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CHAPTER 9 HYDROLOGY

9.1. General

No rivers, streams or any major drainage channels are located on the power station property. To the south-east of the power station there are two seasonal drainage channels. Donkergat River flows into the Sout River, which flows into the sea at the "Ou Skip" caravan park in Melkbosstrand. The power station property receives no runoff from adjacent properties and infiltration rates are expected to be high on natural ground due to the high surface permeability of the unconsolidated sands. The ground may become temporarily waterlogged in limited areas after intense periods of precipitation but there are no hydrological features which would present a safety problem from stream flow or flooding from adjacent properties. There are no dams in the immediate vicinity of the power station which would jeopardise the power station in the event of failure.

9.2. Aquifer Description

The geology of the bedrock underlying unconsolidated sediments in the vicinity of the Koeberg Nuclear Power Plant site has been described in ***References 1, 2, 3***. Bedrock at the site comprises an alternating succession of greywackes and mudstones of the Tygerberg Formation, Malmesbury group. The rock is fractured and has secondary permeability.

Overlying the bedrock are layers of unconsolidated sediments: viz. marine, fluvial and aeolian sands with lenticular pedogenic horizons near the surface. The thickness of these sandy strata overlying the bedrock averages 20 m in the west but reaches 50 m in places in the east.

Both the bedrock and the overlying sediments are water bearing and are considered as aquifers. Whereas the bedrock is a fractured aquifer the sediments act as an unconfined aquifer.

The catchment in which the power station is located extends 12 km inland according to topographic maps and groundwater contours plotted by the Division of Geohydrology of the Department of Water Affairs. In this catchment the ground slope averaged 1 in 80, which is similar to the seaward groundwater gradient and the overall transmissivity has been calculated at $5 \times 10^{-4} m^2.s^{-1}$ (***Reference 4***).

There is a net movement of groundwater towards the sea at an estimated rate of 1×10^{-5} m.s^{-1}. This rate of flow may be influenced by the abstraction of groundwater in the surrounding area, either from Eskom's Aquarius well field or the well fields used to supply the town of Atlantis. At current rates of abstraction, however, the influence on site is expected to be insignificant. The groundwater simulation report (***Reference 4***) showed that seasonal rain variations will not significantly affect the groundwater flow or level in the area around the power station.

9.3. Groundwater Observations

A series of drilling programmes were carried out on the power station property during the site investigation in 1975 and during actual construction. Groundwater conditions were established and the permeability was monitored. The results of this testing are contained in ***Reference 1*** and ***2***.

Prior to any construction taking place the groundwater level below the site was observed in 12 boreholes (see Drawing 0.46/3, Preliminary Site Safety Report, PSSR) for the period March 1972 to March 1973. The depth of the groundwater table below the ground level varied between 0.4 m at borehole 65 (within the foundation area), to 8.6 m at borehole B2 (approximately 185 m east of the reactors). The groundwater table in three boreholes (B1, W1 and W7) to the west of the foundation area, fluctuated by approximately 0.54 m, while the groundwater table in three boreholes (B2, W3 and W4) to the east of the foundation area, fluctuated by approximately 0.55 m. The groundwater table in four boreholes (50, 53, 58 and 65) within the foundation area, fluctuated by approximately 0.70 m.

The gradient of the groundwater table becomes flatter as it nears the sea and has an average slope of 1:70.

The variations in groundwater gradients are shown in Table 9.3 of the PSSR.

Groundwater analyses are presented in Table T.2.3.1.2 of Reference 9.1.

The positions of dewatering wells (deep wells and wellpoints, excavation sumps and monitoring points installed during construction are shown in ***Drawing 28***. This includes three monitoring wells outside the cutoff wall between the excavation and the sea. The results of water quality monitoring of the wells during 1977/8 both inside and outside the cutoff wall are contained in several reports: ***References 5*** to ***9***. The results of the current groundwater monitoring programme are contained in ***Reference 10***

9.4. Permeabilities

Field and laboratory permeability tests on both the overlying sands and the bedrock were carried out during the pre-construction site investigations. The results of the testing are contained in ***References 1*** and ***2***. The permeability of the upper layers of the overlying sands ranged from 1.2×10^{-4} to 3.5×10^{-5} $m.s^{-1}$ and in the underlying marine sands from 4.1 to 5.7×10^{-8} $m.s^{-1}$.

