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Nuclear 1 Geohydrology Peer Review Report

Version - 1

13 August 2015

Gibb (Pty) Ltd.

GCS Project Number: 13-803

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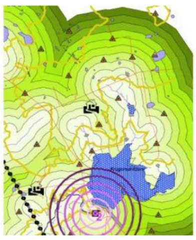


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1 INTRODUCTION

GCS Water and Environment (Pty) Ltd. (GCS) was appointed by Gibb (Pty) Ltd. to conduct a peer review of the geohydrology report compiled by SRK Consulting, titled *Environmental Impact Assessment for the proposed nuclear power station ('nuclear-1') and associated infrastructure: Geohydrology Environmental Impact Report* (Dated November 2014).

The project sites are located at Thyspunt in the Eastern Cape Province, and at Bantamsklip and Duynefontein in the Western Cape Province of South Africa.

2 SCOPE OF WORK

The scope of work for the hydrology peer review study is as follows:

- Assess the document/ report in terms of its fulfilment of its Terms of Reference set;
- Consider whether the report is entirely objective;
- Consider whether the report is technically, scientifically and professionally credible;
- Consider whether the method and the study approach are defensible;
- Identify whether there are any information gaps, omissions or errors;
- Consider whether the recommendations presented are sensible and present the best options;
- Consider whether there are alternative viewpoints around issues presented in the report and if these are clearly stated;
- Consider whether the style of the report is written so as to make it accessible to non-specialists, technical jargon is explained and impacts are described using comparative analogies where necessary; and
- Report on whether normal standards of professional practice and competence have been met.

3 REVIEWED DOCUMENT

The reviewed document is a Geohydrological Assessment Report compiled by SRK Consulting for Gibb (Pty) Ltd. The report is titled 'Environmental Impact Assessment for the Proposed Nuclear Power Station (Nuclear 1) and Associated Infrastructure: Geohydrology Environmental Impact Report' (SRK, 2014) and was based on the Environmental Impact Assessment (EIA) conducted by Gibb in support of Eskom's Nuclear-1 project.

4 COMMENTS AND RECOMMENDATIONS

The underlying sections clarify GCS' hydrological report review, broken into sections as specified in the scope of works.

4.1 Fulfillment of Terms of Reference

- The TOR requirement related to "…and resistance of soil-cement foundations to chemical attack." Is not addressed in the report.
- The rest of the document fulfils the TOR set out at the beginning of the document.

4.2 Report Objectivity

- The report is largely objective. Areas which need attention are highlighted in the forthcoming sections.

4.3 Technical, Scientific and Professional Credibility

- The report is well structured with good references to external data sources. The data presented and associated conceptual models in general agrees with mainstream interpretations of the hydrogeology for the areas investigated.
- A concern with regard to the conceptual models is the interpretations of surface water/groundwater interactions. For Duynefontein and Bantamsklip sites the existence of wetlands in a dry summer climate seems to suggest groundwater contributions to the surface systems. Also due to the locality of the sites near the coast, the groundwater levels are very shallow and typically expected to contribute to the low lying wetlands/seeps/drainage systems. In general I would expect groundwater to contribute to the low lying wetlands/seeps/drainage channels around the proposed sites.

4.4 Defensibility of Methodology and Study Approach

- In general the methodology and study approach is defensible. The baseline info and monitoring data for each site is well described and summarised contributing well to the text summery of the conceptual model. The conceptual model illustration can however be improved to aid in the presentation of recharge-flow-discharge processes at the individual sites.

- Description of numerical model construction, boundary conditions and input parameters could have been explained better. The full ASTM reporting in a public document is probably an overkill, but the components of the ASTM could be better applied to explain how the model was constructed. The eventual predictions will be influenced by the selected boundary conditions, horizontal and vertical discretization, together with the different properties discussed in the document.

4.5 Information gaps, omissions or errors

Information gaps, omissions or errors are specified below for each of the relevant sections in this report. The information gaps may cause difficulty in defending sections of the document.

