Geohydrological assessment of the proposed Weskusfleur Substation in the vicinity of the Koeberg Power Station, Western Cape.

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EXECUTIVE SUMMARY

Eskom Holdings SOC Limited initiated a study to investigate possible alternatives and solutions to address the long term reliability and improvement of the existing 400 kV Gas Insulated System substation at Koeberg Nuclear Power Station in the Western Cape. The current 400kV Gas Insulated System substation has been in operation for almost 30 years and there is a concern regarding its reliability. A new 400/132kV substation (called the Weskusfleur Substation) is required in the vicinity of the Koeberg Nuclear Power Station. There is the requirement for an Environment Impact Assessment (EIA) to be completed prior to the construction of the Weskusfleur Substation and two sites have been identified for the construction of the substation.

The proposed Weskusfleur substation sites are directly underlain by the Springfontyn Formation (Qs). The Springfontyn Formation consists of light grey to pale-red quartz rich sandy soil. At Site Alternative 1 the site comprises light grey calcified dune sand and calcrete. At Site Alternative 4, light grey to pale-red quartzose sand and dune sand exists. Both sites are underlain by aeolian dune sand which is up to approximately 35 metres deep. Below this layer (> 35 m), clay rich material occurs. The bedrock in the area is part of the Tygerberg Formation (Nt) of the Malmesbury Group, which consists of phyllitic shale, siltstone, greywacke and quartzite.

The geological setting, with sands overlying bedrock, has resulted in two aquifer systems beneath the two proposed sites. There is an unconfined primary aquifer within the sands and a semi-confined fractured (secondary) aquifer within the Malmesbury bedrock. The primary aquifer at the two sites is part of the southern extent of the Atlantis Primary Aquifer and the bedrock aquifer is known as the Malmesbury Aquifer. The depth to groundwater in the study area is approximately 10 – 13 metres below ground level. The aquifer yield is quite variable and average borehole yields are approximately 2 ℓ/s. Even the bedrock aquifer in places is very high yielding. The groundwater quality, as indicated by Electrical Conductivity, for both areas is in the range of 200 – 300 mS/m. This water is fairly saline and cannot be used for consumption or irrigation as is and will require desalination prior to use (unless it is planned for other purposes). Both sites have a "medium-high" groundwater vulnerability rating with regard to surface based contamination. Thus groundwater does occur within the area and both potential sites are underlain by groundwater. This factor needs to be taken into account and all measures put in place to ensure the groundwater is protected and not impacted or contaminated.

Regarding the preference of one site compared to the other, the Site Alternative 1 is preferred. It is in closer proximity to the ocean and, in the unlikely event that groundwater contamination does occur, it will have less of an impact on groundwater when compared to Site Alternative 4.

From a geohydrological perspective the proposed building of the Weskusfleur substation can proceed, however all measures must be put in place to ensure groundwater is not impacted. It is good practice to have a groundwater monitoring protocol in place, which is endorsed by the relevant authorities.

TABLE OF CONTENTS

LIST OF MAPS AND FIGURES

LIST OF TABLES

ABBREVIATIONS

CoCT	City of Cape Town
DEA	Department of Environmental Affairs
DRIT	Double ring infiltrometer tests
DWS	Department of Water and Sanitation
EIA	Environmental Impact Assessment
EIR	Environmental Impact Report
GIS	Gas insulated system
ha	hectare
KNPS	Koeberg Nuclear Power Station
kV	kiloVolts
ℓ/s	litres per second
m	metres
MAE	Mean Annual
mamsl	metres above mean sea level
MAP	Mean annual precipitation
MAR	Mean annual runoff
mbch	metres below collar height
mbgl	metres below ground level
mg/ℓ	milligrams per litre
Mm/a	millimetres per annum
mS/m	milliSiemens per meter
NGA	National Groundwater Archive
PBMR DPP	Pebble Bed Modular Reactor Demonstration Power Plant
Sy	Storativity
T	Transmissivity
TMG	Table Mountain Group
WGS84	Since the 1st January 1999, the official co-ordinate system for South Africa is based on the World Geodetic System 1984 ellipsoid, commonly known as WGS84.

GLOSSARY OF TERMS

Aquifer: a geological formation, which has structures or textures that hold water or permit appreciable water movement through them [from National Water Act (Act No. 36 of 1998)].

Borehole: includes a well, excavation, or any other artificially constructed or improved groundwater cavity which can be used for the purpose of intercepting, collecting or storing water from an aquifer; observing or collecting data and information on water in an aquifer; or recharging an aquifer [from National Water Act (Act No. 36 of 1998)].

Fractured aquifer: Fissured and fractured bedrock resulting from decompression and/or tectonic action. Groundwater occurs predominantly within fissures and fractures.

Groundwater: water found in the subsurface in the saturated zone below the water table or piezometric surface i.e. the water table marks the upper surface of groundwater systems.

Hydraulic conductivity: measure of the ease with which water will pass through earth material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (in m/d)

Intergranular Aquifer: Generally unconsolidated but occasionally semi-consolidated aquifers. Groundwater occurs within intergranular interstices in porous medium. Typically occur as alluvial deposits along river terraces.

Intergranular and fractured aquifers: Largely medium to coarse grained granite, weathered to varying thicknesses, with groundwater contained in intergranular interstices in the saturated zone , and in jointed and occasionally fractured bedrock.

Transmissivity: the rate at which a volume of water is transmitted through a unit width of aquifer under a unit hydraulic head (m^2/d); product of the thickness and average hydraulic conductivity of an aquifer.

Vadose zone: the unsaturated zone above the water table and below the ground surface.

Suggested reference for this report:

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Cover photo:

Borehole at Site Alternative 4

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1. INTRODUCTION

1.1 Background

Eskom's core business is the generation, transmission and distribution of electricity throughout South Africa. The Koeberg Nuclear Power Station located in the Western Cape, is a vital source of electricity for South Africa and the reliability of the electrical infrastructure associated with this power station must never be compromised.

Eskom Holdings SOC Limited initiated a study to investigate possible alternatives and solutions to address the long term reliability and improvement of the existing 400 kV Gas Insulated System (GIS) substation at Koeberg Nuclear Power Station in the Western Grid. The current 400kV GIS substation has been in operation for almost 30 years and there is a concern regarding its reliability. A new 400/132kV substation (called the Weskusfleur Substation) is required in the vicinity of the Koeberg Nuclear Power Station to:

- Improve the existing 400kV GIS substation reliability,
- Cater for load growth on the 132 kV network for the 20-year horizon (additional space is required),
- Prevent overloading of existing 400kV busbar,
- Replace 30 year old technology/equipment.

The proposed Weskusfleur Substation is in the vicinity of the Koeberg Nuclear Power Station and there is the requirement for an Environmental Impact Assessment (EIA) to be completed prior to the construction of the Weskusfleur Substation.

The required area for the substation location is approximately 20 – 30 hectares depending on the final location as per the outcomes of the EIA process. The substation will need to account for the current and future needs. The length of the diversion of the power lines will also be determined by the final substation location.

1.2 Objectives of the report

Initially five possible sites were identified for the development of the Weskusfleur Substation, which have been reduced to two possible site options. The two site options are shown in **Figure 1**. As part of the EIA process a geohydrological assessment is required to evaluate the two sites with regard to their suitability and possible impacts.

Figure 1: The two sites (Alternative 1 and Alternative 4) that were considered in this study

1.3 Legislative Framework

The main legislation and applicable guidelines / quality standards covering geohydrological issues applicable to this project are:

- The National Water Act, 1998 (Act No. 36 of 1998) (NWA): Issues include groundwater abstraction / discharge (e.g. for excavation dewatering as opposed to abstraction from supply boreholes) and groundwater quality, Water Use Licence Applications, General Authorisations and General Standards for effluent discharge;
- Department of Environmental Affairs and Development Planning's (DEA&DP) Guideline for Involving Hydrogeologists in EIA Processes (June 2005) (Saayman, 2005);
- Department of Water Affairs and Forestry's (DWAF) Integrated Water Resource Management: Guidelines for Groundwater Management in Water Management Areas in South Africa (DWAF, 2004): Issues includes groundwater resource assessment, allocation and monitoring;
- Eskom Technical Specifications for Site Safety Reports.

The NWA is the principal legal instrument relating to water resource management in South Africa and contains comprehensive provisions for the protection, use, development, conservation, management and control of the country's water resources. In addition, the management of water as a renewable resource must be carried out within the framework of environmental legislation, i.e. NEMA.

For this project there is no plan to make use of groundwater in the either the construction or operation phase for any purposes whatsoever. There is also no plan to abstract groundwater for the dewatering of excavations for the construction of the Weskusfleur Substation.

1.4 Study approach and methodology

The geohydrological assessment involved a number of tasks, namely:

- Task 1: Obtain all relevant data to the project (i.e. obtain data from the National Groundwater Archive (and associated groundwater use databases)). Obtain relevant geological maps and geohydrological maps. Obtain relevant groundwater reports. Compile a project GIS.
- Task 2: Complete a site visit to each of the two potential sites and assess the geohydrology of each of the sites.
- Task 3: Analyse the data, using geohydrological methods and evaluate the suitability of the potential sites for the construction of the substation. Rank the sites based on their suitability.
- Task 4: The results and recommendations will then be documented in a report

1.5 Assumptions

This specialist report has been based on a desk top study and has not included detailed site investigations. No borehole drilling was completed as part of this project, as it was assumed sufficient groundwater data already exists within the area. The geohydrological conditions were assumed to be homogeneous enough so that the extrapolation of data of existing data to the sites under consideration was considered acceptable.

In geohydrology there are three parameters that can be relatively easily measured, namely: groundwater levels (within a borehole / well point), borehole/well point yields, and groundwater quality. All other key parameters, such as transmissivity, storage and recharge, have to be estimated from some form of analytical/numerical process. Geohydrology is therefore an inexact science. However for this project the best judgement of the specialist has been applied.

1.6 Limitations of this study

The main limitation to this study was that borehole drilling on the two alternative sites was not carried out. Thus at the two sites the exact thickness of the upper aquifer and the nature of the lower deeper aquifer is not known. At the two sites the exact groundwater depths, borehole yields and groundwater quality are not known. However, within the context of the proposed development and the negligible impact the construction and operation of the Weskusfleur Substation will have on groundwater, the limitation mentioned is considered acceptable.

2. DESCRIPTION OF THE PROJECT

The study area falls within the City of Cape Town's Metropolitan Municipality in the area adjacent to the existing Koeberg Nuclear Power Station near Melkbosstrand, 30 km north of Cape Town on the West Coast. The area is bounded to the north by the West Coast District Municipality, to the north east by Cape Winelands District Municipality, to the south east by the Overberg District Municipality and to the south and west by the Atlantic Ocean.

The proposed substation is a 2x250MVA; 400/132kV air insulated (AIS), substation. The system will be operated at 400kV and 132kV, however the 400kV yard will be insulated at 550kV and the 132kV yard will be insulated at 275kV levels. This is a requirement due to the marine influence in the area, which requires higher insulation levels.

The construction phase of the substation may entail the following:

- Construction of access routes to the substation depending on the final location as per the outcomes of the EIA process
- Removal of all vegetation within the substation footprint
- Levelling of the site
- Installation of foundations for infrastructure such as transformers, control building and radio tower
- Construction of bunds and oil holding dams (for emergency holding of transformer oil) and fire safety walls
- Compaction and filling with gravel of the area between foundations
- Creation of formal drainage and storm water control measurers
- Delivery and installation of transformers, towers, busbars (conductors) and associated infrastructure
- Redirecting of existing 400kV and 132kV lines to enter and leave the substation
- Connection of the new infrastructure to the existing 400kV network
- Construction of perimeter fencing and lighting.