Subsequent studies of the surficial sandy aquifer in the surrounding areas to the north of the site have indicated permeabilities between 4×10^{-6} and 1×10^{-4} $m.s^{-1}$ (***Reference 15***).

9.5. Computer Simulation of Groundwater Flow

To assist in establishing the groundwater regime and monitoring subsurface groundwater flow, the aquifer around the power station was numerically modelled in 1980 (***Reference 4***).

The aquifer was modelled in the area surrounding the foundations of the power station extending 1000 m inland and 1500 m from north to south along the coast. A 50 m x 50 m grid spacing was selected and water table fluctuations simulated over two years. The period of study began at the commencement of dewatering of the foundation area. The average abstraction rate is recorded at 77 $m^3.hr^{-1}$. This dewatering procedure resulted in a lowering of the water table within and surrounding a bentonite cement cutoff wall around the foundation area. The cutoff wall extended to bedrock over a length of 250 m inland and approached to within 150 m of the shore line. The north-south extent was 300 m. An explicit finite difference technique was employed in solving the equation describing the system (***Reference 4).***

The grid spacing, extent of the model and time scale for satisfactory performance were verified independently. Geohydrological properties of the aquifer, namely, transmissivities of the overlying sandy strata and bedrock and storage coefficients for rising and falling water table, were determined from pump tests. Natural groundwater flow was deducted from information supplied by the Division of Geohydrology of the Department of Water Affairs. Dispersion coefficients were estimated from radio-tracer tests. The geological profile of the aquifer was interpreted from information obtained on the boreholes. The model was calibrated with available borehole data and refined with trial runs. The runs were repeated with modifications to aquifer properties until the variations of the groundwater levels agreed with the measured values. The calibrated model was used to simulate the drawdown of the water table within and outside the cut-off wall surrounding the foundation as the area inside was dewatered.

The model indicated, as occurred in practice, that the general water table immediately surrounding the foundation cutoff fell by approximately 2 m over the 12 month dewatering period, and then returned to equilibrium state as the foundation area was backfilled (***Reference 4***). The presence of the cutoff wall in the aquifer distorted the final equilibrium water levels, and caused a higher inland water level than for the natural state. The water table on the seaward side of the foundation area was lowered but did not drop below mean sea level, with the result that inflow of sea water through the overlying sand deposits was restrained. Nevertheless, there was an inflow of saline water through fissures in the underlying bedrock. This was evidenced by the continual pumping of saline water from borehole 63A after one month of dewatering (***Reference 9***).

The results of the numerical model were calibrated and verified at the time and gave a good indication of the groundwater response to dewatering. The model correctly predicted that seawater intrusion would occur during dewatering.

It also predicted that on cessation of dewatering the groundwater levels would return to normal and the area within the cut-off wall would fill with mainly saline water via the bedrock (***Reference 4***). The initial motivation of the numerical modelling was to predict the inflow of potentially corrosive seawater.

More data are now available on the surrounding surficial sandy aquifers, particularly following the development of the Aquarius well-field (***Reference 16***). More recent models use a higher estimate of infiltration (42% on dune areas) (***Reference 16***) compared to that given by DWA&F and used in the first model. In addition, the original data used to determine the bedrock parameters is 'informal' (***Reference 4***). As the primary pathway for saline intrusion is thought to be via the bedrock, more accurate bedrock aquifer values should be established if further numerical modelling is required.

9.6. Monitoring of Groundwater Chemistry during Construction

Continual sampling and chemical analysis of the groundwater both inside and outside the cutoff wall was carried out during construction for as long as the boreholes remained in existence.

From the analyses carried out it was apparent that over the monitoring period 29 March 1977 to 30 August 1978, there had been little change in the chemical content of the groundwater sampled inside and outside the confines of the diaphragm wall at most of the monitoring points.