- **Section 2.1.17: Numerical Modelling a) Regional Model - Calibration of the steady state flow model (Figure 2.17 and Figure 2.19):** The model cannot be used to predict to 0.1 metre accuracy as the calibration results indicated more than 10 metre error near the coast where the site is expected to be placed.
- **Section 2.1.17 (Figure 2.17 and Figure 2.19): T**he best fit line to the data points is meaningless. A comparison between the data and a 45-degree straight line (line of perfect fit) is required to indicate the relation between measured and simulated head. More applicable statistics are required to evaluate the degree of fit and bais. The same applies for the calibration graphs shown for Bantamsklip (Figure 2.41) and Thyspunt (Figure 2.74).
- **Section 2.2.6: Recharge:** No explanation was given on how the final distribution of effective recharge (Figure 2.4) across the study area was determined. The same is valid for the recharge distribution for Bantamsklip (Figure 2.30) and Thyspunt (Figure 2.55)
- **Section 2.2.7: Depth to Groundwater:** Reference is made to the Hagelkraal Rivier in the text. However, maps in the report refer to the Haelkraal River.
- **Section 2.2.7: Depth to Groundwater:** A cross-section of the Bredasdorp Aquifer would be useful to get an idea of the relative elevations and thicknesses of the units, as this is a high yielding formation where saturated. Significantly more dewatering would be required should sea levels rise and the aquifer unit becomes saturated. The lack of the cross section makes it difficult to assess if this could be significant.
- **Section 2.2.14: Groundwater Use:** A summary of the interaction between groundwater and the wetlands states that the wetlands are fed by the Hagelkraal River and will lose water to the deeper groundwater table of the Bredasdorp Aquifer. However based on the shallow water levels around the wetland it would be expected that groundwater will contribute to the wetland as well, supporting it during the dry summer months.

- **Section 2.2.17: Numerical Modelling:** The K of 0.4 m/day seems unrealistic considering the data quoted for the conceptual model. An average T of 5 m^2/day were calculated from the pumping tests (Section 2.2.4). And Section 2.2.3 indicated that the Bredasdorp Aquifer is only a few metres thick and at the site the saturated thickness ranges from 2 to 6 m, with a median of *c.* 2 m. The K value should therefore be closer to 2.5m/d rather than 0.4 m/day.
- **Section 2.2.17: Numerical Modelling – Figure 2.43:** The model seems to not extend to the illustrated footprint and area where dewatering predictions are made later in Section 2.2.17. The predictions at the edge of a model domain is often a bit suspect.
- **Section 2.2.17: Numerical Modelling – Figure 2.43:** It is questionable why the model was stopped at the coastline. The predictions will be very sensitive to the boundary assumed at the coast. The sea will most likely only be in the top layer leaking into the lower aquifer under dewatering conditions. Vertical hydraulic conductivity would start playing a more significant role than horizontal hydraulic conductivity. The constant heads and the edge of the model domain close the area of prediction is not ideal and could be improved. The same is valid for the other 2 sites.
- **Section 2.1.17 and Section 2.2.17: The calibration and stability of the model is not discussed to a satisfactory level.** There was not a satisfactory fit between the observed and simulated water levels. It should be stated again that the best fit line to the data points is meaningless. Further calibration performance measurements were not shown, such as a water balance data. The numerical solver used was also not stated. It should be noted that not all solvers are stable under saturated/unsaturated conditions. Results may be very non-unique as calibration was done solely against static water level measurements and not against flow in the rivers as well.
- **Section 2.2.17: Numerical Modelling – Table 2.23:** The predicted inflows do not match the data provided in the preceding section. The inflow to the footprint is lower than the sustainable yield calculated for most of the boreholes that were pump tested. This would indicate that the ~1kmx500m footprint can be dewatered at a lower rate than a single borehole would provide sustainably without too much drawdown. Furthermore, the recharge shown in Table 2.17 and Figure 2.30 would at least add 34 m^3/day to the footprint area if the dry season recharge from Table 2.17 is considered. The predicted inflows to the footprint area are less than the local recharge to the footprint area. The water balance data is not shown to evaluate how the numbers provided were obtained.

- **Section 2.2.17: Numerical Modelling – Table 2.25:** Even though a maximum drop in groundwater level in the vicinity of the wetlands was determined to be <1m, the natural fluctuation at the wetland is ~0.2m. Therefore the drop of 1m could be significant.
- **Section 2.2.17: Numerical Modelling – Conclusions:** The statement that the wetlands are fed by the Hagelkraal River and drain to the deeper groundwater table might not be correct as the water table in the lower reaches of the Hagelkraal and wetland are 0.5 metres below the surface (according to water level data). Figure 2.31 showed that the wetland piezometers maintained their water levels several months past the wet season, suggesting that surface water as well as groundwater contributes to the wetland water levels. Therefore, the dewatering of the NPP footprint could have an impact on the wetlands.
- **Figure 2.**58: The down-the-hole EC profile interpretation is not correct. The data shows EC values below the water level. Therefore the depth of the assumed fracture about 12m below surface.