The aim of the EIA process is to identify the possible site where the project can be implemented with the minimal impact on the environment. The actual location of the new substation is determined by a number of factors, including Eskom's negotiation with landowners, environmental factors and technical considerations. As a result of these factors, it is impossible to predict the exact location of the substation within the EIA process. The inherent variation that is likely in the final placement of the substation is factored into the EIA through the assessment of alternative sites. For this project two alternative sites are under consideration.

A final Environmental Impact Report (EIR) is produced and provided to the Department of Environmental Affairs (DEA) with all the alternative sites assessed during the EIA process. Recommendations for the least impacted site are provided for consideration during authorisation. The DEA will issue an environmental authorisation based on the information provided.

A project-specific Environmental Management Plan (EMP) is drafted for the project and this document details the specific controls which must be in place for the duration of the construction phase. An Environmental Control Officer (ECO) who acts as an intermediary between individual landowners, Eskom and the contractors, implements the EMP.

3. DESCRIPTION OF THE AFFECTED ENVIRONMENT

3.1 Climate

Koeberg Nuclear Power Station is situated along the western coast of the south-western Cape. This area is in the climate region of Southern Africa that is generally classified as "Mediterranean Climate". The Mediterranean Climate district, in which Koeberg is situated, has a very low seasonal rainfall variability of below 20%. The pronounced maximum rainfall occurs in winter. The long term average yearly rainfall (27 years) equals 373 mm for the area, with the highest monthly rainfall being July with 65.8 mm and the lowest being February with just 7.9 mm. The highest rain-day frequency is also observed in July. The winter rains occur mostly out of Cumulus and Nimbostratus cloud formations during the winter months as pre- and post-frontal precipitation. During summer, unstable and hot conditions can result in thunder activity which is rare, less than 5 times per year, causing thundershowers out of Cumulonimbus cloud formations. Coastal lows passing the Cape from west to east, sometimes causes drizzle and light rain out of low cloud.

The cold Benguela Current off the coast at Koeberg has a moderating effect on the diurnal temperature. The coldest temperature measured at Koeberg is 2.2°C while the hottest has been 38.2°C. In winter, during times of weak pressure gradients, there is a temperature inversion present in the morning. Inversions also take place when cooler maritime air replaces warm air during onshore flow synoptic conditions.

3.2 Geology

The proposed Weskusfleur substation sites are directly underlain by the Springfontyn Formation (Qs). The Springfontyn Formation consists of light grey to pale-red quartz rich sandy soil. To the west of the Springfontyn Formation is the Witsand Formation which consists of unconsolidated white sand (fine- to coarse- grained calcareous coastal dune sand) (Meyer, 2001). These formations are part of the Cenozoic age (65.5 Ma to present). At Site Alternative 1 the site comprises light grey calcified dune sand and calcrete. At Site Alternative 4, light grey to pale-red quartzose sand and dune sand exists. Both sites are underlain by aeolian dune sand which is up to approximately 35 metres deep. Below this layer (> 35 m), clayey soils with low to medium potential of expansiveness may be expected but this will have no effect on the proposed development due to the significant thickness of the overlying aeolian sands.

The bedrock in the area is part of the Tygerberg Formation (Nt) of the Malmesbury Group, which consists of phyllitic shale, siltstone, greywacke and quartzite.

The closest known fault to Koeberg is the Mamre fault. The Mamre fault strikes north-westwards from Mamre towards Yzerfontein. The Mamre fault results in Cape Granite Suite occurring against Malmesbury Group rocks, implying appreciable, but unknown vertical displacements, and suggesting that the Darling hills represent a horst block. The Mamre fault may tie up with the Klipheuwel fault, which itself may actually continue further north-westwards, implying that it may pass within 14 km east of the Koeberg site.

The Darling fault does not separate Malmesbury Group from Cape Granite Suite, but its wide mylonite zone testifies to its regional importance. Additionally, it lies within 20 km of one of the most important NW-SE trending zones of faulting in the SW Cape, namely the Vredenburg-Stellenbosch-Colenso fault zone and its related faults, many of which are of appreciable displacement. These faults have been active from the Saldanian Orogeny (ca. 550 Ma – 500 Ma ago) to the Mesozoic breakup of Gondwana, and should probably still be regarded as a potential threat to the Koeberg site. The Colenso fault (Schoch, 1976) is the best known of them and ties up with the Kalbaskraal fault. The Colenso fault results in the Cape Granite Suite occurring against Malmesbury Group rocks.

Another such possible shear zone, called the Milnerton fault, has been proposed to occur between Bloubergstrand and Cape Town (Dames and Moore, 1976). The existence of the Milnerton fault is not yet proven.

In the off-shore environment a number of formerly unknown faults have been recently identified and thought to be of Cretaceous age. The Koeberg offshore fault is within 7.5 km of the Koeberg Nuclear Power Station and is the closest known off-shore fault to Koeberg.

3.3 Geohydrology

The geological setting, with sands overlying bedrock, has resulted in two aquifer systems beneath the two proposed sites. There is an unconfined primary aquifer within the sands and a semi-confined fractured (secondary) aquifer within the Malmesbury bedrock. The primary aquifer at the two sites is part of the southern extent of the Atlantis Primary Aquifer and the bedrock aquifer is known as the Malmesbury Aquifer. A lot of work has been done on both aquifers within the study area and the following description is taken mainly from the work of SRK (2011). The following descriptions are sub-divided according to the aquifer types.

3.4 Unconfined primary aquifer

The thickness of the primary aquifer at the site varies between 17 and 25 m, as the rest groundwater level is some 2 to 5 m below ground level (mbgl) and the overall thickness of the sediments is between 15 and 30 m (possibly up to 35 m thick). The sites most probably consist of 3 to 4.5 m of slightly calcareous sand, becoming organic rich with shell fragments below 7.5 m. The lower profile most probably consists of pebbly sand grading into gravels.

The Atlantis Aquifer is an important and significant primary aquifer with two wellfields, namely the Witzand and Silwerstroom wellfields which are managed by the City of Cape Town. The Witzand Wellfield is situated 3 km north-east of Koeberg and supplies groundwater to the surrounding towns, predominantly to Atlantis. This wellfield is situated in the most productive portion of the Atlantis Aquifer system. The Silwerstroom Wellfield is situated 9.5 km north of Koeberg. Other than production boreholes at the Witzand and Silwerstroom wellfields, there are many other existing boreholes in the area, including private production and monitoring boreholes.

Virtually all production boreholes draw groundwater from the medium grained quartz sand horizons of the Springfontyn Formation (Tredoux, 1987), because it is usually the thickest formation present with a relatively high hydraulic conductivity.

3.4.1 Hydraulic properties

Pumping tests and double-ring infiltrometer tests have previously been conducted on the Atlantis Aquifer (Van der Merwe 1980; Bredenkamp and Vandoolaeghe 1982; Scott, 1989 and Weaver 1989). Based on these tests, transmissivity values for the Atlantis aquifer are between 10 and 1 400 m^2/d. Further to the south with an increase in the percentage of fine material and decrease in the saturated thickness of the sands, the transmissivity (T) values decrease. At the existing Koeberg Nuclear Power Station (KNPS), T values of the primary aquifer are estimated to be ~40 m^2/d (Barker 1980 and Murray and Saayman 2000). The Aquarius Wellfield has calculated T values ranging from 15 to 100 m^2/d (Jolly and Hartley 1996).

Along the coastline at the western edge of the KNPS, a T value of 75 m^2/d was obtained (Fleisher, 1993). Analyses of test pumping results of the EIR boreholes drilled on the site indicate T values ranging from 16 to 140 m^2/d for the upper primary aquifer (**Table 1**). K was calculated by dividing T by saturated thickness (i.e. aquifer thickness). Aquifer thickness = borehole depth minus groundwater level.

Hydraulic conductivity (K) for the various formations of the Atlantis Aquifer was found to range between 13 and 35 m/d, with the exception of the Varswater Formation (1 to 3.5 m/d). The average K at the planned PBMR DPP was found to be ~2.6 m/d (Murray and Saayman 2000), with the more permeable, upper layers of the primary aquifer ranging between 3 and 10 m/d, and the underlying, less permeable layers ranging between 0.004 and 0.005 m/d. K values of 25 m/d were reported for the primary aquifer closer towards Atlantis (Bredenkamp and Vandoolaeghe, 1982).

Double ring infiltrometer tests (DRIT) were used to determine vertical K at the artificial recharge basin north-east of Koeberg (Scott, 1989). Based on data derived from the seven DRIT tests, vertical K ranged from 8 to 31 m/d at the recharge basin. Along the coastline at the western edge of the site, a K value of 12 m/d was obtained (Fleisher, 1993). K values for the EIR boreholes in the upper primary aquifer range from 0.9 to 5.6 m/d (**Table 1**).

Table 1: Aquifer parameters of the Upper Primary Aquifer underlying the Duynefontein site (SRK, 2011)

BH No.	Transmissivity T (m^2/d)	Storativity S	Saturated Thickness (m)	Hydraulic Conductivity K (m/d)	Assumed porosity (%)	Max. Yield (ℓ/s)
SRK-KG2	22	0.20	25	0.9	20	5.1
SRK-KG5	140	0.30	25	5.6	20	5.1
SRK-KG8	57	0.11	21	2.7	20	7.0
SRK-KG10	16	0.25	17	0.9	20	5.4
Average	59	0.22	22	2.5	20	5.6

Storativity (Sy) was determined to be between 0.04 (4 %) and 0.05 (5 %) (Murray and Saayman 2000 and Bredenkamp and Vandoolaeghe 1982). Sy values of between 0.198 (19.8 %) and 0.25 (25 %) were determined by Fleisher (1990) for the Atlantis Aquifer. Storativity values determined from the SRK (2011) boreholes range from 0.11 to 0.30 for the primary aquifer (**Table 1**), i.e. 11 to 30 % and are typical ranges for this type of aquifer.

3.4.2 Borehole yields

Yields of >10 ℓ/s are obtained from production boreholes in the Witzand and Silwerstroom Wellfields. Replacement boreholes in the Witzand Wellfield drilled during 1996 yielded between 16 and 18 ℓ/s (Fraser and Weaver, 1996). Borehole yields in the range of 0.5 to 5 ℓ/s are common in the sands underlying the existing KNPS. Two boreholes drilled during 1991 by SRK along the northern boundary of Koeberg yielded 1.7 and 4.2 ℓ/s (Rosewarne, 1989 and Rosewarne, 1995). Ten boreholes drilled to depths of between 25 and 33 m along the Aquarius Wellfield yielded between 2 and 6 ℓ/s (Jolly and Hartley 1996). Maximum test pumping yields obtained from the SRK (2011) study for the four boreholes drilled into the primary aquifer ranged from 5.1 to 7 ℓ/s.

Previous aquifer tests conducted on boreholes drilled into the primary aquifer showed a stabilisation of groundwater level drawdown at sea level or just above, when pumping such boreholes at ~2.5 ℓ/s (Saayman and Weaver 2001).

3.4.3 Groundwater recharge

Estimates of recharge (as a percentage of rainfall) in the vicinity of the site have previously been made by Bredenkamp and Vandoolaeghe (1982), Vandoolaeghe and Bertram (1982), Bertram et al., (1984), Fleisher (1990) and Fleisher and Eskes (1992). Average recharge was estimated to be between 10 and 30 % of mean annual precipitation (MAP).