It was also apparent that, except for borehole 63A, the concentration of sulphate ions over the period 12 April 1977 to 30 August 1978 remained fairly constant in the water sampled inside and outside the bounds of the diaphragm wall.

Groundwater samples from borehole 63A showed an increase in sulphate concentrations from 40 to over 400 $mg.\ell^{-1}$ indicating saline intrusion. Even higher concentrations were recorded (up to 640 $mg.\ell^{-1}$) during a period of suspected contamination of this groundwater monitoring point from surface run-off (***Reference 10***). It is expected that recovery of the water levels in the construction area after dewatering would have resulted in seawater inflows via the bedrock. This will have altered the chemistry of the groundwater in this area. The presence of the bentonite cutoff wall is expected to reduce seaward through flow of fresh groundwater, therefore, it is likely that saline water persists in the subsurface.

9.7. Resistance of the Subfoundation to Chemical Attack

During the design stage laboratory tests on soil cement samples in concentrations of 5% Na_2SO_4 (50 000 ppm) showed no deleterious effects on mechanical properties (***References 11*** and ***12***).

Regular chemical analysis are conducted on the groundwater extracted from the five monitoring boreholes around the soil cement foundation. From the water chemistry tests it is possible to trend the Leaching-Corrosion (LSI) and the Spalling-Corrosion (SSI) sub indices. The Basson index (BI) is calculated to determine the aggressiveness of the water. In all five boreholes the leaching index is dominant which indicates that this mechanism will take priority over attack by sulphates (***Reference 10***).

9.8. Withdrawal of water from boreholes on the farm Kleine Springfontyn

The boreholes on the farm Kleine Springfontyn are part of the Witzand well field supplying water to Atlantis. The position of the boreholes are shown on ***Drawing No. 29***.

The planned abstraction regime from the water supply boreholes at Witzand at current rates is not likely to affect groundwater flow at the Power Station given the distance.

9.9. Groundwater Effects on Site Safety

There are three possible areas were the groundwater may effect the safety of the plant. These are the risk of contamination of the groundwater. the risk of flooding by groundwater and the risk of material degradation by groundwater.

The risk of radioactive contamination of the groundwater from the nuclear island is highly unlikely, since, in addition to all the safety features of the reference station, the design has the advantage of the aseismic vault. In the unlikely event of a radioactive leakage from the nuclear island the aseismic vault would prevent the contamination of the groundwater.

The risk of flooding the nuclear island by groundwater is highly unlikely, for the same reasons as above. Regular inspection of the aseismic vault is conducted to ensure that no groundwater is permeating through the retaining wall of the aseismic vault.

The risk of material degradation by groundwater can be divided into two sections, namely the effects of groundwater on the concrete of the lower raft and retaining walls, and the effects of the groundwater on the sub-foundation. The degradation effects of groundwater on the concrete is controlled by appropriate choice of materials and by the application of the relevant design criteria in accordance with recognised codes. The degradation effects of groundwater on the sub-foundation is addressed in ***Section 9.7***.

9.10. Effect of the Withdrawal of Groundwater from Neighbouring Areas on the Flow of the Groundwater under the site

Existing well fields for groundwater abstraction and artificial recharge basins for augmenting the water supply in the area surrounding Koeberg are shown on ***Figure F-9.1***.

The Aquarius well-field is the closest groundwater abstraction area to the power plant and currently around 40 000 m^3 are abstracted per month by Eskom to supply the power plant. The well field is approximately 6 km to the north east of the plant. Numerical modelling of the impact of abstraction on groundwater levels in the area showed that there would be no significant impact at the plant (***Reference 16***). The model showed drawdown of greater than 1 m only within 500 m of production boreholes.