4.6 Sensibility of Recommendations and Presentation of Best Options

- **Section 6.2: Recommendations:** GCS is not convinced that the numerical models presented can simulate the cut-off wall options for mitigation of dewatering. The vertical and horizontal discretization of the grids are not adequate for this. So the jury is still out if it should be considered. The artificial recharge near the areas of potential impact is in our view a better option.

4.7 Alternative Viewpoints Presentation and Clarity of Statement

- **Section 1.2.3: Assumptions and Limitations:** GCS agrees with SRK (2014) that analytical and numerical processes are required to determine some hydrogeological parameters (eg. transmissivity, storage). GCS further agrees that the best way to improve the confidence in a groundwater model is to collect time series data. Therefore it is crucial that the current monitoring is maintained, the data used to update the numerical model and changes made to the monitoring programme where necessary.

4.8 Accessibility of Style of Report to Non-Specialists

- Technical jargon has been explained in most sections and the report is written well. A non-specialist will be able to grasp the main issues regarding the geohydrological environment. The glossary and abbreviations list are helpful.

4.9 Meeting of Normal Standards of Professional Practice and Competence

- Generally the report meets the normal standards of professional practice and competence.

5 CONCLUSIONS

The areas that need attention include the 3D conceptual flow model illustration and 3D numerical flow model sections:

- The current presentation of a 3D conceptual geohydrological model for each site add little value to a better understanding of the local site conditions, especially regarding the illustration of hydrogeological processes on the site. This could improve.
- It is recommended that better model calibration criteria is used to evaluate whether the model is calibrated or not. Calibration against only heads typically provide non-unique calibrations. Calibration targets should preferably include both heads and flow to provide a more unique calibration. Water balance data regarding the model is also very valuable to obtain insight into the losses and gains to the model area, providing credibility to the model if done correctly.
- During calibration the predicted water levels near the coast were typically within 10m of the measured water levels. This is where predictions are most critical with regard to the impacts of the proposed nuclear plant. Predictions of impacts of less than 10m could therefore be regarded as suspect based on the accuracy of the calibration. The further proximity of the boundary conditions to the nuclear power plants provide further uncertainty. At Bantamsklip it seems as if the model grid does not even extend to the coast, but cuts through the site. All these factors increase uncertainty to the predicted impacts, diluting the value of the report.
- It is not clear where the current on-going monitoring positions (groundwater, springs, etc.) are for the sites. We agree that monitoring is important, but cannot verify that it is adequate. A dedicated map with an explanation that include positions, monitoring frequency and parameters will add value to mitigation recommendations.
- On none of the maps the borehole positions are indicated with Borehole ID's. This would make cross-reference and conceptualization easier.

6 REFERENCES

SRK. (2014). *Environmental Impact Assessment for the proposed nuclear power station ('nuclear-1') and associated infrastructure: Geohydrology Environmental Impact Report*. SRK.

SRK Responses to GCS Nuclear-1 Geohydrology EIR Peer Review (Report Version – 1 of 13 August 2015)