A recharge factor of 25 % of MAP was derived for the area surrounding the Silwerstroom Wellfield, by using a water-balance approach to analyse groundwater monitoring information collected between 1978 and 1982 (Bredenkamp and Vandoolaeghe, 1982).

Fleisher and Eskes (1992) determined natural recharge near the site to be 23 % for vegetated areas and 42 % for non-vegetated areas.

Significant 3H concentrations (>1 TU) in the primary aquifer indicate a fairly dynamic system with groundwater in the aquifer being some 10 to 20 yrs old. The isotope studies of SRK (2011) indicate uniform and localised direct recharge.

The GRA-II data-set provides an 'average' rainfall-recharge factor for the G21B quaternary catchment of 15.4 % using the Chloride Mass Balance (CMB) approach. The recharge in the Duynefontein GRU was estimated to be 15 % of MAP (Woodford, 2007).

Due to the unconfined nature of the upper sediments, recharge takes place over the entire area. Following a review of all available recharge estimates, a site recharge figure of 15 % is considered to be representative for the area.

3.4.4 Depth to groundwater

Seasonal rainfall variation does not significantly affect the groundwater flow direction or groundwater levels at Koeberg. Monitoring data of boreholes in close proximity to the site since 1985 shows no indications of significantly declining water levels. It is, therefore, apparent that groundwater levels have not been negatively impacted by abstraction from the Witzand or Aquarius wellfields. Seasonal trends are evident, as are the short duration influences of groundwater abstraction.

The groundwater level ranges between 2 and 5 mbgl. The depth to groundwater conforms to surface topography. Seasonal and tidal impacts are the dominant factors influencing local groundwater level fluctuations. The Aquarius (1.5 km north-east of Koeberg) and Witzand Wellfields are the closest groundwater abstraction areas to Koeberg. Numerical modelling of the effect of abstraction from the Aquarius Wellfield on groundwater levels showed that there would be no significant impacts at the KNPS (Du Toit et al. 1995).

Monitoring of groundwater levels within the area since February 2008 using data loggers, indicates only minor variation in groundwater levels over two years of data collection.

3.4.5 Direction of groundwater flow

A regional groundwater level contour map was compiled by SRK (2011) using data collected from monitoring carried out by the CSIR and that collected during a hydrocensus conducted during August and September 2004 (Parsons and Flanagan 2006). From this it was interpreted that groundwater flows in a south-westerly direction towards the coast.

According to the results of previous numerical models, even at high abstraction rates at the Aquarius Wellfield, the resulting maximum zone of depression will not reach the site (Murray and Saayman, 2000). The direction of groundwater flow will only be reversed due to over-abstraction at the wellfields up-gradient of the site. Based on information derived from the models, it is not likely that contamination occurring at Koeberg can impact on the major aquifer systems up-gradient. The receiving environment / downstream receptor of any contamination will be the shore zone / ocean.

3.4.6 Hydraulic gradient

The hydraulic gradient across the Koeberg area is ~0.0125 rising to ~0.025 closer to the coast. Groundwater therefore flows under a relatively low gradient towards the coastline.

3.4.7 Rate of groundwater flow

Groundwater was calculated to flow towards the coast at a rate of ~2.6 m/d, which indicates a relatively quick migration across the Koeberg area.

3.4.8 Groundwater quality

The groundwater is generally a sodium (Na) - chloride (Cl) type. EC at the Koeberg site ranges between 85 and 215 mS/m, while at the Aquarius Wellfield, it ranges from 135 to 200 mS/m (Jolly and Hartley 1996). Some 18 wellpoints were previously installed along the coastline (along the western boundary of the Koeberg site), and groundwater EC levels at these wellpoints ranged from 65 to 150 mS/m (Fleisher, 1993). Groundwater samples from four boreholes and wellpoints were collected in close proximity to the Koeberg site and EC levels in these samples ranged from 100 to 250 mS/m (SRK, 2011). Groundwater quality monitoring data are available for the Witzand Wellfield indicates that EC levels vary between 50 and 250 mS/m.

According to the DWAF Quality Guidelines for Domestic Water Supplies (DWAF 1998), the above EC ranges are classified as ideal to marginal for drinking purposes and represents slightly saline conditions.

The quality of the groundwater is a direct result of the closeness of these aquifers to the ocean, i.e. at the end of the flow path and influence of frontal rainfall recharge and sea spray.

3.4.9 Aquifer classification and vulnerability

The Atlantis Aquifer is classified as a Sole Source aquifer system (Parsons 1995 and Parsons and Conrad 1998). Although smallholdings in the vicinity of the site are dependent on groundwater, a reticulated pipeline was constructed during 2002. The primary aquifer system towards the east of the site is therefore classified as a Major Aquifer system vulnerable to anthropogenic impacts (Parsons and Flanagan 2006). Its vulnerability is mainly due to its shallow unconfined water level and high permeability.

3.5 Bedrock secondary aquifer

The secondary aquifer is a semi-confined system which is considered to be in hydraulic connection with the overlying primary aquifer. Interpretation of previous pump test results supports that upward leakage from the Malmesbury Group bedrock secondary aquifer to the primary aquifer can be expected when the water table in the sands is drawn-down to below the piezometric level in the underlying semi-confined aquifer (Murray and Saayman 2000). These two aquifer systems are generally separated by a weathered (clay) zone in the bedrock. The clay horizon constitutes an aquitard, as it has a low permeability that retards and restricts the vertical movement of groundwater, but does not prevent the movement of the groundwater.

The areas east and further inland of Koeberg have outcrops of the Tygerberg Formation of the Malmesbury Group and comprise phyllitic shale and impure sandstone (greywacke) that weather to produce substantial thicknesses of yellow and / or grey clay. These consolidated meta-sedimentary rocks generally underlie the area surrounding the site (if not intruded by granite and dolerite) and form the semi-impervious base of the Atlantis Aquifer. Alternating successions of greywacke, siltstone and mudstone occur on site, with the beds dipping approximately 70° to the east. These consolidated sediments are highly weathered along the upper 10 m.

The Malmesbury Group Aquifer is formed by meta-sediments belonging to the Tygerberg Formation of the Malmesbury Group. The sediments are baked to massive bluish-grey hornfels along their contact with the Cape Granite Suite (not present at Koeberg) and narrow dolerite dykes, both of which have intruded the Malmesbury Group sediments. These dykes, as well as faults in the vicinity of the site, have been delineated by the Council for Geoscience. The bedrock at the site consists of a steeply dipping, interlaminated and bedded succession of greywacke, siltstone and mudstone, with occasional shale interbeds of the Malmesbury Group. Gradational sequences and contacts are characteristic and the beds grade mainly from coarse to fine grain size in upward-fining successions. The degree and depth of weathering varies considerably across the site. Unweathered greywacke is present within 6 m of the bedrock surface, while weathering of mudstone and siltstone extends to 26 m in some places. The bedrock is brecciated along fault zones, and is intensely jointed and often sheared along such fault planes. Quartz veins, pyrite and clay gouge are ubiquitous in the joints and faults, especially where the wall-rocks of the faults are brecciated.

The secondary aquifer is highly anisotropic and aquifer parameters vary significantly across the site. Work done for the (now abandoned) PBMR DPP indicated a T value of 30 m^2/d (Murray and Saayman 2000), probably representing 'fracture' transmissivity. Test pumping completed by SRK (2011) indicate T values ranging from 5 to 180 m^2/d for this aquifer (**Table 2**). Aquifer thickness = deepest water strike – rest water level.

SRK (2011) report that Packer test results for boreholes in the lower bedrock aquifer indicate K values ranging from 0.1 to 6.0 m/d (**Table 2**).

Storage values determined from the EIR boreholes range 0.0001 to 0.0029 for the bedrock aquifer (**Table 2**), indicating confined to semi-confined conditions. These values compare with those obtained by other investigations (Murray and Saayman, 2000).

Table 2: Aquifer parameters of the Lower Bedrock Aquifer underlying the Duynefontein site (SRK, 2011)

BH No.	**Transmissivity T (m^2/d)**	**Storativity S**	**Saturated Thickness (m)**	**Hydraulic Conductivity K (m/d)**	**Max. Yield (ℓ/s)**	**Recommended sustainable yield (ℓ/s)**	**Aquifer Type**
SRK-KG1	19	0.0001	56	0.3	15.0	1.0	Fractured
SRK-KG3	5	0.0009	53	0.1	4.5	0.3	Matrix
SRK-KG4	70	0.0014	42	1.7	15	6	Fractured
SRK-KG6	31	0.0019	37	0.8	10.25	2.4	Fractured
SRK-KG7	113	0.0003	37	3.1	14	4.5	Fractured
SRK-KG9	180	0.0029	30	6	5.1	4	Fractured
Average	70	0.0012	-	2.0	10.64	3.03	-

3.5.1 Borehole yields

Boreholes drilled into the Malmesbury Group Aquifer yield considerably less than the primary aquifer, i.e. <2 ℓ/s. This was supported by an assessment of the Malmesbury Group Aquifer during 2001 (Meyer 2000 and Meyer 2001).

During exploratory drilling at Koeberg, a fracture yielding in excess of 12 ℓ/s was encountered (Saayman and Weaver, 2001). As part of the SRK (2011) study, six boreholes drilled into the Malmesbury Group Aquifer recorded air lift yields of between 2 and 12 ℓ/s (**Table 2**), with a mean yield of ~5 ℓ/s (Flanagan 2008a). These consistently high yields encountered in the secondary, fractured aquifer system are uncommon for such aquifers in the region.

3.5.2 Groundwater Recharge

An interpretation of the previous results by SRK (2011) shows that the groundwater regime is less dynamic in the lower-lying secondary aquifer than in the primary aquifer, which indicates that negligible or no recharge to the Malmesbury Group aquifer occurs in the vicinity of Koeberg. The deeper aquifer is recharged further inland, possibly several kilometres east of the site in areas where the Malmesbury Group outcrops.

3.5.3 Depth to groundwater

Measurement of the piezometric level with the bedrock aquifer at Koeberg indicates that levels vary between 3.4 and 4.3 mbgl (Murray and Saayman 2000).

Groundwater levels measured in the deeper boreholes (i.e. secondary aquifer) and that measured in the shallow boreholes (i.e. primary aquifer) at the planned PBMR DPP differ by <0.5 m (Murray and Saayman 2000). This supports the contention that the Malmesbury Group Aquifer is a semi-confined system and the seasonal groundwater level variation is likely to be insignificant.

3.5.4 Direction of groundwater flow

The interpreted direction of groundwater flow, based on SRK (2011), is also in a south-westerly direction towards the coast.

3.5.5 Hydraulic gradient

The hydraulic gradient across the site is ~0.0125 rising to ~0.025 closer to the coast. Groundwater therefore flows under a relatively low gradient towards the coastline.

3.5.6 Rate of groundwater flow

The rate of flow through the Malmesbury Group Aquifer is estimated to be ~0.003 m/d. This slower flow rate relative to the primary aquifer is a result of the mostly lower transmissivity. Flow rates along individual fractures could be an order of magnitude higher.

3.5.7 Groundwater quality

Groundwater derived from the primary aquifer underlying the planned PBMR DPP and that from the Malmesbury Group Aquifer were of a similar quality (Saayman and Weaver 2001). The similarity in quality supports the hypothesis that the two aquifer systems are to a degree hydraulically connected.

Although EC levels and Na and Cl concentrations are similar, the average iron (Fe) concentration in the secondary aquifer is greater at 3.7 mg/L (as compared to ~ 0.3 mg/L in groundwater in the primary aquifer) (Saayman and Weaver 2001). Based on field measurements the EC levels in groundwater at six boreholes range between 200 and 275 mS/m (SRK, 2011).