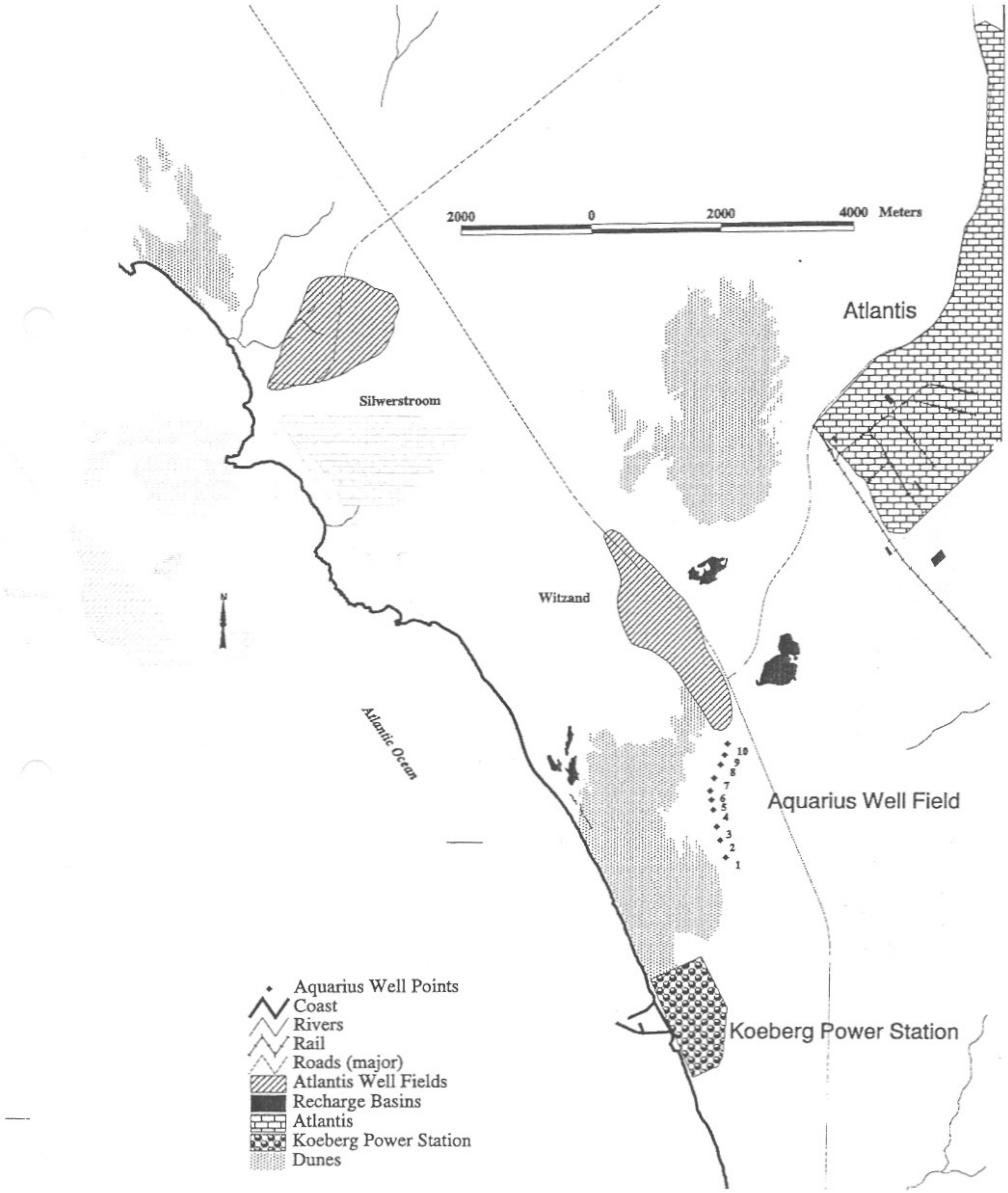
At present the town of Atlantis is supplied with groundwater from two well fields operated by Cape Metropolitan Council: Silwerstroom, approximately 12 km to the north of the site, and Witzand approximately 6 km north of the site. In 1995 2.2 and 3.3 million m^3 were abstracted from the two well fields respectively (***Reference 17***). Two million m^3 of treated waste water and storm water are used to recharge the aquifer in artificial recharge basins approximately 7 km to the north of the power station. Water levels around the wellfields are controlled and are reported to have stabilized and are not thought to significantly impact the groundwater flow regime at the power station. As the aquifer is unconfined the distance to the plant is thought to be the main controlling factor rather than barriers to groundwater flow. Although bedrock highs are known to exist in the area, there is no evidence for continuous no-flow boundaries. Relatively speaking, natural local recharge to the aquifer and the outflow to the sea will be more important factors affecting the groundwater levels around the power station.