GCS Review Comments (*as Quoted)*	SRK Responses
Terms of Reference *requirement related to "soil-cement foundations to chemical attack," is not addressed in the report.*	Thyspunt was addressed in the EIR and this aspect is now also addressed for the other two sites.
Section 2.1.17: Numerical Modelling a) Regional Model - Calibration of the steady state flow model (Figure 2.17 and Figure 2.19): *The model cannot be used to predict to 0.1 metre accuracy as the calibration results indicated more than 10 metre error near the coast where the site is expected to be placed.*	The model residuals (difference between observed and modelled water levels) is <5 m for nearly all boreholes close to the Duynefontein site. This is shown in the new Figure 2.19. The detailing of calibration criteria requirements and calibration results (figures, graphs and spatial & statistical analysis) has been improved for all sites.
Section 2.1.17 (Figure 2.17 and Figure 2.19): *The best fit line to the data points is meaningless. A comparison between the data and a 45-degree straight line (line of perfect fit) is required to indicate the relation between measured and simulated head. More applicable statistics are required to evaluate the degree of fit and bais. The same applies for the calibration graphs shown for Bantamsklip (Figure 2.41) and Thyspunt (Figure 2.74).*	All best fit lines on the calibration graphs have been replaced with 'y=x' and statistical analysis reported in terms of the square of the Pearson product moment correlation coefficient.
Section 2.2.6: Recharge: *No explanation was given on how the final distribution of effective recharge (Figure 2.4) across the study area was determined. The same is valid for the recharge distribution for Bantamsklip (Figure 2.30) and Thyspunt (Figure 2.55)*	Recharge distribution indicated on Figures 2.4, 2.30 and 2.55 is based on the Department of Water Affairs and Forestry's Groundwater Resource Assessment Phase 2 grid-based recharge data-set, as described in the text preceding the figures.
Section 2.2.7: Depth to Groundwater: *Reference is made to the Hagelkraal Rivier in the text. However, maps in the report refer to the Haelkraal River.*	It should be Haelkraal River throughout the report. The text has been corrected accordingly.
Section 2.2.7: Depth to Groundwater: *A cross-section of the Bredasdorp Aquifer would be useful to get an idea of the relative elevations and thicknesses of the units, as this is a high yielding formation where saturated. Significantly more dewatering would be required should sea levels rise and the aquifer unit becomes saturated. The lack of the cross section makes it difficult to assess if this could be significant.*	A cross-section of the Bredasdorp Aquifer has been included in the report (Figure 2.42 in Section 2.2.16) The Bredasdorp Aquifer, where saturated, proved to be low yielding (borehole yields of <1 L/s where tested). Therefore, becoming partially saturated through sea level rise is unlikely to have a significant dewatering impact.
Section 2.2.14: Groundwater Use: *A summary of the interaction between groundwater and the wetlands states that the wetlands are fed by the Hagelkraal River and will lose water to the deeper groundwater table of the Bredasdorp Aquifer. However, based on the shallow water levels around the wetland it would be expected that groundwater will contribute to the wetland as well,*	Monitoring data of wetland piezometers and nearby boreholes at two monitoring sites show flow to be from the Haelkraal River wetlands to the groundwater during both the wet and dry season, i.e. the river and its wetlands are losing systems during all seasons. Cross-sections showing this have now been included in the report (Figure 2-40 in Section 2.2.14).

supporting it during the dry summer months.	
Section 2.2.17: Numerical Modelling: *The K of 0.4 m/day seems unrealistic considering the data quoted for the conceptual model. An average T of 5 m2/day were calculated from the pumping tests (Section 2.2.4). And Section 2.2.3 indicated that the Bredasdorp Aquifer is only a few metres thick and at the site the saturated thickness ranges from 2 to 6 m, with a median of c. 2 m. The K value should therefore be closer to 2.5m/d rather than 0.4 m/day.*	The report text referring to the K of 0.4 m/d was not referring to modelled parameters. It was an initial summary of some of the pumping test results based on depth of boreholes. As much of the Bredasdorp Aquifer near the coast is unsaturated, however, most boreholes are dry. The pumping test results are discussed in more detail in the paragraphs and table that follow in this section. For clarity, this initial paragraph has been removed. The text that follows describes the pumping test results and later goes on to specify the model parametisation which is a T of 3 m^2/d in the steady state regional aquifer.
Section 2.2.17: Numerical Modelling – Figure 2.43: *The model seems to not extend to the illustrated footprint and area where dewatering predictions are made later in Section 2.2.17. The predictions at the edge of a model domain is often a bit suspect.*	Other than where the model follows the coastline and there is a constant head boundary to represent the sea, the closest model boundary to the zone of depression is a minimum distance of 5 km away (to the north-west and south-east). In Figure 2.46 (the old Figure 2.43), the GRU was shown to follow the geological outcrop (out to sea) and the model boundary followed the coastline. This can appear confusing and thus the GRU outline shown in this figure has been updated to now also follow the coastline.
Section 2.2.17: Numerical Modelling – Figure 2.43: *It is questionable why the model was stopped at the coastline. The predictions will be very sensitive to the boundary assumed at the coast. The sea will most likely only be in the top layer leaking into the lower aquifer under dewatering conditions. Vertical hydraulic conductivity would start playing a more significant role than horizontal hydraulic conductivity. The constant heads and the edge of the model domain close the area of prediction is not ideal and could be improved. The same is valid for the other 2 sites.*	The extension at the coastline of lower layers in a groundwater model is only significant if there is a very low K confining layer / aquitard between two higher K aquifers. The Bantamsklip model only has 2 layers – a thin intergranular primary and fractured secondary aquifer with no aquitard between. The modelling is therefore seen as valid in this regard. The reasoning behind the decision has been included in the report.
Section 2.1.17 and Section 2.2.17: *The calibration and stability of the model is not discussed to a satisfactory level. There was not a satisfactory fit between the observed and simulated water levels. It should be stated again that the best fit line to the data points is meaningless. Further calibration performance measurements were not shown, such as a water balance data. The numerical solver used was also not stated. It should be noted that not all solvers are stable under saturated/unsaturated conditions. Results may be very non-unique as calibration was done solely against static water level measurements and not against flow in the rivers as well.*	Detailed validation and verification was undertaken on the models, and are documented in a separate report. These include calibration criteria related to the modelling objectives, water balance, solver details and sensitivity test results. This information now has been summarised for each site and included in the report. It should be noted that no pumping test or river flow data were available during the EIR work, which was undertaken for the purposes of regional, steady state modelling.
Section 2.2.17: Numerical Modelling – Table 2.23: *The predicted inflows do not match the data*	The model inputs and predicted inflow scenarios for Bantamsklip were re-run and the results