Four exploration boreholes were drilled at the planned Koeberg 165 MW Unit 3 location and baseline groundwater quality data has been obtained (Levin, 2001). Tritium data indicated that groundwater in the Malmesbury Group Aquifer is not recharged locally,

3.5.8 Aquifer classification and vulnerability

The Malmesbury Group Aquifer at the site has previously been classified as a Minor Aquifer system, as this aquifer usually has low borehole yields, produces groundwater of variable quality and is of limited significance (Parsons 1995 and Parsons and Conrad 1998). Minor aquifers have a moderate to low vulnerability to anthropogenic impacts.

Based on the EIR drilling results, where blow yields in excess of 6 ℓ/s were encountered, the Minor Aquifer classification may be in question.

3.6 Conceptual groundwater flow model for the area

The conceptual model for the site is based on detailed information and data derived from the SRK (2011) study and extensive previous studies. Key features of the conceptual model are:

- The topography is relatively flat with a gentle slope towards the coast;
- No river channels drain the immediate site;
- The site overlies two aquifer systems, namely the southern extent of the upper-lying primary or intergranular Atlantis Aquifer and the deeper-lying weathered and fractured-rock (secondary) aquifer system of the Malmesbury Group;
- These two aquifer systems are generally separated by a weathered (clay) zone in the bedrock, which constitutes an aquitard;
- The thickness of the primary aquifer at the site is between 17 and 25 m, the rest groundwater level is 2 to 5 m below ground level (mbgl) and the overall thickness of the sediments is 15 to 30 m (possibly even thicker);
- The site is located very close to the coastline and therefore in terms of the hydrological / groundwater cycle, is located in a groundwater discharge zone.
- Groundwater at the site is thus near the end of its flow path; and the interpreted direction of groundwater flow is in a south-westerly direction towards the coast.

In addition, the following specific characteristics and geohydrological conditions apply (based on existing data and information):

- The hydraulic gradient across the site is in the order of 0.01. Groundwater therefore flows under a relatively low gradient towards the coastline;
- Groundwater was calculated to flow towards the coast at a rate of ~2.6 m/d, which indicates a relatively quick rate of flow across the site;

- Due to the unconfined nature of the upper sediments, recharge takes place over the entire area. A recharge estimate of 15 % is considered reasonable for the area;
- Borehole yields in the range of 0.5 to 5 ℓ/s are common in the primary aquifer sands underlying the site;
- High yields ranging up to 12 ℓ/s were encountered in the Malmesbury Group Aquifer, with the mean yield being 6 ℓ/s;
- Based on these preliminary results, the Malmesbury Group Aquifer is a potential additional source for groundwater supply; and
- The secondary aquifer is a semi-confined system which is in hydraulic connection with the overlying primary aquifer.

3.7 Groundwater Use

3.7.1 Regional groundwater abstraction

The town of Atlantis has been largely dependent on groundwater for its water supply since 1976. Water distribution is controlled by the Atlantis Water Resource Management Scheme (AWRMS). The scheme utilises the Atlantis Aquifer, stormwater and recycled wastewater originating from the town. Groundwater is abstracted from the aquifer at 40 boreholes in the Witzand and Silwerstroom Wellfields, softened at a waste treatment plant and then distributed for domestic and industrial use (Flanagan and Parsons 2005). Two basins situated in the dunes to the south-west of Atlantis serve as final retention ponds and provide for the artificial recharge of the aquifer some 500 m up-gradient of the Witzand Wellfield (Wright and Parsons 1994).

Intermediate quality stormwater and treated domestic wastewater is discharged into Basin 7 (southern recharge basin), situated 4 km north-east of Koeberg. High quality stormwater is diverted into Basin 12 (northern recharge basin). This artificial recharge counters the encroachment of naturally poorer quality groundwater (Tredoux et al. 1999). Poorer quality wastewater including treated industrial effluent is discharged into the coastal infiltration basins along the coastline, 3 km north of the site. This poorer quality water cannot be used for recharge into the aquifer and it does not meet the requirements of the DWS general standard for discharge into the Donkergat River and is, therefore, disposed of as close to the coast as possible (Wright and Parsons 1994). Recharge into these coastal infiltration basins produces a subsurface hydraulic mound that acts as a barrier against seawater intrusion and increases the exploitable groundwater resource potential up-gradient at the Witzand Wellfield (Wright and Parsons 1994 and Tredoux et al. 1999).

Groundwater demand from the Witzand and Silwerstroom Wellfields was 0.43 Mm^3/a in 1977 (Dyke 1992), 8.5 Mm^3/a in 1998/1999 (Parsons 1999) and 3.2 Mm^3/a in 2005 solely from the Witzand Wellfield. Based on modelling results, the sustainable 'fresh water' yield of the Witzand Wellfield is 5.8 Mm^3/a (Fleisher and Eskes 1992).

Based on data received from the CoCT 2.6 Mm^3/a of groundwater was abstracted from the two wellfields in 2007, significantly less than what was estimated during 1998 / 1999. The reduced yields and the overall significantly reduced abstraction productivity of the two wellfields is a result of iron-related clogging. There are no visible signs of any negative impacts caused by groundwater abstraction from the Atlantis Aquifer, and the Silwerstroom spring is still flowing in spite of continued groundwater abstraction from the Silwerstroom Wellfield (Parsons, 1999). The discharge rate of the Silwerstroom spring was estimated to be 0.5 Mm^3/a during 1992 (Fleisher and Eskes 1992). The Atlantis Aquifer is fully allocated and no further development or increased abstraction (other than rehabilitating the existing boreholes) will be allowed (Van der Berg et al. 2007).

Groundwater is also used in the vicinity of the site as a source of water for smallholdings, brickmaking and sand mining. Groundwater is predominantly used for small-scale vegetable farming, water for horses and irrigation of commercial lawn. Reticulated municipal water is available to most smallholdings from a pipeline constructed during 2002, but municipal water is only used to a limited extent due to the relatively high cost. Groundwater is still the preferred choice for water supply (Parsons and Flanagan, 2006).

There are approximately 1 000 erven in Duynefontein, of which about 75 % have wellpoints installed for garden irrigation purposes. Duynefontein is considered a high income group area and typical water demand is estimated to be 1800 L/d per household (i.e. 450 L/p/d for a four person household) (SAICE, 1995). The estimated breakdown of domestic water usage indicates that 35 % of water is used for garden irrigation (SAICE 1995). Therefore, an average of some 230 m^3/a of groundwater per erf is abstracted via wellpoints from the primary aquifer, assuming gardens are irrigated each day. This equates to ~173 000 m^3/a of groundwater being abstracted from the area south of the existing KNPS. Based on data collected during the January 2008 hydrocensus, some 30 000 m^3/a of groundwater is abstracted from four boreholes along the Aquarius Wellfield (GCS1, GCS7, GCS9 and GCS10). The groundwater from these boreholes is currently used for stock watering and irrigation purposes, as well as to supply the dam at the conservation offices at the existing KNPS. These boreholes were initially drilled to supply water to the 900 PWR MW Units 1 and 2. However, as the groundwater is relatively high in salinity, the use of these boreholes was temporarily abandoned as desalination by reverse osmosis was not cost-effective (Eskom 2006a). It was previously estimated that 0.5 Mm^3/a of groundwater was abstracted from the Aquarius Wellfield (Parsons 1999). The four boreholes were re-commissioned at the beginning of 2007.

Five monitoring boreholes are situated around the reactors at the existing KNPS (TW1 to TW5). These boreholes are presently solely used for groundwater monitoring purposes (Hön et al., 2007 and Hön and Engelbrecht, 2007). A further six monitoring boreholes have also been recently drilled at the planned PBMR DPP (PBMR1 to PBMR6) to monitor groundwater levels, macro chemistry and 3H concentrations in both the primary aquifer and underlying Malmesbury Group Aquifer (Flanagan 2008b). This monitoring programme commenced during February 2008 (Flanagan and Burgers 2008).

3.7.2 On-site Groundwater Abstraction

Groundwater is presently not used at the site. The nearest abstraction points are from boreholes at the Aquarius and Witzand Wellfields. The six boreholes drilled on-site into the Malmesbury Group Aquifer during the SRK (2011) work yielded between 2 and 12 ℓ/s. The Malmesbury Group Aquifer is presently not utilised in the area and this resource is therefore exploitable, and is a potential source of water for the proposed site.

3.7.3 Ecosystem Water Use and Interaction with Surface Water

The only area in the vicinity of the site where the terrain is sufficiently low-lying to support significant areas of wetland habitat is found 1.5 km south of the site. The slack areas between a series of low lying east-west oriented dunes give rise to a mosaic system of alkaline dune-slack wetlands (Day 2007a). No other natural freshwater systems or springs are known to occur at the site.

The dune wetlands are fed primarily by the seasonal fluctuations in the groundwater table, forming pools of shallow, brackish water during winter. These wetlands are dry in summer when the groundwater table drops. These pools provide a breeding habitat for frogs as well as numerous aquatic and semi-aquatic invertebrates including crustacean fauna that occur in seasonal wetland habitats. Wet season salinities in the wetlands are probably elevated, as a result of marine influences such as sea mists and off-shore winds. The wetlands are considered of high local and regional importance, although their similarity to other wetlands north of the site has not yet been established (Day 2007a).

A series of coastal infiltration basins has been excavated between the dunes and may be linked to an increase in seepage and deterioration of the limestone cliffs along a section of nearby coastal shoreline (Day 2007a and Day 2007b). The coastal infiltration basins are highly artificial habitats, comprising deep, permanent, open-water bodies, vegetated by species that thrive under conditions of nutrient enrichment (Day 2007a and Day 2007b). The coastal infiltration basins provide permanent habitat to a variety of swimming waterfowl, but are of limited value to wading birds. Fish have been introduced to the ponds, primarily to provide an early warning of water quality problems. The coastal infiltration basins are unnatural water features of low quality, but locally rare, permanent freshwater habitat, artificially contributing to plant and animal diversity in the area. They play an important role in terms of providing a hydraulic barrier for the protection of the Atlantis Aquifer from seawater intrusion (Day 2007a).

Several short, perennial streams flow directly towards the Atlantic Ocean in the vicinity of the site. Most of these streams disappear into the flat areas near the coast or cannot maintain open river channels across the coastal dunes (Mawatsan 2006). No rivers flow through the site and the closest significant drainage channel is the Sout River (5 km south of the site) and its largest tributary, the Donkergat River, which discharges into the ocean at Melkbosstrand (Day 2007a).

4. FINDINGS

With regard to potential geohydrological impacts there is no intention to make use of groundwater during the construction, operational or de-commissioning phases. Thus the groundwater impacts will be minimal, however are discussed in more detail in the section below.

4.1 Substation GIS/AIS

- **Alternative 1**:
  - Construction phase – the main impact during this phase is related to possible contamination of groundwater from earth moving equipment, from the temporary storage of fuels and lubricants and during the processing of filling fuel tanks and servicing equipment. It must thus be ensured that no earth moving equipment or generators leak fuel or oil. When parked overnight the equipment must be stored on an area with an impermeable base or have a "fuel-absorbent blanket" placed under the engine. Any generators used must be placed on a sand tray. There must be no spillage when vehicles or generators etc are filled. There must be clear procedures to address a fuel spillage with associated clean up material. The Environmental Control Officer must do everything possible to reduce the risk of oil or fuel spillage. The groundwater in the area is vulnerable to contamination, as it is shallow and the sands are permeable.
  - Operational phase – the potential groundwater impacts are negligible. The sub-station will be built on a solid impermeable foundation.
  - De-commissioning phase – this will be well into the future (possibly more than 30 years away) and all measure must then be taken to avoid contamination of groundwater.
  - Cumulative impacts – it is highly unlikely that there will be any cumulative impacts on groundwater.