9.11. Groundwater Monitoring in the vicinity of the Power Station

It is not intended to artificially control water levels around the power station over the long term. During construction the bentonite/cement cutoff wall was built around the excavation/foundation area and together with a deep-well and wellpoint dewatering system controlled the groundwater level. During the dewatering programme monitoring wells were scattered around the deep-wells and the groundwater levels recorded (PI to P11, ***Drawing No. 28***). Boreholes A, B and C between the diaphragm wall and the sea (in the area of the Cooling Water Intake Works) were monitored to check any ingress of seawater (***Reference 5*** to ***9***).

Currently there is a regular monitoring programme of groundwater levels and hydrochemistry analysis performed on-site. Throughout the life of the power station the groundwater level will fluctuate. Water levels and water quality and the effect of the groundwater on the soil cement foundations will be monitored throughout (***Reference 9*** and ***14***).

FIGURE F-9-1
Map Showing groundwater abstraction points in the area around Koeberg Power Station


2000
0
2000
4000 Meters
Atlantis
Silwerstroom
Witzand
N
Atlantic Ocean
10
9
8
7
6
5
4
3
2
1
Aquarius Well Field
Koeberg Power Station
Aquarius Well Points
Coast
Rivers
Rail
Roads (major)
Atlantis Well Fields
Recharge Basins
Atlantis
Koeberg Power Station
Dunes

REFERENCES

1) **Dames & Moore**, Site Investigations - Units 1 and 2 - Koeberg Power Station, Cape Province, RSA - August 1975

2) **Dames & Moore**, Koeberg Nuclear Power Station, Foundation Report - December 1975

3) **Dames & Moore**, The Probability of the Ingress of Seawater to the area surrounding the Foundations of Units 1 and 2 - Koeberg Power Station ESCOM - July 1977

4) **Dames & Moore**, Koeberg Nuclear Power Station, Boring Programme and Groundwater Simulation - May 1980

5) **Dames & Moore**, First Interim Report on Monitoring of Groundwater Chemistry during Construction - Koeberg Nuclear Power Station ESCOM - March 1977

6) **Dames & Moore**, Second Interim Report on Monitoring of Groundwater Chemistry during Construction - Koeberg Nuclear Power Station, ESCOM - June 1977

7) **Dames & Moore**, Third Interim Report on Monitoring of groundwater Chemistry during Construction - Koeberg Nuclear Power Station - October 1977

8) **Dames & Moore**, Fourth Interim Report on Monitoring of groundwater Chemistry during Construction - Koeberg Nuclear Power Station - April 1978

9) **Dames & Moore**, Fifth Report on Monitoring of Groundwater Chemistry during Construction - Koeberg Nuclear Power Station - December 1978

10) **ESKOM**, Koeberg Nuclear Power Station, Long Term Monitoring of the Soil Cement Sub-Foundation - April 1997

11) **Mecasol Note No 10** - Preliminary Testing Report - Soil Cement - January 1997

12) **Mecasol Note No 29** - Effect of Salt water on the Soil Cement Foundation - 1978

13) **Spie Batignolles**, Soil Cement - Allowable Settlements (Differential Settlements) - June 1977

14) **Dames & Moore**, Long Term Monitoring of Soil Cement - 1978

15) **CSIR,** Groundwater Investigation at Koeberg Power Station, Phase II - Summary Report - Sept 1993.

16) **CSIR,** Simulation of the impact of abstraction from production boreholes to the south of the Witzand well-field, Atlantis - July 1995

17) **CSIR,** Atlantis groundwater management review 1995/6 - January 1997.