provided in the preceding section. The inflow to the footprint is lower than the sustainable yield calculated for most of the boreholes that were pump tested. This would indicate that the ~1kmx500m footprint can be dewatered at a lower rate than a single borehole would provide sustainably without too much drawdown. Furthermore, the recharge shown in Table 2.17 and Figure 2.30 would at least add 34 m^3/day to the footprint area if the dry season recharge from Table 2.17 is considered. The predicted inflows to the footprint area are less than the local recharge to the footprint area. The water balance data is not shown to evaluate how the numbers provided were obtained.	successfully confirmed in the context of the water balance and the conceptual model. The modelling of foundation excavations to 20 mbgl for Bantamsklip was removed as it is not relevant given the shallow depth to bedrock (<10 mbgl) at this site. Therefore, only the '10 mbgl' Bantamsklip foundation excavation scenarios are reported. The detailed water balances have also been included in the EIR. With regard to recharge, the calibrated local recharge at the site is 16.4 mm/a which equates to *c.*15 m^3/day over the footprint area, as shown in the water balance tables.
Section 2.2.17: Numerical Modelling – Table 2.25: *Even though a maximum drop in groundwater level in the vicinity of the wetlands was determined to be <1m, the natural fluctuation at the wetland is ~0.2m. Therefore the drop of 1m could be significant.*	This is now covered in the conceptual model.
Section 2.2.17: Numerical Modelling – Conclusions: *The statement that the wetlands are fed by the Hagelkraal River and drain to the deeper groundwater table might not be correct as the water table in the lower reaches of the Hagelkraal and wetland are 0.5 metres below the surface (according to water level data). Figure 2.31 showed that the wetland piezometers maintained their water levels several months past the wet season, suggesting that surface water as well as groundwater contributes to the wetland water levels. Therefore, the dewatering of the NPP footprint could have an impact on the wetlands.*	This is now covered in the conceptual model.
Figure 2.58: *The down-the-hole EC profile interpretation is not correct. The data shows EC values below the water level. Therefore the depth of the assumed fracture about 12m below surface.*	Acknowledged – Typing error was corrected.
Section 6.2: Recommendations: *GCS is not convinced that the numerical models presented can simulate the cut-off wall options for mitigation of dewatering. The vertical and horizontal discretization of the grids are not adequate for this. So the jury is still out if it should be considered. The artificial recharge near the areas of potential impact is in our view a better option.*	The length of the barrier is correctly defined by the site boundary, however, the modelled width of the barrier is 50 m, as defined by the model cell size. This will not have a major impact on flow directions and modelled drawdowns, however, as the barrier will still act as a flow impeder in the same orientation. The description of the barrier has been amended in the report accordingly. Examples from the excavations for the KNPS and Coega harbour wall are included in the EIR.
Section 1.2.3: Assumptions and Limitations: *GCS agrees with SRK (2014) that analytical and*	We are in agreement with this statement. The recommendations in the report have been further

numerical processes are required to determine some hydrogeological parameters (eg. transmissivity, storage). GCS further agrees that the best way to improve the confidence in a groundwater model is to collect time series data. Therefore it is crucial that the current monitoring is maintained, the data used to update the numerical model and changes made to the monitoring programme where necessary.	embellished on this point, including the urgent requirement for continued monitoring data collection and analysis, and updating of the numerical models (particularly in terms of re-calibration with the latest monitoring and climatic data, transient calibration (with pumping test data) and additional predictive scenarios updated with latest management planning decisions).