- **Alternative 4:**
  - Construction phase - the main impact during this phase is related to possible contamination of groundwater from earth moving equipment, from the temporary storage of fuels and lubricants and during the processing of filling fuel tanks and servicing equipment. It must thus be ensured that no earth moving equipment or generators leak fuel or oil. When parked overnight the equipment must be stored on an area with an impermeable base or have a "fuel-absorbent blanket" placed under the engine. Any generators used must be placed on a sand tray. There must be no spillage when vehicles or generators etc are filled. There must be clear

procedures to address a fuel spillage with associated clean up material. The Environmental Control Officer must do everything possible to reduce the risk of oil or fuel spillage. The groundwater in the area is highly vulnerable to contamination, as it is shallow and the sands are permeable.

  - Operational phase - the potential groundwater impacts are negligible. The sub-station will be built on a solid impermeable foundation.
  - De-commissioning phase - this will be well into the future (possibly more than 30 years away) and all measure must then be taken to avoid contamination of groundwater.
  - Cumulative impacts - it is highly unlikely that there will be any cumulative impacts on groundwater.

- **Alternative – No-go option**: A new sub-station has to be built as the existing sub-station needs to be replaced. Thus this alternative is not an option. However potentially if left as, the substation could have an impact on groundwater as leaks could occur from out-dated transformers and the foundations may have permeable zones resulting in the contamination of groundwater.

4.2 Transmission lines

- **Alternative Corridor 1:**
  - Construction phase – the main impact during this phase is related to possible contamination of groundwater from earth moving equipment, from the temporary storage of fuels and lubricants and during the processing of filling fuel tanks and servicing equipment. It must thus be ensured that no earth moving equipment or generators leak fuel or oil. When parked overnight the equipment must be stored on an area with an impermeable base or have a "fuel-absorbent blanket" placed under the engine. Any generators used must be placed on a sand tray. There must be no spillage when vehicles or generators etc are filled. There must be clear procedures to address a fuel spillage with associated clean up material. The Environmental Control Officer must do everything possible to reduce the risk of oil or fuel spillage. The groundwater in the area is vulnerable to contamination, as it is shallow and the sands are permeable.
  - Operational phase – the potential groundwater impacts are negligible. The sub-station will be built on a solid impermeable foundation.
  - De-commissioning phase – this will be well into the future (possibly more than 30 years away) and all measure must then be taken to avoid contamination of groundwater.
  - Cumulative impacts – it is highly unlikely that there will be any cumulative impacts on groundwater.

- **Alternative Corridor 4:**
    - Construction phase – the main impact during this phase is related to possible contamination of groundwater from earth moving equipment, from the temporary storage of fuels and lubricants and during the processing of filling fuel tanks and servicing equipment. It must thus be ensured that no earth moving equipment or generators leak fuel or oil. When parked overnight the equipment must be stored on an area with an impermeable base or have a "fuel-absorbent blanket" placed under the engine. Any generators used must be placed on a sand tray. There must be no spillage when vehicles or generators etc are filled. There must be clear procedures to address a fuel spillage with associated clean up material. The Environmental Control Officer must do everything possible to reduce the risk of oil or fuel spillage. The groundwater in the area is vulnerable to contamination, as it is shallow and the sands are permeable.
    - Operational phase – the potential groundwater impacts are negligible. The sub-station will be built on a solid impermeable foundation.
    - De-commissioning phase – this will be well into the future (possibly more than 30 years away) and all measure must then be taken to avoid contamination of groundwater.
    - Cumulative impacts – it is highly unlikely that there will be any cumulative impacts on groundwater.

- **Alternative 3 –** No-go: A new sub-station has to be constructed as the existing one is becoming less safe and needs to be upgraded. Thus the "no-go" alternative for the transmission lines is not applicable.

5. ASSESSMENT OF IMPACTS

An impact rating assessment was completed with regard to groundwater levels and groundwater quality (as a combined assessment). Each of the parameters, Extent; Duration; Magnitude; Probability; Significance and Status have been classified according to the ratings table presented in **Table 2**. The impact rating assessment has been sub-divided into the following four phases; i.e. for the Construction Phase (**Table 3**); the Operational Phase (**Table 4**); the Decommissioning and Rehabilitation Phase (**Table 5**) and with regard to Cumulative Impacts (**Table 6**). The significance weighting (S) is determined by combining the criteria in the following formula:

S = (E+D+M)*P; where

E = Extent D = Duration

M = Magnitude P = Probability.

Table 2: Rating tables

- The physical **extent**, wherein it is indicated whether:
  - 1 - the impact will be limited to the site;
  - 2 - the impact will be limited to the local area;
  - 3 - the impact will be limited to the region;
  - 4 - the impact will be national; or
  - 5 - the impact will be international;
- The **duration**, wherein it is indicated whether the lifetime of the impact will be:
  - 1 - of a very short duration (0–1 years);
  - 2 - of a short duration (2-5 years);
  - 3 - medium-term (5–15 years);
  - 4 - long term (> 15 years); or
  - 5 - permanent;
- The **magnitude of impact on ecological processes**, quantified on a scale from 0-10, where a score is assigned:
  - 0 - small and will have no effect on the environment;
  - 2 - minor and will not result in an impact on processes;
  - 4 - low and will cause a slight impact on processes;
  - 6 - moderate and will result in processes continuing but in a modified way;
  - 8 - high (processes are altered to the extent that they temporarily cease); or
  - 10 - very high and results in complete destruction of patterns and permanent cessation of processes;
- The **probability of occurrence**, which describes the likelihood of the impact actually occurring. Probability is estimated on a scale where:
  - 1 - very improbable (probably will not happen;
  - 2 - improbable (some possibility, but low likelihood);
  - 3 - probable (distinct possibility);
  - 4 - highly probable (most likely); or
  - 5 - definite (impact will occur regardless of any prevention measures);
- the **significance**, which is determined through a synthesis of the characteristics described above (refer formula below) and can be assessed as low, medium or high;
- the **status**, which is described as either positive, negative or neutral;
- the degree to which the impact can be reversed;
- the degree to which the impact may cause irreplaceable loss of resources; and
- the degree to which the impact can be mitigated.

The significance weightings for each potential impact are as follows:

- < 30 points: Low (i.e. where this impact would not have a direct influence on the decision to develop in the area),
- 30 - 60 points: Medium (i.e. where the impact could influence the decision to develop in the area unless it is effectively mitigated),
- > 60 points: High (i.e. where the impact must have an influence on the decision process to develop in the area).

Table 3: Groundwater significance rating for groundwater – construction phase

Koeberg substation - EIA									
Groundwater									
Significance Rating Table									
Construction Phase									
GIS Substation - Site 1									
Potential Impact	Mitigation	Extent (E)	Duration (D)	Magnitude (M)	Probability (P)	Significance (S=(E+D+M)*P)		Status (+ve or -ve)	Confidence
Groundwater levels and quality	Nature of impact:								
	with	1	1	0	1	2	Low	-	high
	without	1	2	2	2	10	Low	-	high
	degree to which impact can be reversed:	The impact of the activities during the construction phase are reversible							high
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							high
Alternative 4 GIS substation									
Potential Impact	Mitigation	Extent (E)	Duration (D)	Magnitude (M)	Probability (P)	Significance (S=(E+D+M)*P)		Status (+ve or -ve)	Confidence
Groundwater levels and quality	Nature of impact:								
	with	1	2	0	1	3	Low	-	high
	without	1	3	2	2	12	Low	-	high
	degree to which impact can be reversed:	The impact of the activities during the construction phase are reversible							high
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							high
Alternative no-go option									
Potential Impact	Mitigation	Extent (E)	Duration (D)	Magnitude (M)	Probability (P)	Significance (S=(E+D+M)*P)		Status (+ve or -ve)	Confidence
Groundwater levels and quality	Nature of impact:								
	with	3	5	8	3	48	Medium	-	medium
	without	3	5	8	4	64	High	-	medium
	degree to which impact can be reversed:	The impacts can be reversed - will however take a long time							medium
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							medium
Transmission Line - site 1									
Potential Impact	Mitigation	Extent (E)	Duration (D)	Magnitude (M)	Probability (P)	Significance (S=(E+D+M)*P)		Status (+ve or -ve)	Confidence
Groundwater levels and quality	Nature of impact:								
	with	1	1	0	1	2	Low	-	high
	without	1	2	2	2	10	Low	-	high
	degree to which impact can be reversed:	The impact of the activities during the construction phase are reversible							high
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							high
Transmission Line - Alternative 4									
Potential Impact	Mitigation	Extent (E)	Duration (D)	Magnitude (M)	Probability (P)	Significance (S=(E+D+M)*P)		Status (+ve or -ve)	Confidence
Groundwater levels and quality	Nature of impact:								
	with	1	2	0	1	3	Low	-	high
	without	1	3	2	2	12	Low	-	high
	degree to which impact can be reversed:	The impact of the activities during the construction phase are reversible							high
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							high
Transmission Line - No-Go Alterantive									
Potential Impact	Mitigation	Extent (E)	Duration (D)	Magnitude (M)	Probability (P)	Significance (S=(E+D+M)*P)		Status (+ve or -ve)	Confidence
Groundwater levels and quality	Nature of impact:								
	with	3	5	8	3	48	Medium	-	medium
	without	3	5	8	4	64	High	-	medium
	degree to which impact can be reversed:	The impacts can be reversed - will however take a long time							medium
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							medium

Table 4: Groundwater significance rating for groundwater – operational phase

Koeberg substation - EIA									
Groundwater									
Significance Rating Table									
Operational Phase									
GIS Substation - Site 1									
Potential Impact	**Mitigation**	**Extent (E)**	**Duration (D)**	**Magnitude (M)**	**Probability (P)**	**Significance (S=(E+D+M)*P)**		**Status (+ve or -ve)**	**Confidence**
Groundwater levels and quality	**Nature of impact:**								
	with	1	1	0	1	2	Low	-	high
	without	1	2	2	2	10	Low	-	high
	degree to which impact can be reversed:	The impact of the activities during the construction phase are reversible							high
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							high
Alternative 4 GIS substation									
Potential Impact	**Mitigation**	**Extent (E)**	**Duration (D)**	**Magnitude (M)**	**Probability (P)**	**Significance (S=(E+D+M)*P)**		**Status (+ve or -ve)**	**Confidence**
Groundwater levels and quality	**Nature of impact:**								
	with	1	2	0	1	3	Low	-	high
	without	1	3	2	2	12	Low	-	high
	degree to which impact can be reversed:	The impact of the activities during the construction phase are reversible							high
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							high
Alternative no-go option									
Potential Impact	**Mitigation**	**Extent (E)**	**Duration (D)**	**Magnitude (M)**	**Probability (P)**	**Significance (S=(E+D+M)*P)**		**Status (+ve or -ve)**	**Confidence**
Groundwater levels and quality	**Nature of impact:**								
	with	3	5	8	3	48	Medium	-	medium
	without	3	5	8	4	64	High	-	medium
	degree to which impact can be reversed:	The impacts can be reversed - will however take a long time							medium
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							medium
Transmission Line - site 1									
Potential Impact	**Mitigation**	**Extent (E)**	**Duration (D)**	**Magnitude (M)**	**Probability (P)**	**Significance (S=(E+D+M)*P)**		**Status (+ve or -ve)**	**Confidence**
Groundwater	**Nature of impact:**								
	with	1	1	0	1	2	Low	-	high
	without	1	2	2	2	10	Low	-	high
	degree to which impact can be reversed:	The impact of the activities during the construction phase are reversible							high
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							high
Transmission Line - Alternative 4									
Potential Impact	**Mitigation**	**Extent (E)**	**Duration (D)**	**Magnitude (M)**	**Probability (P)**	**Significance (S=(E+D+M)*P)**		**Status (+ve or -ve)**	**Confidence**
Groundwater levels and quality	**Nature of impact:**								
	with	1	2	0	1	3	Low	-	high
	without	1	3	2	2	12	Low	-	high
	degree to which impact can be reversed:	The impact of the activities during the construction phase are reversible							high
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							high
Transmission Line - No-Go Alterantive									
Potential Impact	**Mitigation**	**Extent (E)**	**Duration (D)**	**Magnitude (M)**	**Probability (P)**	**Significance (S=(E+D+M)*P)**		**Status (+ve or -ve)**	**Confidence**
Groundwater levels and quality	**Nature of impact:**								
	with	3	5	8	3	48	Medium	-	medium
	without	3	5	8	4	64	High	-	medium
	degree to which impact can be reversed:	The impacts can be reversed - will however take a long time							medium
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							medium

