTEIN

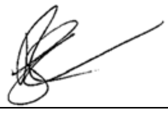
12 **APPENDIX E -** COASTAL ENGINEERING INVESTIGATIONS, BANTAMSKLIP

13 **APPENDIX F -** NUMERICAL MODELLING OF COASTAL PROCESSES, BANTAMSKLIP

14 **APPENDIX G -** COASTAL ENGINEERING INVESTIGATIONS, THYSPUNT

15 **APPENDIX H -** NUMERICAL MODELLING OF COASTAL PROCESSES, THYSPUNT

16 APPENDIX I - MARINE DISPOSAL OF SEDIMENT

Company name	WSP Environment and Energy
Specialist signature	
Date	March 2011