Table 5: Groundwater significance rating for groundwater – decommissioning / rehabilitation phase

Koeberg substation - EIA									
Groundwater									
Significance Rating Table									
Decommissioning / Rehabilitation Phase									
GIS Substation - Site 1									
Potential Impact	**Mitigation**	**Extent (E)**	**Duration (D)**	**Magnitude (M)**	**Probability (P)**	**Significance (S=(E+D+M)*P)**		**Status (+ve or -ve)**	**Confidence**
Groundwater levels and quality	**Nature of impact:**								
	with	1	1	0	1	2	Low	-	high
	without	1	2	2	2	10	Low	-	high
	degree to which impact can be reversed:	The impact of the activities during the construction phase are reversible							high
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							high
Alternative 4 GIS substation									
Potential Impact	**Mitigation**	**Extent (E)**	**Duration (D)**	**Magnitude (M)**	**Probability (P)**	**Significance (S=(E+D+M)*P)**		**Status (+ve or -ve)**	**Confidence**
Groundwater levels and quality	**Nature of impact:**								
	with	1	2	0	1	3	Low	-	high
	without	1	3	2	2	12	Low	-	high
	degree to which impact can be reversed:	The impact of the activities during the construction phase are reversible							high
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							high
Alternative no-go option									
Potential Impact	**Mitigation**	**Extent (E)**	**Duration (D)**	**Magnitude (M)**	**Probability (P)**	**Significance (S=(E+D+M)*P)**		**Status (+ve or -ve)**	**Confidence**
Groundwater levels and quality	**Nature of impact:**								
	with	3	5	8	3	48	Medium	-	medium
	without	3	5	8	4	64	High	-	medium
	degree to which impact can be reversed:	The impacts can be reversed - will however take a long time							medium
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							medium
Transmission Line - site 1									
Potential Impact	**Mitigation**	**Extent (E)**	**Duration (D)**	**Magnitude (M)**	**Probability (P)**	**Significance (S=(E+D+M)*P)**		**Status (+ve or -ve)**	**Confidence**
Groundwater levels and quality	**Nature of impact:**								
	with	1	1	0	1	2	Low	-	high
	without	1	2	2	2	10	Low	-	high
	degree to which impact can be reversed:	The impact of the activities during the construction phase are reversible							high
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							high
Transmission Line - Alternative 4									
Potential Impact	**Mitigation**	**Extent (E)**	**Duration (D)**	**Magnitude (M)**	**Probability (P)**	**Significance (S=(E+D+M)*P)**		**Status (+ve or -ve)**	**Confidence**
Groundwater levels and quality	**Nature of impact:**								
	with	1	2	0	1	3	Low	-	high
	without	1	3	2	2	12	Low	-	high
	degree to which impact can be reversed:	The impact of the activities during the construction phase are reversible							high
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							high
Transmission Line - No-Go Alterantive									
Potential Impact	**Mitigation**	**Extent (E)**	**Duration (D)**	**Magnitude (M)**	**Probability (P)**	**Significance (S=(E+D+M)*P)**		**Status (+ve or -ve)**	**Confidence**
Groundwater levels and quality	**Nature of impact:**								
	with	3	5	8	3	48	Medium	-	medium
	without	3	5	8	4	64	High	-	medium
	degree to which impact can be reversed:	The impacts can be reversed - will however take a long time							medium
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							medium

Table 6: Groundwater significance rating for groundwater – cumulative impacts

Koeberg substation - EIA									
Groundwater									
Significance Rating Table									
Cumulative Impacts									
GIS Substation - Site 1									
Potential Impact	**Mitigation**	**Extent (E)**	**Duration (D)**	**Magnitude (M)**	**Probability (P)**	**Significance (S=(E+D+M)*P)**		**Status (+ve or -ve)**	**Confidence**
Groundwater levels and quality	**Nature of impact:**								
	with	1	1	0	1	2	Low	-	high
	without	1	2	2	2	10	Low	-	high
	degree to which impact can be reversed:	The impact of the activities during the construction phase are reversible							high
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							high
Alternative 4 GIS substation									
Potential Impact	**Mitigation**	**Extent (E)**	**Duration (D)**	**Magnitude (M)**	**Probability (P)**	**Significance (S=(E+D+M)*P)**		**Status (+ve or -ve)**	**Confidence**
Groundwater levels and quality	**Nature of impact:**								
	with	1	2	0	1	3	Low	-	high
	without	1	3	2	2	12	Low	-	high
	degree to which impact can be reversed:	The impact of the activities during the construction phase are reversible							high
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							high
Alternative no-go option									
Potential Impact	**Mitigation**	**Extent (E)**	**Duration (D)**	**Magnitude (M)**	**Probability (P)**	**Significance (S=(E+D+M)*P)**		**Status (+ve or -ve)**	**Confidence**
Groundwater levels and quality	**Nature of impact:**								
	with	3	5	8	3	48	Medium	-	medium
	without	3	5	8	4	64	High	-	medium
	degree to which impact can be reversed:	The impacts can be reversed - will however take a long time							medium
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							medium
Transmission Line - site 1									
Potential Impact	**Mitigation**	**Extent (E)**	**Duration (D)**	**Magnitude (M)**	**Probability (P)**	**Significance (S=(E+D+M)*P)**		**Status (+ve or -ve)**	**Confidence**
Groundwater levels and quality	**Nature of impact:**								
	with	1	1	0	1	2	Low	-	high
	without	1	2	2	2	10	Low	-	high
	degree to which impact can be reversed:	The impact of the activities during the construction phase are reversible							high
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							high
Transmission Line - Alternative 4									
Potential Impact	**Mitigation**	**Extent (E)**	**Duration (D)**	**Magnitude (M)**	**Probability (P)**	**Significance (S=(E+D+M)*P)**		**Status (+ve or -ve)**	**Confidence**
Groundwater levels and quality	**Nature of impact:**								
	with	1	2	0	1	3	Low	-	high
	without	1	3	2	2	12	Low	-	high
	degree to which impact can be reversed:	The impact of the activities during the construction phase are reversible							high
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							high
Transmission Line - No-Go Alterantive									
Potential Impact	**Mitigation**	**Extent (E)**	**Duration (D)**	**Magnitude (M)**	**Probability (P)**	**Significance (S=(E+D+M)*P)**		**Status (+ve or -ve)**	**Confidence**
Groundwater levels and quality	**Nature of impact:**								
	with	3	5	8	3	48	Medium	-	medium
	without	3	5	8	4	64	High	-	medium
	degree to which impact can be reversed:	The impacts can be reversed - will however take a long time							medium
	degree of impact on irreplaceable resources:	There are no irreplacebale resources (i.e. the groundwater is widely distributed throughout the area).							medium

Of the two sites under consideration Site Alternative 1 is preferred from a groundwater perspective. The Site Alternative 1 is closer to the ocean and the groundwater quality is more saline. Thus in the unlikely event that any impact does occur on groundwater it will be less significant at Site Alternative 1 that at Site Alternative 4. **Table 6** and **Table 7** list the preference ratings.

Table 7: Site preference rating based on groundwater considerations

Site preference Rating	Criteria
Groundwater	
Preferred (4)	Site Alternative 1
Acceptable (3)	Site Alternative 4
Not Preferred (2)	-
No-Go (1)	-

Table 8: Description of site preference rating based on groundwater considerations

Study	Site 1	Site 4
Groundwater	Preferred as the site is closer to the ocean and groundwater quality is more saline	The site is also acceptable; however of the two sites it is not the preferred site.

6. MITIGATION AND MANAGEMENT MEASURES

6.1 Construction phase

The main impact during this phase is related to possible contamination of groundwater from earth moving equipment, from the temporary storage of fuels and lubricants and during the processing of filling fuel tanks and servicing equipment. It must thus be ensured that no earth moving equipment or generators leak fuel or oil. When parked overnight the equipment must be stored on an area with an impermeable base or have a “fuel-absorbent blanket” placed under the engine. Any generators used must be placed on a sand tray. There must be no spillage when vehicles or generators etc are filled. There must be clear procedures to address a fuel spillage with associated clean up material. The Environmental Control Officer must do everything possible to reduce the risk of oil or fuel spillage. The groundwater in the area is vulnerable to contamination, as it is shallow and the sands are permeable.

6.2 Operational phase

The potential groundwater impacts are negligible. The sub-station will be built on a solid impermeable foundation.

6.3 De-commissioning phase

This will be well into the future (possibly more than 30 years away) and all measures must then be taken to avoid contamination of groundwater. The issues listed in Section 6.1 are applicable to the de-commissioning as well.

7. CONCLUSIONS

Extensive groundwater work has been completed in the vicinity of the Koeberg Nuclear Power Station, as part of groundwater studies for the existing power station as well as for future nuclear power stations in the vicinity. In addition there is good groundwater potential in the area and many studies have been completed on the Witzand, Silwerstroom and Aquarius well fields. There are two aquifers beneath the Site Alternative 1 and Site Alternative 4 and thus groundwater does need to be taken into consideration in this study.

The planned WeskusFleur Substation is unlikely to have any significant impact on groundwater due to the planned design of Substation. Of the two alternatives presented the site closer to the ocean is preferred, as the groundwater is more saline and in the unlikely event of any impact occurring it will be less significant than if an impact was to occur at the more inland site (Site Alternative 4).

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- Frank van der Kooy (Lidwala) and Gert Greeff (Koeberg – Eskom) for assistance in the field; for providing an overview of the two potential sites and for providing relevant literature.
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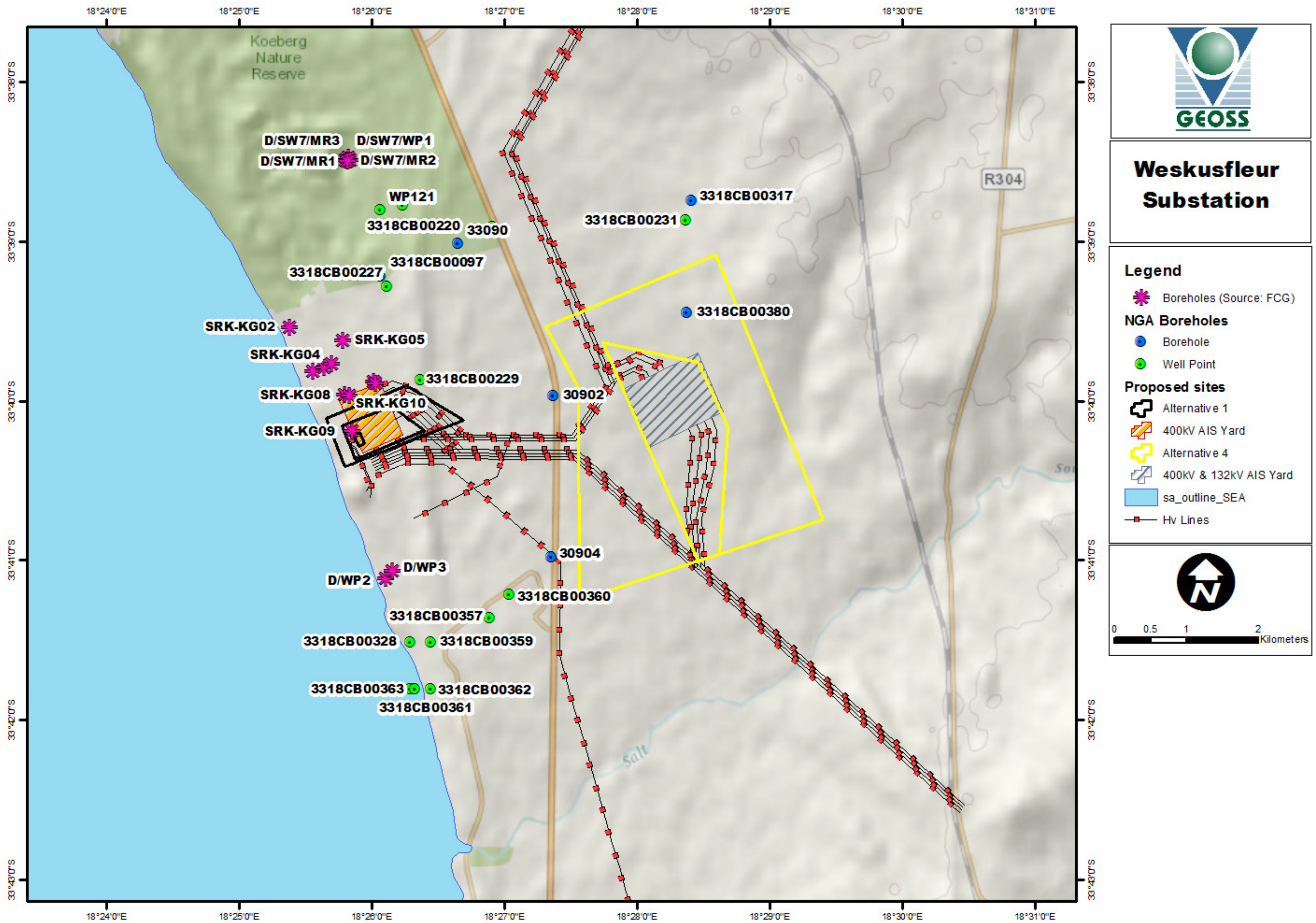
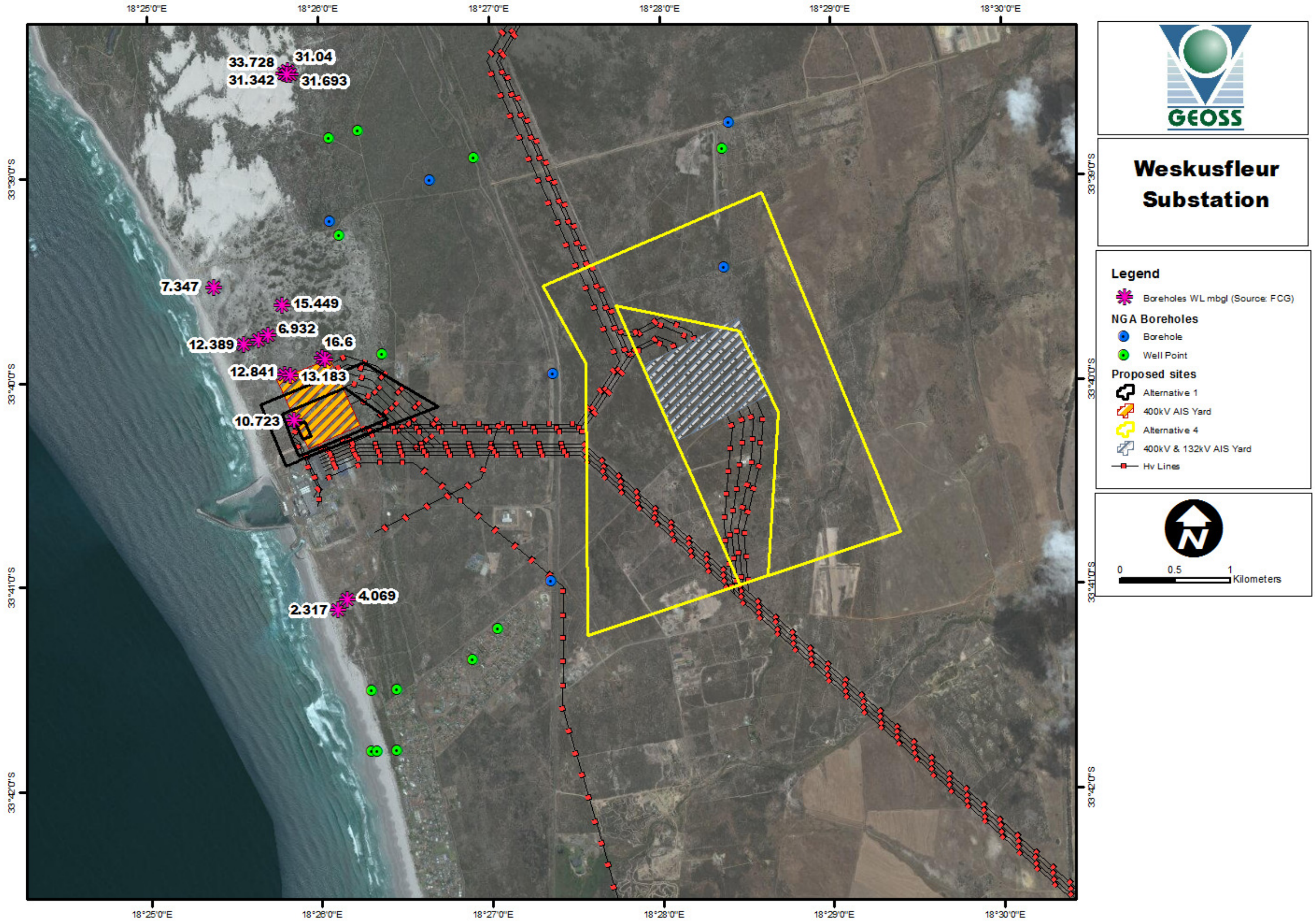
10. APPENDIX A: MAPS

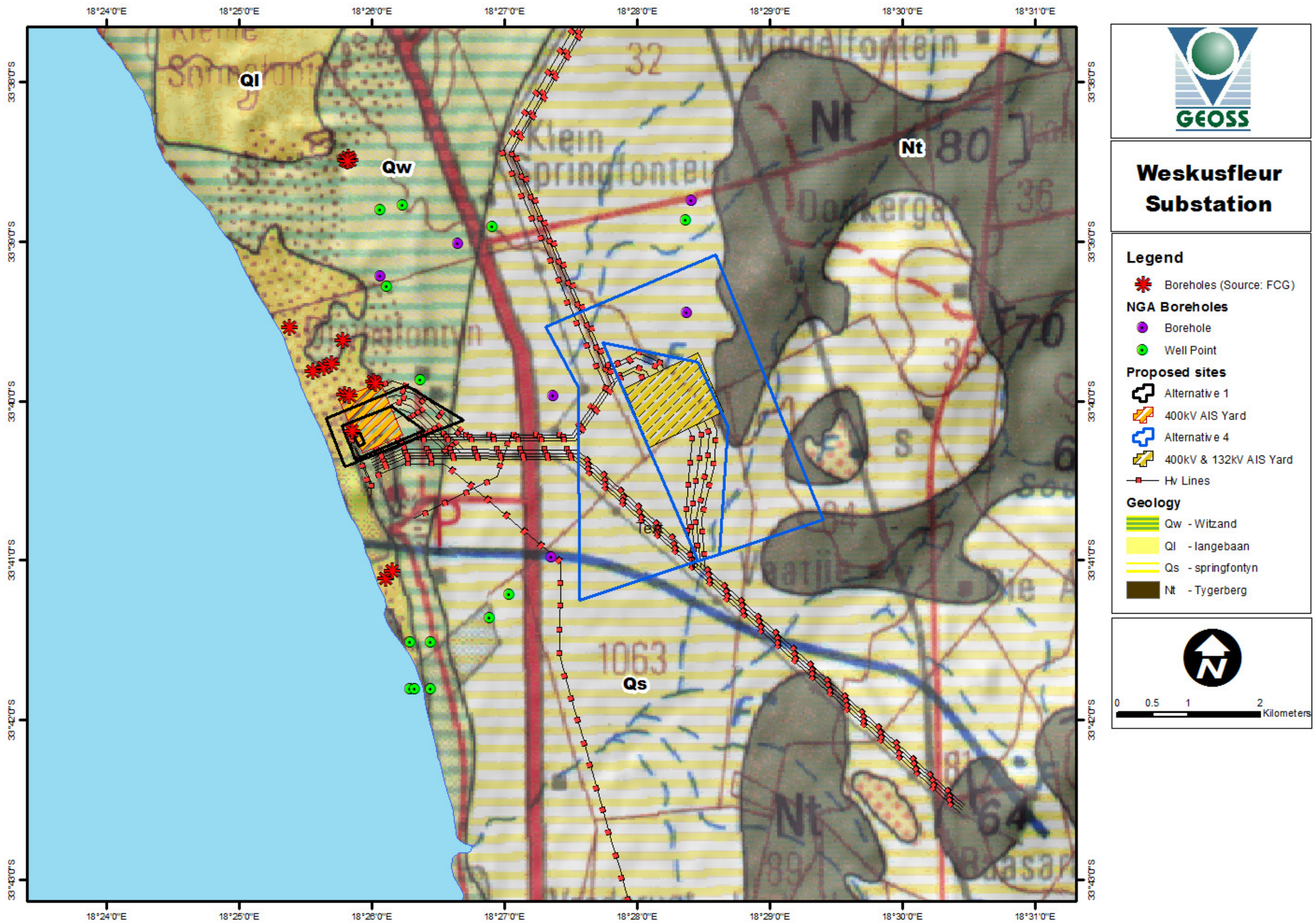
Map 1: Location of the study area within a regional setting



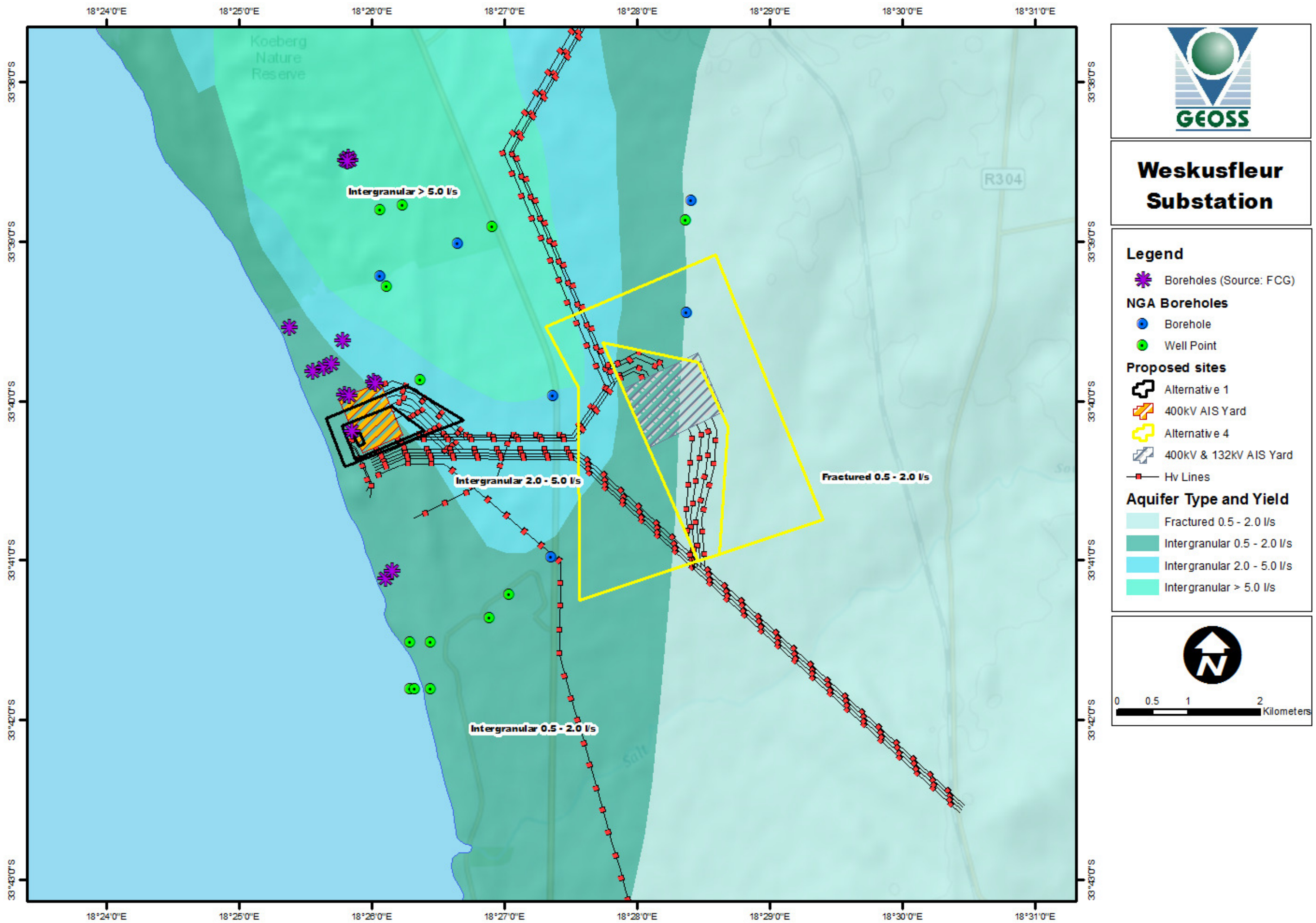
Map 2: The study site and boreholes superimposed on a 1:50 000 scale topocadastral map (3318CB)



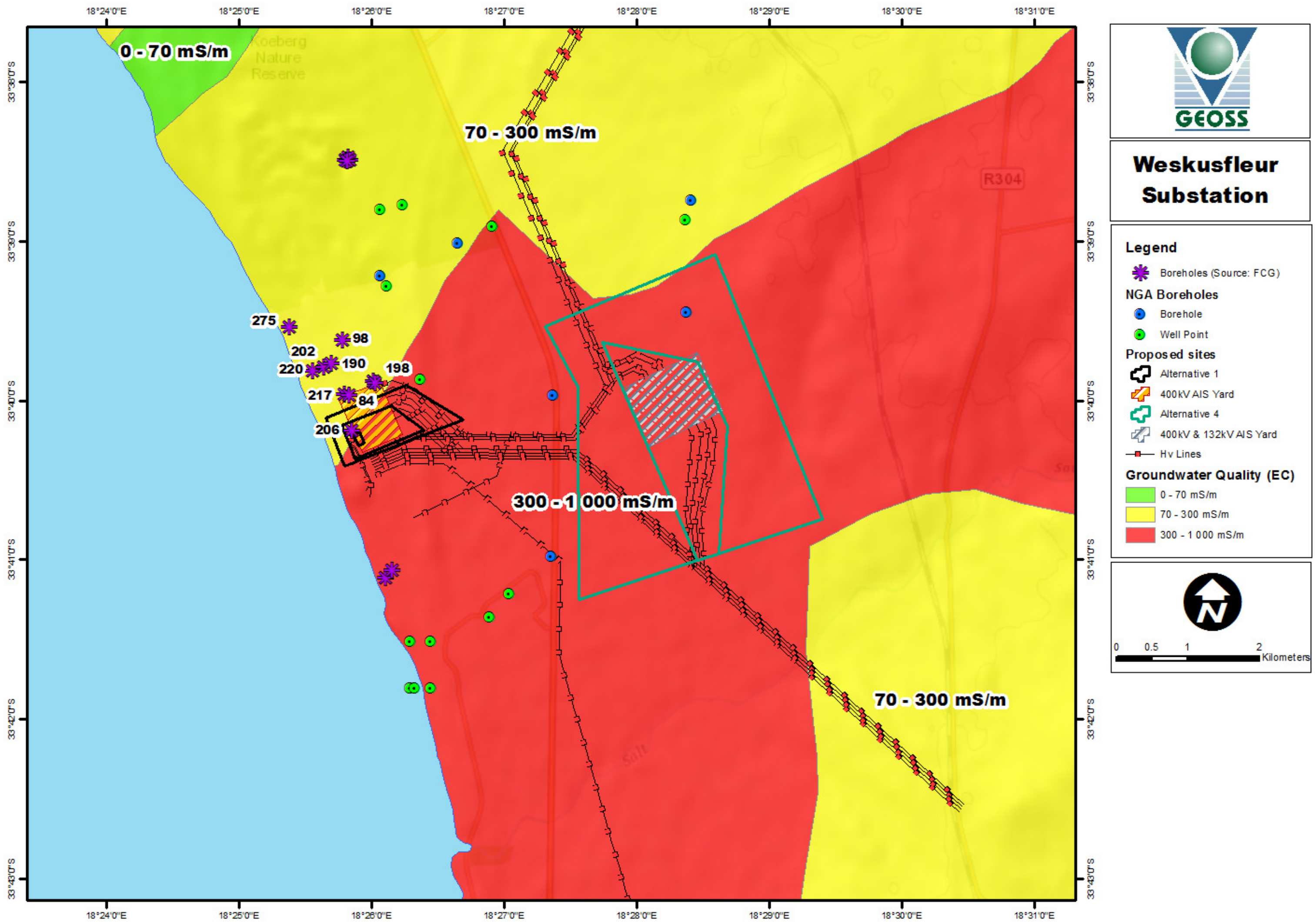
Map 3: The study sitesuperimposed on an aerial photograph and boreholes including groundwater levels (mbgl)



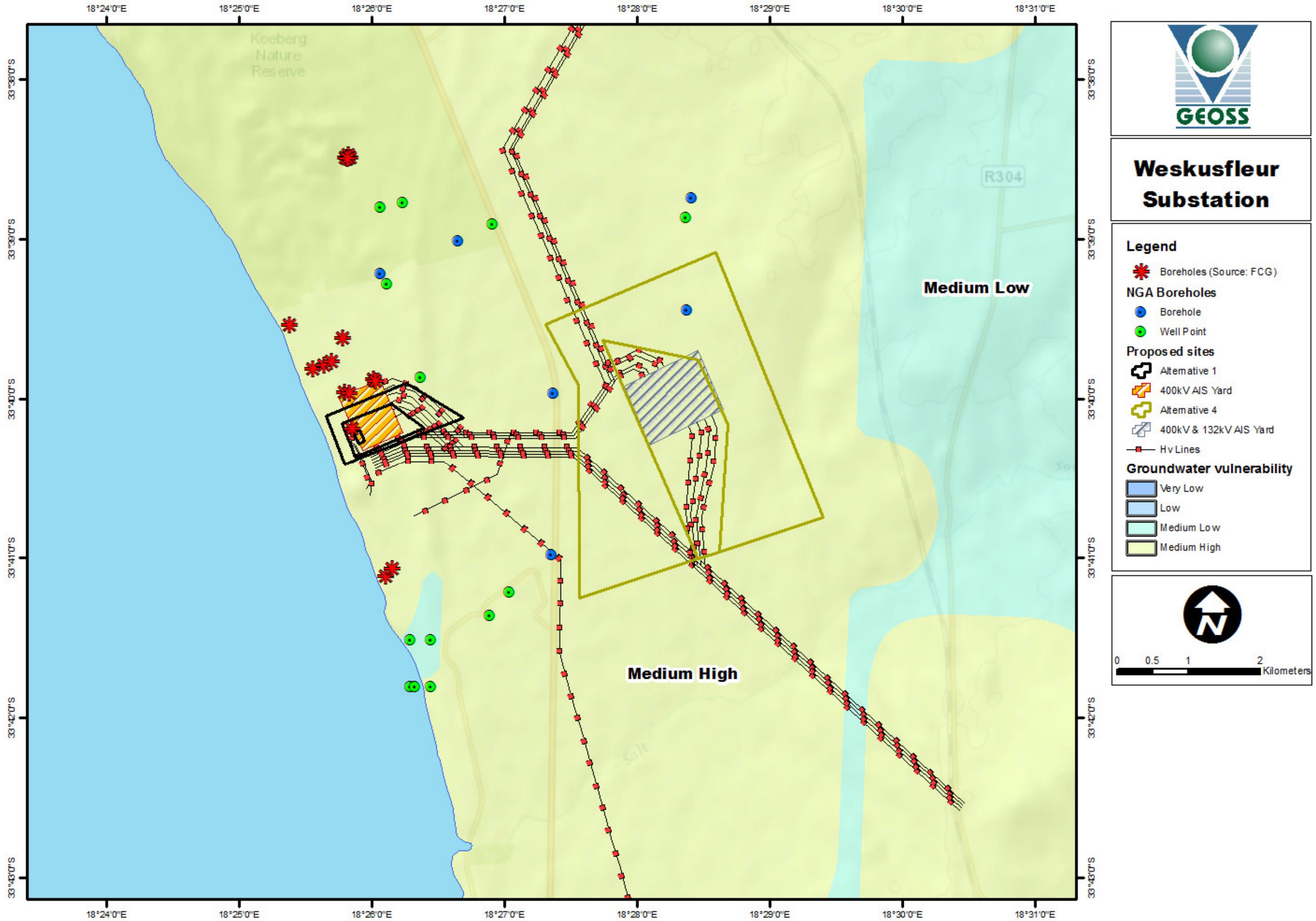
Map 4: Geological setting of the study area and NGA boreholes (Council for Geoscience map: 1 : 250 000 scale 3318 - Cape Town)



Map 5: Aquifer type and yield in the vicinity of the study area (1:500 000 Map sheet – Cape Town 3317 (Meyer, 2001))



Map 5: Groundwater quality (EC) in the vicinity of the study area (1:500 000 Map sheet – Cape Town 3317 (Meyer, 2001))



Map 6: Groundwater vulnerability (DWAF, 2005).

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